SHOULD WE RUBBISH DISPOSABLE NAPPIES ?

An Assessment of Common Claims Against Disposable Nappies

by

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STATEMENT

This thesis contains no material which has been accepted for the award of any other higher degree or graduate diploma in any tertiary institution. To the best of my knowledge and belief the thesis contains no copy or paraphrase of material previously published or written by other persons except when due reference is made in the text of the thesis.

Irene Koroluk

ABSTRACT

This thesis examines the accuracy of common claims made against the disposable nappy on environmental grounds. It focuses on the issues of disposal, fluff pulp manufacture and resource requirements. Selected claims, which are sourced from newspapers, magazines and publications by government and non government bodies, are presented and categorized. The technical and scientific literature relevant to the claims is critically reviewed. Most of the claims presented were found to be exaggerated, inaccurate and based on arguments which had very little to do with disposable nappies.

DEDICATION

This thesis is dedicated to the memory of Tom McElroy whose recent death is a enormous loss to those of us lucky enough to have had our lives touched by him.

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1.1 Aims and Objectives

A great deal has been written on the subject of disposable nappies and their environmental impact over the last several years. Sources of information on nappies and their disposal have included technical life-cycle assessments, periodicals, newspapers, popular magazines, and publications by companies, environmental groups, and governmental bodies. According to Greenpeace, there is enormous public interest on the cloth versus disposable nappy debate. More public inquiries are received about nappies than any other issue (Young 1993).

Many organizations, authors and members of the public assume that using disposable nappies is environmentally irresponsible (Australian Consumer Union 1993; Rathje 1992; and National Center for Policy Analysis 1991). *Choice*, in its most recent publication stated:

> There's no doubt about the popular verdict on this - when it comes to the environment, disposals are villains (Australian Consumer Union 1993: 6)

This common belief is well illustrated by the content in the following claims:

> The trouble is that disposable nappies simply are not disposable. They are an ecological disaster on a large scale, non biodegradable and a potential health hazard to babies and to the public. They contribute to the depletion of limited timber and petroleum reserves ... (Christensen 1989: 331); and

> A country like Australia really can learn from our mistakes. In this case our mistake was to develop a product that was so wasteful and had such bad impact on the environment that we now face serious consequences (Lehrburger 1989 in The Pretty Young Company 1993: 1).

The sources of these claims and others like them that were collected during the writing of this thesis include:

- publications such as the *Earth Care Annual, Today, The Environmental Magazine, Mothering, Simply Living, Australian Wellbeing* and *Parent;*
- newspaper articles from the *Herald-Sun, Age, Mercury, Australian* and *Sydney Morning Herald;*
- government and non government organizations; Centre for Policy Alternatives in the United States of America (USA), cotton nappy manufacturers, cotton laundering services, The Women's Environmental Network, Weed Foundation, Australian Conservation Foundation and Greenpeace; and
- written letters in response to articles published in the above listed sources.

The aim of this thesis is to assess the accuracy of common claims made against the disposable nappy on environmental grounds with regard to their disposal and various matters concerned with their manufacture, including pulp production, bleaching and selected resource requirements.

In order to achieve this aim, the following objectives have been set:

(1) to gather a wide selection of claims made about the environmental impacts of disposable nappies;

(2) to critically review the technical literature of relevance to the claims; and

(3) to draw conclusions on the accuracy or technical justification for the claims.

The broad hypothesis to be tested is that:

> common claims against disposable nappies on environmental grounds are by and large inaccurate.

This study is not concerned with advocating which of the nappy systems (disposable or re-usable) is best for the environment.

1.2 Scope

The study does not subject the disposable nappy manufacturers to the same analysis. This is not to say that manufacturers do not make exaggerated claims about their products, but this area of study was considered beyond the scope of the thesis. In other words, this thesis concentrates on a critical examination of the claims made by those sections of the environment movement who are critical of disposal nappies.

The thesis focuses on issues presented by the environment movement that lend themselves to testing by reference to the scientific literature. It presents Australian published claims when available and where possible evaluates the accuracy of those claims within Australia.

This thesis does not include assessment on the following nappy issues: convenience; cost; excrement containment; health (skin maintenance, comfort and faecal contamination of objects a nappy wearing child comes in contact with); and the use of the sewage system for nappy disposal (i.e. flushing the pulp pad and contents minus the plastic backing down the toilet) rather than reliance on landfill as proposed by Lehrburger *et al.* (1991).

This thesis was subject to several limitations. To begin with, about 90% of the relevant literature concerning disposable nappies was located in the USA and interstate. Due to limitations in funding and high overseas library loan charges, some useful articles concerning single-use nappy disposal and nappy resource requirements, were not able to be obtained. In addition, a number of key articles could not be located by the library. As a result, literature summaries of the unavailable studies were used as a substitute. However, as summaries are only interpretations and condensed versions of initial sources, certain details may be absent.

Several individuals and organizations were reluctant to release information. A few of the companies considered information to be proprietary data, whilst others simply did not have the resources or chose not to respond. This inability to obtain precise and specific data prevented the complete assessment of several of the presented claims against disposable nappies as discussed in Section 4.4.4.

Many of the studies that were used to assess the accuracy of claims concerning landfill and pulp effluent issues were based on laboratory findings. Results from laboratory experiments cannot always be extrapolated to represent various field conditions or effects in organisms not tested. Moreover, the validity of results from studies and analysis is dependent on methods and techniques used by the researchers. Unless one has a background and is familiar with a study's specific field of interest, it is virtually impossible to assess the reliability of results.

Most of the research to date on disposable nappies with regard their resource consumption, environmental releases and disposal has been completed in North America. It is very difficult, and not always possible or desirable, to extrapolate results from one region to another. Also, evaluation of claims concerning environmental releases and energy consumption is compromised, as life-cycle inventories base their figures on industry average data rather than industry specific data.

1.3 Approach and Methodology

Assessing the accuracy of claims against disposable nappies is a very complex task. To achieve a satisfactory result an interdisciplinary and integrative approach is required. Environmental study by its very nature provides such an approach.

The variety of disciplines that will be either involved or touched upon in the evaluation of claims against disposable nappies include paper chemistry, physiology, silviculture, medical microbiology, chemistry, archeology, toxicology, economics, mathematics, statistics, ecology, urban and regional planning, geography, history and zoology.

The research was conducted full and part time from early 1992 to early 1994. The approach was to collect as many claims as possible concerning the environmental impact of disposable nappies. These claims were then divided into related sections and sub-sections.

A variety of literature searches were carried out to obtain relevant technical information. However, for the reasons discussed in Section 1.2, the searches proved less useful than personal communication with certain national and international companies and government and non government organizations. These groups were able to provide a significant proportion of the current literature and information available on nappies, life-cycle studies and pulp manufacturing and bleaching processes.

Personal communication and technical literature of relevance to the claims were then reviewed. Each claim was examined for content accuracy, use of referencing and reliability of original source data. No laboratory work or field studies were carried out.

Initial investigations to determine a viable thesis topic involved correspondence by telephone, person, letter, electronic mail and facsimile with:

- disposable and cotton nappy manufacturers and distributors located in Australia and USA;
- pulp mills involved in the production of fluff pulp for Australian sold nappies; and
- international and national government and non government organizations involved in: resource conservation, protection, management and use; environmental protection and management; scientific and social research, policy formation, review and scrutiny; and dissemination of public information. For a more detailed list of correspondence, refer to Appendix 2.

Information sought consisted of:

- pulping, bleaching and effluent treatment technologies employed by the different mills producing fluff pulp;
- location of pine plantations, mills, and manufacturing plants; and
- existing information and literature available on issues concerning nappy resource requirements and environmental releases throughout the life-cycle of a nappy, problems associated with disposal as well as organization and public opinion on disposable nappies; and

- market figures on nappy sales.

Further information was gathered from periodicals, government files and publications.

The success rate of receiving replies and information, and willingness to help varied with company and organization. Table 8.1 in Appendix 5 provides a summary of how representative or deficient the information provided was.

1.4 Importance of Thesis

The importance of the thesis is that it highlights the extent to which claims made against disposable nappies are based on unsound evidence. The thesis also demonstrates the care that needs to be taken when assessing the accuracy of literature dealing with environmental problems and solutions. Many issues are more complex and involved than the information presented by certain interest groups suggests. This oversimplification of what is 'good' and what is 'bad' for the environment can lead to attention being diverted from the many real environmental concerns and problems to those which are not of great significance.

1.5 History and Life-cycle of the Disposable Nappy

Disposable nappies were first sold in Australia in early 1973. The suppliers were Colgate, Johnson and Johnson and Kimberly-Clark Australia. They were very primitive, bulky and without the following features found today: polyacrylate gel, secondary containment flaps, elastic waists and gender specificity. The super absorbent gel, which soaks up 50 to 100 times its own weight of baby urine, is the result of extensive research and development (Collette 1993).

Fluff pulp and tissue comprise around 70% of the disposable nappy by volume. The other 30% is comprised mostly of polymers (polyethylene, polypropylene, and super-absorbent polymer) and miscellaneous small quantity materials (glue, elastic and tape) (Carrol 1993, pers. comm.).

The fluff pulp found in Australian nappies is sourced from *Pinus radiata* plantations in the USA, New Zealand (NZ) and Australia. Fluff pulp is processed using the Kraft (sodium sulphide and sodium hydroxide) or Magnefite (magnesium bisulphite) process. Magnesium bisulphite pulp is bleached in South Australia (SA) using a peroxide steep bleaching process. Bleaching sequences of Kraft pulp vary from mill to mill which are located in the USA and NZ.

Plastic components are manufactured in Japan and Australia. Nappies are assembled primarily in Australia (90%) and in Japan (10%) (Wright 1992; Carrol 1993, pers. comm.). A flow diagram of the nappy life-cycle is presented in Figure 1.1.

In 1992, annual sales of disposable nappies reached 620 million. The main suppliers are Kimberly-Clark, Australian Pacific Paper Products and Pampers. Disposable nappy brands show minor variations depending on the manufacturer and initial cost. These include differences in pulp and gel content, gender specificity, secondary containment flaps and elastic waists.

1.6 Organization of the Thesis

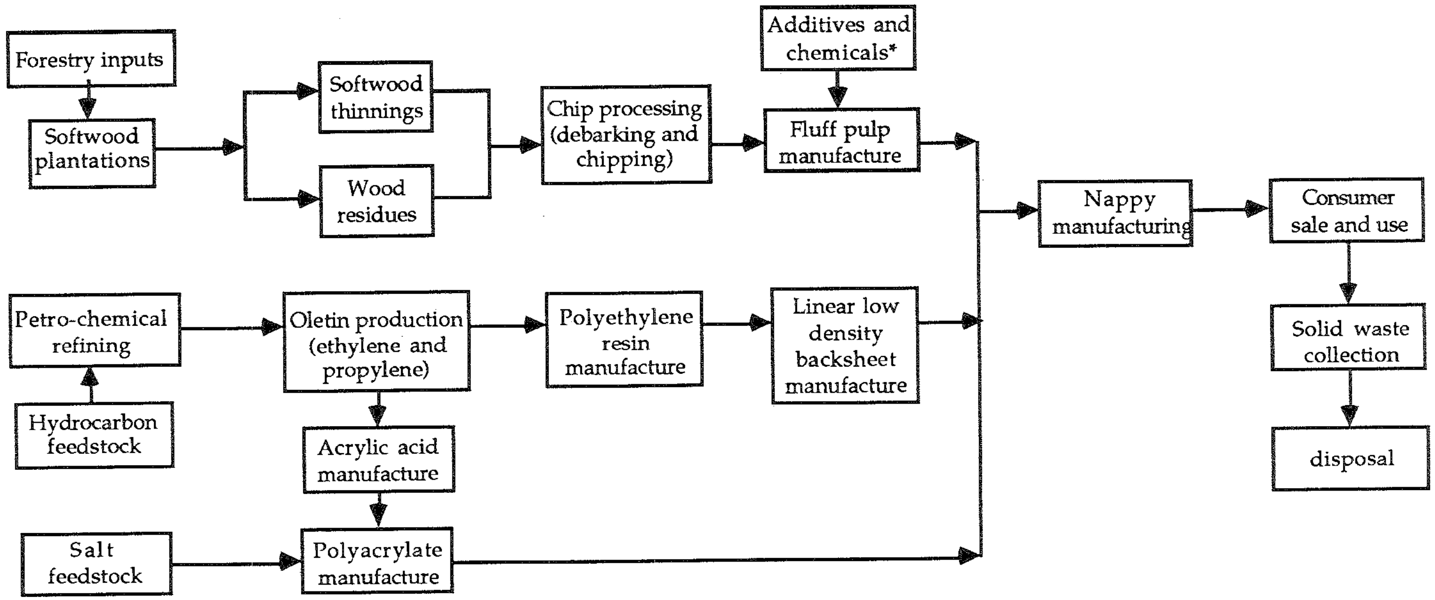
Apart from Chapter 1, the thesis is organized into five Chapters. Chapter 2, titled *Assessment of Claims Against Single-Use Nappies with Regards to their Disposal,* examines: volume nappies occupy in landfills, availability of landfill space; costs associated with nappy disposal; lack of biodegradability; potential pollution threat from bacteria and viruses in excreta derived from disposable nappies; and other disposable problems caused by single use nappies.

The accuracy of claims concerning pulp production, bleaching and health risks associated with bleached pulp product contact are discussed in Chapter 3, *Assessment of Claims Against Disposable Nappies Concerning Pulp Production, Bleaching and Pulp Product Contact.* Chapter 4, focuses on life-cycle assessment. It defines the various types of life-cycle assessments, lists and discusses existing life-cycle assessments on the two nappy systems and examines the limitations of nappy life-cycle assessments. It is titled *An Evaluation of Existing Life-cycle Assessments on Disposable and Cloth Nappies*.

Chapter 5, *Assessment of Claims Concerning Resource Consumption and*

Silviculture Impacts, examines the accuracy of claims against disposable nappies with regard to selected resources (energy, water, plastic and pulp consumption) and silviculture impacts. Chapter 6, *Conclusions*, provides a discussion of the broader issues revealed in the thesis and a summary of conclusions.

Figure 1.1
Disposable Nappy Life-Cycle Flow Chart



Chapter 2

Assessment of Claims Against Single-Use Nappies with Regards to their Disposal

2.1 Introduction

This Chapter examines claims against single-use nappies with regard to the following areas concerning their disposal:

- volume in landfills;
- availability of landfill space;
- costs associated with their disposal;
- biodegradability;
- potential pollution threat from bacteria and viruses in excreta and leachate; and
- other disposal problems.

Each of the above areas will be presented as a separate section. The claims, which have originated from a wide range of sources as discussed in Chapter 1.1, will be examined for content, accuracy, proper use of referencing and reliability of original source data.

2.2 Disposables and their Estimated Proportion in Landfills

A sample of the type of claims against disposable nappies found in the literature concerning their proportions in landfills includes:

(1) They make significant contributions to our growing landfill problems (Allan 1990);

(2) ... mountains of dirty diapers clogging the nation's landfills (LaCroix 1993: 37);

(3) With the exception of newspaper and beverage and food containers, no other single consumer product finds its way into landfills more often (West 1989: 1); and

(4) The problem which gets most attention is the fact that nappies are taking up an increasing amount of space in landfills (Rassaby 1990: 26).

But how accurate are these statements? To find out, weight and volume figures for nappy waste produced in Australia/year will be presented. These figures will then be compared to the amount of total waste produced in

Australia/year. Existing work undertaken will be examined, followed by an analysis of the composition of Australian municipal solid waste. The question of whether nappies are occupying an increasing amount of landfill space will then be answered.

2.2.1 Weight and Volume Figures for Australian Nappy Waste

In Australia about 620 million disposable nappies were used in 1992 (Wright 1993, pers. comm.). As a proportion of nappy changes they represent about a 46% share in the market (Wright 1993, pers. comm.). This is a much smaller share than found in countries such as the USA, Canada and Great Britain, where usage is between 80% and 100% (Lehrburger 1991: 2; Vizcarra *et al.* 1993: 25; and Warmer Campaign 1993).

The 1991 sales figures for disposable nappies, on which calculations will be based, were about 531 million (Wright 1992, pers. comm.). Sale figures for 1991 were used due to Australian waste data being available only for the 1990/1991 period.

Using 1991 nappy sale and population figures, the weight of nappies in landfill per person has been calculated by (Wright 1992, pers. comm.) to be about 4.27 kg/person/year. The volume was worked out to be about 15.25 L/person/year (refer to Appendix 3). How this compares to the annual amount of waste produced per person can be seen in the following paragraphs.

Calculating the total annual volume or weight of garbage is very difficult. Only a fraction of what is thrown out or taken to a disposal site can be weighed or measured for volume. Hence, estimates and methods can be diverse and can only be ever taken as approximate (Rathje 1989: 3). This diversity can be seen by comparing the estimates provided by both the Industry Commission Information Paper (1991) and the Waste Management Authority (WMA) Annual Report (1990/1991) for the Sydney metropolitan region.

WMA total waste quantities received for metropolitan Sydney in the 1990/1991 financial year were 1020 kg/person (WMA Annual Report 1990/1991: 29). The Industry Commission figure for 1989 was 778 kg/person (Industry Commission Information Paper 1991: 12).

Calculations for the total disposal to landfill per capita in Australia are provided by the Industry Commission Information Paper (1991). Their estimates for 1989 per capita are 745 kg, with values by region ranging from a high of 1152 kg for the Australian Capital Territory, to a low of 420 kg for the Adelaide region.

As a proportion of total municipal solid waste (MSW) based on WMA figures for the Sydney region, disposable nappies represent 0.4% by wet weight and 1% by wet volume. As a proportion of domestic waste, which is 32% of the total MSW, disposables are about 1.3% by wet weight and about 3% by wet volume (Wright 1992, pers. comm. [Refer to Appendix 3]). Calculated from Industry Commission figures (1991) for total disposal per person in Australia, disposable nappies represent 0.55% by wet weight and 1.37% by wet volume.

It is reasonable to assume that the volume figures just provided are on the conservative side. This is due to the low density estimation of municipal waste provided by (Wright 1992, pers. comm.). The density value used to estimate nappy volume was 1.5 m^3/t. This compares to the actual achieved landfill space usage rate of 1.39 m^3/t of waste in Metropolitan Sydney (WMA Annual Report 1990 1991: 12). In addition, the Garbage Project (refer to Section 2.2.2) uses a specially designed machine to compact samples to 0.868 p.s.i. The same level of compaction and hence reduction in volume would not be achieved by the compression of a nappy into a milk carton (refer to Appendix 3).

Proportions of nappies in landfills resembling the figures discussed, are confirmed in the work of Professor Rathje and his Garbage Project Team, and a US (sic) Environmental Protection Agency (EPA) report entitled *Characterization of Municipal Solid Waste in the United States: 1990 Update.* Unfortunately no composition breakdown of municipal wastes, which included disposable nappies as a category, could be found in the Australian literature.

2.2.2 Rathje and the Garbage Project's Work on Nappy Waste

William Rathje, Head of the Garbage Project at the University of Arizona and his group of researchers have been analysing rubbish from garbage bins and landfills since the mid 1960s (Rathje *et al.* 1989: 18.) In 1987, the team began to dig into landfills by using bucket auger wells, enabling the systematic recording of landfill contents and an assessment of what was happening to the landfill over time.

The Project has also given a lot of consideration to disposable nappies. From excavations at a variety of locations in the USA between 1980 and 1989, the group has consistently found that:

> ... disposable nappies make up on average no more than 1% by weight of the total solid waste contents, and on average no more than 1.4% of the contents by volume. The range of diaper weights as a percentage of total garbage on all Garbage Project digs has varied only from 0.53% to 1.28%. The range of diaper volume has varied only from 0.53% to 1.82% (Rathje 1992: 162).

Volume estimates were made of all major categories of waste retrieved from landfills by the application of 0.868 p.s.i. to those contents. Although a conservative estimate of pressure exerted on contents under tonnes of rubbish, it is one that removes air from within and between the materials (Rathje *et al.* 1989: 11).

Although the work completed by the Garbage Project is the most comprehensive available, its sample size is limited. Excavations by 1989 had totalled 101 units. Extrapolation from a limited number of samples to represent a large area, according to the USA EPA, can produce a misleading result (EPA 1990: ES2-3).

Volume measurements also have problems. Firstly, there is the difficulty in comparing results from different sets of samples and sites due to varying levels of compaction, physical characteristics of materials and moisture conditions. Secondly, there is no standard method for measuring volume (EPA 1990: 81).

2.2.3 USA EPA Estimates of Nappy Waste

The method used by the EPA to estimate the composition of waste is called material flows analysis. The technique estimates total municipal waste disposal by calculating quantities of commodities and products manufactured in the area under consideration. Adjustments are made for imports, exports, product lifetimes and recycling rates. Organic refuse and a small amount of inorganic refuse is estimated from preexisting sampling study data (EPA 1990: 5).

The EPA approximation for disposable nappies, as a proportion of total USA waste by weight in 1988 was 1.7%. This estimate has been adjusted to include urine and faeces contained within the nappies. By volume, the EPA's estimation is about 3.3% (EPA 1990: 40).

