

Lecture 10

Integrated Waste Management (IWM)

STRUCTURE

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OVERVIEW

From our discussion in Units 1 to 9, it is clear that a single method of waste disposal cannot deal with all waste constituents in an environmentally sustainable way. That is to say, we need a range of management options to achieve the desired results. But, the use of different options (e.g., composting or material recovery) itself depends on functional elements such as the collection and subsequent sorting system employed. In other words, a solid waste management (SWM) system is an integrated system, built on many closely related processes. Instead of focusing on and comparing one option with another (e.g., composting versus landfill), therefore, it is better that we make an attempt to synthesise a waste management system that can deal with the whole waste stream, and then compare their overall performances in environmental and

economic terms. This holistic approach is referred to as *integrated waste management* (IWM), and this, in essence, is the focus of this Unit. Integrated waste management (IWM) systems combine waste streams, and waste collection, treatment and disposal methods with the objective of achieving environmental benefits, economic optimisation and social acceptability. Such a waste management system is environmentally, economically and socially sustainable and is likely to be integrated, market oriented, flexible and operated on regional scale.

Against this backdrop, in this Unit, we will examine the overall waste management system and develop ways of assessing overall environmental burdens and economic costs. We will first introduce you to some critical aspects of IWM such as the characteristics, planning and management, benefits and modelling. In order to assess the economic impact, we will then discuss the life cycle assessment (LCA) technique, which examines every stage of the life cycle of solid wastes – from raw material acquisition, through manufacture, distribution, use and possible reuse/recycling to final disposal. (Note that Unit 6 of *Environmental Management* exclusively deals with LCA). We will then discuss the need for involving the public in waste management activities.

LEARNING OBJECTIVES

After completing this Unit, you should be able to:

- discuss the concept of integrated waste management;
- carry out economic valuation of waste management systems using the LCA technique;
- plan and participate in public education programmes.
- develop an integrated waste management system for your locality involving the public.

10.1 BASICS OF IWM

Wastes are by-products of human activity. Physically, wastes contain the same material found in useful products, but differ only in their lack of value. The lack of value in many cases can be attributed to the unknown and mixed composition of waste. Separating the materials in waste will generally increase their value, if the separated (i.e., recovered materials) have any use.

Basic idea of ISWM is to segregate wet and dry waste at source. Have separators in transport vehicles and track where the waste is being disposed off through GPS in vehicles. Analyse suitable site locations for landfill. By following segregation and tracking any city can be made clean and hygiene. Garbage bins can be removed through this process. Health and safety have been, and still remain, the major concerns in waste management, and, therefore, waste must be managed in such a way as to minimise risks to human health. Today, the society demands a waste management system that is not only safe but also environmentally and economically sustainable. Note that sustainability refers to development that addresses the needs of the present generation without jeopardising the ability of future generations to meet their own needs.

To elaborate, economic cost of a waste management system used to be a major controlling factor in the decision-making process. However, of late, environmental concerns also contribute to the shaping of decisions regarding waste management. Environmental concerns fall under the following two major areas:

- (i) **Conservation of resources:** This needs a general reduction in the amount of waste generated i.e., waste minimisation or waste reduction, as well as material and/or energy recovery from the waste. Recovery of resources from waste should slow down the rate of depletion of non-renewable resources and help lower the use of renewable resources to the rate of replenishment.

(ii) **Environmental pollution:** This is the basis for most current environmental concerns about waste management. Levels of emission of pollutants have increased with rise in human population and their activities, but natural processes do not have sufficient turnover to prevent changes in environmental conditions. In extreme cases of overloading, natural processes may break down completely, leading to drastic changes in environmental quality. Along with this, another specific concern emerges at the local level whenever new facilities for waste treatment are proposed. For example, a planned incinerator raises concerns about the increase in emission levels of dioxins, a landfill raises concerns about the risk of landfill gas and groundwater pollution from the leachate generated in landfill sites, etc.

Waste management must, therefore, be (McDougall, et. al., 2001):

- economically affordable;
- socially acceptable;
- Environmentally effective and safe.

To achieve both environmental and economical sustainability, an integrated waste management (IWM) system is necessary. IWM helps in achieving environmental objectives using economically sustainable systems tailored to the specific needs of a community or region. Figure 1 illustrates the steps involved in IWM

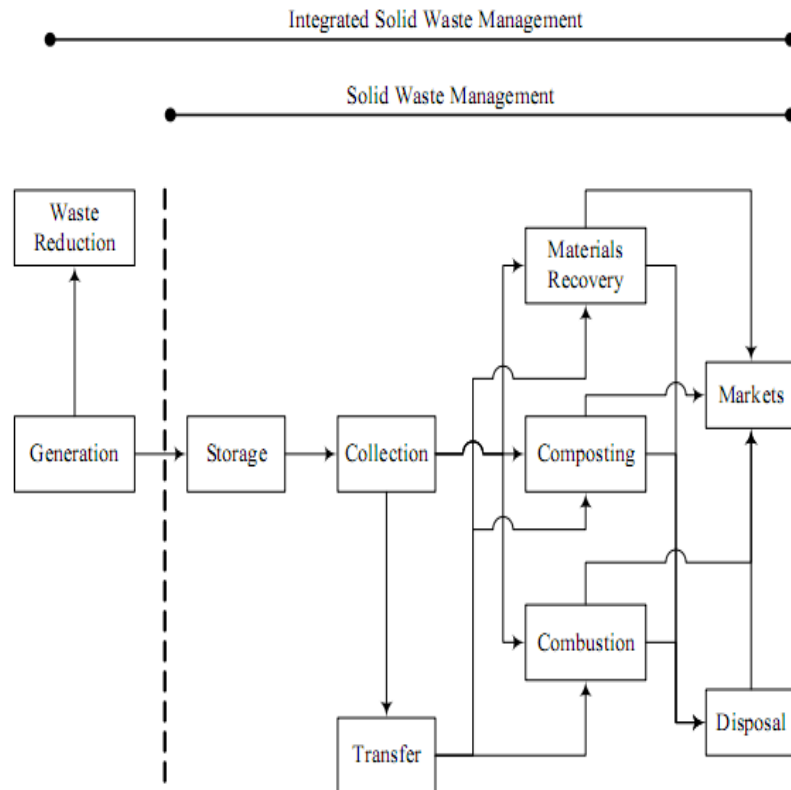


Figure 1: Integrated Solid Waste Management

(Source: Hickman, Jr., H. Lanier, 1999, Principles of Integrated Solid Waste Management, American Academy of Environmental Engineers)

However, in order for an integrated solid waste system to be successful they must be embraced, coordinated, and implemented at the national, state/provincial/regional, municipal, community, and institutional levels.

Before you read any further, let us work through Learning Activity 10.1.



LEARNING ACTIVITY 10.1

Justify the need for an integrated waste management (IWM).

