URBAN SOLID WASTE CHARACTERISATION

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ABSTRACT : After introducing the scope of the Australian National Waste Database and some basic terminology, a review of approaches to waste characterisation is provided. The place of direct sampling and analysis is shown to be a part of a broader range of characterisation tools, each having an appropriate part to play in characterising waste streams.
Guidance, illustrated with examples from case studies, is then provide on the different components of a waste characterisation study; namely, sampling from a waste stream, sorting the sample into its component material types, undertaking physical/chemical analysis on these material types in order to derive the properties of the parent waste stream, and finally presenting the results in a form that can readily be entered into the Australian National Waste Database.

1 Background

1.1 The Australian National Waste Database

This paper reviews methods for characterising urban solid waste streams and describes the role that the Australian National Waste Database (DATABASE) project will play in this field.

The aim of the DATABASE 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. The project was initiated by, and is funded by, the CRC for Waste Management and Pollution Control Ltd (CRCWMPC) and the Environment Protection Agency (EPA).

To achieve the aim of the project, the following objectives have been set:

(1) Review and establish nationally agreed classification systems for various waste groups.
(2) Establish a protocol for sampling and characterising urban solid wastes.
(3) 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.

This paper is therefore concerned with the second objective of providing guidelines for urban solid waste characterisation. Details of activities on other objectives are provided in Moore et al (1994).

Data from waste characterisation studies can be entered into the DATABASE at two levels :

- Detailed "raw data" on the weight of each material type from every sort of waste samples.

- Summary statistical data on the material types in a particular waste stream studied. This is expected to be the major form of data input to the DATABASE initially.

Data supply specifications for both types of input are being prepared, and an outline of the more common summary form is provided in this paper. The "raw data" specification will be based on a prototype Database developed for a waste characterisation study of the Domestic waste stream in four Local Government Areas in the Eastern Suburbs of Sydney, undertaken as part of the DATABASE project.

1.2 Terminology

In order to describe waste, two concepts are required; waste stream amounts and the composition of those waste streams. The attributes of these concepts are shown in the standard waste classification system outlined in Tables 1 and 2, and described in detail in CRCWMPC (1993). In this paper, the methods to determine the composition of waste streams are described. This information should then be linked with waste stream amounts to fully characterise the waste stream; for example, in terms of weight of paper in a waste stream, or weight of paper generated by a meaningful unit, such as person or m2 of office space. Information on waste stream amounts may be obtained as part of the waste characterisation study, or from separate data collection on waste streams in regions to be undertaken for the DATABASE.

Table 1 : Draft Solid Waste Streams Classification system - Abridged

Processing/Disposal Route	**Waste Stream : Principal Source**	**Sub - stream 1 : Secondary Source**	**Sub - stream 2 Measurement/ Transport mode**	**Sub - stream 3 Material composition**
1 Recycling **2 Composting** **3 Incineration** **4 Landfill** **5 On-site**	**A : Municipal Waste**	**1 Domestic waste** **2 Other domestic** **3 Other Council**	0 Weighbridge 1 Truck count 20 Other	0 Mixed
	B : Commercial & Industrial	**X Waste Processing facility**		
	C : Building and Demolition			

Notes :

1 Those descriptors in bold to be the preferred minimum data collected on a daily basis at the gatehouse of the facility.

2 Other descriptors to be used selectively to suit local needs, or in total for intensive surveys or as technology becomes available to make comprehensive routine data collection feasible. Refer CRCWMPC (1993)

2 Approaches to Urban Solid Waste Characterisation

There are three methods for determining the composition of urban solid waste streams (Brunner & Ernst, 1986) :

- Waste Product Analysis
- Market Product Analysis
- Direct Sampling and Analysis

An outline of each of these methods, and an indication of when they should be used, is provided in this section.

2.1 Waste product analysis

In this method, the products of treatment processes such as incinerator bottom ash and flyash are analysed for various chemical elements. From a knowledge of the partition coefficients for these elements through the process, it is possible to infer the chemical composition of the raw waste stream. It is necessary to have a waste processing facility available, and to know the details of materials balances through it in order to apply this technique. Development of the technique is ongoing (Brunner and Schackermayer, 1994), and it offers a reliable and cost effective alternative to conventional direct methods where a suitable treatment process is available.