The EPA and Garbage Project results are slightly higher than the figures provided by (Wright 1992, pers. comm.). It is reasonable to assume that this is due to higher usage of disposables in the USA as compared to Australia.

2.2.4 Accuracy of Claims Against Disposable Nappies Concerning their Proportions in Landfill

All of the sources which this section examines are derived from Section 2.2.

2.2.4.1 Allan 1990

One of the difficulties in assessing the accuracy of Allan 1990, is determining whether or not the annual nappy contribution to Australian landfills of about 2000 m^3 or 86800 t, or alternatively 1% by volume or 0.4% by weight, is significant (calculated from 1992 nappy sale figures, WMA figures and an estimated 140 g weight of a wet nappy provided by (Wright 1992, pers. comm.). The definition of significant will vary from one source to the next.

The Shorter Oxford English Dictionary (1974) defines significant as "important". Lehrburger *et al.* (1991) considers the American contribution of 2% by weight to be significant. Rathje (1992), on the other hand, does not and argues that the removal of disposable nappies from the waste stream would have only an negligible effect on overall waste minimisation.

Disposables do make a contribution to landfills, but that contribution when compared to other materials is small. Brisbane's breakdown of Municipal waste for 1987-1988, for example, shows that food waste made up 18%, wood and leaves 20%, newspapers 9%, other paper products 22%, glass 7%, plastic and rubber 11%, steel 5% and other waste 8% (Durkin and Davis 1989 in the Industry Commission Information Paper March 1991: 54). It has to be acknowledged however, that small amounts of wastes do add up to create larger amounts of waste.

However, it is reasonable to argue that the disposable nappy is too often singled out over other items as being an important contributor to landfill volume. As disposables are here to stay, the efforts of those concerned with reducing landfill volume would be better spent mobilizing the community to degrade items that do not need to go to a landfill such as food and yard refuse in a backyard or community compost area.

If this practice was to be undertaken in the Brisbane metropolitan area for instance, the weight of waste entering Brisbane's landfills would be reduced by 20% to 30%. This compares to a 0.4% weight reduction that would be achieved if disposable nappies were eliminated from entering landfills.

2.2.4.2 LaCroix 1993

This claim is an overstatement written for effect. Nappies do not clog landfills. They are just one item in a landfill mixed in with numerous other items.

In light of the information presented in Section 2.2.4.1, LaCroix 1993 perhaps would be more aptly rephrased from "... mountains of dirty diapers clogging the nation's landfills" to ... 'piles of dirty nappies scattered throughout the nation's landfills.'

2.2.4.3 West 1989

No reference is provided by West (1989: 1). However, the wording of the claim is very similar to a passage in Lehrburger's (1989 in Newton 1990: 107) work titled *Diapers in the waste stream: a review of waste management and public policy issues* . (Lehrburger is in Newton's publication as the original article was not able to be obtained. Newton's work is the most comprehensive summary and interpretation of nappy literature to date).

West (1989: 1) states:

> With the exception of newspaper and beverage and food containers, no other single consumer product finds its way into landfills more often.

Lehrburger's (1989 in Newton 1990: 107) work on the other hand states:

> No other single consumer product ... with the exception of newspapers and beverage and food containers ... contributes so much to our solid waste.

A review of USA nappy and waste literature and Newton's (1990) summary of disposable nappy literature failed to find any other possible source or sources from which this excerpt may have originated.

If the source is indeed Lehrburger's, its subject matter, as his life-cycle analysis indicates, is based on the waste characterization work undertaken by the EPA (Lehrburger *et al.* 1991: 51). However, it appears that the EPA 1985 figures (EPA 1990) have been grouped together by Lehrburger to make disposable nappies appear to be the fourth largest consumer product entering landfills.

This has been achieved by the selective grouping of beverage and food containers into broad categories, but not other consumer products, which in 1985, occupied more landfill space than the 2% taken up by disposables. These categories included: books and magazines which occupied 2.9%; food wastes 9.1%; and furniture and furnishings 4% (EPA 1990: 34 and 38). In addition, the EPA presents beverage and food containers as specific packaging divisions such as glass, plastic, steel and paper and paper-board and not the broad categories depicted by West (1989) or Lehrburger (1989 in Newton 1990: 107).

Newspapers, beverage and food containers in 1985 occupied approximately 20% by weight of landfill space. This total is 10 times the contribution by weight that is generated by disposables.

West (1989) and variations of this claim are cited frequently in the literature. Other sources where this claim has been used include:

(1) Anonymous. (no date) Diapers Cloth Versus Disposables Its Your Choice in *Update on Diapers Revised* (1990) Center for Policy Alternatives, Washington D.C., p. 10.

(2) Mazar, A. (1990) The Disposable Diaper Dilemma in *Update on Diapers Revised* (1990) Center for Policy Alternatives, Washington D.C., p. 29.

(3) Lehrburger, C. (1988) in Lehrburger *et al.* (1991) *Diapers: Environmental Impacts and Life-cycle Analysis* , p. 59.

(4) Provost, S. (no date) Disposable Nappies Filling The Land in the *Daily Planet.*

(5) Rathje, W. (1992) *Rubbish: The Archeology of Garbage*, New York, p. 162.

(6) Anonymous. (1989) Environmental costs of keeping baby dry in *Science News*, Mar. 4, pp. 135-141.

(7) Wirka. J. (1990) Diaper Wars in *The Earth Care Annual* pp. 89-94.

(8) Environmental Choice. (1991) in *Re-Usable Cloth Diapers*.

2.2.4.4 Rassaby 1990

Disposable nappies were first sold in Australia in 1973. They were very simple, large and not at all like the nappies sold today. They are now responsible in Australia for occupying around 2000 m^3, or a little over 100 Olympic size pools of landfill space (adapted from Wright 1992, pers. comm. [refer to Appendix 3]).

Although use of the disposable nappy in Australia has steadily increased, the bulk of the disposable nappy has been reduced by 30 to 50% (Little 1990: 1-7). This has been largely the result of the addition of a super absorbent gelling material called polyacrylate gel, which is capable of absorbing 50 times its own weight in urine (Kimberly Clark [no date]).

It is difficult to estimate whether Australia will reach the same high usage trends shown in countries such as Canada, USA and UK. If it does, the proportion of nappies as a percentage of total waste will increase slightly, and than flatten out once the disposal market share has reached its peak.

Disposable nappies in the USA as a percentage of total waste generation declined from 2% in 1985 to 1.7% in 1988 (EPA 1990: 38). This is a result of declining birth rates and reductions in nappy bulk. It is projected that this trend will continue. Projected generation of disposables in 1995, as a percentage of total generation is 1.2%. It is estimated that this will decrease to 1.1% by the year 2000 and to 1.0% by the year 2010 (EPA 1990: 64-65).

Disposables, as Rassaby (1990) states, are taking up an increasing amount of space in Australian landfills. This is the result of disposables slowly expanding their share in nappy sales. However, as a proportion of overall wastes generated, this increase over the last two decades has been low. Even if disposables reach USA market share proportions of around 85%, the overall increase based on Industry Commission figures (1991) will be from 1.37% to 2.5% by wet volume, or based on (Wright 1992, pers. comm.), from 1.0% to 1.8% by wet volume.

2.3 Availability of Landfill Space

Most claims against disposable nappies on the subject of landfill space availability are similar to the following:

> (1) Disposables are a problem in landfills - in Melbourne it is expected we have 5 years of landfill life left to us!! (Miller 1993); and
>
> (2) Disposables don't go to some magic place where they safely disappear. They remain in landfills ...
>
> In Australia, landfill space is not inexhaustible. In Sydney it is expected to run out within the next six years (The Pretty Young Company 1993: 1)

Assessing whether landfill space is running is out is not a straightforward task. For although suitable locations may be available to site landfills, political factors such as the NIMBY (not in my backyard) syndrome, or ill conceived legislation may act to prevent new landfills from being established (Scarlett 1991: 5)

With regards to landfill availability in Sydney, the WMA (1990/1991: 6), claims that Sydney is facing a landfill crisis with less than six years of landfill capacity remaining (WMA, 1990/1991: 6). This is the same claim made by Miller (1993). This shortage is due to:

- the government abandoning its plans for a regional landfill at Londonderry following opposition from the local community and Penrith City Council (WMA 1990/1991: 19);
- competing demands for potentially suitable landfill sites (WMA 1990/1991: 15); and
- the generation of more solid waste each year due to increasing population.

Similarly, Melbourne in 1990, according to the Industry Commission report had 5 years of landfill site life remaining. The same claim made by The Pretty Young Company (1993). Of the 55 Councils in the Melbourne region, 32 had no landfills within their municipality (Industry Commission Information Paper 1991: 48).

Pioneer International in the Industry Commission Information Paper (1991: 50) partly attributes landfill shortage to government regulations and environmental controls that limit private sector activity in waste disposal. Potential landfill sites, they argue, are available around major cities and abundant space is available to cater for inert materials such as excavation and building wastes, normal household wastes, as well as putrescible wastes.

Other contributing factors that have led to this landfill crisis in major cities include landfills not being replaced by new ones and councils finding it increasingly difficult to obtain approval to operate landfills (Sinclair Knight and Partners 1991: 113). Scarlett (1992: 4), argues that perceived limited landfill capacity can also occur as a result of relevant waste authorities investing in landfill infrastructure to meet only present and near future needs and not needs twenty or thirty years hence (Scarlett [no date]: 4).

According to (Zandi in Scarlett 1992: 4]) landfill capacity and thus space occupied is a function of technologies used. Certain compaction techniques can double or triple the capacity of some older landfills.

The total land area taken up by landfills in Australia is very small. In 1989, landfill sites occupied about 17, 200 ha of land area (Industry Commission 1991: 27). This equates to about 13 km^2, or about 0.0022% of Australia's land area. All of the waste Australians will produce in the next 10 years will occupy an area 1 km^2 and about 195 m high (Wright 1992, pers. comm. [refer to Appendix 3]), which in terms of volume is about 195,000,000 m^3.

Further, many landfills once lined and covered are converted into recreational areas (Scarlett 1991: 4). Many in the USA are designed with a second use in mind such as the John F. Kennedy International Airport (Rathje 1991: 130).

2.4 The Cost of Disposing Single Use Nappies

A sample of the type of claims against disposable nappies found in the literature concerning the costs of disposing single use include:

> (1) We are all aware of the rising cost of trash disposal and the shrinking amount of landfill space in our communities. Disposable diapers, used once and then thrown away, contribute to this problem (Anonymous [no date] in Center for Policy Alternatives 1990: 12).
>
> (2) Dumping costs are increasing dramatically, thanks to the fact that most old landfills are glutted and new ones are difficult to site. ... This means that, on average, parents who use disposable diapers are paying ... some 10 cents on every diaper dollar spent (Anonymous 1990 in Center for Policy Alternatives 1990: 8).

All of the claims put forward by source 1 (Anonymous [no date] in Center for Policy Alternatives 1990: 12) and the first part of source 2 (Anonymous 1990 in Center for Policy Alternatives 1990: 8) are accurate. The costs of rubbish disposal are rising, new landfills in metropolitan regions are becoming increasingly difficult to site and disposables as a component of municipal waste are a small contributing factor in waste disposal.

Calculating the true costs of waste disposal is very difficult as it requires assessment of:

- operational costs;
- opportunity costs of the land;

- actual cost of the site;
- risk of long-term environmental problems;
- immediate loss of amenity from smell, noise, traffic and unsightliness;
- factoring in of rehabilitation once sites are full;
- environmental monitoring during and after the life of a landfill;
- proposed final land-use of the site; and
- future environmental management costs (adapted from Industry Commission Report No 6 1991: 43,45; and WMA 1990/1991: 37).

Sinclair Knight and Partners (1991: 108-109) argue that the majority of assessments that have attempted to cost landfills in Australia have significantly underestimated their real costs. This is because assessments have focused on site development and operating costs rather than other costs such as those listed above. Estimations made by the Industry Commission reports, for example, relate to landfills which have a historically inferior standard of engineering and environmental management (Sinclair Knight and Partners 1991: 108-109).

The Western Australian Environmental Protection Authority (WA EPA) now requires that all new sanitary landfill developments have minimum engineering standards consisting of a sealed lining system which is either natural or artificial, a leachate collection and management system, methane gas collection and flaring/power generation system (Sinclair Knight and Partners 1991: 111).

Costs will also vary depending on site suitability, the amount of earthworks required at each site, the depth of each site, lining requirements and whether leachate collection systems are installed (Sinclair Knight and Partners 1991: 111).

Based on figures for metropolitan Perth and for 1991 dollars, an average site development cost (derived from an average of three sites) is $463,000/ha (Sinclair Knight and Partners 1991: 111-112). The average land cost is $100,000 to $150,000/ha. Establishment cost is therefore about $600,000/ha. Annual running costs, which do not include collection costs, are around $85,000/ha. The required gate charge to recover these costs is around $24/t.

Hence, the true approximate annual cost of disposing all of Australia's nappies (based on WA EPA new sanitary landfill standards, figures from Sinclair and Knight, yearly nappy waste figures by weight in Section 2.2.4, but excluding collection costs), is around $2,083,200 (1991 dollars). The per nappy cost is around 0.34 cents or 1% of the consumer cost of nappies (assuming average nappy cost of about 35 cents). This is 1/10th of the estimate provided by claim 2 (Anonymous 1990 in Center for Policy Alternatives 1990: 8).

Collection costs although excluded in the above analysis can also substantially add to the true cost of waste disposal. This is particularly the case if waste has to be hauled long distances via transfer stations. The additional costs incurred using this method can be seen when depot disposal charges are compared to transfer station charges for the Sydney region in 1991. Council disposal was about $16/t and commercial disposal $20/t. This compares to transfer station council costs of $33/t and commercial costs of $42/t (WMA 1990/1991: 53). This roughly doubles the cost of disposing single use nappies to about 0.7 cents/nappy.

2.5 Lack of Biodegradability

The most common arguments presented against the disposable nappy concern the volume that they take up in landfills and their lack of biodegradability. These two arguments appear in the majority of anti-disposable nappy literature. Examples of sources concerning lack of disposable nappy biodegradability include:

(1) According to recent American research, so called disposable nappies will take approximately 500 years to decompose because of the durable plastic inner lining (Lord *et al.* 1990: 8);

(2) A dirty disposable plastic diaper ... can take 500 years to decompose, "as compared to a cotton diaper which disintegrates in only one to six months (Culviner 1991: 93);

(3) Tasmanian Sue Rogers has designed a new baby pant which is friendly to both the user and the environment. ...
The pads are made from cellulose which breaks down within a few months (Rann 1992: 2);

(4) It is believed the plastic backing on disposable nappies could remain in the environment for up to 500 years before it begins to break down. Therefore the disposable nappies used today could still be around when your great grand-children are in nursing homes (Janson and Janson: 1991); and

(5) The disposables we use on our babies today will be here to haunt future generations for many years to come (Greenpeace NZ: 1991).

To gauge the accuracy of these statements the following issues will be examined:

- biodegradation inside landfills;
- biodegradation rate of landfill contents; and
- whether or not nappies in landfills constitute a problem.

2.5.1 Biodegradation Inside Landfills

According to Rathje (1989: 4), the belief that biodegradation occurs inside lined landfills is generally a common myth. The very nature of most modern landfill design principles, that is, separation of the wastes from the biosphere and hydrosphere, limit biodegradation. Separation is achieved in sanitary landfills by the daily compaction and covering of refuse with clean fill and by the impermeability of natural or artificial liners.

The rate of decomposition by microbial activity is controlled by the availability of water, nutrients and aeration. Microbial activity is also affected by temperature, salinity, nutrients, refuse particle size and pH (Bogner 1990 in Rathje 1992: 442). Waste at the interface between the landfill and air undergoes aerobic decomposition. Once it is buried, and oxygen is excluded anaerobic conditions ensue. Anaerobic bacteria degrade organics in landfills producing methane and other gases, albeit very slowly.

2.5.2 Biodegradation Rate of Landfill Contents

Very limited work has been carried out on rates of biodegradation. Although work undertaken by The Garbage Project is incomplete (Rathje *et al.* 1989: 27), several observed and hypothesized trends have been put forward by the project concerning:

- food waste and garden organics; and
- processed organics.

These categories along with plastic will be considered as separate sub-sections.

2.5.2.1 Food Wastes and Garden Organics

According to Rathje *et al.* (1989: 28) food wastes and yard organics are perceived by the populace to be biodegradable in a landfill. It is often assumed that over time they decompose and create new space for garbage. In reality however, there is no scientific evidence which supports this notion. Data from The Garbage Project indicates that after 25 years 50% to 75% of food and garden organics may biodegrade. However, between 25% to 50% of the most easily biodegradable materials will still be recognizable as a piece of steak, a clump of grass or a pile of leaves (Rathje *et al.* 1989: 28). Construction lumber, for instance, shows no indication of change.

Moreover, Garbage Project data also suggests that yard waste tends to stabilize after initial degradation during the first decade of burial, whilst food waste degrades slowly but uniformly (Rathje *et al.* 1989: 27).

2.5.2.2 Processed Organics

According to the Garbage Project, processed organics such as paper products generally do not seem susceptible to biodegradation. In study sites with little moisture, no noteworthy quantity of paper biodegradation has occurred in 25 years of burial. Retrieved paper grocery bags buried in the late 1960s are still strong enough to hold goods (Rathje *et al.* 1989: 27-28).

However, for all waste samples where moisture content analysis has been performed, as moisture increases in waste samples, the percentage of paper decreases from about 50% paper at 20% moisture, to approximately 20% paper at 60% moisture (Rathje *et al.* 1992: 442). In part of one landfill site (Fresh Kills Landfill), this was attributable to anaerobic methanogenic bacteria found in the sites tidal wetlands (Rathje 1991: 128).

2.5.2.3 Plastics

Upon discarding into a landfill additives incorporated in an (for the purpose of this thesis) inert plastic are capable in moist conditions of migration from the polymer and leaching where they may pose a threat to subsurface water (Radian Corporation 1987: 11). Plastic additives are defined by the Radian Corporation (1987) as chemicals used to polymerize, process, or modify the properties of a plastic.

The additives in linear low density polyethylene plastic (the plastic in which nappies are lined with and packaged in (Plastic Industry Association 1992: 25), that may pose a threat to subsurface water include antistatic agents and flame retardants. Whether flame retardants pose a risk to subsurface water is dependant on the specific flame retardant, its concentration, the polymer in which it is incorporated and the environment to which it is subjected to (Radian Corporation 1987: 83).

The threat from nappy plastic additives would be minimal given that most additives are compounded to remain enclosed in the polymer (Radiation Corporation 1987: 12) and the very small proportion of plastics in landfills derived from nappy linings and nappy packaging. It is calculated by (Wright 1992, pers. comm.), that the ratio of plastic from nappy lining to municipal solid waste by volume is 1/5000 (refer to Appendix 3).

Degradation of linear low density polyethylene plastic in a landfill over several decades would be most unlikely given that the plastic will not be exposed to: UV radiation (which results in a chemical breakdown of the structure); variations in heat and temperature; and physical weathering (Crawford 1985: 26). In addition polyethylenes are characterised by their negligible water absorption and excellent chemical resistance properties (Crawford 1985: 54).

2.5.3 Nappies in Landfills

This section now examines the five quotations given at the start of Section 2.5 in more detail.

Claims that disposable nappies will take 500 years to decompose in a landfill by Lord (1990), Culviner (1991) and Janson & Janson (1991) are not based on sound evidence. Although Lord (1990) argues that recent American research provides such evidence, no reference for the source was found in the book. And although a lengthy literature search was undertaken, it was not possible to determine who first made the claim that disposable nappies take 500 years to decompose.

Plastics have not been around long enough for us to know what happens to them after several decades let alone several hundreds of years in a landfill. Polyethelenes have only been manufactured since 1939, with increased production only occurring since the late 1940s and 1950s (Plastics Industry Association 1992: 3).

The claim by Culviner (1991), that a 'cotton nappy will disintegrate in one to six months' and by Rann (1992), 'that a cellulose pad will break down within a few months' is not based on field evidence. As was discussed in Section 2.5.2.2, processed organics do not seem susceptible to biodegradation unless exposed to moisture. In addition, references or information sources have not been provided by either author.

Decomposition of cellulose pads and cotton nappies in the time frames provided may however occur under test conditions in a lysimeter, which is a simulated sanitary landfill. In these experiments liquid is added and solid waste is often milled. This has the effect of encouraging aerobic biological decomposition for longer periods of time. These conditions, however, do not resemble field conditions.

The argument used by Rann (1992), that a cellulose pad is more environmentally friendly than a plastic backed disposable nappy, is difficult to justify on the following grounds:

- the cellulose pad occupies as much space as a conventional disposable in a landfill due to the slow rate of processed organic decomposition; and
- the negligible difference in the disposal costs of the two nappy systems.

The claims made by Janson and Janson (1991) and Greenpeace NZ (1991), that disposables used today will be around for many generations may well prove to be true. As disposable nappies have only been around for such a short time there has not been the opportunity to do any long term field studies on their rates of decomposition.