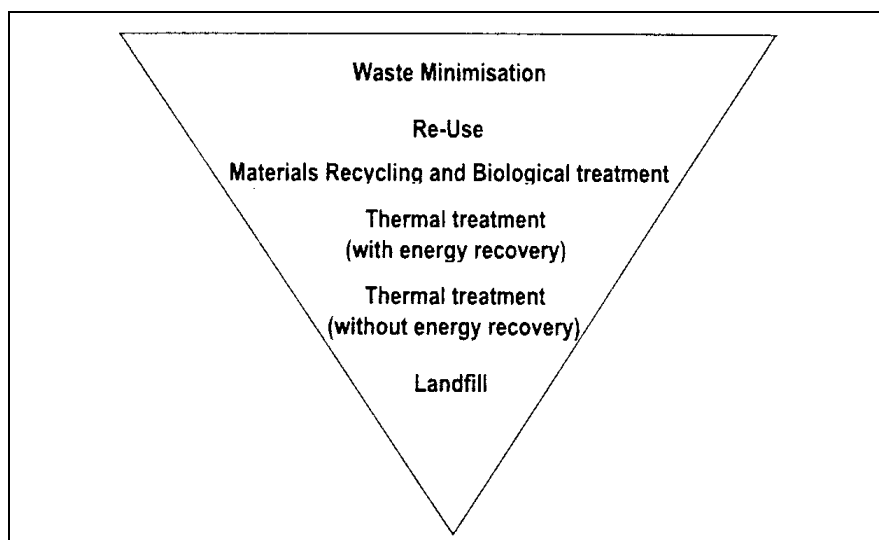
Note:

- a) Write your answer in the space given below.
- b) Check your answer with the one given at the end of this Unit.

IWM involves using a combination of techniques and programmes to manage the municipal waste stream. It is based on the fact that waste stream is made up of distinct components that can be managed and disposed of separately. An integrated system is designed to address a specific set of problems, and its operation is based on local resources, economics and environmental impacts. A well-designed IWM plan can improve system economics and reduce environmental impacts, while fostering public support and involvement in solid waste management (EPA, 1989 and 1995). There is no universal step-by-step method for selecting and developing IWM components and systems. That is to say, the success of any IWM depends largely on the dedication and committed expertise of the decision-makers.

Figure 10.1 below shows a hierarchy of waste management that can be used to evaluate the components of IWM vis-à-vis the needs of the community:

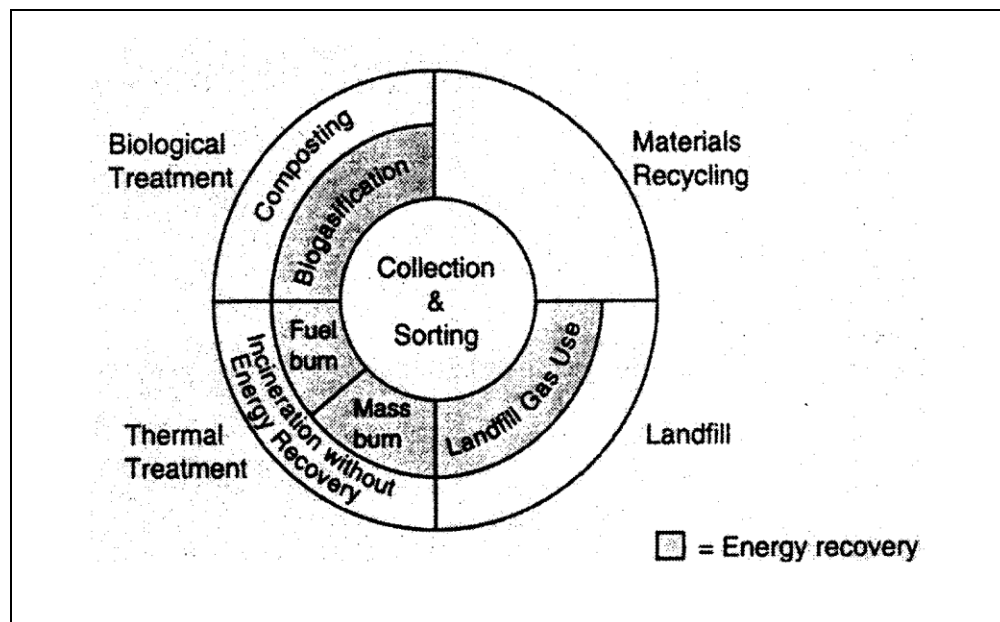
Figure 10.1
Hierarchy of Waste Management



This conceptual tool is useful for goal setting and planning, and all the elements of the hierarchy are interrelated and can be designed to complement each other (McDougall, et. al., 2001).

Besides the hierarchy of preferred waste management options, a holistic approach illustrated in Figure 10.2 recognises that all options have a role to play in IWM:

Figure 10.2
Elements of Integrated Waste Management



The above model (Figure 10.2) illustrates the interrelationships among the parts of the system – the percentage of waste treated by each of the four options will depend on the local conditions. Each option should be assessed using the most recent data available, but the overriding objective is to optimise the whole system, rather than its parts to make it environmentally and economically sustainable and socially acceptable.

Essentially, the overall objective of waste management should be to reduce the amount of waste generated and to manage the waste in a sustainable way by minimising the overall environmental burden associated with the waste management system. However, in one way or another, waste generation is bound to continue as long as there are living organisms, and by extension, waste management is an ongoing process and not a one-time affair. This necessitates the compilation and evaluation of the waste generated and the potential environmental impacts throughout its life cycle. Life cycle assessment (LCA), an environmental management tool, can be used for this purpose. (We will explain LCA later in Section 10.3.)

10.1.1 Characteristics of IWM

The characteristics of IWM include the following:

(i) **An integrated system:** An integrated system combines an optimised waste collection system and effective sorting, followed by one or more of the options, i.e., material recycling, biological treatment, thermal treatment and sanitary landfill. Put differently, an integrated system has control over all types of solid waste materials such as plastic, paper, glass, iron, aluminium, etc. Focusing on a specific material, either because of their ready recyclability (e.g., aluminium) or because of public profile (e.g., plastic), is likely to be less effective in both environmental and economic terms. An integrated system also means control over all sources of solid waste, be they commercial, municipal or domestic. Focusing on a specific source of material (e.g., packaging, domestic or industrial waste) is likely to be less productive than focusing on the nature of the material, regardless of its source.

(ii) **Market oriented:** Any scheme that incorporates material recycling and biological or thermal treatment technologies must recognise that effective recycling of material and production of compost and energy depend on markets for these outputs. These markets are likely to be sensitive to price and consistency in quality and quantity of supply. While working with such schemes, it is important to build markets for outputs, work with secondary material processors and help set material quality standards.