The Waverley Woollahra incinerator in South Sydney, for instance, could be used to reliably assess the heavy metal content of Sydney's waste streams from an analysis of the flyash from its electrostatic precipitators. Using the incinerator as an analytical tool to "prepare" a waste sample of some hundreds of tonnes for elemental analysis is cheaper, and far more reliable, than selecting a one kilogram sample for grinding and sub-sampling down to 1 -3 grams for analysis in the conventional direct method.

More recently, Brunner and Stampfli (1993) have undertaken a materials balance of a construction waste sorting plant, and, combining this with chemical analysis for selected elements in samples from inputs and products, have derived a "materials flux analysis" for the process. This provides efficiently obtained information on input waste characteristics by selective measurement of outputs. It also provides information on how the process might be changed or optimised to achieve certain objectives, eg the concentration of hazardous constituents in a certain fraction which can then be effectively and economically treated, and which leaves the remaining fractions "clean" for higher value reuse potential. Preliminary discussions have been held with a major construction company in Australia to undertake similar studies at construction waste sorting plants here. Brunner and Stamplfli (1993) emphasise the increasing importance that construction wastes are likely to play in our waste (and materials) management systems; both in terms of quantity, and changing quality as the waste arises from materials that have an increasing use of synthetics and potentially hazardous additives.

1.2 Market product analysis

In this approach, a materials balance is undertaken for a material in a region to derive the quantity of that material that would be expected to report to the waste stream. An example for paper in Switzerland is shown in the Figure 1 below. Extensive studies by Franklin Associates have been undertaken in the USA. The method is quick and can be undertaken at little cost where the data is available. Normally, this is limited to regions as defined by country borders, where the data is collected by a Statistics Bureau.

The method can provide a "back of envelope" check for direct waste sampling studies on the amount of major materials types in waste streams. If, for example, the amount of paper in the Municipal waste stream is reasonably well known, and we calculate the total amount of paper expected in all waste streams, it should be possible to derive an expected amount in the Commercial and Industrial waste stream, thereby providing useful information on where our paper recycling efforts should be placed.

The method is also likely to be of use for materials which make up a small % of the waste stream. Determining the amount of dry cell batteries, for instance, in direct sampling and analysis studies is either very unreliable or very expensive. Market product analysis, if possible at a regional level would give a quicker, cheaper and more reliable result.

2.3 Direct waste sampling and analysis

In this conventional approach, sampling from a particular waste stream in a region is undertaken before manually sorting it into its material types. Subsequently, additional physical and chemical analysis such as moisture content, density under standard pressures, specific energy (calorific value) and elemental analysis may be undertaken. This is the most common method employed in Australia, and may be the only method practically available for determining the material composition in some regions.

The remainder of this paper concentrates on the Direct Waste Sampling method. Its relative disadvantages in relation to determining elemental concentrations, and the amount of small % components in the waste stream should be borne in mind, and the possibility of utilising some of the developing methods described in this section should be considered in the preliminary design phase of waste composition studies.

3 Sampling from Urban Solid Waste Streams

3.1 Background

Almost all of the direct sampling and sorting studies that have been undertaken have been carried out on the Domestic sub-stream of the Municipal waste stream (refer Table 1 for terminology). There have been very few reported studies in Australia, or internationally, of the other waste streams. The study by Brunner and Stamplfli (1993) uses a Waste Product Analysis approach, and is exceptional in terms of detail provided. Preliminary, and generally not widely published studies, have been undertaken for :

- Other Domestic waste in Woollahra, and Commercial and Industrial waste from a tertiary institution (University of NSW) as part of the DATABASE investigations.
- Building and Demolition waste, and selected Commercial and Industrial waste streams by the former Waste Management Authority of NSW.
- General Commercial and Industrial waste in Melbourne for the Resource Recovery and Recycling Council of Victoria.
- Limited international studies on a range of industries for composition (Savage, 1993; Tseng, 1994) and for unit generation in kg/meaningful unit/week (Savage, 1993; Diserens, 1993).