To say as Greenpeace NZ (1991) does, that 'disposables will be here to haunt future generations for many years to come' is an overstatement. They are no more likely to haunt us than any other waste we put out into landfills. If anything, the threat they may pose in a landfill is minimal when compared to the many other toxic materials such as paints, nail polish remover, batteries, pesticides and cleaning agents.

2.6 The Potential Pollution Threat from Bacteria and Viruses in Nappy Excreta and Leachate Excreta

A sample of the type of claims against disposable nappies found in the literature concerning the potential pollution threat from bacteria and viruses in nappy excreta, and leachates derived from disposable nappies include:

> (1) Soiled nappies are known to carry over 100 viruses which multiply in the rubbish (Lord *et al.* 1990: 7);
>
> (2) Bacteria from the human faeces can breed in the warm and moist environment of a landfill and then be leached out into the environment (Kroesa 1990: 33) (Greenpeace);
>
> (3) Littering of disposables leads to scavenging by birds and animals and represents a public health risk (Allan: 1990); and
>
> (4) Once they are used, ... disposable diapers enter the household trash stream and ultimately end up in landfills, creating an immediate public health hazard. Leachate containing viruses from human faeces (including live vaccines from routine childhood immunizations) can leak into the earth and pollute underground water supplies (Jorgenson 1985 and Peterson 1974 in Lehrburger and Snyder 1988: 61).

Each of the above quotations will be examined for content accuracy in the following sections.

2.6.1 Lord *et al.* 1990

The first part of this claim is correct. More than 100 different types of virus are known to be excreted in human faeces (Arnold 1989: 90; Melnick and Gerba 1980).

However, contrary to the information presented in the second part of this claim, viruses can only replicate when they are in other living cells. They cannot multiply or replicate in faeces. To produce disease, viruses must enter a host, come in contact with susceptible cells, replicate and then produce cell injury (Jawetz *et al.* 1991: 389).

2.6.2 Kroesa 1990

Only the first section of this claim will be examined, that is, 'bacteria from human faeces can breed in the warm and moist environment of a landfill'. The issue of leachate contamination will be examined in Section 2.6.4.3.

The information presented in the first part of this claim is incorrect. Bacteria from human faeces do not usually breed in a landfill environment. Faecal bacteria are adapted to living in humans. For faecal bacteria to reproduce environmental factors such as pH, ion concentration and temperature must resemble conditions encountered when in a human. The environmental conditions in a landfill are very different, harsh and far from ideal.

Most waste in a modern sanitary landfill is separated from the biosphere and hydrosphere by daily compaction and covering and by natural or artificial liners. This reduces the availability of liquid water to bacteria which is essential for bacterial reproduction. Although bacteria may survive in a dry state it is unable to multiply. Unless spores are formed, death usually results upon drying (Ackerman and Dunk-Richards 1991: 44).

The relatively high temperatures of around 60°C achieved during the first aerobic stages of waste biodegradation would usually kill most faecal bacteria unless spore formation occurred (Collins and Kennedy 1992: 3). Bacteria tends to grow best and survive at the temperatures they normally encounter. For human faecal bacteria this is around 35°C (Ackerman and Dunk-Richards 1991: 42-46). In addition, faecal bacteria cannot usually compete against the normal flora of the landfill such as the cellulolytic organisms, the acidogens and the methanogens.

However, some species of bacteria develop a very resistant endosperm which allows bacteria to survive in a dormant state when environmental conditions become unfavourable. This process does not involve multiplication. In this form, spores are much more resistant to environmental factors such as drying, heating and chemicals and may remain viable for years. Germination of the spore occurs only when conditions become favourable again to growth (Duguid *et al.* 1978: 24-24).

2.6.3 Allan 1990

The littering of disposables as argued by the Allan (1990) may lead to scavenging by fauna which may then represent a public health risk. Collins and Kennedy (1992: 5) suggest that there is a possibility that animal vectors such as flies and insects may transmit infection to other sources after coming in contact with infected nappy waste. Seagulls and other birds may also scavenge nappies and thus contaminate food sources with their droppings (Collins and Kennedy 1992: 5; and Arnold 1989: 90).

2.6.4 Jorgenson 1985 and Peterson 1974 in Lehrburger and Snyder 1988

To examine the accuracy of this claim, the following topics need to be explored:

- the amount and type of pathogens added to a landfill by the addition of disposable nappies;
- the ability of pathogens from disposable nappies to survive or retain their infectious properties in a landfill environment;
- the ability of those pathogens to migrate through the landfill into the surrounding environment; and
- human resistance to pathogens associated with nappy waste in landfills (adapted from Newton 1990: 3)

2.6.4.1 The Amount and Type of Pathogens Added to a Landfill by the Addition of Disposable Nappies

Landfills receive an assortment of materials from industrial, commercial, institutional and household sources. Items that may contribute to the pathogenic load include food waste, pet faeces, medical waste, sewerage sludge and used personal care products such as tampons, disposable nappies, condoms, tissues and sanitary napkins (Newton 1990: 3).

The specific nature and amounts of pathogens that these sources contribute are not known. Isolation of certain viruses in culture systems is difficult and expensive (Melnick and Gerba 1980). It is not always apparent whether samples are negative for viruses or whether they are simply not detected (Ware 1980: 7). Moreover, most studies on disposable nappies, faecal pathogens and landfills has been undertaken in the USA.

The pathogens that could be potentially found in human faecal matter are listed in Table 2.1 (Atlas *et al.* 1986 in Newton 1990: 7). The incidence of these pathogens that may enter landfills via nappies is very difficult to estimate (Suflita 1992: 1492). However, the contribution nappies make is considered small by: Newton 1990: 3; Rathje 1992; Driscoll 1974 in Newton 1990: 52; and Cooper 1975 in Newton 1990: 50 and significant by Pahren 1987 in Newton 1990: 34-35.

According to Suflita (1992: 1492) only one study exists that looks at the incidence of enteroviruses (viruses shed in faecal matter) in nappies prior to the nappies being deposited in a landfill. That study, which was completed by Peterson (1974), found that about 3.5% of the sampled nappies contained enteroviruses.

A sampling study by Pahren (1987 in Newton 1990: 5) of 11 categories of municipal waste found that disposable nappies contributed the highest percentage of faecal coliforms in one out of two years (35.9% in 1975) and the third lowest in the other year (0.6% in 1974).

A study by Cooper *et al.* (1990 in Newton 1990: 5) using 16 lysimeters (10 simulating landfills and 6 simulating open landfills) examined the impact disposable nappies have on landfill and open dump leachate bacteria and virus counts. The study concluded that the number of total and faecal coliforms in leachate was not measurably different from lysimeters with nappies than lysimeters without nappies.

Other estimates of the incidence of pathogens in disposable nappies are based on the proportion of the population infected with an organism at any given

TABLE 2.1
PATHOGENS THAT MAY OCCUR IN FAECAL MATTER AND THEIR POTENTIAL EFFECTS

BACTERIA	DISEASE
Salmonella tyhpi	Typhoid fever
Salmonella paratyphi *S. sendai* *S. typhimurium*	Paratyphoid fever
Shigella dysenteriae *S. flexneri* *S. boydii* *S. sonnei*	Bacillary dysentery
Escherichi aco (certain serotypes)	Epidemic diarrhoea (may be fatal in children)
Salmonella spp. (1200 serotypes)	Acute gastroenteritis
Psuedomonas aeruginosa	Otitis media Lower respiratory disease
Vibrio cholerae	Cholera
VIRUSES	
Poliovirus	Paralytic poliomyelitis
Coxsackievirus Group A Group B	 Aseptic meningitis Herpangina Aseptic meningitis Acute infantile myocarditi: Upper respiratory diseases
Echovirus	Aseptic meningitis Enteritis Respiratory illness Rash diseases
Adenovirus	Respiratory illness (croup)
Reovirus	Respiratory illness Enteritis
Norwalk virus	Enteritis
Infectious hepatitis	Jaundice
Rotavirus	Infantile enteritis
FUNGI	
Candida alblicans	Candidiasis

time. In Australia, it is difficult to determine rates of infection for nappy wearing children. The reasons for this according to Victorian research include:

- data on infectious diseases not being complete. Hearsay suggests that many infectious diseases go unreported;
- there is no requirement for some infectious diseases to be reported;
- broad categories, for example, 0-9 years; and
- many people being undetected carriers of infectious diseases.

However, figures suggest that infection rates of reported diseases where contamination can occur through the faecal/oral route are small. In Victoria in 1992, (population of about 4,448,818 [Australian Bureau of Statistics 1994, pers. comm.]), the reported cases of giardiasis for the 0-9 age group was about 180 for males and 150 for females. The number of cases for hepatitis A was 15 for males and about 10 for females. The numbers for salmonellosis was 54 for children under 1 and 197 for children between 1-4. Totals for typhoid and paratyphoid for the 0-9 age group was 5 and the totals for yersiniosis for the 0-4 age group was 20 (Carnie 1992). Hence, it would be reasonable to assume that in Victoria, the number of nappies contaminated with pathogens would be reasonably low.

2.6.4.2 The Ability of Pathogens from Disposable Nappies to Survive or Retain their Infectious Properties in a Landfill Environment

Numerous experiments, most of which have used lysimeters, have investigated the ability of pathogens to survive or retain infectivity in landfills. Only a few studies have focused on the ability of pathogens from disposable nappies to survive or retain their infectious properties in landfill environments.

Faecal bacteria, as we have seen in Chapter 2.6.2, are unlikely to survive in a landfill environment unless it forms spores. With regards to enteric viruses, it is difficult to predict their survival time in a landfill. Viral persistence will vary greatly depending on the type of enteric virus and the conditions encountered in a landfill. The most important factor in virus survival is probably temperature. The lower the temperature the longer the virus will persist (Melnick and Gerba 1980: 80-81).

In the USA, the incidence of infection in children under the age of 2 of rotavirus is around 10%. The incidence of *Giardia* infection for children in day care centres between the ages of 1-3 is 8-26% and 1-3% for children not in day care centres. The incidence of infection in a community is affected by factors such as socioeconomic status, race, region of residence and climate.

An examination of 200 disposable nappies for (hepatitis A, rotavirus, *Giardia* and *Cryptosporidium*) from various landfill sites by Gerba (Rathje 1992: 163-164), found evidence of a live virus in only one nappy. Even with that nappy, there was uncertainty as to whether the virus arrived with the nappy, or was contaminated after arrival.

In another study by the Garbage Project (Suflita *et al.* 1992: 1493) 70 nappies were collected from the Fresh Kills landfill. The oldest nappy was buried in 1965 and the most recent in 1988. The majority of nappies were dated from 1980 to 1988. No viable pathogenic viruses or protozoa were detected in any of the nappies. However, there is a low probability that the Garbage Project's negative findings were due to chance alone. It was thought that the average temperature of the Fresh Kills Landfill (29.4°C) inactivated the pathogens.

Studies of the landfill material itself have suggested long periods of bacteria survival. A study by Kinman *et al.* (1986a in Newton 1990: 8) found that although total counts had decreased, faecal streptococci and total coliform still remained in 19 lysimeters at the end of a 10 year study. In another lysimeter study by Kinman *et al.*, (1986b in Newton 1990: 8) *Clostridium perfringens* and standard plate counts were comparatively high in almost all samples tested after five years. It should be noted that there are problems of trying to apply laboratory results to virus survival under field conditions.

Studies looking at leachate from landfills and lysimeters have found that faecal organism numbers tend to decline with time. In a study by Sobsey (1978: 858), 22 leachate samples from 21 different landfills in the USA and Southern Canada were examined for enteric viruses from all sources. The sites represented a wide range of landfill conditions, with leachate sample size ranging from 10.3 to 18 L in volume. Enteric viruses identified as poliovirus types 1 and 3 were found in one of the leachate samples where solid waste disposal practice was inadequate.

Sobsey (1978) concluded that leachates from properly operated sanitary landfills do not constitute an environmental or public health hazard due to enteric viruses. This is due to the low concentration of viruses in raw leachates, viral loss from thermal inactivation, removal in soil and dilution in ground or surface waters. However, it should be noted that only a small percentage of the total leachate produced by the lysimeter was examined for the presence of viruses.

Engelbrecht *et al.* (1974) using an experimental lysimeter and two different detection methods did not identify any virus in the leachate that had 10^{10} plaque forming units of type 1 poliovirus added to it. This was due to either inactivation of virus in the lysimeter, restriction of virus movement through the lysimeter or some additional mechanism of inactivation.

The concentrations of total plate count bacteria, total coliforms, faecal coliforms and faecal streptococci decreased with time of lysimeter operation or leaching. It was also observed that the leachate had an inactivation property when indicator bacteria, a bacterial pathogen and virus samples were added to it. The older the leachate sample, the greater were its inactivation properties (Engelbrecht *et al.* 1974).

Cooper *et al.* (1974 in Sobsey 1978: 862-863) only occasionally detected low levels of enteric viruses in leachates from a series of pilot scale municipal solid waste lysimeters. Viruses were detected in leachates only from lysimeters that were very rapidly brought to field capacity.

Engelbrecht *et al.* (1975 in Newton 1990: 48) fractionated leachate using ultrafiltration and reverse osmosis techniques. Based on this procedure, it appeared that the relatively high concentration of free heavy metals such as iron and zinc and/or short chain fatty acids may be responsible for the inactivation of the test bacteria and viruses.

2.6.4.3 The Ability of Pathogens from Disposable Nappies to Migrate through the Landfill into the Surrounding Environment

Assuming that pathogens from nappies manage to survive high temperatures of the landfill environment, lack of moisture, absence of essential nutrients and the toxicity of the leachate, how likely are they to migrate to a water source?

The distance micro-organisms may travel through a landfill and soil depends on variables such as: the size of the organism; the pore size of the soil medium, the surface properties of the organism and the soil particles; the clay content of the soil; the presence of cations; pH; moisture; and the presence of organic matter.

There is no definitive evidence concerning pathogen movement through the soil or landfill. Some studies claim that pathogens show considerable movement (Pohland and Engelbrecht 1976; and Glotzbecker 1974 in Newton 1990: 11), while others suggest it is limited (McGauhey and Krone in Newton 1990: 11).

The principal obstacle to virus movement is adsorption of the microbes to the solid waste and soil surrounding the fill (Sobsey *et al.* 1975). There is also the possibility that if the virus is retained by waste or soil for a long enough period it may become inactivated. This would be more likely to occur in drier climates (Ware 1990: 69).

However, isolation of unidentifiable virus types from a groundwork observation well located 402 m down gradient from a sanitary landfill have been reported (Gerba 1987 in Newton 1990: 35), as has bacteria 900 m from a landfill site (Engelbrecht and Amirhor 1975 in Senior and Shibani 1990: 94).

2.6.4.4 Human Resistance to Pathogens Associated with Nappy Waste in Landfills

For microorganisms to be pathogenic, they must cause infection or infection and disease in a host. The sequence of events that leads to this include: transfer of the pathogen to the host; invasion of the host's tissue; multiplication; and injury of the host (Brock and Brock 1978: 225).

If pathogens are present in a water supply, there must be a critical number present for there to be a public health threat. What that infective dose is, however, is difficult to define. Any population exhibits a great variety of resistance to infection. Factors that cause this variation include: age; diet;

the presence of chronic or acute diseases; level of fitness; and genetically determined differences in infection susceptibility (Newton 1990: 12).

2.6.4.5 Evaluation of the Accuracy of Jorgenson 1985 and Peterson 1974 in Lehrburger and Snyder 1988

The information presented in this Chapter seems to suggest that the public health risk posed by disposable nappies is very small in properly operated landfills. This is supported by a variety of sources (Collins and Kennedy 1992; Rathje 1992; and Newton 1990).

The very nature of most modern landfill design principles, that is, separation of the wastes from the biosphere and hydrosphere, limits the opportunity of contamination and exposure of the public. For an infection to occur a host has to firstly come in contact with a pathogen, which then has to penetrate a variety of defence mechanisms. Under a daily covering of soil, contact and penetration is most unlikely. Contamination in open fills by animal vectors may, however, be a possibility.

It has been suggested that the potential exists for live attenuated viruses used in immunization programs such as the Sabin polio vaccine to revert back to a virulent wild virus strain in the environment (Melnick 1960 in Ware 1980: 101). Again, under a layer of soil, viral contact with a host is most unlikely. In addition, even if contact did occur, the majority of the Australian population are vaccinated against the polio virus.

Other avenues of infection include: pathogens from nappies becoming airborne during solid waste collection and deposition; or pathogens from nappies entering a water source. With the former avenue of infection Newton (1990: 1) concludes that:

> It is highly unlikely that any airborne pathogens derived from disposable nappies in the solid waste stream will give rise to public health problems.

With regards to the second issue, leachate with pathogens from a variety of material sources not contained or treated at a landfill site, or inadequately treated, may find its way to a watercourse (Collins and Kennedy 1992). The greatest chance of this occurring would be if the landfill was sited next to a rivulet, on land with a high water table or a major watercourse. According to Newton (1991: 1), however:

> The likelihood of pathogen contamination of a public water supply by landfilling municipal solid waste containing soiled disposable nappies is very small.

This is supported by all studies discussed in this Chapter which focused specifically on nappies in the landfill environment. For pathogens to reach a water-course they have to survive lack of moisture, thermal inactivation, absence of nutrients, acidic urine contained within some of the nappies, competition from other microorganisms, high concentration of free heavy metals and inactivation from leachate. In addition, evidence indicates that adsorption of pathogens onto other waste limits their movement.

Hence disposable nappies are most unlikely to create, as source 4 (Jorgenson 1985 and Peterson 1974 in Lehrburger and Snyder 1988: 61) puts it 'an immediate public health hazard'. It is also most unlikely that leachate containing pathogens from nappies will pollute water sources. The claims made by source 4 are not referenced and have little scientific basis. No studies could be located that correlated an outbreak of infectious disease with the pathogen content of disposable nappies. It is true, however, that once they are used, the majority of disposable nappies end up in landfills.

2.7 Other Disposal Problems

(1) They cause blockages in the sewerage system (Allan 1990) (Australian Conservation Foundation).

(2) ... and maintenance problems in sewage disposal plants (The Women's Environmental Network 1989).

Single use nappies flushed down the toilet do cause blockages in the sewerage system as stated by Allan (1990) and maintenance problems in sewage disposal plants as stated by The Women's Environmental Network (1989).

A study by Molloy (1991) has attributed a substantial portion of the 14,000 annual sewer blockages in Melbourne to disposable nappies and other larger personal sanitary products. The annual repair bill for these blockages in Melbourne is around $2,000,000. There is also a significant screening and handling nuisance associated with collecting and disposing of screened items of which disposable nappies are a component (Molloy 1991).

Plastics from feminine hygiene items, disposable nappy liners, toilet deodorizer baskets, cotton bud tubes and synthetic non-woven wiping cloth all contribute to the small volume of plastics that end up as small particles in the digested sludge or in the treated effluent from the Werribee Farm and the South Eastern Purification Plant in Victoria. These plastics may: limit sludge reusability and saleability, clog irrigation systems; and cause accumulation of small plastic particles in receiving waters and beaches.

2.8 Conclusion

A major problem of assessing claims made against disposable nappies concerning their disposal in landfills is the limited amount of information and data available. The majority of studies examining, for example, pathogenic organisms were completed before the 1980s and are based on laboratory findings rather than field research. Unfortunately, laboratory research is not always representative of what happens out in the field. For instance, ground waste in lysimeter experiments will degrade more rapidly than the same waste in a normal landfill environment.

Another problem is the reliability of isolation methods used to obtain viruses and bacteria from municipal waste. According to Ware (1980), it is frequently not known whether samples are negative for viruses or whether they are simply not detected. In addition, there are only a few studies available that focus specifically on disposable nappies or on pathogen survival in the field.

Another problem is that most of research completed on pathogens in landfills have been completed in the USA. Landfill environments in Australia may be different. For instance, the pH of landfills in the USA tend to be acidic, whilst in Australia they tend to be alkaline (Hobart City Council 1993, pers. comm.; Newton 1990: 14). This may effect the survival rate of microorganisms.

Several recommendations are provided in Chapter 6, Table 6.1, Summary of Conclusions.

Chapter 3

An Assessment of Claims Against Disposable Nappies Concerning Pulp Production, Bleaching and Pulp Product Contact

3.1 Introduction

The accuracy of claims concerning nappy disposal were evaluated in Chapter 2. This Chapter will continue claim evaluation with regards to:

- health impacts associated with pulp production, bleaching and dermal contact with nappy products; and
- environmental consequences associated with pulp production and bleaching.

Before claims against disposable nappies are evaluated, the following topics will be examined:

- fluff pulp processing;
- fluff pulp bleaching;
- organochlorines (chloroform and chlorophenols and dioxin);
- impact of organochlorines in the environment; and
- strategies of reducing organochlorines in Kraft pulp mill effluent.

In addition, the primary data sources used by the Weed Foundation from which many of their claims against disposable nappies are based, will be reviewed. The Weed Foundation is one of the main North American environmental organizations opposing the use of disposable nappies.

