EV5V - CT94 - 0383

EVALUATION OF TECHNICAL PRIORITIES FOR THE TREATMENT OF INDUSTRIAL WASTE

SUMMARY FINAL REPORT

MARCH 1996

Key Words : environmental impacts; life cycle analysis; waste treatment; impact pathways.

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I. OBJECTIVES

The effective management of wastes throughout the world is a challenging and complex problem. Faced with extensive diversity within the waste streams, variable treatment processes, methodologies and capacities, as well as fluctuating economic and social conditions, both government regulatory agencies and waste management specialists, public and private, must find the means to balance and optimise the decision making process in order to effectively manage wastes.

Life Cycle Assessment (LCA) has emerged as a useful tool for compiling and presenting information on resource use and environmental impact in a way which can be used to support decisions, including decisions over waste management. LCA strives to calculate the global environmental impacts associated with a particular material or product - such as packaging - from primary raw materials or resources, through utilisation, to waste for final treatment or disposal. Impact Pathway Analysis (IPA) has emerged as an approach to assessing the effects of environmental emissions which considers localised effects rather than the « globalised » impact assessment part of Life Cycle Assessment. In developing this research, the critical question was posed : can we use Life Cycle Analysis (LCA) and Impact Pathways Analysis (IPA) to evaluate the choice and implementation of different methods for treating various waste streams ? What are their particular roles in informing decisions ? Are they complementary, exclusive or even contradictory ? Are these techniques sufficient to assess the environmental impacts (including human health impacts) of waste treatment technologies and facilities ? Can these approaches provide a more rational alternative to applying the existing arbitrary waste treatment hierarchy ?

This research looked at three different case studies, each with different scenarios :

- LCA and IPA as applied to a treatment technology : incineration of waste ;
- LCA and IPA as applied to a product : used tyres ;
- LCA and IPA as applied to a generic material : waste plastic.

In each case two or three different scenarios were examined by LCA and by IPA, to assess their environmental impacts on local, national and international levels. The approach followed was :

- To identify, evaluate and assess the impacts from different treatment options by application of LCA and IPA ;
- To convert these impacts into transparent quantified effects ;
- To evaluate these methods as means to justify best practice in waste treatment, and to guide in selecting sites and in matching facilities to local conditions.

The research also looked at the methodologies themselves, evaluated their strengths and weaknesses and identified where further development was needed to operationalise them for waste management.

II. METHODOLOGY

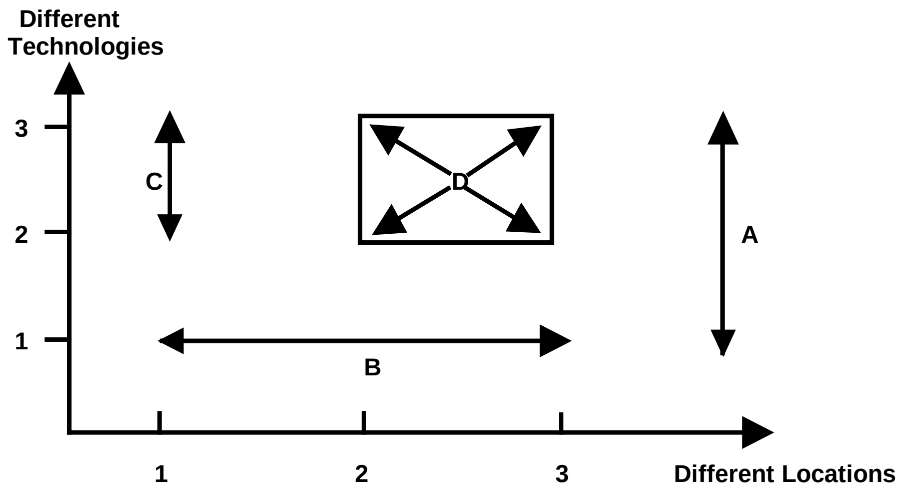
The work drew on current methodological developments in both Life Cycle Assessment (LCA) and Impact Pathway Analysis (IPA).

LCA and IPA are both tools to structure qualitative and quantitative information on environmental impacts in ways which aid decision-making. The two approaches, start from the same facts on resource use and emissions although IPA only uses a subset of the data forming the Life Cycle Inventory. They use different information on the environmental processes involved, and are therefore to be applied in different ways and in different applications. The differences between the uses of the two approaches are illustrated in Figure1.

