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Unit Production Indices of Hazardous Waste Generation for Measuring Environmental Performance

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SUMMARY : A series of governmental and industry initiatives have led to the need for environmental quality indices against which industry can measure their performance in the field of hazardous waste management. The National Waste Database project is developing a database of information on the generation of hazardous waste. This paper identifies possible indices that will be able to be derived from this information and which may be suitable measures of environmental performance for industrial facilities. The Database and information derived from it will also provide data for the application of materials flux analysis to the preparation of regional environmental management plans.

1 INTRODUCTION

Increased awareness of the need to maintain and enhance environmental quality has led to the development of processes such as the Ecologically Sustainable Development (ESD) consultations, and subsequently to a series of strategies to improve environmental quality. Government initiatives in this area include :

- The Intergovernmental Agreement on the Environment (IGAE, 1992))
- State of the Environment Reporting
- The proposed National Pollutant Inventory (NPI)
- The National Waste Minimisation and Recycling Strategy (1992)

Industry has also initiated environmental improvement programs amongst various Industry Association members, sometimes in advance of government incentives. Important recent initiatives in the area of hazardous waste include :

- ACIC (Australian Chemical Industry Council) Responsible Care Program
- ACM (Australian Chamber of Manufactures) Best Practice Environmental Management Program

All of these programs have environmental improvement objectives and require, implicitly or explicitly, the development of environmental quality indices against which performance can be measured. It is important to develop rational measures so that benchmarks can be established and facilities can measure their improvement over time, against both their own and industry-wide standards.

Many areas of human activity demonstrate the power of monitoring and feedback in influencing behaviour towards desired ends, including the field of waste minimisation (Hirschhorn, 1991). This means that the establishment and monitoring of environmental quality indices itself is likely to result in improved performance,

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through simple actions of "paying attention" to the processes related to the environmental quality index, or in, in reverse terms, Eisenhower's words "the uninspected inevitably deteriorates".

This paper examines possible environmental quality indices which may be appropriate in the field of minimising the potential for environmental degradation from hazardous waste generation by industry, utilising information which will become available as the National Waste Database becomes established. A brief introduction to the National Waste Database is provided before possible indices for individual industrial facilities are described. The paper concludes by illustrating how the information from the Database and the derived indices could be used in the development of a single environmental quality index and a regional waste management model, using the Materials Flux Analysis tool (Baccini & Brunner, 1991) described in the complementary paper for this seminar.

2 THE NATIONAL WASTE DATABASE PROJECT

2.1 Background

The governmental initiatives described in the Introduction, other recent waste management policies such as the Kerbside Recycling Strategy (1992) and the ANZECC National Packaging Guidelines (1991), a series of policies developed by the Ecologically Sustainable Development consultation process in Australia, and Australia's participation in the development of Agenda 21 (UNCED, 1992) will all require the establishment of national waste monitoring and database systems.

Some policies such as the National Waste Minimisation & Recycling Strategy have already set targets to be met within specified time frames (reduce solid waste being disposed to landfill by 50 % by the Year 2000, compared with 1990 levels), while others require the establishment of monitoring systems and subsequent formulation of goals as typified by the following recommendations in Agenda 21 (UNCED, 1992) :

- " To strengthen procedures for assessing waste quantity and composition changes...by the year 2000, governments should ensure the capacity to assess and monitor waste trends and to have established waste reduction programs."

- " Reduce the production of wastes destined for final disposal according to formulated goals, based on weight, volume and composition."

2.2 Project Need

An examination of the current state of waste data collection and reporting in Australia (CRCWMPC, 1992) has highlighted how inadequate current systems are in meeting the demands placed on them by the new and developing waste policies described above. There is an urgent need to develop uniform methods of classification, data collection and storage so that the target setting and monitoring demands of these waste policies can be met.

2.3 Aim and Objectives

The aim of the project is to establish a database on waste generation in Australia which can be used by State and Commonwealth environmental and waste management agencies, and other interested organisations to set and monitor the achievement of national waste minimisation targets.

To achieve this aim, the following objectives will need to be met:

(a) Review and establish nationally agreed classification systems for various groups.
(b) Establish a protocol for sampling and characterising urban solid wastes.
(c) Establish a national waste generation database to provide fundamental information on the generation of different types of waste by region and in relation to relevant parameters.
(d) Review Australian and overseas waste generation trends and suggest waste minimisation benchmarks for each waste type by region.