An appropriate "meaningful unit" needs to be selected for undertaking these studies of other than Domestic waste streams. For instance, waste stream amounts and material type amounts/% per student, or patient or $ of turnover etc as appropriate to the process being studied. As with all waste composition studies, a range of factors relating to operational, institutional, policy and regulatory circumstances need to be documented so that the results of the study can be interpreted and compared with other studies.

The authors believe that the characterisation of Commercial and Industrial, and Building and Demolition waste streams is still in the research phase, and that the data on the variability of waste composition and amount in these streams is not sufficient to be able to develop confident sampling guidelines (ie we do not know what the distributions look like for these waste streams). In support of this, Klee (1993) in a study for the U.S. EPA concludes that :

" The assumptions of traditional sampling theory often are unjustifiable when estimating the quantity and composition of solid waste arriving at a given location, such as a landfill site, or at a specific point in an industrial or commercial process. "

Materials balance approaches at the regional and facility level may provide a better solution to the problem of understanding the characteristics of these waste streams.

3.2 Sampling from Domestic Waste Streams

Samples for analysis of material types by %, and by weight, may be collected from :

- The generator, prior to collection in compactor trucks. This has the advantage of providing detailed information on the distribution of waste composition from individual generators, and avoids the cross contamination associated with compaction in the collection vehicle. However, it is labour intensive and expensive, and inconvenient, to collect sufficient bins before the collection vehicle starts its round.

- The compactor truck at a landfill or a transfer station. In this case the sample needs to be mixed with a front end loader, and a 100kg size sample selected for composition analysis. Knowledge of the collection route of the compactor truck enables the data to be interpreted in terms of kg of waste produced per person or household, and in relation to socio-economic factors.

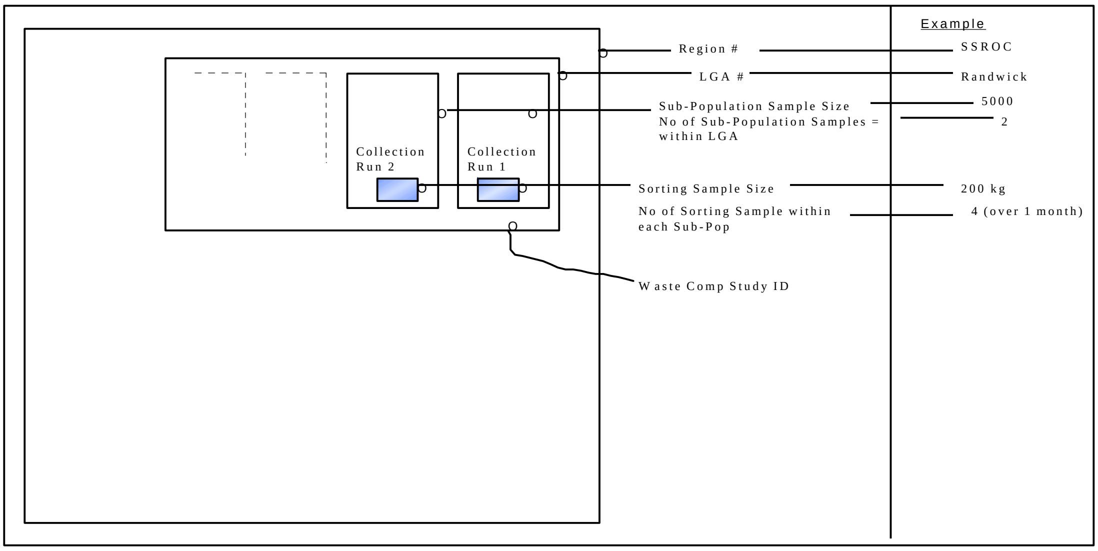
- From the bunker of an incinerator. In this instance a number of trucks from known collection routes can be required to dump in one area of the bunker, and the overhead crane can be used to mix the waste and to select a 100 - 200 kg sample for sorting analysis. This is the approach used in the Eastern Suburbs waste characterisation study. Parallel samples taken from bins were also undertaken to be able to compare the results from these two methods for the one generation area.