Life Cycle Assessment starts from a “cradle-to-grave” analysis, which follows all the material and energy flows associated with a human activity from the “cradle” (primary resources such as minerals or fossil fuels) to the “grave” (emissions and inert waste), to quantify the resource usages and environmental emissions (see Section 3.1.1). Although part of the Life Cycle (the “Foreground” or “Core” system - see Section 3.1.2) may be in a known location, the emissions from the processes making up the rest of the Life Cycle are not geographically localised. Therefore the environmental effects of the emissions can only be assessed in terms of their potential global impacts (see Section 3.1.3). For this reason, LCA is best suited to generic comparison of alternative technologies to be used at unspecified locations. This is shown as Case A in Figure 2.1.

Impact Pathway Analysis, by contrast, starts from information on the environmental emissions from a specific installation in a specified place. The starting point for IPA is therefore a subset of the information used in the LCA, representing only the emissions from the Foreground system. IPA examines the dispersion of these emissions in the environmental medium to which they are released, possible transfer to other media, and their take-up by humans or other living “receptors”. IPA has been developed primarily for use in supporting decisions over the siting of a predetermined plant or process, corresponding to Case B in Figure 2.1, where only local environmental impacts are considered. A comparison between LCA and IPA results should thus concentrate on the site-specific elements. However, in this work the use of IPA for background processes was also investigated by a “uniform world” model with an appropriate population density.

Decisions over waste management are not always as simple as Cases A and B. It may be necessary to select a technology to be used on a known site - i.e. Case C in Figure 2.1. More generally, the decision may involve selection of both the technology and the siting of an installation to treat a waste stream ; this is shown as Case D in Figure 2.1. Cases C and D involve both geographically localised impacts and impacts and resource usages arising at unspecified sites elsewhere in the Life Cycle ; i.e. they should involve elements of both Life Cycle Assessment and Impact Pathway Assessment.



A. Established application of Life Cycle Assessment (LCA).

B. Established application of Impact Pathway Assessment (IPA).

C. Requires both LCA and IPA.

D. Requires both LCA and IPA.

↔ Choice to be supported

Fig.1. : Application of Life Cycle Assessment and of site-specific approaches such as Impact Pathway Analysis (adopted from a suggestion by Dr. G Huppes).

The work was used as an opportunity to test the System Extension approach to avoiding Allocation in LCA. Materials and energy recovered from the waste were assessed by crediting the system with the burdens from activities displaced by their recovery. The total Life Cycle Inventory then comprised direct burdens from the plant itself plus indirect burdens associated with provision of materials and energy to the plant minus avoided burdens describing the “environmental credits” for material and energy recovery. This also enabled the Inventory to be used as the basis for IPA : the direct burdens arise at a known location so that their effects on human health can be assessed in the usual way, whereas indirect and avoided burdens are not localised and can therefore only be assessed by some “uniform world” approach. A detailed local IPA was only carried out for one case, a waste incinerator located in a suburb of Paris. All the other processes were evaluated at a more general level, although the population densities exposed to the direct and to the indirect and avoided burdens were not necessarily the same.

III. MAIN RESULTS

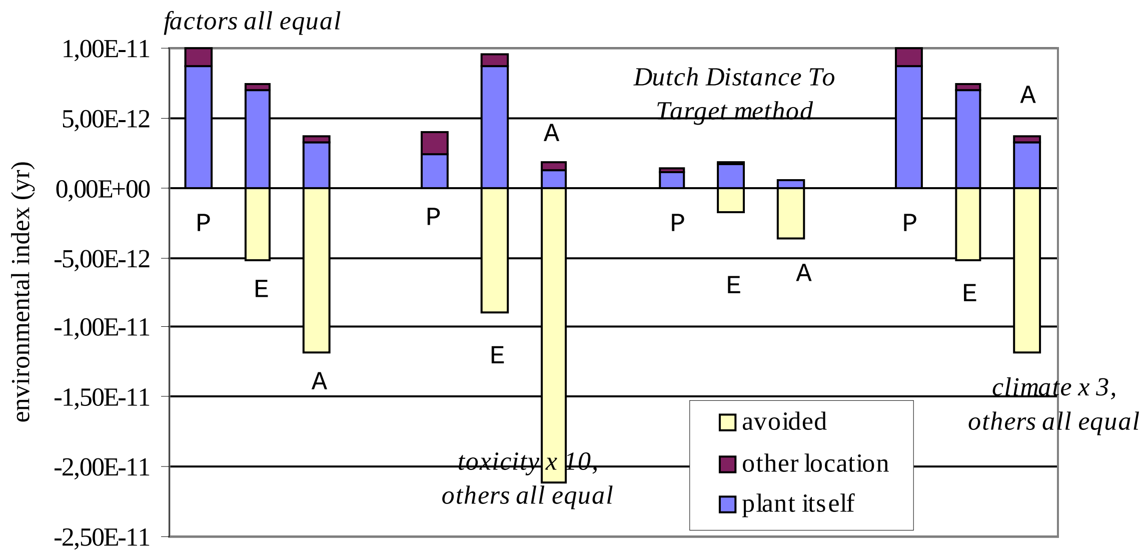
The quantitative results refer to three cases :