The Database will cover both solid waste (non-hazardous waste arising from municipal, commercial, industrial, building and demolition activities) and hazardous waste (generally liquid industrial wastes which are precluded from disposal to the sewerage system) disposed to off-site treatment and disposal facilities. Details of the solid waste component are provided in a recent paper by Moore et al (1993), and are related to, but are not the focus of this paper. Database activities related to the hazardous waste field are described in the remainder of this section.

2.4 Hazardous Waste Component of the National Waste Database

Hazardous wastes for the purpose of the National Waste Database are those wastes which are not allowed to be disposed of to the sewer or to municipal solid waste landfills, and if the generator has no means or treating and disposing of them on-site, they must be tankered to an off-site treatment plant. Each State has their own regulations defining hazardous wastes, sometimes by the use of "Prescribed Waste lists". Most of the major metropolitan areas in Australia have established manifest systems which track and record the transport of these hazardous wastes from the generator to the treatment plant, and in so doing build up a database of information on their generation.(see Figure 1)

Different classification systems have been used to characterise the manifested wastes, with the 1986 AEC system being the basis of the systems used in Sydney, Victoria and S.A., and simpler lists being used in Brisbane and Perth. ANZECC is currently revising the AEC classification system for use in a National Manifest System which will facilitate the transfer of hazardous wastes between States and which will enable data from different States to be compared.

The National Waste Database project, in the hazardous waste field, will :

- Contribute to the revisions to the hazardous waste classification system being undertaken by ANZECC, by suggesting structures and details which will inherently improve the integrity of the data (removing potential ambiguity) and enable the Australian system to be directly compared to International systems developed by the OECD and UNEP.

- Obtain aggregated monthly data on the generation of each type of hazardous waste in each region covered by a manifest system and using the national hazardous waste classification system. Data will be aggregated by industry type using 4 digit ASIC (Australian Standard Industry Classification) codes, which are entered onto the manifest forms and subsequently into the manifest database.

- Transfer the monthly data into a relational database, such as dBASEIV, with the waste entity having attributes of waste type (using the revised ANZECC classification system), waste quantity, month generated, ASIC code of generator, treatment type provided, and region in which generated.

- Generate standard reports on the generation of waste types in each region on a routine basis and prepare special reports on request. The design of these reports will be developed through initial consultation with users, followed by trialing and refinement. Preliminary examples are shown in Figure 2.

With the exception of leaching tests for determining the hazardous characteristics of wastes, sampling and analysis protocols for hazardous wastes are unlikely to require the attention and development that will be devoted to solid wastes.

2.5 Linkages to Other Databases

The hazardous waste database will be a sub-set of the proposed National Pollutant Inventory (NPI), which will attempt to record all emissions from facilities in a similar manner to the US EPA Toxics Release Inventory. NPI data will have to be aggregated by region to enable it to be complementary with data from the National Waste Database. This will be easily achieved as the NPI will know either the exact location of the facility (from a GIS) or at least its postcode.

An important link to the extensive ABS database is via the ASIC code. This will enable relationships between waste generation and a range of standard economic and demographic statistics to be investigated. It is these relationships which could form the basis of a series of Unit Production Indices of hazardous waste generation that could be useful measures of environmental performance in regions and in industry groups.

3 UNIT PRODUCTION INDICES OF HAZARDOUS WASTE GENERATION

3.1 Existing Practice

Currently, monitoring and reporting of hazardous waste generation consists of graphs of total waste generation in a region over time (Figure 3 & 4), or tables of major waste types (Table 1). Occasionally relationships between GDP and total hazardous waste generation are used to compare countries (Figure 5). These are very useful but coarse measures of trends in hazardous waste generation and do not readily enable detailed comparison among cities.

In Australia there have been only two isolated published analyses of the relationship between hazardous waste generation and what would be regarded as significantly related factors; the relationship between hazardous waste type generation and population in Australian cities in 1989 is illustrated in Figure 6 (Joint Taskforce on Intractable Waste, 1990), and the relationship between hazardous waste type generation and production employees in various ASIC industry groups in Sydney in 1990 is illustrated in Table 2 (Moore & Chelliah, 1992). These analyses were undertaken as part of studies to estimate quantities of hazardous wastes generated in regions of Australia not yet covered by a manifest system. They point to the potential, however, to develop rational and meaningful indices of hazardous waste generation.

3.2 Objectives for Environmental Quality Indices for Hazardous Waste

Appropriate objectives for environmental quality indices for hazardous waste generation by industry would include :

- the ability to relate hazardous waste generation to causative factors such as population, production employees in different industry groups, value added in different industry groups, quantity of product in industry groups.