The intended use of the data needs to be borne in mind when deciding on sampling location. Ideally, sampling should be undertaken at the point in the waste management system that coincides with where the material will subsequently be segregated for recycling or processing (if this is one of the aims of the study). If this is not possible, then judgements will have to be made by the classification staff as to whether the waste would be likely to be contaminated after the changed collection procedures were put in place.

An illustration of the attributes of a waste sampling study that enable it to be defined and understood by others is shown in Figure 2. This information will be sought by the DATABASE when waste composition data is supplied so that the design of the sampling/sorting study can be appreciated. The attributes of the sampling strategy are :

- Sub- Population sample size, being the number of people represented in the area from which the waste sample is to be derived. Typically it would be the number of people served by a particular waste collection truck, or the number of people served by a fleet of trucks on a particular collection day.
- Number of Sub-Population Samples. In the above example this would be the number of collection trucks sampled, and number of collection days sampled respectively.
- Sorting Sample Size, being the weight of the waste sample taken from the Sub-Population that is actually sorted into its component material types. This is typically 100 - 200 kg.
- Number of sampling and sorting events for each Sub-Population; being the number of 100 - 200 kg waste samples sorted during the Study for each Sub-Population.

Figure 2 : Composition Study Sampling Design Description



3.3 Number of Samples and Sample Size

Once a (Domestic) waste stream for a particular region with certain socio-economic and waste management system characteristics is chosen for analysis, the details described in Section 3.2 can largely be determined. What needs to be selected is the number of sorting samples and the size of each of those samples. Pioneering work by van den Broek (1969) and Ho et al (1981, 1983) and work in North America related to characterising wastes for their energy content in the 1970s, and more recently for their resource recovery potential (Savage, 1993), has led to the development of guidelines on this issue.

The DATABASE is currently evaluating the applicability of the following recent guidelines using data collected by the project for four councils in the Eastern suburbs of Sydney :

- ASTM D 5231 - 92 : Standard Test Method for the Determination of the Composition of Unprocessed Municipal Solid Waste.
- PROTOCOL, a computerised solid waste quantity and composition estimation system for microcomputers (Klee, 1993).
- The British Colombia Ministry of Environment Guidelines, also adopted by the NZ Guidelines, and apparently similar to the ASTM standard. (Gartner Lee, 1991).

As indicated in the foregoing discussion, determination of materials with small % in waste streams will either have poor reliability with a small number of samples or will require large numbers of large samples to achieve reasonable reliability. Experience of the DATABASE has confirmed the recommendations of others (ASTM, 1992, Tchobanoglous et al, 1993) that a preferred sample size for Domestic waste sampling from post compactor collection points is about 100kg. The purpose for which the data will be used has to be included in choosing the "governing component" (ASTM, 1992) which is used to determine the number of samples to collect to achieve a desired confidence level. For example, a study for a preliminary regional waste planning exercise will require less precision than a composition study being undertaken to enable the detailed design of an incinerator or a highly mechanised sorting plant to proceed. All materials with a % composition greater than the governing component will have a higher level of confidence associated with their data, while all components with % composition less than the governing component will have less than the desired level of confidence. Typically 90 % confidence level is chosen.

As an interim suggestion, the ASTM standard is suggested as the best guide to use to assist in the design of a sampling strategy. Inevitably, engineering judgement will need to be employed to make best use of the usually limited budget. The DATABASE project welcomes input from the experience of those involved in waste characterisation studies, and comment will be sort on a draft before a suggested Guideline is presented in this area.

4 Sorting of Samples from USW Streams

4.1 Selection of Sorting Categories

Once a 100 kg sample has been collected, it needs to be sorted into its material types, as specified in Table 2. Table 2 is a draft which has received ANZECC endorsement for a 12 month trial. Feedback from users, including the DATABASE characterisation work, is likely to lead to some changes in the "final" form. For example, major items such as disposable nappies will possibly have there own category so that they are not "hidden" in the A09 category. In addition, a supplementary guide on how particular products should be classified will be provided.

The draft classification has an additional column (not shown in Table 2) to provide additional breakdown to the information collected during the sorting study. This "Material Detail Sub-Category 2" is not specified, but is left to the designer of the study to develop to suit the purposes of the study. For instance, a further breakdown into contaminated and uncontaminated paper types might be necessary if the study is investigating the potential for further recovery of paper for pulping; if hydro mulching is being investigated, this may not be of concern.