3.2 Fluff Pulp Processing

Fluff pulp is the name given to the wood fibre used in disposable nappy products. Two chemical pulping processes (Kraft and Magnefite) are used to produce fluff pulp for Australian Nappies. The Kraft process is employed in NZ by New Zealand Forest Products (NZFP) and in the USA by Weyerhaueser. The Magnefite process is used by Kimberly-Clark in SA.

The Kraft process uses a mixture of sodium hydroxide and sodium sulphide as the chemical agents for the removal of lignin in the pulping process. The

Magnefite process is the sulphite process which uses sulphur dioxide and magnesium bisulpite as the pulping chemicals (Simons 1990: 5).

3.3 Kraft and Magnesium Bisulphite Pulp Bleaching

Kraft chemical pulps contain residual lignin which at present needs to be to be removed before the pulp can be bleached. Bleaching is the process by which pulp whiteness in increased through lignin solubilisation. Bleaching also increases softness and absorption capabilities of pulp.

Different Kraft mills employ different bleaching sequences. The Kinleith Mill (NZFP), for example, uses 100% chlorine dioxide substitution. That is, no elemental chlorine is used. The mill's bleaching sequence is O D - E/O - D (Johnsson 1993, pers. comm.). This means that the pulp is treated firstly with an oxygen bleach, followed by a chlorine dioxide bleach, followed by alkaline extraction with a little bit of oxygen together in the same tank and completed by a final chlorine dioxide bleach. The USA Kraft mills producing fluff pulp for Australian nappies were not willing to release information concerning their bleaching sequences.

The strategy for bleaching magnesium bisulphite pulp is quite different. Kimberly-Clark's Tantanoola mill in SA uses a peroxide steep bleaching process (Trafford 1993, pers. comm.). In this process, the pulp is dried to the stage where it is just moist. Hydrogen peroxide, which is the bleaching chemical, and a small amount of alkali are then mixed in with sodium hydroxide. The sodium hydroxide raises the pH which allows for more efficient bleaching by the hydrogen peroxide. The pulp is then placed in heaps outside for a few days to bleach. The steep bleached pulp is then fluffed up by agitation and then dried in a tank where it is further agitated and heated by hot air or steam. This method of bleaching uses no chlorine or chlorine containing chemicals and secondly does not remove lignin but only changes its chemical structure (Kuys 1993, pers. comm.).

3.4 Organochlorines

'Organochlorine' is the term given to a broad range of compounds that are either manufactured or occur naturally. Some of the major classes of organochlorines include: volatile compounds; pesticides, herbicides and agricultural compounds; polychlorinated biphenyls (PCBs); chlorophenols and chloroguaiacols; and polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) (Volkman 1991).

Organochlorines are the result of many natural and human activities. Human activities include: application of pesticides; herbicides and agricultural compounds; PCBs from the chlorination of biphenyl; incomplete incineration of poly vinyl chloride (PVC) plastic and other materials; and from by-products and impurities in manufactured chlorinated aromatic compounds (Volkman 1991). Natural sources include: forest fires; volcanoes (Bettis 1991: 19); microbial decomposition and fermentation and production by oceans (Enell *et al.* 1991).

3.5 Chlorinated Organic Compounds in Bleached Softwood Kraft Mills

Around 90% of the chlorine used in bleached Kraft mills ends up as common salt. The remainder, around 10%, becomes bound to organic material removed from the pulp. This organically bound chlorine may be defined as either AOX (adsorbable organic halides), TOX (total organic halides) or TOCI (total organically bound chlorine) (Berry *et al.* 1991; Crooks and Sikes 1990).

A breakdown of chlorinated organic material present in spent liquors from bleached softwood Kraft mills using AOX is given by Berry *et al.* (1991). Around 80% of the organic bound chlorine has a molecular weight greater than 1000 (MW>1000). This material is often referred to as chlorolignin. Chlorolignin characteristics include: relative high water solubility; less than 10% chlorine content by weight; inability to penetrate cell membranes; and limited possibility of further breakdown into compounds toxic to aquatic organisms such as chlorinated dioxins (Berry *et al.* 1991).

The remaining 20% or so of organically bound chlorine is categorized as low molecular weight material (MW<1000). Of this, approximately 17-19% is made up of relatively water soluble compounds which are easily hydrolysed or metabolized during effluent treatment. Examples of these compounds include chlorinated acetic acids and chlorinated acetones (Berry *et al.* 1991).

The remaining 1% (it could be as high as 3%) is referred to as EOX (extractable organically bound halogen). This fraction is of concern as it is potentially toxic, relatively fat soluble and potentially bioaccumulable. Of greatest environmental concern, however, is the fraction of this material that has a partition coefficient greater than 1000 (log P_{ow}>3). This fraction, which is thought to be as little as 0.1%, may contain minute traces of compounds such as PCDDs, PCDFs which are highly lipophillic, bioaccumulable and have a high level of chlorine substitution. This fraction may also contain the very much less toxic, polychlorinated phenolic compounds (PCPCs) (Berry *et al.* 1991).

Another class of organochlorines that may occur in kraft mill effluent is chloroform (a volatile organochlorine) (Volkman 1991: 2). The organochlorines that may be found in Kraft pulp mill effluent will be discussed in greater detail below.

3.5.1 Chloroform and Chlorophenols

Although chloroform can be found several kilometres downstream from a mill its potential for bioaccumulation in aquatic organisms and adsorption onto particles and sediments is low (Volkman 1991: 3). Chlorophenols on the otherhand adsorb rapidly onto particles and are detected in high concentrations in sediments around effluent discharge points (Xie *et al.* 1986 in Volkman 1991: 6). They are found in mg/L quantities in mill effluents using chlorine bleaching (Volkman 1991: 6). Chlorophenol formation is influenced by the lignin content of the pulp. Although chlorophenols are biodegradable, their rate of biodegradation depends on treatment conditions (Berry 1991: 48)

3.5.2 Dioxin

Dioxins are any one of a total of 210 isomers. There are 75 PCDDs and 135 possible PCDFs. Within this class of compounds there is great variance in toxicity depending on molecule geometry and stereochemistry details (Volkman 1991: 12). However, only 17 of 210 dioxin isomers are believed to be of toxicological concern (Berry *et al.* 1991: 46).

According to Buckland *et al.* (1991: 18) all of the known sources of dioxins are man made. Other authors disagree and argue that dioxin can be produced naturally by combustion processes that occur naturally in the environment (Enell *et al.* 1991 and Bettis 1991: 19).

Dioxins are: highly lipophilic, that is, they readily partition into fat of living organisms; strongly bioaccumulated; and metabolized or degraded in the environment only very slowly. For example, the half-life of 2,3,7,8,-tetrachlorinated dibenzo-p-dioxin (TCDD) (the most toxic isomer) in soils is estimated to be greater than 20 years and in humans to be between 5-7 years (Buckland *et al.* 1991: 17).

3.6 Impact of Organochlorines in the Environment

Organochlorines in an aquatic environment will partition between the water, suspended solids, bottom sediments and the biota. Whether an organochlorine will cause a deleterious effect on biota will be depend upon:

- nature of the organochlorine;
- quantity of the organochlorine to which biota has been exposed;
- amount that will absorbed by the biota;
- once absorbed, the amount that will actually wield an toxic effect;
- genetic variation in susceptibility of a organism;
- lipid content;
- size and age of organism;
- level of organic matter (compounds bound to suspended solids or sediments are not always easily available to aquatic organisms); and
- position of organism in the food chain (the higher up an organism is located in the food chain the greater is the uptake of a persistent organochlorines such as dioxin) (Nowak 1991: 34; Brown 1991: 73 and Priestly 1991: 98).

Studies examining the effects of organochlorines have demonstrated no clear-cut and consistent effects (Priestly 1991: 95). Current technology has not allowed researchers to answer many basic questions about organochlorines. For example, it is not known which toxic effects are of greatest concern (cancer, immuno-toxicity, reproductive impairment, hepato-renal toxicity or neurotoxicity) (Priestly 1991: 88). Similarly, the means by which dioxin can produce effects in organisms is strongly debated and not fully understood (Ahokas 1991: 53).

Much of the work that has been completed on the effects of organochlorines in the environment has focused on PCBs (which have no relevance to the pulp and paper industry) and dioxins. Some of the observed effects of dioxins are discussed below.

Dioxin compounds administered to organisms in the laboratory have shown a variety of effects which include immunosuppresive responses in mammalian species, birth deformities in mice, promotion of liver tumours in rats, reproductive disorders, reduced growth, fin necrosis in fish and death (Ahokas 1991: 55 and Crooks and Sikes 1991: 69).

Effects are dependent upon concentration of the organochlorine compound, method of administration, species being tested on and duration of exposure. For a more comprehensive coverage of effects on organisms refer to the following reports: National Council of the Paper Industry for Air and Stream Improvement, (NCASI) 1987; Crooks and Sikes 1990 and Ahokas 1991. Very little field research has been undertaken which has investigated the effects of pulp mill effluent on aquatic life on site (Nowak 1991).

TCDD exposure effects in humans include: immunological, neurological, dermatological, systemic, neurological and some psychological effects (Ahokas 1991: 56). A more comprehensive coverage of human effects is provided in the following studies: McNeil 1991; Priestly 1991; Ahokas 1991; and NCASI 1987.

TCDD, according to Brown (1991: 69), does not act directly on DNA. This view, is supported by the National Council of the Paper Industry for Air and Stream Improvement , which states "TCDD acts as a cancer promoter rather than an initiator" (NCASI 1987: 21). A promoter is a carcinogen that acts as a catalyst to enhance the effects of an initiator. It cannot act without the initiator. An initiator is a carcinogen that modifies the genetic message of the cell that it enters. The resulting mutation is then transferred from generation to generation.

3.7 Strategies of Reducing Organochlorines in Kraft Pulp Mill Effluent

Several methods can be implemented by pulp mills to eliminate or reduce the presence of toxic chlorinated compounds. One method is to minimise or eliminate potential dioxin precursors that may be present in raw materials used in the pulp mill. These precursors include: defoamers contaminated by dibenzo-p-dioxin (DBD) and dibenzofuran (DBF); as well as wood chips obtained from lumber that has been treated with Poly Chlorophenol (PcPs) (Berry *et al.* 1991: 47 and Crooks and Sikes 1990). Defoamers, for instance, can be reformulated with purified oils. There is evidence, however, by Voss *et al.* (1988 in Berry *et al.* 1991: 47), that suggests that some precursors such as DBF may be present in the wood itself (Berry *et al.* 1991).

The second method is to change Kraft pulp bleach plant operating conditions. Necessary changes and measures include: high levels of chlorine dioxide substitution; good chemical mixing (Berry *et al.* 1991: 47); and the treatment of pulps with alkali and oxygen prior to bleaching with chlorine (Simons Consultants 1990: 9).

Organochlorines that are not considered toxic can be reduced by decreasing the lignin content of pulps entering the bleaching process, decreasing the amount of chlorine and chlorine compounds and by various secondary biological treatments (Berry 1992). With modern processes and effluent treatment plants concentrations can be reduced to below detectable levels (Neilson 1990 in Volkman 1991: 6).

This thesis will now turn its attention to examining claims against disposable nappies concerning dermal contact with nappy products, as well as other health and environmental impacts associated with pulp production and bleaching.

3.8 Pulp Product Contact

Claims against disposable nappies concerning health risks babies face from constant skin contact include:

> (1) Evidence of health risks to the infant as a result of placing ... bleached pulp close to the skin, especially when nappy rash is present, is startling (Provost [no date]).
>
> (2) The use of chlorine to bleach pulp for nappies produces the toxic component dioxin ... may even be a health hazard to babies using disposable nappies (Rassaby 1990: 26).
>
> (3) It has been questioned whether studies have taken into account the greater sensitivity of babies' skin considering their contact with nappies for up to three years. Also of concern is that dioxin is readily absorbed by fat molecules

> and migration through the skin of babies would be aided by creams commonly used during nappy changes (Rassaby 1990: 28).

Only one study could be located which assesses the potential health risks from dermal exposure to dioxin in paper products. The study was completed by NCASI in 1987. This study also provides levels of TCDD and tetrachlorodibenzofurans (TCDF)s in a variety of paper products. With regards to disposable nappies, TCDF was measured at 7.2 and 8.8 parts per trillion (ppt). TCDD was not detected at detection limits of 2.1 and 2.6 ppt (NCASI 1987: 78).

Conclusions by NCASI, based on experimental work, a review of envirological data and other relevant information, indicate that there is little likelihood of dioxin migration from nappy fluff pulp to urine to baby skin (the postulated method of dioxin transfer) (NCASI 1987: 29). This is contrary to the claims made by Provost (no date) and (Rassaby 1990).

The low level of risk posed by disposables to infants is attributable to: dioxin having a very strong affinity for organic matter and thus limited potential of migration to a solution; analysis of possible mechanisms and rates of dermal absorption of dioxin; data on migration on soils and related compounds; a non pulp liner separating the pulp from the skin; and the amount of urine available to the skin being small (NCASI 1987: 56).

This risk is further reduced by: Kraft mills producing nappy pulp for the Australian market using 100% dioxin substitution; pulp mills continually improving and upgrading their environmental standards; and no detectable traces of organochlorines found in NZFP fluff pulp (no data was obtained on dioxin levels in USA pulp) (Johnsson 1993; Berry *et al.* 1992 and Balousek 1993). Nappies manufactured using the Magnefite process and bleached by peroxide steep bleaching do not contain organochlorines, as the bleaching process, uses no chlorine or chlorine containing chemicals. For the infant or baby, virtually safe concentrations of TCDD in nappy fluff pulp, corresponding to a 1 in a 1,000,000 life time cancer risk is 2,000,000 parts per trillion (NCASI 1987: 78).

However, serious nappy rash may increase absorption of TCDF (assuming it is present in the nappies) if no barrier creams such as zinc oxides are applied to prevent urine contacting the skin. This is based on evidence supplied by Ulsumar *et al.* (1978 in NCASI 1987: 61). With regard to lipophilic ointments such as vaseline, it is thought that dioxin (if present) is retained in the cream and therefore will not penetrate the skin (NCASI 1987: 44).

One of the concerns raised by Rassaby (1990: 28) is that babies' skin is more sensitive than adult skin. Whether this claim is accurate or not is difficult to establish given: the small amount of research that has been undertaken which has compared chemical penetration through the skin at different ages; the very few studies that have specifically looked at newborn skin absorption; and the conflicting conclusions reached by different authors from what evidence there is (Fisher 1985: 213; Behl *et al.* 1985).

According to Behl *et al.* (1985), a number of studies suggest that there is a strong indication that infant skin is more permeable than adult skin. This view is in contrast to Fisher (1985: 221), who states that "it does appear that the barrier properties of the full term infant may be every bit as good as those of the adult with respect to at least some materials".

Structural studies by Holbrook (1982 cited in Fisher 1985) have implied that the epidermis of the full-term infant is similar to that of the adult, but in a transitional stage of development. The premature infant, however, displays increased skin permeability due to little strateum corneum, which is regarded as the main factor controlling percutaneous absorption in humans (Marzulli 1962 in Behl *et al.* 1985)

It is important to realise that any chemical that penetrates an infant's skin will be more concentrated in the infant body than in an adult body (a child has less body volume per unit area of skin than an adult) and thus will have a greater systematic effect. Also, the nappy region may be about twice as permeable to toxicants on the skin as the back (NCASI 1987: 61).

3.9 Environmental Consequences Associated with Pulp Mill Effluent

Claims against disposable nappies concerning environmental consequences resulting from fluff pulp manufacture and bleaching will be presented and evaluated one at a time.

3.9.1 Rassaby 1990

> Another of the issues associated with disposable nappies is the problem of dioxin. ... The paper industry is a major source of the most toxic form of dioxin 2,3,7,8-TCDD.
>
> TCDD dioxin is regarded as the most toxic man-made chemical. It is the most potent carcinogen yet tested in animals (Rassaby 1990: 28).

Although dioxins (TCDF and TCDD) are produced at very low concentrations in pulp mill effluent (usually <50 parts per quadrillion) (Volkman 1991: 1), they are an environmental concern and problem (refer back to Section 3.5). In fish, for example, bio-concentration factors of dioxin pulp mill effluent vary from 1000 to around 140000 (Brown 1991: 73). These levels of dioxins may pose a health problem for both the fish and consumers of fish (Government of Canada 1991b).

Dioxin 2,3,7,8-TCDD (sic) is the most toxic dioxin (Ahokas 1991: 54). However, the paper industry is not a major source of dioxin pollution. According to Bettis (1991), only about 1% (about 570 g) of the total dioxin released in the USA is from the pulp and paper industry. In Sweden, this figure is estimated to be approximately 6% (Buckland *et al.* 1991).

TCDD is the most toxic man made chemical. The only compounds more toxic than TCDD are natural compounds such as Botulinus (Ahokas 1991: 51). According to Volkman (1991: 7), animal studies have shown that 2,3,7,8-TCDD (sic) is one of the most (not the most as quoted in the end of the claim) powerful carcinogens ever tested in animals.

3.9.2 Weed Foundation (no date a)

> Every year, bleached pulp mills dump one million metric tons of chlorinated organic compounds into our lakes, rivers and oceans, including deadly dioxins and furans. A recent Canadian government report stated that "...chlorinated organic compounds commonly discharged from bleached pulp mills have demonstrated such chronic effects as deformities, and embryo and larval mortalities in fish. These chronic effects include significant irreversible factors which jeopardize the continuance of species and the integrity of the ecosystem". Quite simply chlorine kills ... or severely damages species

exposed even to low levels of bleaching by products (Weed Foundation no date a).

The source of the first 4 sentences is Government Canada *et al.* (1991: viii a). The volume of organochlorines dumped into the Canadian aquatic environment (first sentence of the claim) has been reproduced correctly from the Government of Canada report by the Weed Foundation. However, no source for the effluent volume is provided by the report. The report also does not refer to organochlorines as 'deadly dioxins and furans'. The estimate of chlorinated organic effluent stated for by the Government Report for Canada is 4 times the estimate provided by Crooks and Sikes (1990: 68) for total organically bound chlorine (TOCI) discharged into the global environment.

The first quote which is in the second sentence ("... chlorinated organic compounds commonly discharged ..."), has left out from the beginning of the passage the following four words "Laboratory studies using individual" chlorinated organic compounds commonly discharged ... Exclusion of these words alters the meaning of the passage, as effects of compounds in the laboratory are quite different to the effects of compounds in the field. For instance, concentrations of toxins administered to organisms in the laboratory may be different to the concentrations found in organisms and available to organisms in the natural environment (Nowak 1991: 35-36). No source is provided by the Government of Canada Report *et al.* (1991 a) for the organism, species and ecosystem effects described.

In regards to the last passage chlorine in low doses does not kill. It is added in small doses to the urban water supply which the populace consumes, it is used in swimming pools, disinfectants and many other household products. Whether chlorines or organochlorines effect species is dependant on numerous factors which were discussed in Section 3.6.

3.9.3 Weed Foundation (no date b)

One of the pulp and paper industry's standard comebacks to the toxic waste problem is that life expectancy of humans hasn't suffered, that we're still living to grand old ages, maybe even longer than before. But look more closely at human health statistics: sperm counts are down, the number of birth defects has doubled over the last twenty five years and cancer statistics are still on the rise. One in three Canadians will contract some from of cancer, not including non-melanoma skin cancers (Weed Foundation no date b).

The Weed Foundation was unable to provide a source for its initial statement when asked by the author. There are countless factors which may or may not act to affect life expectancy. It lacks sense to select one source, in this case the pulp and paper industry, and attribute negative human health effects to it. In addition, the organochlorines in effluent are cancer promoters and not initiators as discussed in Section 3.6.

3.10 Review of the Primary Data Sources used by the Weed Foundation.

Claims originating from the Weed Foundation in Canada were obtained from an Environmental Kit from the Tasmanian Conservation Trust titled 'Stop the Whitewash' Campaign. The kit was made up of a collection of claims made by the Weed Foundation regarding: sanitary products such as nappies, sanitary napkins and tampons; and health impacts arising from pulp mill effluents including organochlorines. Newspaper articles concerning organochlorine impacts were also included. One of the major aims of the campaign was "to compel manufacturers to get the chlorine bleach out of sanitary products and diapers" (Weed Foundation 1992).

Only one of the forty or so claims presented in the Kit by the Foundation was referenced. It was therefore decided to write to the group and request the sources or primary data from which their "fast facts" were based. The group forwarded 12 scientific studies, 9 general articles, 4 reports, 5 newspaper articles and 2 government booklets.

3.10.1 Scientific Studies

Of the 12 scientific studies sent, 6 examined the human and mammalian health effects of PCBs (Tilson *et al.* 1990; Brown *et al.* [no date]; Jacobson *et al.* 1990 a; Swain 1987; Levin *et al.* 1988; Jacobson *et al.* 1990 b). PCBs like dioxins, are a group of organochlorines. However, they belong to a different class of compounds (Volkman 1991: 5). PCBs had widespread use from the 1930s till the 1970s when manufacturing ceased and were used in electrical capacitors and transformers, cable, carbonless copy paper, small electric parts and microscope immersion oil (Tilson *et al.* 1990). PCBs do not occur in pulp mill effluent or in paper products and as such are not relevant as primary or secondary data sources. One might question as to why they were included in the material forwarded.