- the ability to set and monitor targets for generation of different waste types for individual industry groups, and to be able to establish benchmarks for individual facilities to aim for in those industry groups.

- the ability to develop quantitative criteria and possibly one index for an industry group or individual facility to aim for, ie to go beyond waste minimisation of total hazardous wastes in general terms towards rationally developed criteria which specify how much of each type of waste should be the target generation rate for each industry/facility.

Ideally there would be an "Environmental Quality Index (EQI) function" for hazardous waste minimisation which would allow individual facilities to determine which mix of reductions of the various waste type quantities per unit production would yield the best improvement in environmental quality (maximise the EQI function) for a given investment. Furthermore, if this EQI for hazardous waste minimisation was developed through industry/government/community consultation, industry would have the opportunity of arriving at an agreed outcome via a process developed by themselves which best met the varying constraints on individual facilities. This would avoid the problems which will inevitably be encountered in trying to implement blanket targets such as reducing all waste by 50% by a specified date.

3.3 Suggestions for Hazardous Waste Indices

By linking the hazardous waste generation module in the National Waste Database with the ASIC related information from ABS, it should be possible to derive the hazardous waste indices described below. The limitations of each are also outlined.

- *Annual quantity of each hazardous waste type per head of population in a region*. This is illustrated in Figure 6 and suffers from the limitation that most waste types will be related to industrial activity and will only indirectly be related to population. However, some waste types such as oils, oily water and grease trap waste may show a stronger correlation to population than industrial activity in some regions.

- *Annual quantity of each waste type per production employee in each ASIC industry group*. An example of this is shown in Table 2, and similar tables for each year will be generated by standard reports from the National Waste Database for each region which adopts the ANZECC National Hazardous Waste Classification and Manifest system. Currently this is limited to Sydney, Victoria and South Australia, but should become more widespread from 1994.

  The index suffers from not directly allowing for the influence of increased productivity, ie if waste generation remains constant, an increase in productivity would imply an increase in waste generation per production employee. This could be allowed for, if productivity could be reliably measured by ASIC industry group and an adjustment made back to an index year of, say 1990. A related issue is the trend over the past decade to privatisation, both in the private and public sector; contracting out of support and service functions may move employees out of the waste generating ASIC group into another group, again leading to an incorrect result of higher waste generation per production employee. Production employees rather total employees are used in an attempt to avoid this difficulty, but the extent to which this is successful is uncertain.

- *Quantity of each waste type per $value added in each ASIC industry group*. This measure would overcome the productivity complication of the above measure and would yield some interesting answers or part answers to questions such as :

  - which industry groups generate the lowest waste per $ of value added ? An EQI function for hazardous wastes would be a necessary precursor to satisfactorily answering this question.

  - if agreement on a sustainable level of anthropogenic emissions to the environment of a region could be agreed to (emissions arising from hazardous waste generation being one of a number), what mix of industries would be best suited to that region and what is the optimum economy which could be sustained ? ie given the normal range of constraints that determine a limited range of alternative industrial mixes which could be developed in a region (supply of resources and skilled labour and market demands etc), which particular mix provides the greatest contribution to the economy within the environmental constraints imposed by sustainable hazardous waste and other waste emissions.

- *Quantity of each waste type per unit of goods (or services?) produced by the ASIC industry group*. This measure would be one of the most useful as it directly removes the uncertainty associated with the productivity of employees (including how much overtime that each employee might work). Appropriate units of production such as tonnes of steel produced, tonnes of aluminium produced, number of vehicles (or an equivalent standard vehicle which would account for differences between types of vehicles) should be able to be decided upon with advice from Industry Associations. This measure would be of particular use to individual facilities in monitoring their performance against waste minimisation benchmarks, and for industry and government in setting and monitoring benchmarks.

3.4 Form of the Environmental Quality Index Function for Hazardous Waste Generation

As indicated in the preceding discussion, all waste types are not equivalent in terms of their potential to cause environmental harm and there is a need to develop a single index or function which can give an overall measure for a variety of combinations of waste types produced in a region by an industry group, or an individual facility.

