APPLICATION OF LCA TO SOLID WASTE MANAGEMENT STRATEGIES

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SUMMARY: Solid waste management is changing and evolving rapidly which makes it the subject of many debates. Waste management in developed countries is governed by legislation. The main environmental objective is to reduce the amount of waste generated. However, even after this has been achieved, waste is still produced. Is then necessary to manage the waste in an environmental sustainable way by minimising the environmental impacts associated to waste. Life cycle assessment (LCA) is an emerging environmental tool that attempts to predict the overall environmental impact of a system (product or service), that makes it applicable to waste management systems. In this communication, an overview of LCA methodology and one possible way it could be applied to waste management practices is presented. This methodology is based on ISO 14040.

1. INTRODUCTION

Municipal solid waste includes all solid materials useless or unwanted resulting from human activities and discarded by man. Disposal of municipal solid waste starts to be a problem when the amount and the environmental effects of such disposal arise and become a health risk for life on earth. Is then very important to improve management solid waste systems.

The functional elements of a solid waste management system include wastes handling and collection, separation, processing and transformation, and final disposal. Separation could occur before and/or after collection. Processing and transformation includes recycling, incineration and composting. The final disposal is landfilling.

In order to evaluate the environmental burdens associated with waste management, each functional element has to be evaluated in terms of materials and energy consumption and emissions released and products recovery. This analysis allows the development of an environmentally sustainable system for solid waste management i.e. a system that reduces as much as possible the environmental impacts of waste management (White et al, 1995).

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2. LIFE CYCLE ASSESSMENT

Life cycle assessment (LCA) is a technique for assessing the environmental aspects and potential impacts associated with a system (product system or service system) by: (i) compiling an inventory of relevant inputs and outputs of the system; (ii) evaluating the potential environmental impacts associated with those inputs and outputs; (iii) interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study (ISO 14040, 1997).

The system is the collection of materially and energetically connected processes, which performs one or more defined functions. On waste management the systems are the disposal options that are assessed in a relative way, i.e. comparing alternative systems for the objective function: waste disposal, and environmental burdens associated.

Life cycle assessment includes (Figure 1):

- definition of goal and scope,
- inventory analysis
- impact assessment
- interpretation of results

2.1. Definition of goal and scope

Definition of goal and scope is the first step of a LCA study. Both should be well defined as they state the ultimate goal and detail of the study.

The goal of an LCA includes: the intended application, reasons for carrying out the study and the intended audience (ISO 14040, 1997).

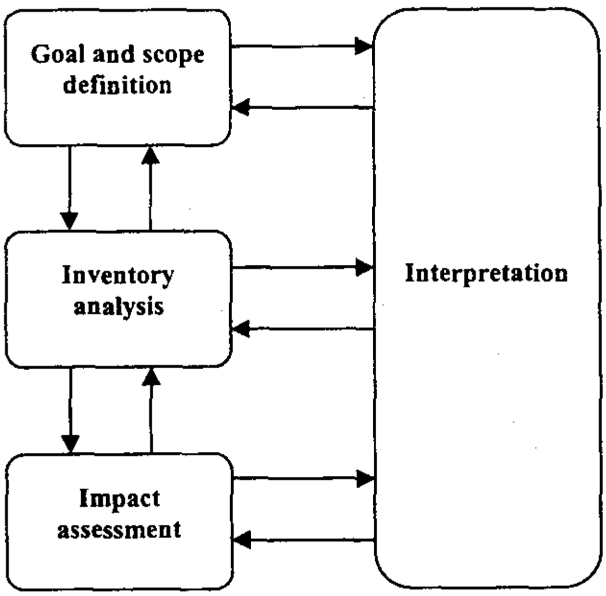

Figure 1. Phases of a life cycle assessment study.

When defining the scope, it should be noted that being LCA an iterative technique, it could be modified during the study as the informations are collected.

On waste management, the goal definition basically defines the options that will be compared and the intended use of the results. Usually, the goal is to compare incineration, landfilling and recycling.