Three of the studies looked at the health impacts of TCDD/Fs on: rats (Lucier *et al.* 1991); monkeys (Barsotti *et al.* 1979); and mice (House *et al.* 1990). It is impossible to extrapolate the results of these laboratory studies to the effects of dioxins in pulp mill effluent. The reasons for this include: a range of 4 orders of magnitude in dioxin toxicity depending on the species of animal (Crooks and Sikes 1990: 69); laboratory studies not being the same as field conditions; and enormous variations between dioxin exposure in the laboratory and residual exposure in the natural environment (Nowak 1991: 36).

The remaining 3 studies (Krowke *et al.* 1990; Sullivan *et al.* [no date] and Schecter 1990) examine the transfer of dioxins from mother to baby via the placenta and mothers' milk. These studies are of some relevance as dioxins from pulp mills producing nappy fluff pulp may make a very small contribution to the dioxin load in the environment. However, nappy fluff pulp manufacture accounts for less than 1% of the paper pulp product market (Wright 1992; Australian Bureau of Agricultural and Resource Economics 1992).

3.10.2 General Articles

Nine general articles were included in the 'Stop the Whitewash Kit'. Article 1 by Kroesa (1993), examines pulp mill effluent, organochlorines and recent research. The article itself has many inaccurate and false claims. Two of these inaccurate claims are presented and examined below.

(1) Pulp mills are the largest single source of organochlorine emissions in Canada.

Organochlorine emissions are made up of many different classes of compounds. They are the result of many natural and human activities as listed in Section 3.4. A list of critical pollutants by Government Canada *et al.* (1991 b) indicates that pulp mills are only a small component of organochlorine emissions in Canada.

(2) Dioxin is an extremely toxic organochlorine and chronic exposure to even minute amounts can lead to cancer, suppressed immune systems and reproductive failure.

As discussed in this Section 3.5.2, only 17 of the 210 dioxin isomers are regarded as toxic or of environmental concern. Of the ones which are considered toxic, toxicity is dependent on the factors listed in Section 3.6. Dioxin does not cause cancer (refer to Section 3.6). Suppressed immune systems and reproductive failure have been effects observed in the laboratory rather than in the field (refer to Section 3.6).

The article by Colborn (1992) is concerned with PCBs, dichlorodipenyltrichloroethane (DDT) and dichlordiphenyldichloroethylene (DDE). Although they are organochlorines, they have no relevance to the pulp and paper industry. The article by the Board of Health (1991) again has no relevant information that can be used to substantiate the claims made by the Weed Foundation. The article is a guideline for nappy use and disposal. The Rohleder (1991) article examines the 1953 Seveso Dioxin accident. The source of the dioxin contamination is herbicide manufacture and not pulp processing.

Other irrelevant articles include: Myers and Colborn (1991) which examines pesticides; Cummings (1992) which is a personal letter based mostly on opinion and not fact; The Women's Environmental Network (1990) which is a summary of a study which compares the levels of dioxins and furans in milk obtained from industrial areas with cleaner rural environments; and Jacobson and Jacobson (1988) which examines the methods of assessing prenatal toxic exposure on cognitive functioning in humans.

However, the article by Grandjean *et al.* (1987) may be of relevance if the pulp process used to manufacture nappies produces dioxins.

3.10.3 Newspaper Articles

The reliability of newspaper articles will vary from newspaper to newspaper and from writer to writer. Some articles are written by practising scientists and trained journalists, whilst others are written by writers who do not have a background in the topic they are writing on. Some articles are short and hence cannot present all the information and background required to fully understand the issues under discussion.

The point being that it is not possible to attribute the same degree of technical reliability to a newspaper article as it is to a technical book or paper which has been through a process of peer review.

3.10.4 Government Booklets

The two Government booklets that were forwarded to substantiate Weed Foundation Claims were by Government Canada *et al.* (1991 b) and International Joint Commission (1992).

The booklet by Environment Canada is a summary of available data on toxic chemical concentrations in the Great Lakes and the effects of those chemicals on a variety of organisms residing in the basin. The report attributes most of the toxic contaminants to urban industrial discharge, municipal sewage treatment plants, air deposition, organochlorine pesticides in the form of run off from farm land, and leachate containing hazardous chemicals from landfill sites and emissions from combustion sources. Pulp and paper mills are depicted only once in the Appendix as sources of dioxins.

Information presented by the Joint Commission (in its Sixth Biennial Report Under the Great Lakes Water Quality Agreement of 1978 to the Governments of The United States and Canada and the State and Provincial Governments of the Great Lakes Basin) from a variety of sources and from its own evaluation of data, is often contrary to many of the claims presented by the Weed Foundation concerning environmental effects of dioxins. This is well illustrated when comparing the two statements below with the initial claims presented by the Weed Foundation:

> A Government of Canada report released in March 1991 reported that "toxic chemical found in the Great Lakes can have subtle effects on cellular metabolism." These "may not be adverse health effects in themselves and their ability to predict the eventual occurrence of adverse health effects is unclear." Nonetheless, such subtle effects "are undesirable and support the need for a reduction in our exposure to such substances"; and

> The Commission recognizes that scientific data are open to interpretation and that, notwithstanding the confirmed cause-effect link in some cases, unequivocal conclusions may be difficult to reach in others, especially if individual studies are considered in isolation. With low contaminant concentrations, subtle effects and potentially confounding factors, unequivocal evidence of injury to humans by persistent toxic substances may be difficult or impossible to obtain (International Joint Commission 1992: 21-22).

3.11 Conclusion

Some sections of the environmental movement are making claims against disposable nappies in relation to pulp production. Some of these claims (as shown in Sections 3.9.1, 3.9.2, and 3.9.3) are implying that organochlorines produced from bleaching are a major health and environmental problem. In fact, examination of this issue has shown that not all the pulp processes produce organochlorines. In Australia, the Magnefite process does not produce any organochlorines and in NZ, scientific evidence shows that organochlorines are below detection limits. Data was not forthcoming from the USA pulp mills. Moreover, only a very small proportion or organochlorines in pulp mill effluent are considered to be harmful (Section 3.5).

Looking more broadly at organochlorine emissions, the scientific reports examined, indicate that organochlorine levels from pulp mill effluent are below levels considered environmentally dangerous. In addition, the paper industry is only one of a number of possible sources of organochlorines. The literature also shows that certain organochlorines are considered to be cancer promoters. There is definitely reason to look critically at this issue, however, the technical literature does not substantiate the claims made against disposables and the paper industry which imply that they are responsible for many of the environmental problems associated with organochlorines.

The literature shows that there are many ways that mills can reduce the amount of organochlorines released. This might be seen as justification by some environmental groups for exaggerating the issue. By increasing public concern about environmental releases from pulp mills, the pulp and paper industry is forced to adopt stricter pollution control measures to stay in favour with the public.

Evidence made available in 1987 is inconclusive regarding the question of TCDD/F dermal absorption from nappies. The report does, however, argue that there is little likelihood of dioxin migration from nappy fluff pulp to urine to baby skin. Concentrations of TCDF found in disposable nappies appear to be many orders of magnitude below critical levels. Further, improvements in Kraft pulping and bleaching technologies and the absorption capabilities of nappies since 1987, have served to further reduce any risk that may have been present. The issue is not relevant to nappies manufactured using the Magnefite process.

In terms of organochlorines released in pulp mill effluent and absorbed through dermal contact, there is very little scientific evidence indicating that they are the problem they are made out to be by the claims presented. There is no doubt that the claims displayed in this Chapter are exaggerated. They are an example of claims which use scientific information inaccurately, to promote a cause which in this case, has very little to do with disposable nappies.

Chapter 4

An Evaluation of Existing Life-cycle Assessments on Disposable and Cloth Nappies

4.1 Introduction

Having examined the environmental burdens associated with pulp production and bleaching in Chapter 3, this Chapter now focuses on 'life-cycle assessment'. This is a very important aspect to the thesis because the life-cycle assessments undertaken on nappies provide the most comprehensive information available with regards to environmental releases, resource requirements and manufacturing processes. As subsequent work will be based on this information, it is crucial that a thorough analysis of the life-cycle method be undertaken.

This Chapter first defines the various types of life-cycle assessments. It then lists and briefly discusses existing life-cycle assessments on the disposable and cloth nappy systems and then concludes by providing information on the limitations of nappy life-cycle assessments.

4.2 Definition

The concept of 'life-cycle assessment' is comparatively new. Work on various components of these assessments date back to the 1960s. Development of the modern life-cycle assessment occurred in the mid 1970s. This was a result of both the progression of the life-cycle method in Europe and landmark studies by the Midwest Research Institute in the USA.

Life-cycle assessments have the potential to provide policy makers, the public and professionals a means of identifying, assessing and solving the environmental concerns associated with products, processes and activities. For this to occur, however, a great deal of work is still required on all components of this type of assessment.

According to the Society of Environmental Toxicology and Chemistry (1991) a life-cycle assessment should be made up of the following three separate but interrelated parts.

(1) Life-cycle Inventory

An evaluation of a product or process throughout its life-cycle in terms of its:

- total resource requirements (energy, water, raw materials)
- total environmental releases (solid wastes, waterborne wastes, atmospheric emissions).

(2) Life-cycle Impact Analysis

The potential and resulting environmental effects associated with the resource requirements and environmental releases of a product or process throughout its life-cycle. Effect categories can include:

- ecological effects;
- habitat modifications;
- human effects; and
- noise pollution.

(3) Life-cycle Improvement Analysis

Approaches of reducing the environmental burdens associated with the resource requirements and environmental releases of a product, or process, or activity throughout its life-cycle. These approaches may be quantitative and qualitative. They may include changes in:

- processing;
- waste management;
- raw material use; and
- recycling.

A useful additional component in the inventory stage is called sensitivity analysis. This is a test which shows how final results can vary given changes in baseline data and initial assumptions.

Most life-cycle assessments completed to date have concentrated chiefly on the inventory component.

4.3 Life-cycle Inventories Undertaken on Nappies

Over the last two decades a small number of life-cycle assessments have been carried out to compare the two types of nappy systems. Similar to other life-cycle assessments these studies have focused primarily on the inventory component. The ones examined in this thesis include:

(1) A Life-cycle Inventory of Children's Disposable and Cloth Diapers Subject to Canadian Conditions (Vizcarra *et al.* 1993);

(2) Diapers: Environmental Impacts and Life-cycle Analysis (Lehrburger 1991);

(3) Disposable versus Reusable Diapers: Health, Environmental and Economic Comparisons (Little 1990); and

(4) Energy and Environmental Profile Analysis of Children's Disposable and Cloth Diapers (Franklin Associates 1993).

Studies 1 and 3 were prepared for Procter and Gamble Inc. and study 4 for the American Paper Institute, Diaper Manufacturers Group. Study 2 on the other hand was a report to The National Association of Diaper Services (a laundry based, re-usable cotton nappy industry). Studies 2, 3 and 4 are subject to American conditions and study 1 to Canadian conditions.

For simplicity:

- study 1 will be referred to as University of British Columbia;
- study 2 as Arthur D Little;
- study 3 as Franklin Associates; and
- study 4 as Lehrburger *et al.*

All of the studies have slight variations in the parameters they have chosen to evaluate. These parameters and variations are presented in Table 4.1.

4.4 Limitations of Nappy Life-cycle Assessments

A detailed discussion of life-cycle assessments has been undertaken by the Society of Environmental Toxicology and Chemistry (SETAC) and SETAC Foundation for Environmental Education, Inc. (1991). Many of the shortcomings discussed in the workshop report titled "A Technical Framework For Life-Cycle Assessments" are directly applicable to the nappy life-cycle assessments listed in Section 4.2. The critique in the following sections draws on several of the weaknesses raised in the report.

TABLE 4.1
PARAMETERS EVALUATED BY FOUR NAPPY LIFE CYCLE STUDIES

Parameters	University of British Columbia	Lehrburger *et al.*	Arthur D Little	Franklin Associates
Energy consumption	YES	YES	YES	YES
Water consumption	YES	YES	YES	YES
Raw material consumption	YES	YES	YES	NO
Waterborne wastes	YES	YES	YES	YES
Sensitivity analyses	YES	NO	NO	NO
Impact analysis	NO	LIMITED	NO	NO
Improvement analysis	NO	LIMITED	NO	NO

These issues include:

- standardization of methods;
- data detail
  - specificity of data,
  - age of data,
  - accuracy and detail of data,
  - source and documentation of data; and
- sensitivity analysis.

Although the issues will be discussed separately, there is significant overlap between the categories.

4.4.1 Standardization of Methods

There is a lack of consistency in the way life-cycle studies are carried out. This makes it very difficult to compare results between different studies analysing the same systems or to gauge the accuracy of a study. Some of these problems include:

- varying assumptions between the nappy studies;
- varying units used to assess nappy impacts within the parameters listed in Section 4.2; and
- varying use of type of data, as discussed in Section 4.4.2.

4.4.1.1 Varying Assumptions

All of the nappy life-cycle assessments analysed have varying initial assumptions (or baseline data) from which all resource requirements and environmental releases are calculated. This lack of assumption standardization makes it very difficult to accurately compare results between the studies. It also greatly influences the conclusions reached by life-cycle studies.

The most obvious varying assumption is the cloth to disposable nappy usage ratio as shown in Table 4.2. To enable a direct comparison between the nappy assessments, the usage ratios given in the University of British Columbia's assessment were converted from daily to weekly rates (Vizcarra, *et al.* 1993: 24).

The greatest variation in nappy change rates between the four life-cycle studies occurs with cotton nappies. This difference is highlighted when a percentage comparison is undertaken between Little's study and the other studies. Little's total for cloth used per baby per week is 78% higher than the University of British Columbia, 34% higher than Lehrburger and 25% higher than Franklin Associates.

Just how influential these assumptions can be in altering conclusions can be seen in Table 4.3. The Table presents variations in energy use for one washing regime estimate for the University of British Columbia, together with adjustments for Arthur D Little and the average number of nappies per week for all studies. Chapter 5 discusses in detail how the average figures and those of Arthur D Little were calculated. This Table illustrates how laundering energy consumption is directly related to the number of nappies used per week.

TABLE 4.2
NUMBER OF CLOTH AND DISPOSABLE NAPPY CHANGES WEEK ASSUMED BY FOUR NAPPY LIFE CYCLE STUDIES (CALCULATED FROM DATA IN EACH REPORT)

Nappy	University of British Columbia	Lehrburger *et al.*	Arthur D Little	Franklin Associates
Disposable nappies	37.8	37.1	44.8	38.2
Cloth nappies	47.6	63.7	84.7	67.9

TABLE 4.3
ESTIMATES GIVEN BY UNIVERSITY OF BRITISH COLUMBIA FOR ENERGY CONSUMED (MJ) IN LAUNDERING OF CLOTH NAPPIES TOGETHER WITH RECALCULATIONS FOR ARTHUR D LITTLE AND THE AVERAGE NAPPIES USED PER BABY PER WEEK

Life-cycle assessment	Energy consumed in home laundering (MJ)
47.6 nappies per baby per week (University of British Columbia)	169 MJ/week
59 nappies per baby per week (Average number of nappies for all studies)	211 MJ/week
84.7 nappies per baby per week (Arthur D Little)	290 MJ/week
Assumes: 20 nappies/wash, hot (60°C), warm (30°C) rinse and 32 % line dried.	

Other different assumptions which have noteworthy effects on assessment results include: the market share in cloth nappies; home laundering habits (as shown in Section 4.4.5); washing machine capacity; and washing machine water usage figures (as shown in Section 4.4.2).

4.4.1.2 Varying Units

Table 4.4 shows the degree to which units used to assess environmental impact vary between the studies. The major problem associated with unit variation is the difficulty in making comparisons between the studies.

TABLE 4.4
RANGE OF UNITS USED TO DESCRIBE WATERBORNE WASTES BY FOUR LIFE-CYCLE STUDIES

Life-cycle assessments	Units used
University of British Columbia	Units of kg /baby-week
Lehrburger *et al.*	Units of lbs/1,000 nappy changes
Arthur D Little	Units of lbs/average weekly nappy requirements
Franklin and Associates	Units of lbs/1,790 nappy changes

4.4.2 Specificity of Data

A problem throughout the nappy assessments is the lack of discussion regarding the type of data used. The selection of average, worst case, best case or case specific data can have enormous effects on inventory results. Life-cycle studies should document and discuss in detail the type of data used, its limitations and the impact on the study results it will have.

A good example that illustrates the extent of variation that can occur between best case and worst case data is water consumption and home laundering. Approximate water usage in L/kg of washing, in a complete cycle, for the four studies is provided in Table 4.5. In each case, the units used in the original report have been converted to litres of water per kilogram of washing load.

TABLE 4.5 CALCULATED ESTIMATES OF VOLUME (L) OF WATER CONSUMED PER (kg) OF WASHING FOR HOME LAUNDERING BY FOUR NAPPY LIFE-CYCLE STUDIES	
Life-cycle asssessments	Water volume used (L/kg)
University of British Columbia	93 L/kg
Lehrburger *et al.*	80 L/kg
Arthur D Little	85 L/kg
Franklin and Associates	87 L/kg

Choice Magazine (Australian Consumer Union 1991: 33) also provides water usage figures for a complete wash cycle for washing machines sold in Australia. A selection of these figures is provided in Table 4.6.

TABLE 4.6 AVERAGE VOLUME (L) OF WATER CONSUMED PER (kg) OF WASHING FOR HOME LAUNDERING FOR THREE AUSTRALIAN SOLD WASHING MACHINES	
Washing machine type	Water volume used (L/kg)
Thor W 1116 RX	15 L/kg
Asko	19 L/kg
Panasomic	35 L/kg

As the information in Tables 4.5 and 4.6 indicate, there is great variation in the estimates of water consumption per kg of washload between the two sources. This can be explained in part by both the small washload size used by the nappy studies compared with Australian Consumer Union Analysts (see Table 4.7) and by the larger capacity washing machines used in North America.

Another factor which would have an impact on home laundering water consumption figures is the actual weight of nappies washed per cycle. As can be seen in Table 4.7 the load weights used by the three life-cycle studies examined are very low compared to what washing machines sold in Australia can hold. If larger load sizes were initially assumed by the studies, the water consumption, energy consumption and environmental emission results would be significantly different. In each of the three studies presented in Table 4.7, load size is calculated from water consumption data from the studies and then converted to kg per load.

TABLE 4.7
CALCULATED VALUES OF WEIGHT (kg) PER HOME LAUNDERED WASHING LOAD OF COTTON NAPPIES FOR THREE LIFE CYCLE STUDIES COMPARED TO AUSTRALIAN CONSUMER ASSOCIATION ANALYSISTS

Life-cycle assessments	Washing load size
University of British Columbia	1.8 kg/load
Arthur D Little	1.9 kg/load
Franklin Associates	2.0 kg/load
Choice Analysts	4.6 kg/load

If the Arthur D Little and Franklin and Associates assessments were recalculated using a 4 kg wash load, as well as the most efficient water figure provided by *Choice*, water consumption for the laundering component of the analyses would be reduced by around 85%. This would have a large effect on water consumption conclusions.

As has been demonstrated, the choice of initial data types used can have a significant effect on resource requirements and environmental release evaluations. For the results to be meaningful, the data needs to be as detailed as possible. It needs to be collected from specific plants undertaking the processes rather than from industry averages and regulatory limits. Where averages are used, sensitivity analysis should be performed to assess the ranges in resource requirements and pollution releases (SETAC 1991: 18-19).

4.4.3 Age of Data

Recent data should be used in life-cycle assessments. Failure to do so may result in information not being representative of current practise. The age of data may also introduce bias when for example one piece of data used is one or two years old, whilst another is greater than five years old.

A good example of this type of bias occurs in Arthur D Little's study. Waste water figures and median waste characteristics of cotton manufacturing are referenced in the text as EPA, 1979 (Little 1990: III-15). There is no entry of this reference in the bibliography. In contrast, the only reference on pulp and paper statistics occurs in the bibliography and is dated 1989. However, as no entry of this reference exists in the text, one cannot be totally confident that the environmental release data for pulp manufacture was derived from this source.

Assuming that the pulp pollution data was collected from the 1989 reference, the ten year difference between the two sources of data could have a significant effect on emission results, especially given the speed in which many industries are updating their technologies to reduce environmental pollution. Whether this was deliberately done by Arthur D Little one cannot say. However, other nappy assessments have more up to date cotton references, which in the Franklin and Associates study are dated 1985 and 1989.

As there is insufficient referencing and documentation of where data is obtained in the nappy assessments, it is difficult to determine the extent to which dated data is used, or the level of bias resulting from this.

4.4.4 Source and Documentation Data

All of the nappy assessments contain insufficient source or documentation data to permit meaningful review. This problem is apparent with regards to: consumer laundering and nappy use habits; the manner in which energy consumption, water consumption and environmental releases were calculated for the two nappy systems; and the methods used to acquire manufacturing and processing data.

Using Little's analysis as a case study, the laundering practices in the report are based on a number of assumptions chosen to be representative of typical practices in the USA. These assumptions include: number of cloth nappies used; percentage drier drying versus line drying; and number of laundry loads per week. The primary sources used to determine these assumptions comprise:

(1) Proctor and Gamble, Disposable Diaper Habits and Practices Study (1986); and

(2) Proctor and Gamble, Market Research Study (1985).