As a starting point for discussion, the authors suggest that the EQI function for hazardous waste generation in a region could be of the following form :

$$EQI_{hw} = \sum \{[X_i - a_i W_i]/X_i\} \qquad (1)$$

where X_i = the agreed sustainable load for generation of hazardous waste type i, at a standard water content

W_i = the generation rate of waste type i in the region

a_i = coefficient related to the amount of water in Wi, equal to 1.0 if the same as the standard content

n = the number of waste types in the ANZECC hazardous waste classification system, currently about 100

This function does not take any account of possible synergistic effects among different hazardous wastes. If the region had no generation of hazardous waste, then the EQI_{hw} would equal n, about 100. If all generation rates were less than the agreed sustainable load, then the EQI_{hw} would give a measure of the status of the region. A Target EQI_{hw} could be set and progress towards it monitored.

If $W_i > X_i$ for one or more of the waste types then the EQI_{hw} function (1) above cannot be used (one cannot have credits from one waste type transferred to another, eg one cannot conclude that it is acceptable to have 10 times the sustainable load of mercury being produced because there are no other wastes being produced). Instead, we now sum the negative components of (1) to give a measure of unsustainability.

X_i will depend on the capacity and type of treatment and disposal facilities in a region, particularly the residual emissions from these facilities, and on the nature of the receiving environment. As noted earlier in this paper, hazardous wastes are taken to be those wastes with hazardous characteristics requiring off-site treatment and disposal. On-site treatment and disposal of hazardous wastes and treatment and disposal of other wastes would need to be taken into account when determining what X_i should be. Alternatively, the EQI could be expanded in scope to cover some or all of these other waste groups.

4 CONCLUSION

The utility of the EQI function is dependent on the ability to determine X_i (even if/though we cannot determine X_i, EQI has use as a conceptual tool for discussion and consensus purposes). There are two approaches that are currently available to enable X_i to be determined (Baccini & Brunner, 1991) :

- Ecotoxicology
- or, Material Flux Analysis

Baccini and Brunner provide a discussion on the place of each of these approaches in being able to assess X_i and conclude that, for most waste types, the more pragmatic and simpler Materials Flux Analysis will be more appropriate, or will at least provide an alternate perspective. In the longer term ecotoxicology may be sufficiently developed to provide better estimates.

Materials Flux Analysis was developed by Brunner and Baccini and is described in Brunner's presentation to this seminar, and in other publications by these authors (1991, 1992). The reports from the National Waste

Database will facilitate the application of Materials Flux Analysis to waste and materials management in Australia.

If an EQI_{hw} could be determined for a region, we could, via a political process, arrive at a desirable Target EQI_{hw} . We would then have the problem of allocating this environmental quality resource amongst current and possibly additional future generators of hazardous wastes. This is essentially an economics problem, and standard and developing economics tools , using the various forms of hazardous waste indices described in Section 3.3 as measures of resource units, should be able to be used its solution. For instance, trading in rights to hazardous waste index units may lead to an efficient allocation of the environmental quality resource.

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ABBREVIATIONS

AEC	Australian Environment Council
ABS	Australian Bureau of Statistics
ANZECC	Australian & New Zealand Environment & Conservation Council
ASIC	Australian Standard Industrial Classification
CRCWMPC	Cooperative Research Centre for Waste Management & Pollution Control
ESD	Ecologically Sustainable Development
EQI	Environmental Quality Index
GIS	Geographic Information System
IGAE	Intergovernmental Agreement on the Environmental
NPI	National Pollutant Inventory
UNCED	United Nations Conference on Environment & Development

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Figure 1
Operation of Manifest System in Australia

(Source : Maunsell, 1991)

Figure 2
Example Reports from Trial Hazardous Waste Database

(These are preliminary figures and are subject to alteration as source data is checked and the Database becomes refined. They are provided to illustrate the sort of information that will become available from the Database. This data should not be used for any purpose other than that noted herein.)

Figure 3
Generation of Hazardous Waste in Sydney
(Source : WMA of NSW Annual Report, 1990/1991)

Figure 4
Generation of Hazardous Waste in Adelaide
(Source : SAWMC Anual Report, 1990/1991)

Figure 5
Hazardous Waste Generation in the Pacific Basin
(Source : Pacific Basin Consortium for Hazardous Waste Research, 1990)

Figure 6
Comparison of Hazardous Waste Generation in Australian Cities
(Source : Joint Taskforce on Intractable Wste, 1990)

Table 1
Quantities of Waste Types in Adelaide

(Source : SAWMC Annual Report, 1990/1991)

Table 2
Annual Quantity of Each Waste Type per Production Employee in Each ASIC Group in Sydney, 1990
(Source ; Moore & Chelliah, 1992)