(iii) **Flexibility:** An effective scheme will need the flexibility to design, adapt and operate its system in ways which best meet the current social, economic and environmental conditions. These are likely to change over time and vary by regions. Using a range of waste management options in an integrated system gives the flexibility to channel waste via different treatments, as economic or environmental conditions change. For example, paper can be recycled, composted or incinerated with energy recovery. The options used can be varied according to the economics of paper recycling, compost production and energy generation at the time.

(iv) **Socially acceptable:** For waste management systems to operate effectively, public participation is necessary. Low participation rates in recycling and other schemes can be improved by effective communication. Objection to waste management facility siting can be minimised through appropriate design of facility, and public consultation and education. Where system changes are necessary, effective communication material will inform the public about the benefits of the new system (environmental, economic and social) and thereby increasing the chance of that system being accepted. Public participation in the waste management facilities will also have an effect on the acceptance of the overall waste management system. The integrity of the waste management system is also essential. The public must be confident that any material they source-separate for recycling is sent for recycling and not landfilled or incinerated. Good public support is as essential to a waste management system as good planning and effective management. (We will deal with these aspects in Section 10.4).

10.1.2 Planning for IWM

The strategic planning for IWM refers to the concept that we must plan for a long term, and the planning process should involve anticipated changes that are likely to occur in the future. It is crucial to build flexibility into all elements of waste management systems. To reiterate, IWM is an ongoing process that has no set beginning or end. The review of new alternatives and evaluation of operations should be performed continually, and planning, development, monitoring and evaluation of options take place simultaneously. Various steps in the IWM planning must follow a conceptual outline discussed below (EPA, 1989 and 1995):

(i) **Organise the framework:** Building local expertise is the primary goal of waste management. Many decision-makers are unfamiliar with the details of various waste management alternatives, even though the issue may not be technical or complex in nature. Investigating and implementing some low technology waste management options such as source reduction programmes,

pilot scale recycling, etc., can help them develop their own expertise in areas that may have been previously unfamiliar. Building expertise will better prepare them for implementing larger programmes and will lower the risk of making costly planning mistakes.

(ii) **Understand the institutional and regulatory climate:** It is important to understand and account for local opportunities and constraints when planning a waste management system. The planning should be done according to the political, institutional and economic realities of both local communities and neighbouring political jurisdictions. The knowledge of laws and guidelines affecting municipal waste planning is equally important.

(iii) **Address local waste management issues:** The most fundamental planning factor is to understand the nature of solid waste and its management in the local community. This requires total waste stream assessment, and after having come to grips with all the factors involved, goals and objectives for its management can be decided.

(iv) **Evaluate waste management alternatives:** Evaluating alternatives is the most time consuming activity while developing IWM plans. Dozens of options must be compared and evaluated and feasibility of each option within the local constraints determined.

(v) **Foster public education and involvement:** The involvement of citizens who have been educated about the benefits of proper municipal waste management can be one of the most beneficial aspects of an IWM system. For many municipal waste management options, public participation is one of the main keys of success. Through public education and involvement, one can create opportunities for community members to be a part of the solution to the solid waste dilemma.

(vi) **Understand project financing:** Project financing can be performed in a variety of ways within the community and the selection of financing method is based largely on the degree of risk that the community is willing to take, as the

financing method selected can significantly impact the cost incurred by the community.

(vii) **Evaluate new waste management alternatives:** Evaluating new waste management alternatives are necessary to ensure that the local system is as successful as possible. Even the most successful and innovative waste management programmes experiment with new techniques and technologies. Integrated waste management, being an ongoing process, requires continuous attention.

10.1.3 Implementing IWM

As a community moves towards programme implementation, managers must constantly remind themselves to keep the overall programme in perspective. By viewing the project as a whole, no individual element should be paid too much or too little attention. Programme momentum should be sustained at a slow, but steady pace. Issues that can delay or derail a programme must be recognised and appropriately dealt with. Public support must be fostered and confidence in the ability of the community to successfully implement a programme ensured.

To keep a waste management programme in its proper perspective, attention must be paid to the following, popularly referred to as five “Ps”:

(i) **Planning:** Although, it may seem obvious that planning is needed to implement a successful programme, in practice, the need to formulate and follow a well-devised and comprehensive plan is sometimes forgotten. A leaking landfill or other waste management problems may pressure a community to act quickly; hasty actions cause mistakes, which in turn result in delays and wasted resources. While all possible situations cannot be anticipated, many good models, based on successful programmes, do exist, and programme developers are encouraged to use them, when possible, to formulate their own programmes. Planning is especially important because of the potentially large number of factors in the waste management process. Political bodies, waste generators, waste haulers, regulatory agencies, construction contractors, plant operators,

energy and material buyers, landfill site owners and citizens must be included for a programme to be successful. Each group has the potential for contributing to or delaying or derailing a project. By formulating and continually reviewing a project plan, programme managers can minimise the chances of a major component of the programme being missed.

(ii) **Price:** Decisions regarding the adoption of alternative strategies for managing waste must continually be based on sound economic analysis that considers the resources of the community and the anticipated environmental impacts and benefits. The community is usually willing to support higher cost waste management options as long as there is confidence that the programme is well run, economically efficient and environmentally sound. Comparing costs and benefits against action is essential for long-term success.

(iii) **Publicity:** Successfully implementing a waste management programme can take a number of years and a commitment of community resources. Support for a programme can erode quickly, unless attention is paid to keeping the programme on the public agenda and maintaining strong and positive public support. A comprehensive plan for informing the public about the programme's progress should be developed and implemented at all stages. Special effort should be made to generate public support before elected bodies vote on programme expenditures. The programme must be seen by the public as something to be proud of, as an example of the progressiveness of the community and its commitment to a clean environment.

(iv) **Political support:** Sustained political support during the long and costly implementation process is vital to the programme's ultimate success. Political support is often crucial to obtain finance and to ensure that the programme gets the resources needed to construct facilities and operate them efficiently. Political leaders should also be kept informed of the programme's progress on a regular basis so that political support for the programme grows as the decision-making body reaches the point of actually committing its public or private resources to implementing the long-term programme. Newly elected political officials must also be informed about the community effort.

(v) **Perseverance:** A community waste management programme must be prepared for the long term. Some projects can take five to ten years to implement and are complex and expensive. A community choosing to implement a programme must be willing to commit the necessary resources to see it through. The ultimate key to success is the will to persevere until the programme is in place.

10.1.4 Benefits of IWM for developing economies

The management of municipal solid waste (MSW) is an integral, but much neglected, aspect of environmental management in many developing countries. The waste management systems, where already in place, in a majority of the developing economies are often characterised by inadequate collection services, little or no treatment and uncontrolled dumping. Thus, a lack of an effective mechanism for waste management and infrastructure coupled with severely limited resources warrant a simple, but robust, IWM system in these countries. The establishment of IWM system will require the following (McDougall, et. al., 2001):

- Data on waste composition. Collection of reliable data, considered the foundation of IWM, is required for effective planning of collection, transport and treatment of MSW.
- Progress from uncontrolled dumping to the use of simple sanitary landfills.
- Separation of organic waste, which can be composted, from MSW.
- Institutionalised involvement of personnel in the separation and collection of recyclable materials.