The level of detail that needs to used in the study will be determined by the aims of the study. It is recommended that at least the categories in the "Material Type" column be sorted, and that additional categories be added to suit the needs of the study. By using the Material Type categories as a basic minimum, studies undertaken in a variety of regions for differing purposes will be able to be compared, thereby enhancing the value of the data.

4.2 Layout and Safety Issues.

The layout of the sorting operation for a 2 - 3 person team is shown in Figure 3. This was found to be the most efficient for the categories chosen for the Eastern Suburbs of Sydney study. Details of equipment will be provided in a Guidance Manual being prepared by the DATABASE project. Equipment required is simple and consists in general terms of scales, protective clothing and equipment, sorting equipment and clean-up supplies.

Sorting of waste streams is a potentially hazardous operation. A guide on safety issues associated with sorting Domestic waste has been prepared by the DATABASE and is being reviewed by a technical review group. Each study needs to consider the particular hazards that may arise from a particular waste stream, and to design in precautions to minimise the risk of injury to waste sorters.

An issue that needs to be considered early in the design of the study, is the time required for vaccinations against tetanus and hepatitis to take effect. If sorters are not immune, this may take six months, a significant time in most characterisation studies.

4.3 Sorting Operation

Waste samples are manually sorted on a table into the material type categories chosen for the study. 25 - 50 kg lots from the sample are sorted, and their as received wet weight recorded on prepared forms.

5 Analysis of Material Types from Sorted Samples

Following sorting of the waste stream sample into material type fractions, additional physical and chemical analysis may be undertaken on these sorted materials. Analyses may include bulk density, moisture content, size (sieve) analysis, proximate analysis(ash, volatile matter, fixed carbon), specific energy (calorific value) and elemental analysis.

Keeping in mind the inherent difficulty in obtaining reliable results for some of these parameters by direct sampling and analysis, a database of values will be developed over time so that typical values can be derived for materials in different waste streams. This will enable desk studies to be undertaken to provide an initial estimate of these values for waste streams, based only on the material type sorting study results.

A survey of international methods has been undertaken, and a manual based on the Australian Standards for analysis of coal and coke has been developed. A summary of the appropriate AS is provided in Table 4. This is available in draft and is currently being reviewed by users. Liaison with laboratories that have undertaken this work in the past, and trialing of the methods at the University of NSW's laboratories indicates that there should now be no implementation problems with these recommended methods. As expected, the majority of modifications relate to the preparation of the sample for analysis. Worked examples based on the work in project are included in the Manual.

Table 4 : Suggested Standards for the Physical/Chemical Analysis of Waste

Parameter	Component	Code	Title
Total Moisture		AS1038.1	Part 1: Higher rank coal - Total moisture
Proximate Analysis	- moisture	AS1038.3	Part 3: Proximate analysis of higher rank coal
	- ash	AS1038.3	Part 3: Proximate analysis of higher rank coal
	- volatile matter	AS1038.3	Part 3: Proximate analysis of higher rank coal
Gross Specific Energy		AS1038.5.1	Gross Specific Energy of Coal and Coke
Total Sulfur		AS1038.6.3.1	Ultimate Analysis of Higher Rank Coal - (Eschka method)
Chlorine		AS1038.8	Coal and coke - Chlorine - Eschka method)
Ultimate Analysis	- hydrogen		Perkin-Elmer Model 240B Elemental Analyser
	- carbon		Perkin-Elmer Model 240B Elemental Analyser
	- nitrogen		Perkin-Elmer Model 240B Elemental Analyser