These two reports, however, are not available for public scrutiny. Proctor and Gamble consider the data to be proprietary data. Refer to Appendix 4. As such, methodological details such as sample size, survey type, or whether or not the sample was representative of the USA population cannot be confirmed. There is accordingly a strong degree of uncertainty whether the practices described are indeed representative of the racial, socioeconomic and class mix of the USA population.

Proctor and Gamble similarly will not disclose any details concerning their pulp mill pollutant load, the pollutant levels in their solid waste, emission rates of air pollutants, rates of water usage, their bleaching sequence and the percentage of ClO_2 substitution. This makes it impossible to cross check pollution emission data and review.

This lack of documentation data is extended to an inadequate description of the procedures used to obtain environmental pollutant loads. As the methodologies used have not been given, reliability of the data cannot be determined.

4.4.5 Sensitivity Analysis

The use of sensitivity analysis in inventories allows us to see how significantly results can be affected by changes in baseline data. This is a very useful method given the degree to which changes in assumptions can vary results, the numerous uncertainties in data and suspect primary or secondary data.

As shown in Table 4.1 the only nappy life-cycle assessment to undertake this kind of evaluation is the University of British Columbia. Both single and multiple variable tests were undertaken.

Single variables that affected the energy consumption and atmospheric emissions of the two nappy systems included: cloth to disposable diaper ratio; market share in cloth diapers; number of laundry loads per week; washing/rinsing water temperatures; percentage of drier-drying and line drying; and drier time. The extent to which one variable can affect resource consumption and environmental releases can be seen in the percentage increase column in Table 4.8. In this Table, two assumptions are made about how frequently cloth nappies are changed compared to disposable nappies.

TABLE 4.8
RESOURCE CONSUMPTION AND ENVIRONMENTAL RELEASES OF HOME LAUNDERED CLOTH NAPPIES AT A CLOTH/DISPOSABLE RATIO OF 1.26 AND 2.00
(ADAPTED FROM VIZCARRA ET AL. 1993)

Parameter	1.26:1	2.00:1	Percentage Increase from 1.26 to 2.00
Energy consumption (MJ/baby-week)	151	240	59 %
Water consumption (m^3/baby-week)	0.798	1.089	36 %
Raw materials consumption (kg/baby-week)	0.414	0.656	58 %
Atmospheric emissions (kg/baby-week)	0.116	0.184	58 %
Waterborne wastes (kg/baby-week)	0.171	0.272	59 %
Solid wastes (kg/baby-week)	1.624	2.280	40 %

The sensitivity tests with multiple variables that were tested in combination were wash/rinse water temperatures, drying time, and percentage of drying in a drier versus line drying. Significant affects on energy consumption and atmospheric emissions were observed. They depended on the combinations of the variables used and can be seen in the following two examples taken from the University of British Columbia study (Table 4.9).

These examples demonstrate how sensitive results in life-cycle assessments are to changes in baseline data. For an analysis to be meaningful, especially given the variability of data used, sensitivity analysis should be an essential component of the assessments framework.

TABLE 4.9
TOTAL ENERGY CONSUMPTION (MJ/BABY-WEEK)
AT VARIOUS LEVELS OF WASH/RINSE WATER TEMPERATURES, DRYING TIME AND PERCENTAGE OF DRIER-DRYING AND LINE-DRYING

Hot wash (60°C) Warm rinse (27.4°C)	Line dry	Drying time (minutes)		
		38	58	65
100 % drier		184	216	227
68 % drier		165	186	194
0 % drier	123			

Warm wash (27.4°C) Cold rinse (12.2°C)	Line dry	Drying time (minutes)		
		38	58	65
100 % drier		120	151	162
68 % drier		100	122	129
0 % drier	59			

4.4.6 Data Accuracy and Detail

The degree of information from environmental release data can depend largely on how that data is presented. Emission data in life-cycle inventories is usually listed arbitrarily or grouped under particular headings (as is the case with all of the nappy assessments), alphabetically or by weight. This manner of listing can often fail to provide in depth information about what has been measured, the accuracy of the measurements and the potential severity of the environmental effects. In addition, measurements and units often have no concentration values or dilution factors which some would argue would make measurements meaningless.

These problems become apparent when several waterborne waste categories are examined from the University of British Columbia study (Vizcarra *et al.* 1993: 52).

4.4.6.1 Phosphorus

Phosphorus occurs in a variety of compounds that may or may not be available to the biota. It may be dissolved or bound in suspended solids. It is transitory and mobile in time and space and has, when available to biota, varying utilization rates (Gordon 1981 in Blake 1991: 39). The concentration of phosphorus is affected by factors such as water temperature, presence of other metals and salts, dissolved oxygen content, and pH (Connell 1981: 130). Other factors include absorption processes, mineral-water equilibria, the activities of bacteria, fungi and plankton (Wetzel 1983; Fukuhara and Sakamoto 1988 in Blake 1991: 38).

The problem of presenting quantitative emissions of phosphorus as a single element include:

- meaningless gross measurements, as concentration values and dilution factors are not provided;
- difficulty in knowing the relative quantities of available and unavailable (soluble and insoluble) phosphorus entering the environment; and
- the non-description of the chemical forms present in the emission. Due to the very rapid cycling times in the environment, varying absolute concentrations with water chemistry and temperature and uncertain responses by plants to known concentrations, providing data as elemental phosphorus makes any assessment of the environmental impact of emissions problematic.

4.4.6.2 Problems with other Categories of Chemical Species:

Problems with other categories include:

- many of the elements presented, such as nitrogen, occur in the environment in a number of different forms, such as nitrite or nitrate;
- there is no indication of whether a compound is harmful to the

environment;

- there is no mention of detection limits. It is not clear whether the data means that no presence of a substance was found, or whether concentrations were below detection limits;
- a weight of acidity or alkalinity is meaningless. A more operative indicator would be pH;
- some elements such as sulphides occur naturally in the environment as a result of decomposition. It would be difficult to determine what is introduced and what is natural; and
- duplication of many of the pollutants. For example metal ion and chromium.

From this critique it can be seen that there are enormous problems in the manner waterborne waste data is presented. These problems are not specific to waterborne wastes in the University of British Columbia report. Comparable flaws occur throughout the data in all nappy assessments.

In addition, according to the SETAC (1991) report the following information could also be included in life-cycle assessments: whether or not a pollutant is a greenhouse gas; whether it is carcinogenic, bioaccumulative, persistent, or contributes to acid precipitation.

4.5 Conclusion

This Chapter has demonstrated that the four nappy life-cycle assessments examined are very limited in their accuracy. Results and conclusions reached by the studies are largely dependent on initial assumptions, the specificity of data, and the sources of original data. Examples were provided which show how variations in data input can alter results. There is also inadequate explanation about the methods used to obtain environmental release data which makes replication impossible and reliability questionable. Table 6.1, Summary of Conclusions, provides a list of improvements that may help overcome some of the problems with life-cycle studies.

Chapter 5

Assessment of Claims Concerning Resource Consumption and Silviculture Impacts

5.1 Introduction

Chapter 4 examined the accuracy of life-cycle assessments with regard to their evaluation of environmental releases, resource requirements and manufacturing processes. This Chapter will use the information and understanding gained from Chapter 4, to assess the accuracy of claims concerning energy and water consumption. Pulp and plastic consumption and silviculture impacts will also be examined.

A sample of the type of claims against disposable nappies found in the literature concerning resource consumption includes:

> (1) Other resources used in nappy manufacture include large quantities of water, energy ...
>
> Massive numbers of trees are cut down and converted into fluff pulp for nappies. 70% of a disposable nappy is fluff pulp padding. One nappy manufacturer estimates that the conventional process of pulp manufacture produces only 500 nappies to one typical pine tree (Rassaby 1990:27);
>
> (2) This means that over 1 million trees worth of disposable nappies are thrown out each year in Australia (Pretty Young Company 1993); and
>
> (3) They use large quantities of ... petroleum in their manufacture of ... plastic (Allan 1990).

Each of the following resources (water, energy, petroleum and timber), as well as silviculture impacts will be examined for content accuracy in the following Sections.

5.2 Energy Use

To determine whether disposable nappies use large quantities of energy it is necessary to compare the energy it takes to keep one baby in disposable nappies to the energy it takes to keep a baby in cloth nappies and the energy consumed by household appliances and household activities.

5.2.1 Energy Involved in Keeping a Baby in Disposable Nappies Compared to the Energy Involved in Keeping a Baby in Cotton Nappies

Various results are provided by the four life-cycle studies (Vizcarra *et al.* 1993; Lehrburger 1991; Arthur D. Little Inc. 1990; and Franklin Associates, Ltd. 1990) for the life-cycle energy associated with keeping a baby in disposable nappies compared to the energy in keeping a baby in cotton nappies. As the energy calculations depend on the assumed number of nappies used per time frame, laundering habits, washing machine capacity and washing machine water usage figures, they should be used with caution.

Four estimates based on empirical surveys of the number of nappies used per week and the calculated average for both disposable and cloth nappies are presented in Table 5.1. The significant feature of this Table is that babies in cloth nappies are changed significantly more often than babies in disposable nappies.

TABLE 5.1
NUMBER OF CLOTH AND NAPPY CHANGES PER WEEK ASSUMED BY FOUR NAPPY LIFE-CYCLE STUDIES (CALCULATED FROM DATA IN EACH REPORT)

Nappy type	University of British Columbia	Lehrburger *et al.*	Arthur D Little	Franklin Associates	Average
Disposable nappies	37.8	37.1	44.8	38.2	39.5
Cloth nappies	47.6	63.7	84.7	67.9	58.7

Note: the average for cloth nappies omits the figures given by A D Little as they appear inordinately high.

Four calculated estimates of life-cycle energy associated with disposable nappies have been converted to uniform energy units megajoules (MJ) and are presented in Table 5.2 (1 MJ is approximately equal to the energy required to heat 3 L of water from 20°C to boiling point, or make around 12 cups of coffee [Plastics Industry Association 1992]). A value judgement was made by the author to omit A D Little's energy consumption results, as it was felt that the very low results, would bias the data.

TABLE 5.2
ESTIMATES GIVEN BY FOUR LIFE-CYCLE STUDIES FOR ENERGY CONSUMED (MJ) IN THE MANUFACTURE OF DISPOSABLE NAPPIES PER NAPPY AND PER BABY WEEK (CALCULATED FROM DATA IN EACH REPORT)

	University of British Columbia	Lehrburger *et al.*	Arthur D Little	Franklin Associates	Average
MJ/baby week	158 MJ	136 MJ	6 MJ	140 MJ	144.7 MJ
MJ/nappy	4.17 MJ	3.67 MJ	0.13 MJ	3.55 MJ	3.8 MJ

Note: calculation of average energy per baby week and the average energy per nappy omitted the figures given by A D Little as these were inexplicably low.

It is frequently argued that the use of disposable nappies represents energy intensive behaviour, whilst the use of cloth does not (Lehrburger 1991; Rassaby 1990; Greenpeace NZ 1991; Scaletta 1991; and Anonymous 1990: 54). However, cloth nappies require energy to produce and to wash. This energy is highly dependent on the number of nappies used per week, the washing regime, water machine usage figures, washing machine capacity and nappy load size.

The life-cycle studies provide information on the energy involved with the production of cloth nappies. These figures vary substantially (by a factor of almost 2). The range of estimates given by A D Little and the University of British Columbia together with the average calculated from four life-cycle studies is presented in Table 5.3.

The University of British Columbia life-cycle analysis has provided detailed estimates of the energy consumed in home laundering of cloth nappies under various washing regimes. To indicate just how these estimates are sensitive to the initial assumption about the number of nappies used per baby per week, the University of British Columbia estimate for one washing regime has been recalculated in Table 4.3, Chapter 4, using the highest (Little: 84.7), lowest (University of British Columbia: 47.6) and average (58.7) estimate of nappies used per week, as given in Table 5.1.

TABLE 5.3
RANGE OF ESTIMATES GIVEN BY UNIVERSITY OF BRITISH COLUMBIA AND A D LITTLE FOR ENERGY CONSUMED (MJ) IN THE PRODUCTION OF CLOTH NAPPIES TOGETHER WITH THE AVERAGE FIGURE CALCULATED FROM FOUR NAPPY LIFE-CYCLE STUDIES

	University of British Columbia	A D Little	Average
Energy (MJ) per baby per week	19.64 MJ	33.78 MJ	24.55 MJ

The variation in energy consumption in home laundering is very high given the possible combination of laundering options. At on extreme, nappies can be washed in hot water, rinsed in hot water and dried in a tumble drier. At the other extreme, nappies can be soaked in a bucket of bleach in cold water, rinsed by hand in cold water and line dried.

There is no data available to the public as to what represents a typical washing regime in Australia or North America. University of British Columbia life-cycle data, supplied by Proctor and Gamble Inc. USA, indicate that the typical Canadian nappy washing regime consists of a warm wash, a cold rinse and a 68% rate of tumble drying (Vizcarra 1993). In Australia, where weather conditions are milder, it is reasonable to assume that the tumble drier is used less frequently to dry cotton nappies.

Table 5.4 gives the range in energy consumption under various washing regimes as calculated by the University of British Columbia life-cycle analysis and the author. The University study assumes in its calculations an average of 47.6 cloth nappies per baby per week. The calculations have been adjusted up to the average of 58.7 nappies used per week as shown in Table 5.1.

TABLE 5.4 MAXIMUM AND TYPICAL ESTIMATES GIVEN BY UNIVERSITY OF BRITISH COLUMBIA ADJUSTED TO THE AVERAGE OF 58.7 NAPPIES USED PER WEEK AND AUTHOR'S MINIMUM CALCULATIONS FOR ENERGY (MJ/WEEK) CONSUMED IN LAUNDERING OF CLOTH NAPPIES		
Maximum	Typical	Minimum
221 MJ	195 MJ	Negligible
Maximum: 60° C wash, 30° C rinse and 100% tumble dried for 65 minutes. Average: 30°C wash, 30° rinse and 68% tumble dried for 58 minutes. Minimum: Cold soak in bucket of bleach, cold rinse and 100% line dried.		

If the energy used in producing these nappies is included, we arrive at the total energy required to keep a baby in cloth nappies for 1 week. This is presented in Table 5.5.

TABLE 5.5 TOTAL ENERGY REQUIRED TO KEEP A BABY IN CLOTH NAPPIES FOR 1 WEEK (MJ/BABY/WEEK)		
Maximum	Typical	Minimum
245 MJ	219 MJ	About 24 MJ
Assumes 58.7 nappies used per week.		

From the above Tables, it can be seen that there is a very high variation in the energy associated with keeping a baby in cotton nappies depending on the frequency with which nappies are used and the laundering habits. The maximum total energy requirement for cotton nappies, assuming 58.7 nappies per week, is 69% higher than the average weekly energy consumed in the manufacture of disposable nappies. At the other extreme, the minimum total energy required to keep a baby in cloth nappies for 1 week is 16% of the average energy consumed in the manufacture of disposable nappies.

5.2.2 Energy Involved in Keeping a Baby in Disposable Nappies Compared to the Energy Consumed by a Variety of Household Appliances and Tasks

The State Electricity Commission of Victoria (SECV), publishes annually, estimates for the amount of energy typically consumed by household appliances in Victorian Households. Household appliance figures from 1993, as well as figures for shower time derived from Sustainable Solutions Pty and Focused Energy Ltd (1993), are compared to the energy used by the cotton and disposable nappy systems as shown in Table 5.6.

From Table 5.6 it can be seen that the energy consumed in keeping a child in disposable nappies is higher than the energy consumed in many of the non-discretionary household energy consuming tasks. The typical energy consumed in operating incandescent lights, a refrigerator or a freezer is lower than the typical energy involved in disposable nappy use. For example, the energy used by a large domestic refrigerator/freezer (two-door 410 L capacity frost-free refrigerator/freezer) is less than half of that involved in keeping a baby in disposable nappies.

It should be noted that with any energy using tasks, individuals can influence total usuage and so these figures are averages representing a wide range of individual uses.

However, the energy consumed by using disposables is small when compared to certain energy-intensive discretionary uses of energy in the home such as using a heated water-bed or taking very long showers. For example, taking a 4.5 minute shower each day for a week consumes 90 MJ per week. Taking a 20 minute shower each day therefore consumes 400 MJ per week. The difference, 310 MJ, can be considered a discretionary use of energy and is more than twice the average energy used in keeping a child in disposable nappies.

The real issue at hand is whether the use of disposable nappies is energy intensive compared to using cloth nappies. This comparison is neither simple nor straightforward, as the energy associated with using cloth nappies is highly dependent on the number of nappies changes and on laundering practices. Using disposable diapers can be more energy intensive than using cloth nappies, but it can also be much less energy intensive.

TABLE 5.6
ENERGY CONSUMED (MJ/WEEK) BY VARIOUS HOUSEHOLD ACTIVITIES COMPARED TO ENERGY INVOLVED IN KEEPING A BABY IN DISPOSABLE NAPPIES FOR 1 WEEK

Activity	Energy
Disposable nappies average	145 MJ/week
Cotton nappy laundering (maximum)	245 MJ/week
Cotton nappy laundering (minimum)	24 MJ/week
Single electric blanket	9 MJ/week
Incandescent light (5*60 watt lights)	32 MJ/week
Spa	36 MJ/week
Heated towel rail	72 MJ/week
Water bed	212 MJ/week
Colour console stereo	22 MJ/week
Two door 410 L frost free refrigerator	68 MJ/week
280 L freezer	68 MJ/week
Single door 250 L refrigerator	34.5 MJ/week
2000 Watt oil filled radiator used 12 hours/day	227 MJ/week
4.5 minute shower each day for a week	90 MJ/week
20 minute shower each day for a week	400 MJ/week

Note 1: calculations of energy use for household appliances are based on typical ratings of appliances and typical weekly hours of use from SECV (1993).
Note 2: calculations of shower energy use are obtained from Sustainable Solutions Pty and Focused Energy Ltd (1993:8.8).
Note 3: shower energy calculations assume water temperature of 45° C and water volume of 15 L/minute.
Note 4: nappy calculations omit A D Little's figures.

From Tables 5.5 and 5.2 it can be seen that a typical pattern of cloth nappy use for American and Canadian households (given the assumptions made by the life-cycle studies) involves a total energy consumption of 219 MJ/baby/week, whereas an average pattern of disposable nappy use involves a total energy consumption of 145 MJ/baby/week. This is only 66% of the energy consumed in a typical pattern of cloth nappy use. Hence for this case, the accusation that disposable nappies use more energy than cloth nappies is incorrect.

If the two most extreme cases are taken and compared (44.8 disposable nappy changes per week which gives an adjusted figure of 165 MJ/week) with the lowest energy intensive pattern of cloth nappy use (24 MJ/week), the difference is 141 MJ per week. This is approximately equivalent to one eighth of the energy consumed by a typical Australian household in one week (Australian Consumer Association 1992 b). It is about half of the energy consumed by using a heated water bed over a period of one week, about half the energy consumed in using a 2000 W oil filled electric radiator for 12 hours per day for one week, and about the same as extending the time in the shower each day from four and a half minutes to seven minutes. Thus, even if a very high energy pattern of disposable nappy use is compared with a very low energy pattern of cloth nappy use, the difference in energy use is significant, but lower than many other household discretionary energy uses.

The difference in energy consumption between a high and a low energy pattern of cloth nappy use is 221 MJ (Table 5.5). Therefore, there is far more to be gained in terms of energy conservation by discouraging energy intensive patterns of cloth nappy use than there is by encouraging households to switch from disposable nappy use to cloth nappy use. If the switch were made from disposable nappies to cloth nappies, and both followed typical USA and Canadian patterns of use, the total amount of energy consumed by that household would actually increase by 50 MJ per week. If the switch was from a an energy intensive pattern of disposable nappy use to an energy intensive pattern of cloth nappy use, the total amount of energy consumed by the household would increase by about 100 MJ per week. Only if the switch were from a typical or high energy pattern of disposable nappy use, to a low pattern of cloth nappy use, would energy be conserved by up to 171 MJ/week.

5.3 Water Use

Determining whether disposable and cloth nappies in Australia use large quantities of water is an impossible task with existing data given: the enormous variation of estimates presented by the four life-cycle studies (Table 5.7); and the enormous differences in estimates of water consumed per kg of washing for home laundering between the life cycle studies and the Australian Consumer Association (Table 4.4 and 4.6).

Four calculated estimates of life-cycle water use associated with the manufacture of disposable and cloth nappies and in the laundering of cloth are presented in Table 5.7. The estimates have been converted to uniform units (L/nappy use).

However, an indication of the amount of water required to produce one tonne of fluff pulp is provided by NZ Pulp Industry figures. Calculations from these figures indicate that about 1.7 L of water is needed to produce the fluff component for each disposable nappy (Johnsson 1993, pers. comm.). It is not known whether this water figure is representative of other mills. Water requirements from industry for plastic and other components were not obtained.