Given the available resources and MSW composition, the waste hierarchy for waste management (See Figure 10.1) is evidently too rigid to be relevant to developing countries. In other words, the characteristic flexibility of IWM offers a more realistic opportunity to improve waste management by addressing local conditions.

Although technical and financial resources are limited, developing economies still have the potential to significantly improve waste management. For example, moving from open dumping to simple sanitary landfill in conjunction with separation and composting of organic waste is likely to result in significant benefits. This prevents, or at the very least minimises, the pollution of surface and groundwater by leachate, migration of combustible gases (methane), odour and breeding of disease carriers. The institutionalised involvement of scavengers in the collection, sorting and recycling of materials helps improve their living conditions, bring to them dignity, reduce the health risks they are exposed to, supplement their income and increase recycling rates. A careful analysis of market conditions for recyclable materials and compost could be conducted to prevent imbalances that could affect their final prices. In essence, an IWM can provide an environmentally effective, economically affordable and socially acceptable waste management system.

10.1.5 Waste management modelling

Optimising the waste system to reduce environmental burdens or economic costs requires the burdens and costs to be predicted. Put differently, modelling of waste management systems is necessary. Several models can be produced for predicting environmental burdens. This is a new branch of applied science, which has resulted in the development of a new environmental management tool. The modelling technique used very often is life cycle inventory (LCI) of solid waste, which we will explain in Section 10.2.

Modelling in general can be divided into the following two areas:

- (i) model structure, which will determine how the model will work;
- (ii) data acquisition for verification and validation of the model (McDougall, et. al., 2001).

Even the best models are useless without accurate, relevant and accessible data. Through the efforts of a range of agencies/ bodies, many different pilot

schemes, both on small and large scales, have been set up and data are becoming available, because of which it is now possible to model IWM schemes, based on actual data.

A word of caution is necessary here. Modelling may sound a purely academic exercise, but in reality, it has several practical uses, some of which are listed below:

- The process of building a model focuses attention on missing data. Often the real costs, in either environmental or economic terms, for part of the waste chain are not widely known. Once identified, the missing data can either be sought out, or, if not existing, analysis can be carried out to gather the relevant data.
- Once completed, a model will define the current status of waste management, both by describing the system and by calculating the overall economic cost and environmental burden.
- A model can also be used to predict environmental burdens and likely economic costs in the future. Such a forecast may not be 100% accurate, but will give a workable estimate to work out a future strategy.
- Modelling allows other calculations to be made, which can then be used to define the sensitive points in the system. This will show the changes that will have the greatest effects in reducing costs or environmental burdens.
- Modelling the waste system will allow prediction of the likely amounts of reclaimed material available, which will, in turn, allow informed investments in the necessary equipment.

 **LEARNING ACTIVITY 10.2**

List the steps involved in implementing IWM.

Note:

- Write your answer in the space given below.
- Check your answer with the one given at the end of this Unit.

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We will now discuss the role of life cycle assessment in solid waste management. You may also refer to Unit 6 of the **Environmental Management** Course for a detailed discussion of LCA techniques.

10.2 LIFE CYCLE ASSESSMENT (LCA)

Life cycle assessment (LCA) is a compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle. It is an environmental management tool increasingly used to understand how a product or service is provided from 'cradle to grave' (McDougall, et. al., 2001). That is to say, the technique examines every stage of the life cycle – from raw material acquisition through manufacture, distribution, use, possible reuse/recycling to final disposal. In addition, every operation or unit process within a stage is included and for every operation within a stage, the inputs (i.e., raw materials, resources and energy) and outputs (i.e., emission to air, water and solid waste) are calculated. These inputs and outputs are then aggregated over the life cycle. The environmental issues associated with these inputs and outputs are then evaluated in the life cycle impact assessment (LCIA). Conducting LCAs for alternative products or services thus allow for improved understanding and comparisons.

10.2.1 Benefits of LCA

Life cycle assessment is an inclusive tool. The life cycle inventory phase is essentially an accounting process or mass balance for a system. All necessary inputs and emissions in many stages and operations of the life cycle are considered to be within the system boundaries. This includes not only direct inputs and emission for production, distribution, use and disposal, but also the indirect inputs and emissions. It is essential that all the processes are included within the boundaries to conduct a fair and transparent analysis. LCA offers the prospect of mapping the energy and material flows as well as the resources, solid wastes and emissions of the total system, i.e., it provides a system map that sets the stage for a holistic approach. Comparing such system maps for different options, whether for different products or waste management systems, allows the identification of areas, where environmental improvements can be made.

Looked at from a different standpoint, the concern about the environment is sometimes expressed in terms of individual issues, such as acidification. The power of LCA is that it expands the debate on environmental concerns beyond a single issue and attempts to address a broad range of environmental issues. The system map also allows other environmental information and assessment tools to be incorporated in conjunction with LCA.

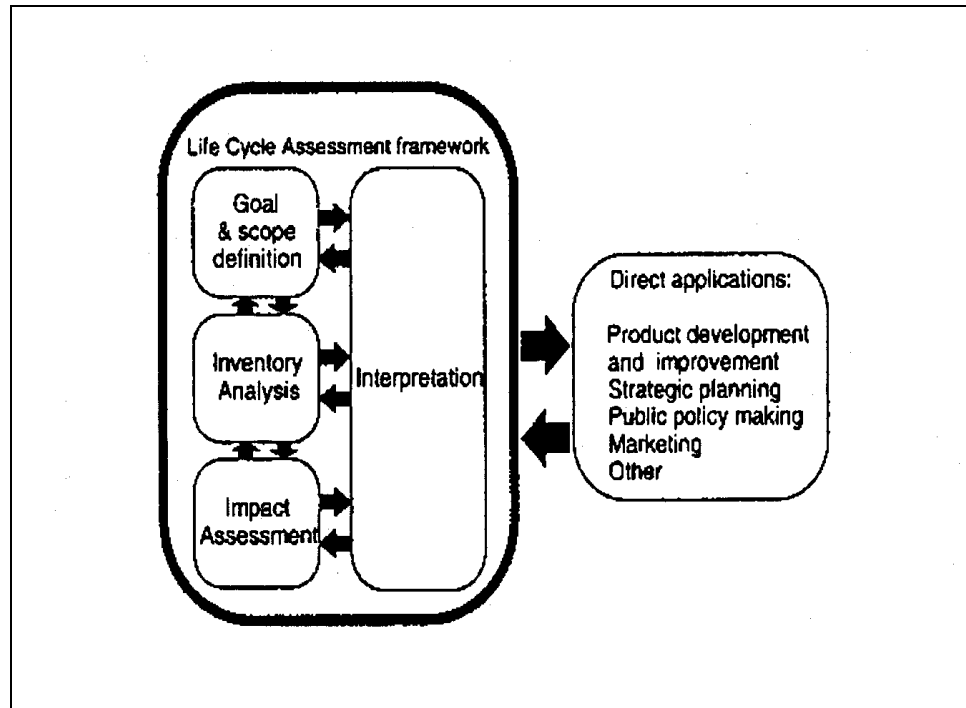
10.2.2 LCA phases/stages

LCA consists of the following four phases or stages:

- (i) **Goal definition and scope:** At this phase, the functional unit for comparison is defined as well as the study purpose, system boundaries, life cycle stages, unit processes and scope of assessment.
- (ii) **Life cycle inventory analysis (LCI):** This involves the process of accounting for all the inputs and outputs of the product system over the life cycle, resulting in a list of raw material and energy inputs, and individual emission to air, water and solid waste.
- (iii) **Life cycle impact assessment (LCIA):** This phase associates the inputs and outputs with particular environmental issues, e.g., ozone depletion, and converts the inventory of material, energy and emissions into representative indicators, e.g., an aggregate loading of ozone depleting chemicals.
- (iv) **Life cycle interpretation:** This phase evaluates the significance of the inputs, outputs and indicators of the system life cycle. (Note that this stage is the least accepted or defined.)

Figure 10.3 illustrates the four-phase structure of LCA.

Figure 10.3
LCA Phases



Source: McDougall, et. al., 2001

Referring to Figure 10.3, in what follows we will discuss these phases/stages in detail.

Goal and scope definition

The goal of an LCA study must unambiguously state the intended application, objectives and intended audience. It should state the reason for performing a specific study and define the options that are to be compared and the intended use of the result. The intended use will influence the type of study and the type of data required. This stage also involves identifying the system boundaries (i.e., technical, geographical and time) and the procedures to handle the data. Rules and assumptions must be documented, especially with respect to allocation rule for co-products, open loop recycling and aggregation. All the decisions that need to be taken, while carrying out an LCA should be made in light of the purpose of

the study. A clearly defined goal will partly address the need for transparency and will help ensure whether or not the result is fit for use.

Transparency is essential throughout the life cycle procedure. This allows data tracking and calculation verification to be carried out, if necessary. A complete and transparent record of a study is compiled in a final study report. The scope of study should be sufficiently well defined to ensure that the breadth, depth and details of the study are compatible and sufficient to address the stated goal.

In defining the scope of a LCA study, the following must be clearly described:

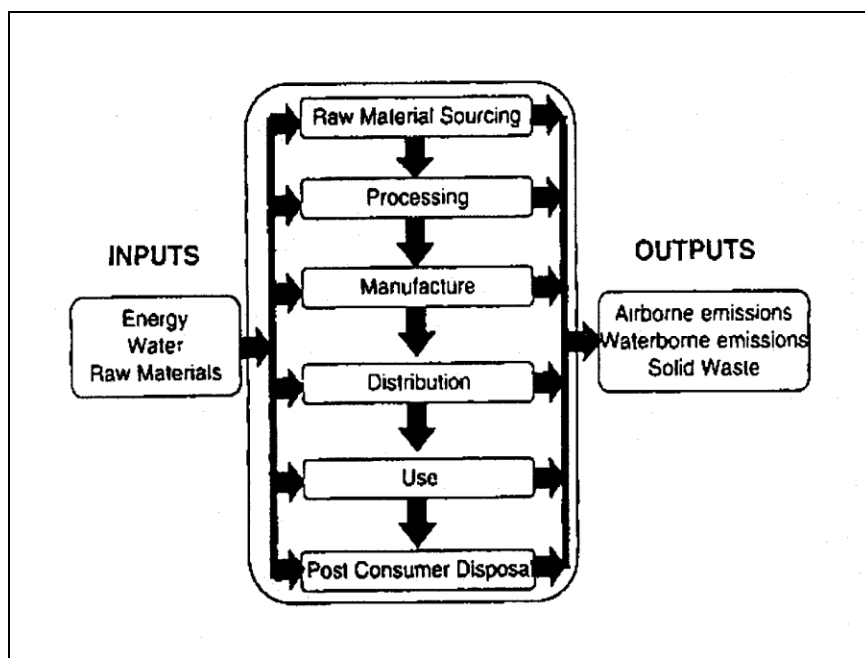
- **Product system:** A product system is a mix of operations connected by flows of intermediate products, which performs one or more defined function. The system should be defined in sufficient detail and clarity in such a way as to allow another practitioner to duplicate the life cycle inventory analysis. Product systems are subdivided into unit processes, and each unit process encompasses the activities of a single operation or a group of operations. Unit processes are linked to one another by flows of intermediate products and/or waste for treatment and to other product systems by product flows.
- **Functional unit:** The scope of an LCA study clearly specifies the functions of the system being studied. A functional unit is a measure of the performance of the functional outputs of the product system, and the products or services are compared on this basis. Being the corner stone of an LCA study, the functional unit provides the reference point to which both inputs and outputs are related and allow a clear comparison of LCA results. The stages and unit processes connected to the functional unit are known as the product system, which we described above.
- **System boundaries:** The system boundary defines the unit processes that will be included in the system for modelling purposes. Ideally, the product system should be modelled in such a manner that inputs and outputs at its boundary are *elementary flow*, i.e., the material/energy entering the system under study has been drawn from the environment without previous human transformation, or the material/energy entering the system under study is discarded into the

environment without subsequent human transformation. The system boundaries, i.e., the stages, operations, inputs and outputs included and omitted within the assessment, need to be defined. In any LCA, defining the functional unit and the boundaries of the system being assessed are both important steps. Reporting the functional unit and the boundaries used needs to be clear and detailed with any omissions stated and justified. This is important in giving the actual results.

Life cycle inventory analysis (LCI)

A life cycle inventory analysis is concerned with the data collection and calculation procedures necessary to complete the inventory. This stage accounts for constructing a material and energy balance for each step in the life cycle. The analysis of all inputs and outputs for each stage in the life cycle can then be combined to give the overall life cycle inventory of the product or service. The procedure, as shown in Figure 10.4, entails describing the life cycle as a series of steps and then calculating the inputs and outputs for each of these steps:

Figure 10.4
The Stages of a Product's Life Cycle



An LCI provides enormous knowledge and insights into the operation of a given system, which can provide the basis for applying and integrating other environmental information and assessment tools into a system for comparison. For LCI, the main categories of data required are:

- specific data for production, distribution and waste management;
- generic data for energy production, raw material transportation and extraction.