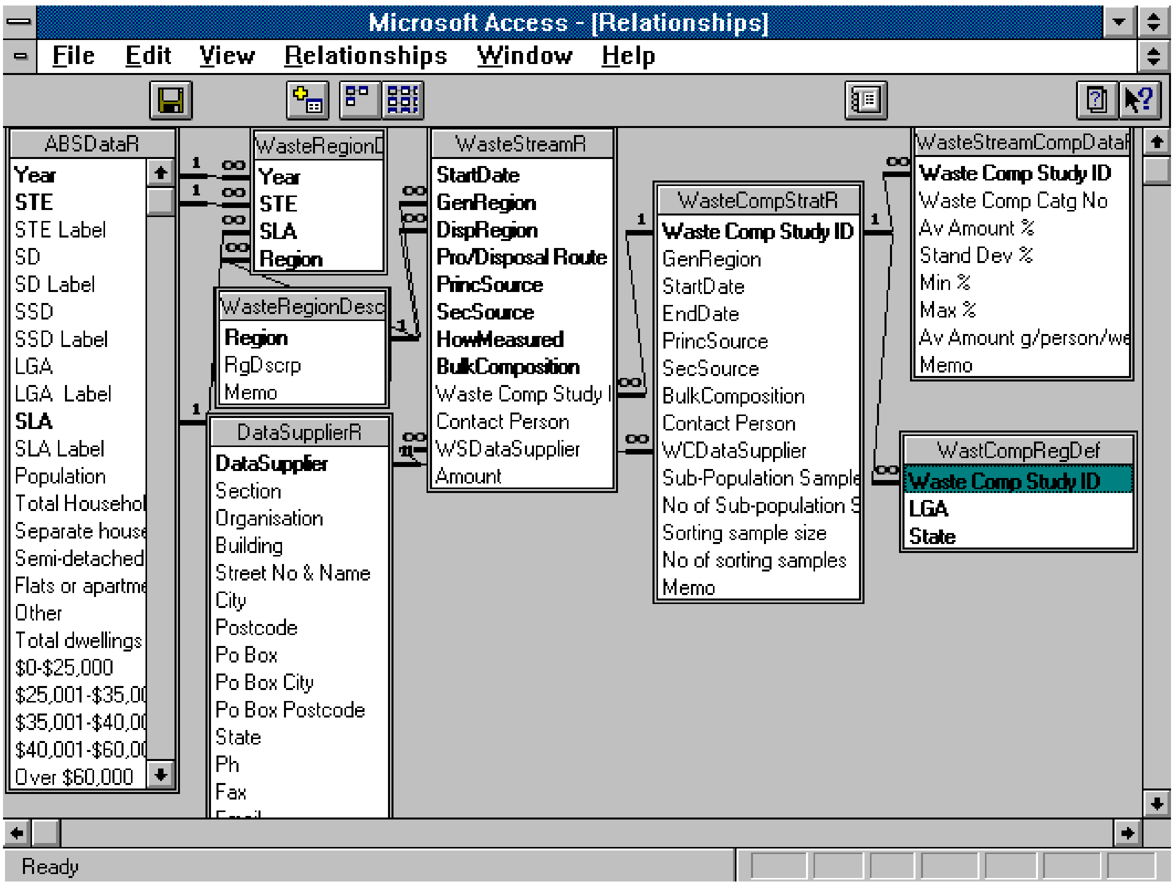
The standards that have been developed to date relate mostly to the disposal route of incineration. As landfill design evolves to include a higher level of input from the chemical engineering process design field, additional characterisation of a waste stream's biochemical properties will required. This is still a developing field and will not be included in detail in the Manuals being developed for the DATABASE.

6 Presentation of Results

The results from the study should be presented in a manner to meet the aims of the study. In addition, for the data to gain additional value, presentation in a form suitable for easy input to the DATABASE is desirable. This will enable access to the data by a larger number of users, and will enable those contributing data to have access to a larger reference base which will enhance the value of their data for their own immediate needs.

The summary statistical data from waste composition studies will be incorporated into the Waste Streams Databse, using Microsoft ACCESS version 2.0. The (current) structure of this Database is illustrated in Figure 4. If a waste composition study "matches" a defined waste generating region, then information on waste stream amounts, waste composition and regional socio-economic factors can be combined to produce meaningful reports. If the waste sampling area does not match a waste generating region, then information on waste generation amounts will need to be collected as part of the composition study, or professional judgement will need to be used to extract appropriate data on waste generation from the Database.