Incineration of household, hospital and industrial wastes.
The analysis was based on three plants for which data were available, located in France, Portugal and the Netherlands.
Treatment of a specific product : waste tyres.
Three treatment processes were studied : incineration, pyrolysis, and incineration in a cement kiln. This part of the research was based on data from UK.
Treatment of a generic material : plastic waste.
Pyrolysis and incineration were studied, on the basis of Dutch data.

For each case study, the results were to provide both a comparison between different technologies and a comparison between the two methodologies.

III.1. LCA Results

Figure 2 below is shown as an example of LCA results. For the presentation of the LCA results, the figures are separated into four items : firstly the « plant itself », which represents the actual emissions at the waste treatment site. Secondly, the « other location », corresponding to the background emissions associated with materials and energy used in the treatment process ; thirdly, the « avoided » items, which represent the reusable energy and materials. The □total□ figure is the sum of these three.



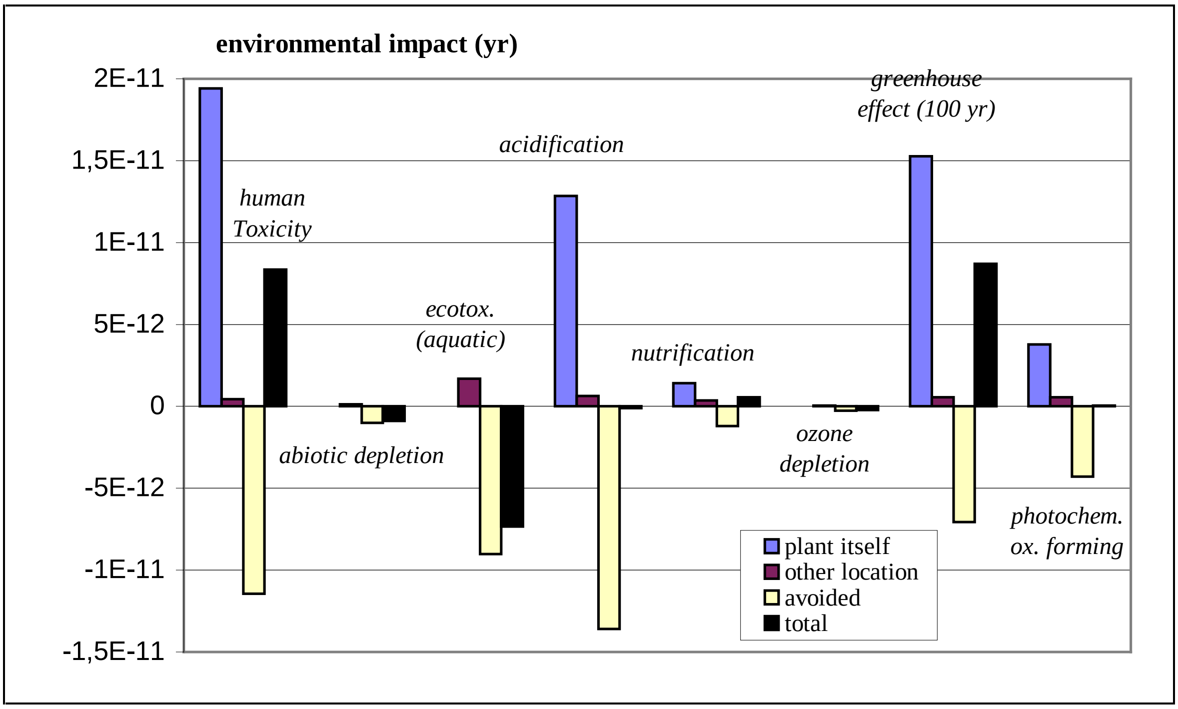


Fig.2. : LCA Results for the incinerator located in the Paris region,
environmental themes.