Data quality requirements should address time related, geographical and technological issues, the precision, completeness and representativeness of the data and the consistency and reproducibility of the methods used throughout the LCA. LCI should also undergo sensitivity and uncertainty analysis. Sensitivity analysis can help identify whether any of the assumptions made have a significant influence on the outcome of the LCI, and if so, which assumption has the greatest influence. Uncertainty analysis is essential and identifies those parameters for which the margins of uncertainty have a large influence on the result, and subsequently, the margins of uncertainty for these parameters can be improved. The data and results should not be used without understanding their quality and limitations.

Life Cycle Impact Assessment (LCIA)

The LCIA phase aims to examine the product system from an environmental perspective using category indicators, derived from the LCI results. It also provides information for the interpretation phase (see the discussion below). The LCIA phase of an LCA study provides a system wide perspective of environmental and resource issues for product or service system. To achieve this, LCIA assigns LCI results to specific, selected impact categories. (Note that an impact category is used to group certain LCI results that are associated with a particular environmental issue.) For each impact category, appropriate indicators are selected and a characterisation model is used to calculate the indicator result. The collection of the indicator results and the LCA profile provide an

environmental context for the emission and resource use associated with the product or service system.

LCIA is composed of several mandatory elements that convert LCI result to indicator results. There are also optional elements for normalisation, grouping and weighting of the indicator results and data analysis techniques. The various important elements of LCIA are:

- **Classification and selection of impact categories:** The classification stage requires the identification of inventory data relevant to each specific impact category and the assignment of the appropriate LCI results to each category. Data may belong to more than one category, e.g., NO_x has a global warming and an acidifying effect. The impact categories are selected based on the goals and scope of the LCA study.
- **Characterisation:** The aim of characterisation is to provide a basis for the aggregation of the inventory results into an indicator for each category. Each impact category requires a specific model to convert the inventory results into the indicator. For example, in case of global warming, the most common indicator used is Global Warming Potential (GWP) in CO₂ equivalents. There are two steps in this calculation – each greenhouse gas is first converted into carbon dioxide equivalents based on particular characterisation factors and the individual carbon dioxide equivalents are then added into a total indicator.
- **Normalisation:** This involves relating the characterised data to a broader data set or situation, as in, for example, relating the SO_x emission to a country's total SO_x emission. Normalisation can provide insights but should be treated with caution, as results can differ significantly, if different data sets are used. Normalisation is often omitted from LCA studies.
- **Weighting:** This is the process of converting indicator results of different impact categories into scores by using numerical factors based on values. Weighting may include aggregation of the weighted results into an overall score. This is the most subjective case of an LCA, which is based on value judgement and is not scientific. Different individuals or organisations may have different

preferences or values. Different parties, therefore, are likely to reach different weighting results based on the same indicator results.

Life cycle interpretation

Life cycle interpretation is a systematic technique to identify, qualify, check and evaluate information from the results of the life cycle inventory (LCI) analysis and/or LCIA of a product system, and present them in order to meet the requirements of the application as described in the goal and scope of study. The interpretation stage of the LCA process is closely linked to the iterative nature of the process of scope definition, inventory analysis and impact assessment. Interpretation involves a review of all the stages in the LCA process.

There are a few sub-phases at this stage of an LCA, and these are:

- **Identification of significant issues:** Based on LCI and LCIA phases of LCA, the objective of this sub-phase is to structure the results from LCI or LCIA phases in such a way as to determine the significant issues, including any implications of the particular method used and assumptions made, allocation rule, cut-off decisions, choice of indicators and characterisation.
- **Evaluation:** The objectives of the evaluation sub-phase are to establish and enhance the confidence and reliability of the result of the study. The result of evaluation should be presented in such a way as to allow the reader a clear and understandable view of the outcome of the study. To achieve this, a completeness check (ensuring that all relevant information for interpretation is available and complete), a sensitivity check (assessing the reliability of the results by assessing the uncertainty of the significant issues affecting the conclusion) and a consistency check (determining whether the assumptions, methods and data are consistent with the goal and the scope) must be carried out.
- **Conclusions, recommendations and reporting:** Drawing conclusions from a study should be done interactively with the other elements in the life cycle

interpretation phase. Preliminary conclusions must be checked to ensure that they are consistent with the goal and scope of the study. Recommendations should be based on the conclusions of the study and the final report shall present a complete, unbiased and transparent account of the whole study.

Note that an LCA will allow the trade-offs associated with each option to be assessed, which is economically affordable, socially acceptable and environmentally effective.

While LCA, used with other environmental information and assessment tools, helps improve the environmental performance of a product or service, public involvement and education is necessary for a sustainable solid waste management system. We will study this next in Section 10.3. But, first, let us work out Learning Activity 10.3.



LEARNING ACTIVITY 10.3

List the stages of LCA.

Note:

- a) Write your answer in the space given below.
- b) Check your answer with the one given at the end of this Unit.

10.3 PUBLIC EDUCATION AND INVOLVEMENT

Developing integrated solutions for waste management problems requires public involvement. To operate a waste management programme economically and efficiently, significant cooperation is expected from waste generators, regardless of the strategies chosen – buying products in bulk, separating recyclables from non-recyclables, dropping off garden trimmings at a compost site, removing batteries from materials sent to a waste-to-energy facility, or using designated containers for collecting materials. To sustain a long-term programme support, the public needs to know clearly the purpose and necessity of desired behaviours.

Involving people in the waste management requires a significant educational effort by the community. Ineffective or half-hearted education programmes may confuse the public, reduce public confidence or elicit hostility towards the programme. Successful education programmes must be consistent and ongoing. Public education stimulates interest in how waste management decisions are made, and when citizens become interested in their community's waste management programmes, they frequently demand to be involved in the decision-making process. Communities should anticipate such interest and develop procedures for involving the public. When the public is involved in programme design, it helps ensure the smooth running of the programmes (EPA, 1989 and 1995).

We now discuss some aspects of public education and involvement in Subsections 10.3.1 and 10.3.2.

10.3.1 Planning a public education programme

Successful public education plans are the result of careful planning. By developing a realistic education plan, you can assess the situation and know where best to direct their efforts and resources. This will benefit from taking advantage of all opportunities to work with the community. The process of

developing an education and involvement plan provides an opportunity to involve the community in the planning process at an early point. The education plan must begin by introducing people to waste management needs and concepts, explaining clearly how to participate, and then effectively encouraging them to adopt the desired waste management behaviour.

Once the public participates in the programme, incentives and reinforcements can be used to maintain and increase participation rates. Developing an effective education programme requires planning and research. Programme developers must use different strategies for different groups, such as homeowners, apartment dwellers, business people and school children. Grounded on a sound information base, an effective education programme moves people through a series of stages (EPA, 1989 and 1995). Let us describe each of these stages now.