TABLE 5.7
ADJUSTED ESTIMATES GIVEN BY FOUR LIFE-CYCLE STUDIES FOR WATER CONSUMED (L/NAPPY USE IN THE MANUFACTURE OI DISPOSABLE NAPPIES AND IN THE MANUFACTURE AND LAUNDERING OF CLOTH NAPPIES (CALCULATED FROM DATA IN EACH REPORT)

	University of British Columbia	Lehrburger *et al.*	Arthur D Little	Franklin Associates
Disposable nappies	10.7 L/nappy (excluding toilet rinsing)	19.8 L/nappy (gross water) 4.6L/nappy (net water) (excluding toilet rinsing)	1L/nappy	4.7L/nappy (excluding toilet rinsing)
Home laundering	24L/nappy (including toilet rinsing)	14.9L/nappy (gross water) 13.1L/nappy (net water) (including toilet rinsing)	12.2L/nappy	18.5L/nappy (including toilet rinsing)

Note 1: The home laundering figures for Arthur D Little assume 90 % home laundering and 10 % commercial laundering and 44.8 disposables and 84.7 cotton nappies used per week.
Note 2: Gross water according to Lehrburger et al. includes intake water plus recycled water. Net water is measured by waste water discharge, exclusive of agricultural runoff.
Note 3: Arthur D Little figures no not mention whether toilet rinsing is included or excluded.

5.4 Pulp

The woodchips that are converted to fluff pulp to produce disposable nappies are sourced from *Pinus radiata* plantation thinnings and wood waste. They are not sourced as Rassaby (1990) suggests, from typical mature trees. Unwanted thinnings in softwood plantations are removed several times throughout a plantations 25-40 year life-cycle. The removal of thinnings enables the remaining trees to develop into trees suitable for veneers and sawlogs (The Pulp and Paper Manufacturers Federation of Australia Limited [no date]).

Although Rassaby's (1990) claim that "massive numbers of trees are cut down and converted into fluff pulp for nappies" is true, it excludes the fact that the softwood resource is a renewable one that is replanted once harvested and that it is predominantly thinnings that are cut down. Without addressing the point of whether softwood plantations are needed at all, it is acknowledged that the use of thinnings from plantations creates greater profit for those involved in the pulp and paper industry. The claim that around 70% of the disposable nappy is fluff pulp padding is correct.

To produce the 620 million nappies used in 1992 in Australia, around 74,000 t of green woodchips were required (Wright 1993, pers. comm.). This is about the same amount as is needed to produce 150 million 200 g tabloid newspapers, or supply Victorians and some interstate readers with the Melbourne Age newspaper for 44 weeks (assumes: 1993 Age circulation figures; each nappy weighs 34 g; 2 kg of green woodchips for every 1 kg of newsprint; and 1,377 t/week required to produce the Melbourne Age) (Age Newspaper 1994, pers. comm.).

The point being the quantity of chips used to produce a years worth of disposable nappies is less than needed to supply Australians with just one major newspaper. One might ask whether the paper or nappies have greater social value if one is to be critical of wood use for nappies.

For the purposes of assessing the claims made by Rassaby (1990) and The Pretty Young Company (1993), it will be assumed that mature trees are used to manufacture fluff pulp. Given this assumption, estimates provided by Australian Newsprint Mills (ANM, pers. comm.), indicate that around 250,000 trees or 185 ha of harvested pine forest are required to produce 74,000 t of green woodchips (Randall 1994, pers. comm.). This is around 1/4 of the estimate stated by The Pretty Young Company (1993). Further, based on the above estimates, one individual typical pine tree will produce around 2,800 nappies. This is more than five times the figure provided by Rassaby (1990). It is important to note that calculations are based on Tasmanian yields and are only rough estimates.

5.5 Plastics and Hydrocarbons

Australian disposable nappies in 1992 used approximately 6,500 t of plastic (assuming 10.53 g of plastic and other solid polymeric material [Wright 1992, pers. comm.]). In percentage terms, this represents just over 0.065% of the total consumption (weight) of plastic resin consumed in Australia in 1992

(1,000,000 t). Or alternatively, a day's use of disposable nappies uses about the same amount of plastic as 7 shopping bags (Wright 1993 pers. comm.; and Ahmed 1992).

Plastics are made from crude oil, gas and coal and account for about 2% of the oil and natural gas consumed in Australia. Disposable nappies, therefore, account for about 0.0013% (just over one 1/100 of a percent) of total Australian annual natural gas and oil consumption. This compares to the 95% of petroleum products used for heating, cooking and transport. According to the Plastics Industry, most of the raw material used to manufacture plastics comes from gases which are waste products in petroleum refining. These are gases that would be otherwise flared-off and wasted (Plastics Industry Association 1992 and Plastics Industry Association [no date]). Given these figures, the claim that disposable nappies use large quantities of petroleum in their manufacture of plastic made by Allan (1990), is in relative terms, an exaggeration.

5.6 Silviculture Impacts Associated with Pine Plantations in Australia and New Zealand

A sample of the type of claim made against the disposable nappy concerning silviculture practices is provided below:

> (1) Woodchipping, which is an integral part of paper pulp production, leads to the devastation of entire areas of forest. The environmental consequences include nutrient deficiency in soils, erosion, silting of creeks and death of dependent wildlife (Rassaby 1990: 27).

The pulp used in Australian nappies is sourced from Australian pine plantations from SA and Victoria. The remainder comes from Central North Island, NZ and from USA plantations.

It is not appropriate to attempt a justification of current forest practices in just a few paragraphs. The issues concerning forestry are very complex. There is some damage, but cotton crops also cause some damage. Instead just a few points are raised which serve to demonstrate that well managed plantations need not be a serious environmental threat.

With regard to the first part of the above claim, depending on the forestry practises employed, wood chipping and the establishment of tree plantations can lead to the clearfelling of large tracts of vegetation and thus loss of habitat for flora and fauna. This is what happened in the Green Triangle region in South Australia and Victoria and in the Central North Island of NZ many decades ago.

What many people arguing against disposable nappies seem to forget, is that disposable nappies are not responsible for the creation of these plantations. Disposable nappies use only a small proportion of the pulp produced by these plantations. However, it is acknowledged that they do contribute a small part to the overall demand of this resource.

A common view held by the paper industry is that softwood plantations are similar and perhaps more beneficial to the environment than other agricultural crops. Advantages of pine plantations over agricultural crops include: less soil disturbance as harvesting takes place only every few decades and not annually; the ability of trees to lower the water table; and the less fertilizer use (The Pulp and Paper Manufacturers Federation of Australia Limited [no date]).

Another advantage of using plantation trees is that subsequent harvesting and plantings does not lead to further loss of flora and fauna habitat (unless expansion occurs in native bushland). Also, the rates of soil structure deterioration in pine plantations is much lower than what is observed with agricultural crops (Smethurst 1994, pers. comm.).

A review of the literature by Squire *et al.* (1991), concluded that decline in second rotation yields in South Australian and Victorian soils in the Green Triangle region was attributable to: silviculture practices such as slash burning that compact the soil and deplete organic matter; and failure to remove weeds which reduce the availability of moisture to pines.

However, due to improved knowledge and management practices, this decrease in second rotation productivity in the green triangle has been turned around to an increase in third rotation productivity (Smethurst 1994, pers. comm.; and Squire 1991). In addition, soil is not washed off site in these plantations and compaction is not a severe problem that cannot be remedied (Johnsson 1993, pers. comm.).

Soils in NZ are much more productive than those found in Western Victoria and SA. Due to steeper slopes and higher rainfall there is, during harvesting and planting, a higher erosion hazard. However, with proper care, soil loss on steep slopes in the first few years of harvesting can be largely restricted (Smethurst 1994, pers. comm.). Specific locations of radiata plantations in the USA were not able to be obtained. Thus it is not possible to comment on the impact of American forest practises.

Damage of soils in pine plantations is not the result of the pine trees themselves. It is usually the result of bad management practices and or lack of appropriate information on appropriate site specific practices. As communication with soil scientists or foresters from USA and NZ plantations was not established, it is difficult to address the claims made by Rassaby with regard to nutrient deficiency in soils, erosion, or silting of creeks from these plantation areas.

Nevertheless, information provided by NZFPs stated that: catchment and biological reserves are set aside for water and flora and fauna protection (15% in the Northland and 8% in the Kinleith area); there is minimum burning of felled areas (less than 5% are burnt); and there is careful monitoring of water and soil values (Johnsson 1993, pers. comm.).

In conclusion, inappropriate silviculture practices in softwood plantations may lead to environmental consequences which include nutrient deficiency in soils, erosion and siltation of creeks. In SA, research suggests that erosion, siltation and soil nutrient loss (due to changes in management practices) are not problems. It is impossible to assess the situation in NZ and the USA without further information.

To state that woodchipping leads to the devastation of entire areas of forest as stated by Rassaby is true only if the previous land category was natural bush. Pine plantations are an exotic species which resemble a crop and as such are not comparable to the complexity which is found in native forests. Although large trees are removed when pine plantations are harvested, the ecosystem, unlike a native forest, is a very simple one and one that can be easily re-established.

5.7 Conclusion

The manufacturing of disposable nappies involves the use a variety of resources. When we focus exclusively at the resources consumed by disposables, the quantities appear high. For instance, the manufacturing of disposables for the Australian market in 1992 consumed around 74,000 t of green woodchips, 6.5 t of plastic, around 7,500 MJ/week of energy (assuming life-cycle data is reasonably accurate) and an estimated 1,054,000,000 L of water for the disposable nappy pulp component (assuming NZ Industry figures are representative of pulp industry water use). The quantities of resources consumed by smaller components are excluded.

The first important issue at hand however, is not the quantity of resources that disposables use, but whether the quantity of resources used by disposables is high compared to the alternative (cloth nappies). The second issue that needs examination is how the resources used in disposables compare to the resources used by other discretionary activities and activities undertaken for convenience. The third issue is whether or not the issue of resource use is really a concern or problem.

It is clear that disposable nappies (excluding small quantity materials such as super-absorbent polymer, glue elastic and tape) do consume two resources that cotton nappies do not: pulp and plastic. Unfortunately, no straightforward and simple comparison exists on the question of whether disposable nappies are more energy and water intensive than the use of cloth nappies. This is due to the variations that may occur in home laundering practices and the questioned accuracy of life-cycle assessment results.

With regard to energy consumption, using disposables can be either more energy intensive or less energy intensive than using cloth nappies (assuming the manufacturing of disposables used around 145 MJ/week of nappy use). Using disposables is more energy intensive if cotton nappies are soaked in cold water in a bucket of bleach, rinsed by hand in cold water and line dried (about 24 MJ/week), but less energy intensive if cotton nappies are washed with hot water, rinsed with warm and 100% dryer dried (245 MJ/week). Unfortunately no data exists as to what represents a typical Australian household pattern of washing cotton nappies.

With regard to water, the variations provided by the four life-cycle studies and the assumed volume of water consumed per kg of washing were to large to enable an accurate comparison.

Disposable nappies, like many consumer items and activities are used for convenience. Their purchase and use is a decision and choice made by the consumer. Although it is acknowledged that consumers are influenced by a complex mix of pressures including advertising, peer pressure and consumer pressure. In this regard, the choice to buy disposable nappies is no different than the choice available to some people to travel to work in a car rather than to walk or use public transport; have a long shower rather than a short one; buy a newspaper; and use new plastic bags at the grocery shop rather than reusing old ones. For instance, having a 20 minute shower each day rather than a four minute shower is more than twice the average energy used in keeping a child in disposable nappies.

The final issue is the question of whether it really matters that disposables use the resources they do. With regards to energy, disposables (assuming low energy use by cotton nappies) do have an impact given that energy is largely non renewable and the numbers of disposables used. With regard to pulp, the pulp resource is a renewable one and as such it seems unreasonable to argue that it is being wasted on disposables given that: it is mostly thinnings and waste that are used to manufacture fluff pulp; and that plantations are replanted once harvested. Pollution released and resources used in the manufacture of pulp such as fertilizers are not part of the pulp issue.

The amount of plastics consumed by disposable nappies compared to the total amount of plastic resin consumed by Australians is negligible (1/1,000 of a percent). In addition, most of the raw materials used to manufacture plastics comes from waste products in petroleum refining. It is to difficult to comment about the water resource given the variation in its availability.

The claims against disposables presented have argued that disposables use large quantities of resources. They have, however, failed to acknowledge that the alternative method of excrement containment also has resource impacts, that is, water and energy consumption. They also fail to mention that the trees being chopped down are plantation softwood trees which if correctly managed can be considered a renewable resource.

The claims concerning the amount of trees required to produce fluff pulp are exaggerated, whereas those concerning silviculture impacts are promoting a cause which has very little to do with disposable nappies.

Chapter 6

Conclusion

6.1 Conclusion

This thesis has met its initial aim and has examined in considerable detail the accuracy of common claims made against the disposable nappy on environmental grounds with regard to disposal, organochlorine releases associated with pulp manufacture and bleaching, and selected resource requirements. Also examined were the accuracy and problems associated with the use of life-cycle assessments.

All the objectives set out in Chapter 1 were met. That is: a comprehensive selection of claims made about disposable nappies was collected (some of which were presented); the technical literature of relevance to the claims was reviewed; and conclusions were drawn on the accuracy and technical justifications for the claims.

The hypothesis that "Common claims against disposable nappies on environmental grounds are by and large inaccurate" was supported in all the main areas examined. Many of the claims were shown to be: exaggerated; over simplified; not based on fact or current available technical information; and some were found to be promoting environmental causes which had very little to do with disposable nappies.

Assessment of claims against the disposable nappy reveals that there are a number of broader issues and themes repeated in the claims addressed in each Chapter.

The first of these concerns the extent to which environmental claims are more complex and involved than presented by certain sections of the environmental movement and other organisations. For instance, the issue of landfill availability it not just a simple matter of the community producing too much rubbish. It involves complex issues such as: public opposition (NIMBY syndrome); compaction technologies (which can double or triple the capacity of certain landfills); lack of funding; limitation of private sector activity; and the difficulty in obtaining new landfill permits.

Another such example is the debate over organochlorines from the pulp and paper industry. Concentrations and types of organochlorines released in pulp mill effluent vary from mill to mill and are a result of different manufacturing procedures, varied environmental guidelines and regulations, types of wood, types of processes, background levels already present in the environment, age of mill, and effluent treatment procedures. Hence, a criticism on environmental grounds that applies to one mill, may not necessarily apply to another. The same argument also holds true for industries which use the performance of their most up to date plant to illustrate their environmental friendliness, rather than the performance of their average or worst case plants.

Within arguments put forward by some environmental groups critical of disposable nappies there are views expressing a set of values which may not either be justified scientifically or held by the scientific community. These beliefs are beliefs held within a small section of the environmental movement, which in itself is a small section of the larger community.

Certain sections of environmental literature concerning behaviours and activities to 'look after the planet' suggest or make the assumption that certain activities or commodities are environmentally unsound, whilst the alternatives are not or have minimal impact. For example, many critics of disposable nappies fail to consider the impacts of the alternative cotton nappy system. These impacts include pollution of waterways from detergents, faeces and fabric softeners and, depending on method of laundering, an intensive use of water and energy.

Inaccurate information, presented by, in this instance, a small section of the environmental movement may promote patterns of behaviour and adoption of activities that may under scrutiny prove to be less environmentally friendly. For example, the perception that it is alright to dispose of organics such as food wastes but not all right to dispose of plastics may act to decrease the rates of household composting of food and garden wastes as it may be assumed that these wastes will decompose quickly in a landfill. It is more than likely that the circulation of inaccurate beliefs is not restricted to environmental groups and is apparent in many environmental and non environmental issues.

The assumption that certain activities or commodities are environmentally unsound, whilst the alternatives are sound or have minimal impact may also lead individuals and households, who wish to act in an environmentally friendly manner, not to examine the impact that all of their combined activities have on the environment.

However extreme and inaccurate claims do have a benefit. Exaggerated claims against industry practices often force truth out and forcecompanies to release technical information concerning their practices and procedures. Exaggerated claims also cause industry to adopt more environmental friendly methods and practices as has occurred in the pulp and paper industry in most Western countries as discussed in Chapter 3.

Much of the information used by certain segments of the Green movement to promote the case against the disposable nappy is obtained from what is already written and not from analysis and research completed by the environmental groups or from evaluation of the technical literature. A good example of this is the claim that "no other single consumer product with the exception of newspapers and beverage and food containers contributes so much to our solid waste". Although this claim was shown to be inaccurate, it is one that is frequently cited in the anti-disposable nappy literature. Failure to use reliable information may act to prevent meaningful debate on environmental issues: distort the facts even further; act to make individuals feel unnecessarily guilty; and complicate the adoption of activities that are more environmentally friendly.

It is worth noting again that the critical examination of claims in this thesis has focused on those made by the environment movement and not those made in advertising and promotion of disposable nappies. Thus it is not possible to comment on any distortions or value laden statements put to support the other side of the argument.

The realisation has to be made, however, that many environmental groups are understaffed and lack necessary resources, time, and scientific and technical expertise to allow lengthy examination of environmental issues. In-depth investigation of any issue requires a considerable investment of time and money as is well indicated by the budgets, equipment and staff numbers of research organisations such as the Australian Consumer Union, CSIRO and Universities.

Review of the environmental literature concerning disposables has shown there to be numerous inconsistencies and very selective use of available information. For example, Greenpeace, in a media release stated that disposables use large amounts of energy and water in their manufacture. Also stated on the same page was that laundering services are a competitive alternative. No where in the release was it mentioned that commercial laundering services consume energy (in their use of washing machines and driers), water, and add pollutants to the sewerage system. However, to be fair, it is mentioned that the best alternative to disposables is washing and line drying at home (Greenpeace 1993).

Other inconsistencies are shown in the Kooshies Environmental Fact Sheet. Although the Fact Sheet states that the life-cycle assessments are incomplete, a favourable conclusion from the life-cycle analysis completed by Lehrburger et al. (1991), is used to support the environmental benefits of the cotton nappy. The fact sheet also suggests that faecal matter going into a landfill represents a public health risk, whilst faecal matter going into the sewerage system does not (The Pretty Young Company 1993). People such as Crennan (1992) have pointed out that the centralised water-borne sewerage system is far from sensible as it leads to polluted aquatic environments, is very costly, and uses excessive amounts of water.

It is also important to acknowledge that although disposables use relatively small amounts of resources, many small uses add to create a larger use. Just because a certain consumer item or activity's resource requirements are small, does not make it acceptable, or without an environmental impact. However, it is reasonable to suggest the efforts in trying to convince people not to use disposables might be better used to convince people of other behaviour changes such as car pooling, using public transport, wasting less water in their gardens and insulating their houses.

Before we criticise an individual's or household's choice in using a product of convenience, we have to make sure that we firstly examine the environmental impacts of our own behaviour. This can be achieved by focusing not only on the environmental effects of the single product in question, but on the environmental effects of the whole range of discretionary choices and activities we engage in day to day living. For example, a household that uses disposables, but line dries clothes, uses public transport, does not buy newspapers, composts its household wastes and washes dishes by hand would have far less environmental impact than a family who does not use disposables but always uses a clothes dryer, a dishwasher, a car to get to work, buys newspapers and throws all of its rubbish out.

Review of the Life-Cycle Study technical literature has shown that it too has many shortcomings including bias and inappropriate use of data. For example, when estimates of water consumed in the manufacture of nappies and in the laundering of cloth nappies provided by four life-cycle studies is standardized, the ranges of estimates varied enormously (Table 5.7). The lowest disposable nappy estimation is 1 L/nappy, whilst the highest is almost 20 L/nappy. The lowest home laundering estimation is 13 L/nappy and the highest is 24 L/nappy.

These disparities are attributed to: differences in assumptions (such as assumed number of cloth and disposable nappy changes per week, differences in calculated estimates of volume of water consumed per kilogram of washing for home laundering and differences in assumed rates of toilet rinsing of faecal matter for disposable nappies); poor statistics; and use of industry average rather than industry specific data.

Given that all of the studies were completed between 1990 and 1993, fluff pulp being produced predominantly by one paper company, the methodology being reasonably similar, the number of disposables used in any year being a constant figure, one could argue that these research findings are not 'objective' or 'value free', but that they are advocacy positions. Especially as the vast majority of findings support the views of the organisations for which the studies were being carried out for.

In conclusion, if claims against a product on environmental grounds are to be made, the authors making the claims need to make sure that the claims they make are factual. This thesis has shown that many of the criticisms directed against the disposable nappy are not based on sound evidence. A list of points that may overcome some of the problems associated with inaccurate claims are provided in Table 6.1. If certain sectors of the environmental movement continue to focus on environmental issues from a very narrow and simplistic perspective, they face the risk of diverting attention from the behaviours and activities that are causing many real environmental concerns and problems.

TABLE 6.1

SUMMARY OF CONCLUSIONS

Many of the claims against disposable nappies examined in this thesis have been shown to be inaccurate. The claims are often over simplified. Many of the incorrect claims are based on personal beliefs about issues such as landfill. The tendency to exaggerate and incorrectly interpret and carry these incorrect interpretations forward would be minimized if the following practices were carried out:

- proper referencing of claims;
- definition of key words such as significant or small, as words of this nature have different meanings to different people;
- provision of better evidence to support claims made; and
- construction of claims based on reviewed evidence from technical and scientific literature.