The scope definition is strictly associated with the breath, the depth and the detail of the study. The following items shall be considered and clearly described.

2.1.1. Function

The function of systems under comparison, is the purpose for which they are designed. In the case of waste management is to disposal waste in a sound environmental way. It is important to note that in some cases, a complementary or secondary function is performed as energy production on incineration plant or materials recovery on recycling units. On these cases, the system model must be incorporated with a credit for the emissions that are avoided by this additional function of the system. The energy production from a conventional source and the extraction of raw materials should be included on the respective systems of incineration and recycling with a negative value.

2.1.2. Functional unit

The functional unit is the reference unit of systems inputs and outputs i.e. the unit whose environmental impacts will be defined, usually expressed as an amount of product or material. Examples of functional units on waste management are unit weight of municipal solid waste, unit number of «household equivalents» of solid waste collected, quantity of solid waste collected from a given geographical area.

2.1.3. System and System boundaries

For each system, the main life cycle stages are defined and should include the stages of each option. For instance, on incineration, one should include:

- transport,
- combustion,
- gas cleaning,
- energy recovery,
- ash stabilisation and
- solid wastes landfilling;

and, on landfilling:

- transport,
- landfilling operations,
- leachate treatment,
- gas treatment and
- energy recovery.

On recycling, besides transport, the recycling process itself and wastes treatment.

System boundary is the interface between the system and the environment. The environment is the source for all inputs and a sink for all outputs from the system. Systems should be modelled in such a way that inputs and outputs at its boundaries are elementary flows, i.e. material or energy flows entering or leaving the system without subsequent human transformation. System boundary generally includes process sequence, transport operations, generation of energy and raw materials production.

The scope of the study should also include allocation procedures, types of impact and the methodology of impact assessment and subsequent interpretation to be used, data requirements, assumptions, limitations and data quality requirements (ISO 14041, 1998). These will be not discussed here.

At this stage, each system should be well defined as a sequence of unit processes and related inputs and outputs identified. Figure 2 presents the general template.

3. INVENTORY ANALYSIS

Inventory analysis involves data collection and calculation procedures to quantify relevant material and energy inputs and outputs of the systems (ISO 14040, 1997). For each unit process included in the system, use of resources and energy and emissions associated are identified and quantified. Data collection is the most time consumption task of a life cycle assessment. Data are categorised as primary and secondary: primary data are plant-specific or process specific data, which the LCA practitioner can directly access or influence the data collection process. Secondary data are publicly available data whose have not been collected specifically for the purpose of conducting LCA's and for which the LCA practitioner has no input into the data collection process. On waste management, and for each system, inputs and outputs have to be quantified.

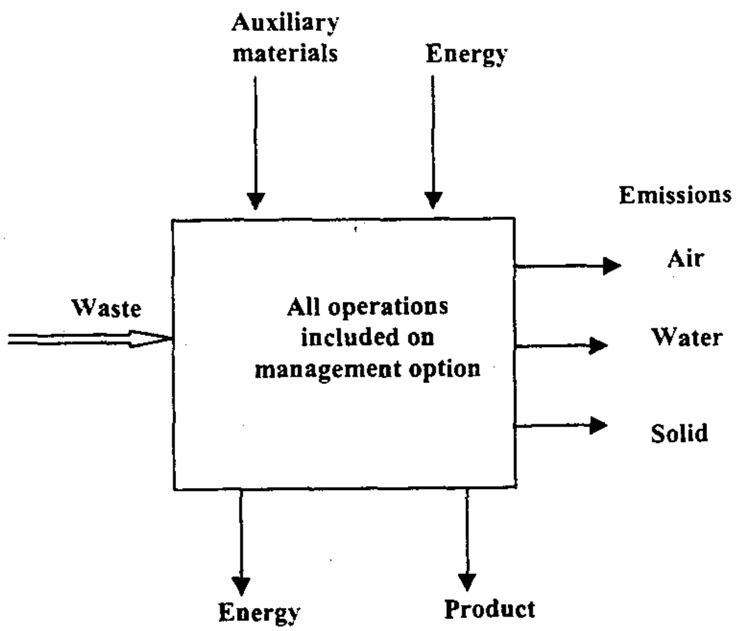

Figure 2. General template for waste management options.