Awareness

At the awareness stage, people encounter a new idea or a new way of doing things. At this stage, they do not possess enough information to decide whether a change in behaviour is a good idea or whether they should be concerned. The goal of the awareness stage is to let people know that a different way of handling waste may be preferable to the historical way and that good reasons for considering a change in their waste management practices do exist. A variety of methods can increase awareness, in which low-cost methods include news articles and public service announcements, or shows on radio and television and high cost efforts include television commercials or billboards. Over the long term, education in schools is the best way of raising awareness; the school curriculum must include the concepts of source reduction, recycling composting and other waste management techniques. Besides educating the next generation of citizens, school programmes indirectly help make parents aware of waste issues because children frequently take home information they have learned and discuss it with their parents.

Interest

In the second stage, individuals who are now aware of waste management issues seek additional information. They may seek one-to-one exchanges with waste management professionals, educators, and so on or they may seek information about how they are involved in implementing a waste management initiative or an effective public policy. Making changes in required local waste management practices, such as mandatory recycling or garden trimmings disposal bans, will clearly stimulate interest (sometimes even in the form of political opposition!). At this stage, programme developers may need a variety of methods to explain the programme. Making public speeches, offering tours of waste management facilities, creating exhibits for fairs and preparing written material such as newsletters can help stimulate public interest in the programme.

Evaluation

At the evaluation stage, individuals decide whether to go along with the programme. Even if the law requires specific behaviour, achieving voluntary compliance is easier administratively and politically than strong enforcement. An easily understandable and convenient programme will have the best chance of success. Research has shown that for even well promoted programmes, initial participation is about 50%. Initial high participation rates, therefore, should not be expected. Even for mandatory programmes, convenience is a major factor in determining participation. For example, the convenience of curbside pickup normally makes participation in waste management programmes higher than for drop-off programmes. As a result, some communities only provide drop-off service for garden trimmings, so that it becomes more convenient not to collect grass clippings or home compost. A combined curbside and drop-off programme may be the most convenient. To make this happen, education should stress the role of individuals in the programme, their contribution to its success and the most convenient level of participation.

Trial

By the fourth stage, individuals would have decided to participate in the new activity. This is a crucial step for every programme. For example, if individuals try garden composting or a volume-based system and encounter difficulty, they may choose not to adopt the desired conduct, and the programme could lose political and public support. By this stage in the educational programme, therefore, everyone should have the information, describing exactly what they are expected to do. The community programme must then provide the promised service in a highly reliable fashion. At the trial stage of a volunteer programme, a pilot project can also help stimulate participation. Programme organisers should assure citizens that the pilot project's goal is to evaluate various strategies, respond to public feedback and make any changes required to improve programme efficiency and reliability. Citizens may be more willing to try a project, if they know whether the project is short-term and that any concerns they may have will be taken into account in developing a long-term effort. During the trial stage, public hearings may be helpful by giving citizens an opportunity to voice their opinions about the project.

Adoption

If the education programme has been well planned and implemented, public support and participation should grow. Educational efforts at this fifth stage focus on providing citizens with positive feedback concerning programme effectiveness. A newsletter or other regular informational mailing can help inform citizens about the programme's progress and any programme changes. Community meetings can serve to reward and reinforce good behaviour and answer questions. Local officials should be informed of programme participation rates to generate political support for programme budgets and personnel needs.

Maintenance

At the sixth stage, the programme progresses smoothly. The use of a variety of intrinsic and extrinsic incentives will maintain and increase participation. Intrinsic

incentives are largely information in nature, designed to induce citizens to perform the desired conduct and to provide a personal sense of well-being and satisfaction. Some studies, for example, have shown that the ideals of frugality, resource conservation and environmental protection over the long run were strong intrinsic motivators for those participating in recycling and reuse programmes. Extrinsic incentives are tangible and direct rewards for performing the desired conduct, such as reduced fees or monetary payments. For example, the smaller the waste volume generated, the lesser the generator (of wastes) must pay for waste management. A maintenance programme may employ both the types of incentives, while continuing with basic education.

10.3.2 Planning public involvement

Participation of local residents should begin at the very early stage of the programme development. For example, it should begin even at the stage of making decisions regarding the overall waste management strategy that best meets the community's economic and environmental needs. The strategy should consider source reduction and other options in addition to the facility being proposed. The public must also accept responsibility for its role in implementing sound and cost effective waste management solutions.

Developing a written plan for seeking public involvement is important. Written procedures help insure the inclusion of all important interests and legal requirements. The plan will show involved citizens and groups at which points in the process they can express opinions and how to be most effective in communicating their views. In fact, a written, publicly available plan lends credibility to the programme. The "issue evolution-educational intervention" (IEEI) model provides public involvement throughout the decision-making process (EPA, 1989 and 1995). This model comprises an eight-stage process for developing and implementing public policy. The IEEI process ensures that the public will have a meaningful voice in deciding how best to manage solid waste. The process is not simple, and requires a commitment from the community for time and resources. Each of these stages is described below:

(i) **Concern:** In the first stage, an event puts waste management on the public agenda. The public begins to ask questions. At this stage, a procedure for providing accurate and reliable information to the public is important. Eliminating misconceptions and establishing a firm educational base for public discussion is the key. Educational institutions, offices, governmental associations and regulatory agencies can provide information. Education programmes should target local officials, as well as the public. Showing concern and a willingness to take proper action is most important. A focus group can help define important public issues, and a community service organisation can provide a forum for discussion.

(ii) **Involvement:** As discussion of the issue begins, regulatory officials, persons from neighbouring communities, local waste management experts, environmental and business groups and others should be encouraged to participate. Bringing representatives of interest groups together and providing a forum for communication is a valuable activity. Cultural diversity is another consideration when seeking input from the broadest possible spectrum of the community.

(iii) **Issue resolution:** Interest groups should make clear their points of agreement and disagreement. The various groups should then attempt to understand and resolve points of conflict. Determining what people can agree on is also important. All parties need to understand the motivation and circumstances of the other community interests in the process.

(iv) **Alternatives:** The participants should develop a list of available alternatives and each alternative should have a list of potential sites for facilities. At this stage, participants should use the same criteria to analyse comparative economics, environmental impacts and other aspects of each alternative. Each interest group should scrutinise carefully the analyses prepared by others. Results of analyses of various alternatives should be communicated to local officials and input sought from the public and others.

(v) **Consequences:** At this stage, involved parties should determine and compare the economic and environmental effects of each alternative. They should also evaluate consequences in light of community resources and goals, and the public must understand the results of choosing one alternative over another. All involved interest groups should acknowledge the benefits and costs associated with each alternative.

(vi) **Choice:** The deciding body must decide, at this stage, an alternative or a combination of alternatives chosen for implementation. In addition to publicising the chosen alternative or alternatives, decision-makers should clearly communicate the reasons behind each choice by explaining the necessary trade-offs, the efforts made to consider the interests of each affected group and the anticipated impact of the chosen alternative or alternatives on the community. This will help develop a broad community consensus, enabling the community to better withstand legal and political challenges. (We should not, however, expect a 100% support from all the interest groups involved to the chosen alternative or alternatives!)