Figure 4 : Waste Stream Database Structure



A detailed Data Supply Specification has been prepared for supply of Data. From this, a number of standard reports will routinely be generated by the DATABASE on waste stream amounts (by year, region, generation rate, disposal route) and waste stream composition. The standard waste composition reports are listed in Table 5. Special reports combining the entities in the Database (see Figure 4) are possible.

Table 5 : Standard Waste Composition Reports

USW/WSC1 :	Composition of a Waste Stream by Material Type
Description :	Summary of the average composition of the waste stream studied, by material type
Content :	Details of Region, Period and Waste Stream sampled; average and other statistical parameters of each material type in the waste stream, expressed as % and/or kg/person/week. Presented as a graph (pie chart) and in a table.
USW/WSC2 :	Composition of Material Type in Waste Stream by Material Detail and Material Detail Sub-Category 1.
Description :	For each of the Material Types in USW/WSC1, a breakdown of its sub-categories of Material Detail and Material Detail Sub-Category 1 is provided.
Content :	Details of the Waste Stream and the Material Type being reported on; then a graph and table showing average and other statistical parameters on the make up of the Material Type; expressed as % or kg/person/week.

7 Conclusions

George Savage in a paper reviewing the history and utility of waste characterisation studies (Savage, 1993), concludes that :

" While data on waste characteristics have been compiled over a 20 - 30 year period, the fact that most of these data have been gathered under a variety of methods reduces the ultimate utility f the information. Standardised methods of analysis and development of databases under a similar set of methods are needed for the planning and design of cost effective and efficient solid waste management systems just as they were and are currently for other resource related industries such as steel, petroleum and coal. "

It is hoped that the high level of cooperation apparent among various authorities in the development of the DATABASE will see this plea realised in Australia, in advance of other international activities in this field.

Acknowledgments

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References

Broek, E van den 1969, *An Evaluation of Municipal Refuse as Fuel*, ME Thesis, University of NSW, Sydney.

Brunner, P. H. & Baccini, P. 1992; Regional Material Management and Environmental Protection, *Waste Management & Research Journal*, Vol 10, No. 2, pp. 203 - 212.

Brunner, PH and Ernst, WR 1986; Alternative Methods for the Analysis of MSW, *Waste Management & Research*; Vol4, pp 147 160.

Brunner, PH and Schackermayer, E 1994; pers. comm. at TU Wien, May 1994.

Commonwealth EPA 1992, *National Waste Minimisation and Recycling Strategy*, CEPA, Canberra.

CRC for Waste Management & Pollution Control 1993, *Draft National Solid Waste Classification System : Submission to ANZECC,* CRCWMPC, Sydney.

Diserens 1993; Study of waste generation amounts in small to medium commercial and industrial establishments in Lausanne, Switzerland. Lausanne City internal report.

Gartner Lee Ltd 1991: Procedural Manual for Municipal Composition Analysis, for BC Ministry of Environment, 1991.

Ho, G. E. 1983, Predicting Solid Waste Quantity and Quality - A Case Study of the Perth Metropolitan Area, *Civil Engineering Transactions*, IEA, pp. 264 - 270., Canberra.

Klee, A J 1993; New Approaches to Estimation of Solid Waste Quantity and Composition, in ASCE Journal of Environmental Engineering, Vol 119, No 2, March/April 1993, P 248.

Moore, S. J., Kung, B., Tu, S-Y, Toong, P. & van den Broek, B. 1994, Progress Towards the Establishment of a National Waste Database for Australia, *Proc. Second National Solid and Hazardous Waste Convention,* Melbourne, May 1994, WMAA, Sydney.

Musa, E and Ho, G E 1981; Optimum Sample Size in Refuse Analysis, in ASCE Journal of Environmental Engineering Div, Vol 107, No EE6, December 1981, p 1247.

Savage, G 1993; The History and Utility of Waste Characterisation Studies, *Proc. 86th Annual Meeting and Exhibition of the Air and Waste Management Association*, Denver, Colorado, June 13-18 1993.

Tchobanoglous, G et al 1993; Integrated Solid Waste Mangement, McGraw Hill

Tseng, Eugene; consultant to California Integrated Waste Management Board, pers comm June 1994.

Footnotes

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