On incineration, inputs includes:

- mixture of wastes,

- materials for flue gas treatment and ashes stabilisation,
- energy for transport and other operations;

and, outputs:

- air emissions from stack,
- water emissions,
- stabilised solid wastes,
- energy recovery.

On landfilling inputs are:

- mixture of wastes,
- energy for transport and other operations,
- auxiliary materials for leachate and gas treatment;

and, outputs:

- air emissions from gas emission after treatment,
- water emissions,
- inert solid wastes,
- energy recovery.

At this stage, all inputs and outputs flows for each unit process of each system are defined and quantified.

4. IMPACT ASSESSMENT

Impact assessment stage aimed at evaluating the significance of potential environmental impacts using the result of the life cycle inventory analysis (ISO 14040, 1997). On impact assessment stage, environmental burdens are translated to potential environmental effects or impacts. This means that, each inventory item, such as SO_2 emission, CO_2 emission, coal use, is translated to environmental impact or effect such as acid rain, acidification and habitat alteration.
The methodological and scientific framework for impact assessment is still being developed.

The general framework of life cycle impact assessment (LCIA) stage is composed of several mandatory elements that converts LCI results to indicators results. The mandatory LCIA elements are (ISO/DIS 14042, 1998):

- selection of impact categories, category indicators and models,
- assignment of LCI results (classification) to impact category,
- calculation of category indicator results (characterisation).

Impact categories are by definition the class representing environmental issues of concern into which LCI results must be assigned. Category indicator is a quantifiable representation of an impact category and the category endpoint is an attribute or aspect of natural environment, human health or resources, identifying an environmental issue of concern for example forest and vegetation.

Impact categories are considered as having a global, continental, regional and local effect. The selected impact categories should be consistent with the goal and scope of the study. Examples of these impact categories are (White et al, 1995): depletion of non-renewable resources-global, global warming-global, ozone depletion-global, human toxicity-continental/regional, acidification-continental/regional, noise-local and smell-local. On waste management studies, besides the large scale effects impact categories, also local effects must be considered.

5. INTERPRETATION OF RESULTS

Life cycle interpretation is the last phase of a LCA study. The data from the inventory analysis and impact assessment are analysed, discussed and evaluated in order to enable conclusions and recommendations to be used by decision-makers.

Life cycle interpretation comprises three elements (ISO/DIS 14043, 1998):

- identification of significant issues,
- evaluation and
- conclusions, recommendations and reporting of the significant issues.

Identification of significant issues is based on the inventory and impact assessment results, that can be inventory parameters, impact categories indicators or unit processes, accordingly with the goal and scope of the study. On waste management, if local impact categories are determinant, these should be considered as significant issues.

Evaluation is made to establish and enhance the confidence and reliability of the study. Evaluation should include the following checks:

- completeness, to ensure that relevant information and data needed is available and complete;
- sensitivity, to assess the reliability of the results, assessing the influence of uncertainty on conclusions;
- consistency, to determine whether the assumptions, methods and data are consistent with the goal and scope.

This is obviously an important role on the life cycle assessment study credibility and utility.

On waste management strategies. since data for emissions and allocation procedures are still under development, this phase could have a great influence on the study results.

6. CONCLUSIONS

An overview of LCA methodology based on ISO 14040 to apply on waste management practices is presented. Further developments are needed on standardised methods for this application in order to create credible procedures for helping on decisions-makers with responsibility on setting up environmentally sustainable systems, mainly at local level, where decisions are taken. LCA is a potential tool for this development. Special care should be taken on the interpretation phase, since, due to the lack of data, assumptions and significant issues definition play an important role.

7. REFERENCES

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