(vii) **Implementation:** At this stage, the decision-makers should describe the steps necessary to implement the chosen strategy. They should also try to mitigate potential adverse impacts, which the chosen alternative or alternatives may have on relevant interest groups.

(viii) **Evaluation:** The community should continually evaluate the model and solicit input from affected groups. The impact of decisions should be communicated routinely to the public and to the local officials. Ongoing evaluation helps provide an information base for making future waste management decisions, and the existing programmes will continually improve, if they respond to changing conditions and public input.

After learning ISWM and role of LCA in ISWM let us now consider policy on IMSW management by Government of Karnataka state as a final section of the unit.

10.4 Policy on Integrated municipal solid waste management Karnataka

The policy of IMSW by the Government of Karnataka aimed at catalysing modernisation of MSW management services uniformly in the state and includes

- Specific plans to improve seven components including
 - ✓ Segregation
 - ✓ Storage at source
 - ✓ Primary collection
 - ✓ Secondary storage
 - ✓ Secondary transport
 - ✓ Treatment
 - ✓ Landfill
- Minimisation of human contact with waste and increase in its mechanical handling.
- Specific normative standards are followed. Standard tool kits for build-operate-transfer (BOT) and operation & maintenance (O&M) practices are followed; for all type and size of local bodies manuals on specifications of equipments, vehicles, guidelines on treatment and landfill of wastes are issued. This manual as well includes approach for information, communication and education.
- Specifications for type of vehicles that can be used for primary collection such as auto tippers, tricycle and push cart are mentioned. And for secondary storage such as variable capacity metal containers and others advisable are highlighted.
- Recommendations for class I and non class I cities are mentioned for secondary transport using hydraulically operated systems. For example for class I twin container and dumper placer can be used and for non class I single container and tractor placer can be used.
- Recommendations on treatment and disposal facilities for various types of towns are also given based on MSW Rules 2000. Suggestions given for class I cities are to have both treatment and sanitary landfill where as for Non class I to have only engineering landfills.



LEARNING ACTIVITY 10.4

List the stages to be considered for public participation in the management of solid wastes.

Note:

- a) Write your answer in the space given below.
- b) Check your answer with the one given at the end of this Unit.

SUMMARY

In this Unit, we discussed the concept of integrated waste management (IWM) system and said that it aims at reducing the amount of waste generated and managing the waste in a sustainable way by minimising the overall environmental burden. We also pointed out that an integrated system is designed to address a specific set of local solid management problems, and its operation is based on local resources, economics and environmental impacts. We then discussed the characteristics, planning, implementation and various benefits of IWM. Subsequently, we explained the stages involved in, and the relevance of,

life cycle assessment (LCA) technique as an environmental management tool. We closed the Unit by stressing the need for public participation to sustain solid waste management activities.

SUGGESTED READINGS

Areivala, S.J.(1971). *Solid Wastes Disposal in India*, Central/Public Health Engineering Institute. Nagpur.

Arne Vesilind, William Worrel and Reinhart Debra, 2002. *Solid waste Engineering*, Thomson Brooks/Cole, Singapore.

Ramachandra T.V. and Saira Varghese K. 2003. *Exploring possibilities of achieving sustainability in solid waste management*, Indian JI Environmental Health, 45 (4):255-264.

Tchobaanoglous, G., Theisen, H., and Samuel A Vigil, 1993. *Integrated Solid Waste Management*, McGraw-Hill, Inc., New Delhi.

Environmental Management in Developing Countries, 1995, *Waste Management Vol II*, Institute for Scientific Co-operation, Tubingen.

Flinotoff, R (1984). *Management of Solid Wastes in Developing countries*, WHO Regional Publications, South East Asia Series No 1.

Ramachandra T.V., 2009. *Management of Municipal Solid Waste*, TERI Press, New Delhi.

Ramachandra T V, 2011. Integrated management of solid waste, Chapter 30, In: *Environment security: Human and animal health*, (Eds. Sudhi Ranjan Garg), Published by IDBC Publishers, Lucknow, India. Pp:465-484.

<http://ces.iisc.ernet.in/energy/SWMTR/TR85.html>

<http://wgbis.ces.iisc.ernet.in/energy/paper/researchpaper.html#sw>

REFERENCES

US Environmental Protection Agency (1989). *Decision-Maker's Guide to Solid Waste Management, Vol 1*, Washington.

US Environmental Protection Agency (1995). *Decision-Maker's Guide to Solid Waste Management, Vol II*, Washington.

McDougall, F. R., White, P. R., Franke, M., and Hindle, P (2001). *Integrated Solid Waste Management: a Life Cycle Inventory*, Blackwell Science, UK.

Ramachandra T.V., 2009. Management of Municipal Solid Waste, TERI Press, New Delhi.

Ramachandra T V, 2011. Integrated management of solid waste, Chapter 30, In: Environment security: Human and animal health, (Eds. Sudhi Ranjan Garg), Published by IDBC Publishers, Lucknow, India. Pp:465-484.

Lecture 10

Model Answers to Learning Activities

LEARNING ACTIVITY 10.1

Waste is an inevitable product of society. Historically, health and safety have been the major concerns in waste management, and solid waste management practices were initially developed to address these concerns, which were the result of indiscriminate dumping of waste without proper collection and disposal. Managing this waste is now a need that society has to address. In addition to ensuring human health and safety, a sustainable system for solid waste management systems must be environmentally effective, economically affordable and socially acceptable. An integrated approach to solid waste management can deliver both environmental and economic sustainability. An integrated system would include an optimised waste collection system and efficient sorting followed by options such as material recycling, biological treatment, thermal treatment and landfill.

LEARNING ACTIVITY 10.2

The steps involved in implementing IWM are planning, price, publicity, political support and perseverance. A well-devised and comprehensive plan is necessary to implement a successful programme. Planning should involve political bodies, waste generators, haulers, construction contractors, etc., as each group has the potential to strengthen or derail a project. Sound economic analysis that considers the resources of the community and adverse impacts on the environment is necessary to adopt alternative strategies for managing waste. A plan for informing the public about the programme's progress should be developed and implemented as the programme succeeds. The support for a programme can erode quickly, unless attention is paid to keeping the programme on the public agenda and maintaining strong and positive public support. Political support is often crucial to obtaining finance and ensuring that the programme

gets the resources needed to construct facilities and operate them efficiently. A community waste management programme must be prepared for the long term. The ultimate key to success is the political and public will to persevere until the programme is in place.

LEARNING ACTIVITY 10.3

The stages are goal and scope definition, life cycle inventory analysis (LCI), life cycle impact assessment (LCIA) and life cycle interpretation.

LEARNING ACTIVITY 10.4

The stages are concern, involvement, issue resolution, alternatives and consequences.