As can be seen, the emissions are grouped into a number of recognised impact categories : human toxicity, abiotic depletion, ecotoxicity, acidification, nutrification, ozone depletion, greenhouse effect, photochemical oxidation. It can be seen that reusable materials (shown as bars below zero) have a substantial magnitude, related to the contributions of the waste incineration itself. However, the impacts associated with materials and energy supplied to the plant are very small, and this conclusion applied to all the cases studied. Overall, the findings show the importance of including material and energy recovery, and the value of the “avoided burdens” approach to describe them.

Weighting scenarios were then applied to these results *illustratively*, in order to obtain insight in the sensitivity to subjective weighting factors. Figure 3 shows the weighted results for the three incineration plants, according to four different sets of relative weights. The LCA approach is seen to provide a clear comparison between the three processes. For these cases, the Dutch AOO technology appears to give the best performance. However, this is not a true comparison, since the operations for which data were available referred to different waste streams at the three sites. The results in Figures 2 and 3 are therefore to be interpreted as providing illustrations of the methodology rather than evaluation of the three processes.

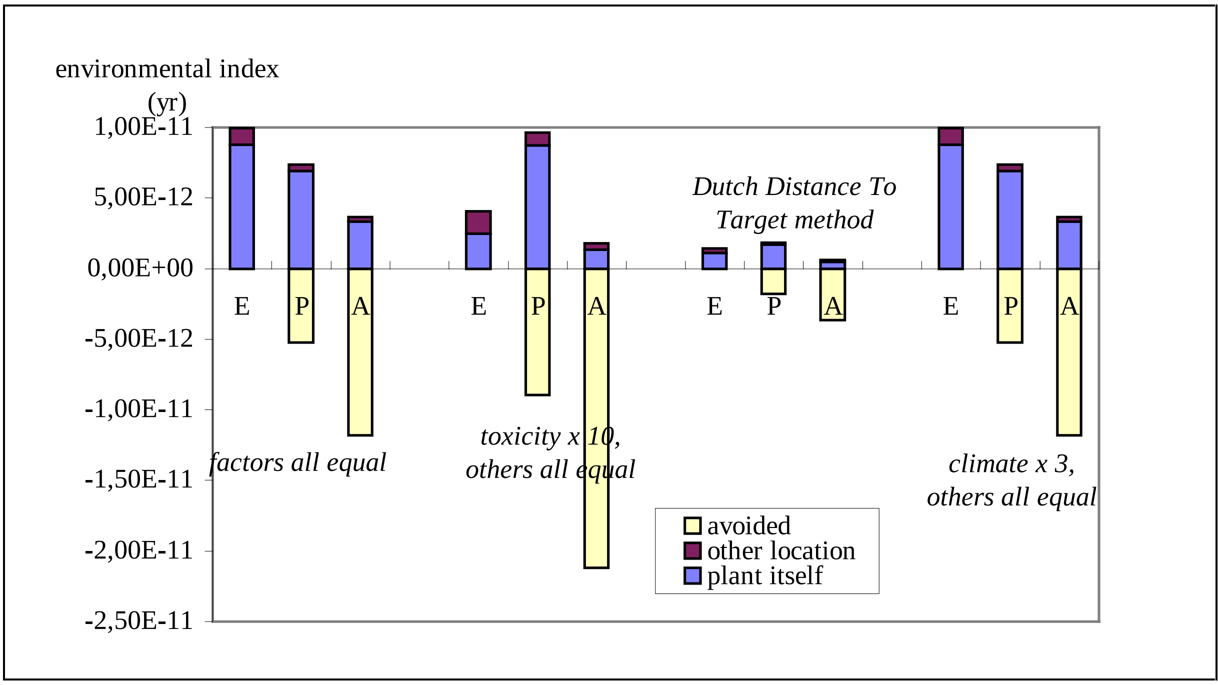


Fig.3. : Comparison of three incineration plants environmental performances, according to four weighting scenarios. E : Estarreja (Portugal) ; P : Paris (France) ; A : A.O.O. (The Netherlands).