There are many shortcomings and inadequacies in the scientific and technical literature on the subject of nappies.

There is a need for further research and investigation into landfill issues which may include, but is not limited to:

- decomposition rates of landfill materials in a variety of regions, countries and environments;
- characteristics and conditions of Australian landfills;
- infectivity of viruses when adsorbed to material in a variety of landfill environments;
- factors affecting pathogen survival in a variety of landfill environments;
- pathogen survival in inappropriately sited and operated landfills; and
- specific effects of disposable nappies in landfills

There is need for further research and investigation into issues associated with pulp mill effluent, this may include, but is not limited to:

- effects of pulp mill effluent on aquatic life at discharge point;
- methods of reducing effluent loads;
- design of closed loop systems; and
- alternative methods of bleaching that are economically feasible

There is also a need for improvements in the methodology and approaches used in the inventory component of the nappy life-cycle assessments. This includes but is not limited to:

- standardization of life-cycle inventory methods and assumptions;
- establishment of a standard list of waste sources and pollutants;
- identification of data sources;
- the obtainment of resource requirement and environmental release;
- figures from specific plants rather than from industry averages; and
- greater explanation of the methodological assumptions used.

The broader implications of this study demonstrate that there is there is a great need to bridge the gap between the scientific and popular press that relates to issues like this, and to better address the mismatches between knowledge, beliefs behaviour and environmental aspirations.

7.0 References and Bibliography

7.1 References

(See also written and spoken communications, p. 102).

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8.0 Appendices

Appendix 1 Abbreviations and Acronyms

USA:	United States of America
NZ:	New Zealand
WMA:	Waste Management Authority
MSW:	Municipal Solid Waste
EPA:	Environmental Protection Authority
WA EPA:	West Australian Environmental Protection Authority
SA:	South Australia
NZFP:	New Zealand Forest Products
PCB:	polychlorinated biphenyl
PCDD:	polychlorinated dibenzo-p-dioxin
PCDF:	polychlorinated dibenzofuran
PcP	polychloro phenol
PVC:	poly vinyl chloride
AOX:	adsorbable organic halogen
TOX:	total organic halogen
TOCI:	total organically bound chlorine
MW:	molecular weight
EOX:	extractable organically bound halogen
PCPC:	polychlorinated phenolic compounds
TCDD:	tetrachlorinated dibenzo-p-dioxin
NCASI:	National Council of the Paper Industry for Air and Stream Improvement
DNA:	deoxyribose nucleic acid
DBD:	dibenzo-p-dioxin
DCDF:	tetrachlorodibenzofuran
DDT:	dichlorodipenltrichloroethane
DDE:	dichlorodiphenyldichloroethylene
SETAC:	Society of Environmental Toxicology and Chemistry
SECV:	State Electric Commission of Victoria

Appendix 2 Correspondence

Correspondence by either letter, telephone, electronic mail or facsimile occurred with the following sources:

Disposal Nappy Companies

- Proctor and Gamble Australia
- Proctor and Gamble USA
- Australian Pacific Paper Products
- Kimberly-Clark Australia;

Australian Organizations and Government Bodies

- Melbourne Metropolitan Board of Works
- Australian Water and Waste Water Association
- Australian Cotton Foundation
- Queensland Department of Primary Industry
- SA Woods and Forest Department
- Pacific Waste, Melbourne
- Australian Bureau of Agricultural Resource Economic
- Australian Pulp and Paper Industry Technical Association of Australia and NZ
- National Association of Forest Industries
- Australia Consumer Union
- Pulp and Paper Manufacturers Federation of Australia
- University of Tasmania;

American Organizations and Government Bodies

- Center for Policy Alternatives
- Reason Foundation
- New York Consumer Union
- Environment Protection Authority;

Other Bodies, Organizations and Individuals

- Warmer Campaign, England
- William Rathje, University of Arizona
- Carl Lehrburger, USA
- WEED Foundation, Canada
- Friends of the Earth, Australia
- Greenpeace, Australia and NZ
- Australian Conservation Foundation;

Australian Cotton Nappy and Alternative Cotton Nappy Distributors

- Coles/Fossey, Victoria
- Richard Allen, Victoria
- Snuggerlite, Victoria
- Stuart C, Victoria
- The Pretty Young Company, Sydney;

Nappy Fluff Pulp Producing Mills

- Millicent Mill, S A
- Georgia Pacific, USA
- New Zealand Forest Products
- Flint River Mill, USA.

Appendix 3 Summary of information and data provided by Wright (1992)

NAPPIES AND MUNICIPAL SOLID WASTE QUANTITIES AND BREAKDOWN

- Nappies in landfill are 1.3% by wet weight of *domestic* wastes.

- *Domestic* wastes are 32% of total *municipal solid wastes* (MSW), hence

- Nappies are 0.4(2)% by wet weight of municipal solid wastes (MSW).

- Nappies are 1.0% by wet volume of MSW.

- Nappy plastic* is about 1/5000 of the total volume of MSW (the plastic volume being calculated from its weight and density).

- Nappy plastic generated per year (and going to landfill)

  = 0.33 litre/person (average Australian)
  = 1.0 litre/3 person household (average)
  = 25 litre/1 baby household.

- Nappy plastic/MSW ratio

  = 1/5000

= 1 middy (beer volume) of plastic person/year	versus	8 wheely waste bins (200L each) of MSW/person/year
= 2 Olympic swimming pools (all Australia)	versus	10,000 olympic swimming pools of MSW/year (all Australia)

- The annual generation rate of MSW is a volume of 1 km square by 20 m high (19.5 m more precisely). This is based on an ABS figure and is equivalent to 8,000 olympic swimming pools. Based on WMA data we get 10,000 pools/year (above).

NAPPIES IN LANDFILL

Aim:

To estimate the proportion, by weight and by volume, of disposable nappies in landfill in Australia.

Basis for Calculations:

Do the sums for 1991 for which we have data for wastes in Sydney and for nappy sales in Australia.
Use the Sydney waste data as the basis and extrapolate on a population basis as warranted.

Sales of all disposable nappies in the whole of Australia in 1991 = 531 M

(Greg Lowe 23.10.92)

Use Medium Huggies® as a "standard nappy".
A Medium Huggies® weighs 53.4 g (1991 spec)
A Medium Huggies® has 10.43 g of plastic and other solid polymeric material (not SAM) that would not degrade in landfill (H W sums 26.9.91)

viz: plastic" in nappies = 10.43/53.4
= 20%

Australian population in 1991 = 17.4 M
Yearbook 1991, p 120 extrapolate)

Average nappy consumption averaged over whole population (adults & babies)
= 531 M nappies/17.4 M people
= 30.5 nappies/person/year

Dry weight of nappy = 53.4 g

What is the **wet weight** of nappies?

Feeding:

Hillary Wren (mother) says feed is 120 ml 5 times a day.

ie. feed = 600 ml liquid/day (probably 90 to 95% water)

As some of this would evaporate (skin and lungs) urine and faeces would be less.

Urination:

Debbie Carpenter estimates 60 - 80 ml per excretion at 6 to 8 times a day. Viz, a range of 360 - 640 ml/day.

A total *urine* amount of *520 ml/day* seems conservative and gives (with 87 g/nappy):

wet weight of 1 nappy = 140 g

(Average nappy use is 6/day)

Weight of nappies to landfill (average in Australia):

<u>Wet</u>	<u>Dry</u>
= 140 g x 30.5/pers/yr	= 53.4 g x 30.5/pers/yr
= 4.27 kg/pers/yr	= 1.63 kg/pers/yr

Volume of nappies to landfill (per person basis):

One Medium Huggies® nappy (dry) was compressed into an empty milk carton, and occupied volumes from (HW Note 14 Dec '92)

500 ml → high compression to 570 ml → medium compression

The high compression value of *500 ml per dry nappy* seems reasonable for landfill given the weight of garbage around it.

The wet volume with 87 ml of test water was essentially the same.

Viz: Volume = 500 ml/dry or wet nappy

For the average person's use of 30.5 nappies a year

Volume of nappies = 15.25 L/pers/year

Total Municipal Waste Quantities:

Total municipal waste = 1.02 t/pers/year (W M A 90/91, p 28)

Volume occupied by municipal waste - Australian average taken as:

Municipal waste volume = 1.5 cubic metres/L
(H W 's Note to file 14 Dec '92)

Total Municipal Waste Volume

= 1.02 x 1.5
= 1.53 metres cubed/pers/year

Hence, in summary the quantities and proportions (as percentage) of nappies in municipal solid waste are:

PER PERSON/YEAR (AUSTRALIA, 1991)

	NAPPIES		MUNICIPAL SOLID WASTE (MSW) (WET)	NAPPIES/MSW %	
	DRY	WET		DRY	WET
WEIGHT kg	1.63	4.27	1020	0.16	0.42
VOLUME L	15.25	15.25	1530	1.00	1.00

The ***wet*** weight amounts and ratios are probably the most pertinent. They relate to what *goes* to landfill.

In terms of what is *in* the landfill after some time, the amount of *dry* nappies is more pertinent (the material can be expected to have partially dried out), but we have no estimate of what the *dry* amount of the MSW total is, hence the proportion by dry weights is not very valid).

The most relevant figures are:

Nappies are about ***0.4 % by weight of municipal solid wastes (wet basis)***

Nappies are about ***1% by volume of municipal solid waste (wet basis)***

VOLUME OF COMPRESSED NAPPY

Dry Nappy in a milk carton

Height (med to high compression) = 25 - 15 cm
= 10 cm

(still gaps in corner)

ID = 7 X 7 CM = 49 cm^2 area

Therefore, Volume = ***490 mL***

Nappy WET with *87 mL* of H_2O to simulate the urine volume used in the sums.

Compressed down to 16 cm (easier to compress than when dry - flows better into the corners).

Hence ***Volume*** = 49 x (25 - 16) cm^3

= ***441 mL***

DENSITY OF MUNICIPAL SOLID WASTE

Purpose:

A figure for the average density of municipal solid is needed for estimating the volume of MSW.

Fraction of nappies in landfill:

MWDA Annual Report, 87/88, p 14 says:

> "The Authority met its target of 1.63 metres cubed per tonne for 1987 and the 1988 target has been set at 1.62".

WMA Annual Report 1990/91 p 12 states that:

> "The Authority achieved landfill usage rate of 1.39 cubic metres space usage per tonne of waste; well within target of 1.45 cubic metres per tonne for 1989/90".

Given that the WMA operations would be one of the most advanced in the country, it is reasonable to assume that other states and country landfills would be at lower densities (less compaction) than Sydney's wastes.

Accordingly, a value of *1.5 cubic metres/tonne* is reasonable as an Australia wide figure. This is almost certainly conservative. Most other places would probably be above the earlier MWDA value of 1.63.

AREA FOR AUSTRALIA'S MUNICIPAL WASTE

Amount of waste generated = 13 Mt/yr
(ABS p 257 "Australia's Environment")

Density of waste:

1.5 m^3/t (HW Note to file)

therefore, Volume of waste in 1 year = 13 x 1.5 M m^3/yr

= 19.5 M m^3/yr

Now if put on an area of 1 km x 1 km

The Height $= \frac{19.5 \times 10^6 \text{ m}^3}{10^6 \text{ m}^2}$

= 20 m

In ten years, size = 1 km x 1 km x 195 m high

Australia's Land Area = 7.68 M km^2 (Year Book 1991)

So this *1 km^2 area* $= \frac{1}{7.7\ 10^6}$ of the area

$\approx \frac{1}{80,000}$ of 1% of area

COMPONENTS IN DOMESTIC SOLID WASTES (1986/87 DATA)

Aim:

To put disposable nappy compositions into a detailed breakdown of municipal solid derived from the detailed *1986 & 1987* data.

Method:

Assume the weight and volume ***proportions*** of nappies and MSW calculated for ***1991*** apply to this more segregated data of 1986/87 (see chart attached).*

Hence:

Weight of (wet) nappies = 950 kg x 0.42%/pers/yr

= ***4.0 kg/pers/year for 86/87 data***

(this compares with the 1991 weight (wet) of 4.27 kg/pers/year - see HW Note 14 Dec '92).

Domestic solid waste is 31.8% of the total Municipal Solid Waste (MSW).*

Nappies as part of Domestic Waste

By (wet) weight 4.0 kg/302 kg

= 1.3% (w/w) (wet)

and = $\frac{4.0}{4.27} \times 15.25 \times \frac{100}{302 \times 1.5}$

= 3.15% (v/v) (wet)

In summary

Nappies are about 1.3% by *weight of domestic* wastes (wet basis)

Nappies are about 3% by *volume of Domestic* wastes (wet basis)

* NSW Recycling Status and opportunities, (P 13 and P16) MWDA Jul 88.

QUANTITY OF PLASTIC FROM NAPPIES

Aim:

To estimate the quantities of plastic from nappies on an average household basis and compare with Municipal Solid Waste.

- either Australian average, or a household with a baby.

Data:

531 M Nappies (1991)
17.4 M people (Australia, 1991)
10.43 g 'plastic'/nappy
0.96 kg/L density of polyethylene (assumed for all 'plastic' in nappy).
1.02 t/person/year of municipal solid waste (MSW), (WMA 1990/91 p28).
Density of MSW = 1.5 m^3/t (HW 14.12.92)
1 Olympic Swimming Pool = 50 m x 25 m x 2 m
= 2500 m^3

NAPPY PLASTIC ; weight and volume

Aust/Year		per/person/year		per 3-person household/year
= 531 M x 10.43g				
= 5538t ÷ 17.4 (÷0.96 kg/L)	=	318g	=	954g
= 5769 m^3	=	0.332L	=	1.0L
≈ 2 olympic swimming pools	≈	1 middy (volume of beer)		

MUNICIPAL SOLID WASTE ; weight and volume

Aust/Year		per/person/year	per 3-person household/year
17.75 Mt		1.02t	3.06t
		x 1.50 m^3/t	
26.6 Mm^3		1.53m^3	4.6t
≈ 10,000 olympic swimming pools	≈	8 wheely waste bins (200 Litre each)	

1 Baby Household:

For an actual household with a baby using disposables,

the weight of nappy plastic	=	53.4 g x 0.20 x 6/day x 365 days/year
	=	**23.4 kg plastic/1 baby household/year**
	=	**24.4 L plastic/1 baby household/year**

RATIO OF NAPPY PLASTIC TO MUNICIPAL SOLID WASTE (by volume)

$$= \frac{0.332\ L}{1530\ L}$$

$$= \frac{2.2}{10000} \approx \frac{1}{5000}$$

This 5000 to 1 ratio of total MSW to nappy plastic can be used either

on a per capita basis;

eg. 1 middy of plastic/person/year, compared to 5000 middies or 8 wheely waste bins of municipal solid waste, or

a total Australian basis

(as per earlier memo to John Van Steenberg (September 27, 1991));

2 olympic swimming pools of nappy plastic per year, compared with 10,000 olympic swimming pools of municipal solid waste.

Procter&Gamble

The Procter & Gamble Company
Winton Hill Technical Center
6100 Center Hill Avenue, Cincinnati, Ohio 45224-1788

April 28, 1993

Ms. Irene Koroluk
Center for Environmental Studies
University of Tasmania
Department of Geography & Environmental Studies
GPO Box 252C
Hobart, Tasmania
Australia 7001

Dear Ms. Koroluk:

I recently sent off a package of information in response to your February letter. This is in response to you letter of April 13 to Mr. A. G. Payne. I am unable to send the P&G report on diaper habits and practices as it contains potentially proprietary information..

Since your interest seems to be in the consumer practice area, I am taking the liberty to send an alternative reference. It is a study reported in the Forest Products Journal by author P.M. Smith and K.D. Sheeran. The study is titled "A Profile of Consumer Preferences for Baby Diapers". A copy is enclosed.

I trust this meets your needs. Let me know if I can be of further help.

Sincerely yours,

Robert L. Campbell, Ph.D.
The Procter & Gamble Company
Paper Products Division
Manager
External Technical Relations

RLC:lkn
response to letter

TABLE 1.1
SUCCESS RATE OF ACHIEVING REPLIES FROM ORGANIZATIONS, GOVERNMENT BODIES AND INDIVIDUALS

	Reply to initial correspond-ence	Reply to second attempt at correspond-ence	Provided answers (where possible), to questions asked	Provided reference material requested	Provided additional useful reference material	Provided names of people and relevant authorities to contact when unable to answer request	Provided requested data and calculations	Provided requested primary data and literature to support claims	Whether information refused, effected outcome of thesis
Disposal Nappy Companies									
Proctor and Gamble Australia	Yes	-	Yes	Yes	Yes	Yes	NR (Not relevant)	NR	NR
Proctor and Gamble USA	Yes	-	Most. However, vague answers concerning location of plantations. Bleaching sequence not provided	Most. Two articles concerning life-cycle studies were considered to contain proprietal information and were refused)	Yes	Yes	NR	No primary data provided on forestry practices, pulp manufacturing practices or American diaper use habits	Effected assessment of forestry practices and assessment of life-cycle studies.
Australian Pacific Paper Products	Yes	-	Most. Lacked the resources to answer specific questions.	NR	-	-	-	-	No
Kimberley-Clark Australia	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Australian Cotton Nappy Manufacturers and Distributors									
Coles/Fossey, Victoria	No	No	-	-	-	-	-	-	-
Richard Allen, Victoria	No	No	-	-	-	-	-	-	-
Snuggerlite, Victoria	No	No	-	-	-	-	-	-	-
Stuart C, Victoria	No	No	-	-	-	-	-	-	-
Alternative Cotton Nappy Manufacturers									
The Pretty Young Company, Sydney	Yes	-	Yes	Yes	Some	NR	NR	NR	NR
Australian Organizations and Government Bodies									
Melbourne Metropolitan Board of Works	Yes	-	Yes	Yes	NR	NR	NR	NR	NR
Australian Water and Waste Water Association	Yes	-	Yes	Yes	NR	NR	NR	NR	NR
Australian Cotton Foundation	No	No	-	-	-				
Queensland Department of Primary Industry	Yes	-	Yes	NR	NR	Yes	NR	NR	NR
SA Woods and Forest Department	Yes	-	Yes	NR	NR	Yes	NR	NR	NR
Pacific Waste, Melbourne	Yes	-	Yes	NR	NR	NR	NR	NR	NR
Australian Bureau of Agricultural Resource Economics	Yes	-	Yes	NR	NR	NR	NR	NR	NR
Australian Pulp and Paper Industry Technical Association of Australia and NZ	Yes	-	Yes	Yes	Yes	Yes	NR	NR	NR
National Association of Forest Industries	Yes	-	Yes	Yes	NR	Yes	NR	NR	NR
Australian Consumer Union	Yes	-	Yes	NR	NR	NR	NR	NR	NR

	Reply to initial correspond-ence	Reply to second attempt at correspond-ence	Provided answers (where possible), to questions asked	Provided reference material requested	Provided additional useful reference material	Provided names of people and relevant authorities to contact when unable to answer request	Provided requested data and calculations	Provided requested primary data and literature to support claims	Whether information refused, effected outcome of thesis
Pulp and Paper Manufacturers Federation of Australia	Yes	-	Yes	NR	Yes	NR	NR	NR	NR
University of Tasmania	Yes	-	Yes	Yes	Yes	Yes	Yes	NR	NR
American Organizations and Government Bodies									
Reason Foundation	Yes	-	Yes	Yes	Yes	NR	NR	Yes	NR
Center for Policy Alternatives	Yes	-	NR	Yes	Yes	NR	NR	NR	NR
New York Consumer Union	Yes	-	Yes	Yes	NR	NR	NR	NR	NR
Environment Protection Authority	Yes	-	NR	Yes	NR	NR	NR	NR	NR
Other Bodies, Organizations and Individuals									
Warmer Campaign, England	Yes	-	NR	Yes	NR	NR	NR	NR	NR
William Rathje, University of Arizona	Yes	-	Yes	NR	Yes	NR	NR	NR	NR
Carl Lehrburger, USA	No	No	-	-	-	-	-	-	-
WEED Foundation, Canada	Yes	-	NR	Yes	NR	NR	NR	No	No
Friends of the Earth, Australia	No	No	-	-	-	-	-	-	-
Greenpeace, Australia and NZ	Yes	-	Yes, but limited by time and knowledge	Yes	NR	No	NR	No	No
Australian Conservation Foundation	Yes	-	Yes, but limited by time and knowledge	Yes	NR	No	NR	No	No
Nappy Fluff Pulp Producing Mills									
Millicent Mill, SA	Yes	-	Yes	Yes	NR	NR	Yes	NR	NR
Georgia Pacific, USA	Yes	-	Provided glossy pamphlets, vague and very general answers. Did not provide bleaching sequence and specific information on pulping practices	NR	NR	Yes	No	NR	No, as general discussion of Kraft processing was undertaken to address claims.
New Zealand Forest Products	Yes	-	Yes	NR	NR	NR	Yes	NR	NR
Flint River Mill, USA	No	No	-	-	-	-	-	-	No, as general discussion of Kraft processing was undertaken to address claims.