III.2. IPA Results

Figure 4 shows the results obtained by applying IPA to the emissions from the Paris plant. For the toxic emissions, the predicted human health impacts are expressed as expected mortality. They were also expressed as economic costs - in effect, a kind of weighting system - using a notional figure of 2.6 million ECU as the value of a human life. For the local impacts, the "costs" of morbidity. Impacts proved to be much smaller than mortality. Thus, morbidity was therefore not considered for the other cases. The estimates of the "cost" of carbon dioxide emissions were obtained from a different project (Extern E) and cover a range of impacts dominated by effects other than mortality. It is particularly significant that the dominant impacts result from particulate emissions, whose effects are not usually assessed in LCA. Particulates proved to dominate the human health impacts for most of the processes considered. Including the avoided impacts reduced but did not completely offset the human health impact of particulates over the whole Life Cycle.

Pollutant	Emissions (kg/ t waste)	Impact (deaths / t waste)	Cost (ECU/t waste)
Particulates	0.43	2.6 E-05	68.0
CO_2	577.8	(1)	8.1
SO_2	0.15	6.04 E-08	0.16
NO_x, NO_2 equiv.	0.79	1.54 E-07	
Cd	0.0005		0.044

Fig.4. : Incineration on Paris plant - Foreground emissions, impacts and damage costs.

1 At the present time there are not plausible values for mortality impacts of global warming ; current consensus values for ECU / t of CO_2 include some mortality but are dominated by other costs. The corresponding values for Deaths / t waste have been removed.

IV.SCIENTIFIC INTEREST AND POLICY RELEVANCE

IV.1. Scientific interest

Both Life Cycle Assessment and Impact Pathway Analysis have roles in guiding decisions over waste management. LCA should be used at the policy level, to compare technological alternatives. The system boundary must be drawn sufficiently wide to incorporate the effects of recovering materials or energy from the waste, to express the resulting “environmental credits” as avoided burdens. It is helpful to distinguish between the Foreground System (comprising the waste treatment operations themselves and all related operations affected by the decision) and the Background System (comprising activities which exchange materials and energy with the Foreground but are otherwise unaffected by the Foreground System). This distinction simplifies collection of data for the Inventory, and also identifies explicitly those direct emissions from the Foreground System whose location is known and which can therefore be treated by impact pahtway analysis. To the list of burdens normally covered by the Life Cycle Inventory, the research has identified atmospheric emissions of particulates as an important component which must be considered in the future.

Impact Pathway Analysis can be used to guide decisions over the siting of waste treatment facilities, and over the selection and use of pollution abatement processes. IPA is at present limited to scope, considering only the human health effects of emissions released to and dispersed in the atmosphere. Within this category, impacts are dominated by mortality, with morbidity negligible by comparison. IPA is best suited by examining the local impacts of emissions from the plant itself, and this is a further reason for making the distinction between Foreground and Background Systems. Foreground impacts can be based on local meteorological conditions and population distribution. Emissions from the Background System (allowing for avoided burdens) can only be estimated in a more general way using a “uniform world” model with an appropriate average population density. At this level of assessment, the health impacts estimated for the LCA approach and by IPA should correspond. The ranking of pollutants for the two methods is broadly consistent, with the exceptions of particulates (omitted from LCA) and dioxins (currently given more weight than IPA). However, IPA currently covers a small range of pollutants, and this needs to be extended. IPA should also be developed to cover other media and inter-media transfer, an approach which is being explored already in LCA.

IV.2. Policy relevance

All three cases illustrate the importance of having data whose reliability and representativity is known, and of allowing for the environmental credits quantified through avoided burdens. For selection of the best technology, this turns out usually to be more significant than direct emissions from the Foreground process. However, neither approach necessarily leads immediately to identification of the preferred option. In LCA, ambiguities can arise because the ranking of the possible options is different in different impact categories. Because IPA only considers one impact category it hides this ambiguity, but introduces another one as the relative weighting to be attached to localised impacts of emissions from the plant itself versus generalised emissions from the Background. These two kinds of ambiguity are inherent in the two approaches, and they show the need for an agreed approach to weighting impacts which differ qualitatively and geographically.

Further research should be devoted to systematic comparison of processes for treating a waste stream with a single representative composition, using the methodologies explored on this work but examining the significance of a full range of operations including collection and landfilling, and examining systematically the sensitivity of the comparison to the weighting factors used.