LIFE CYCLE ASSESSMENT OF MANAGEMENT OPTIONS FOR WASTE FARM PLASTICS

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INTRODUCTION

The New Zealand Agrichemical Education Trust received funding from the Ministry for the Environment's Sustainable Management Fund and a number of regional councils, farming and industry organisations to study the sustainable management of waste agrichemicals and waste farm plastics.

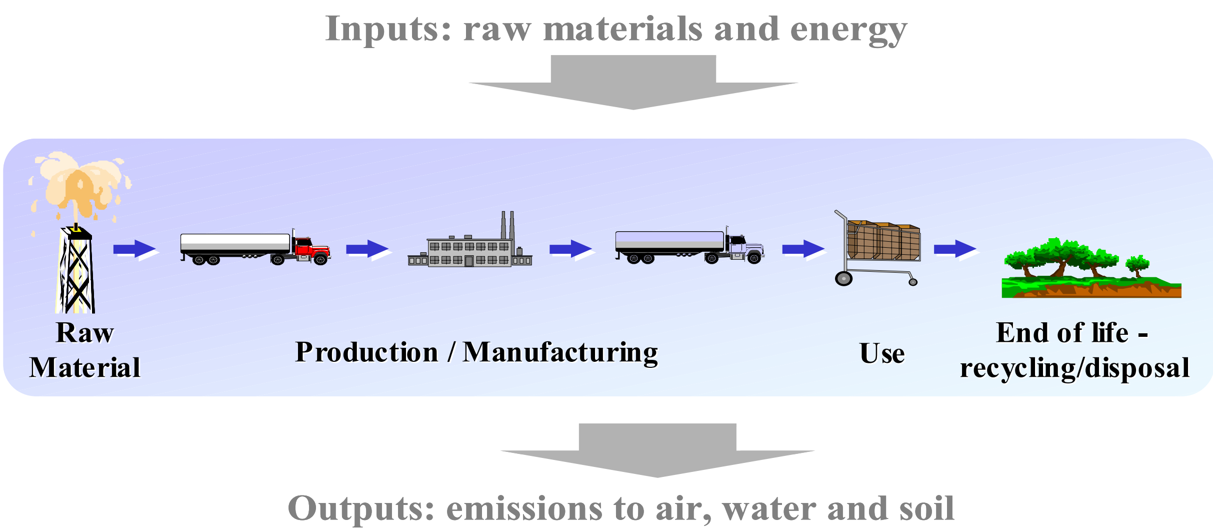
As part of this larger project, URS New Zealand was commissioned to undertake a life cycle analysis of the different options available for the management of waste farm plastics. The objective was to evaluate and compare the environmental effects different options for managing waste farm plastics.

LIFE CYCLE ASSESSMENT

Life Cycle Assessment (LCA) is a systematic approach for quantifying the inputs and outputs and associated environmental impacts during the lifecycle of a given product or system. The approach is represented in Figure 1.

In an LCA study, the system being investigated is modelled using a "cradle to grave" approach. Each process within the study linked to various industrial systems supplying and transporting inputs and carrying away and disposing of outputs. For example, the use of electricity takes account of all the environmental flows and releases to air, water and land that occur as a consequence of extracting/mining fuels and converting the inherent energy contained therein into electricity at the point of consumption.

Figure 1 Life Cycle Assessment



In many instances LCAs establish a baseline from which it is possible to identify opportunities for improvement. Having established a baseline, it is then possible to make comparisons against alternative scenarios.

One limitation of LCA is that quantitative analyses can generate debate regarding the number of assumptions made. For example, the size, type, fuel efficiency and distance travelled of an "average" truck carrying materials from a farm to a disposal point. With multiple "averages" and assumptions a "quantitative" result can have wide confidence limits. However, where comparative scenarios are modelled using the same base assumptions, the quantitative results can provide a high level of confidence in respect of comparative effects.

It is important to note that conventional LCA does not address social or economic impacts. In addition it does not take account of environmental risks associated with the behaviour of people, or breakdown of systems or processes.

PROJECT SCOPE

The LCA addressed the management of waste farm plastics from the point at which they are discarded by the farmer.

The project addressed two types of farm plastics:

- high density polyethylene (HDPE) chemical containers; and
- low density polyethylene (LDPE) plastic films, such as hay bale wrap, silage wrap and plant mulch.

The project used two regions, Hawke's Bay and Canterbury, in which to base scenarios to estimate and compare the environmental effects of different management options.

The management scenarios assessed and compared for both HDPE chemical containers and LDPE film were:

- status quo;
- on-farm burial by all farmers;
- on-farm burning by all farmers;
- drop-off at collection facility for recycling;
- drop-off at a transfer station for landfill disposal;
- drop-off at a transfer station for incineration with energy recovery.

SYSTEM BOUNDARIES

The functional unit was defined as:

> "The collection and treatment/disposal of waste farm plastics generated within a region over the period of one year."

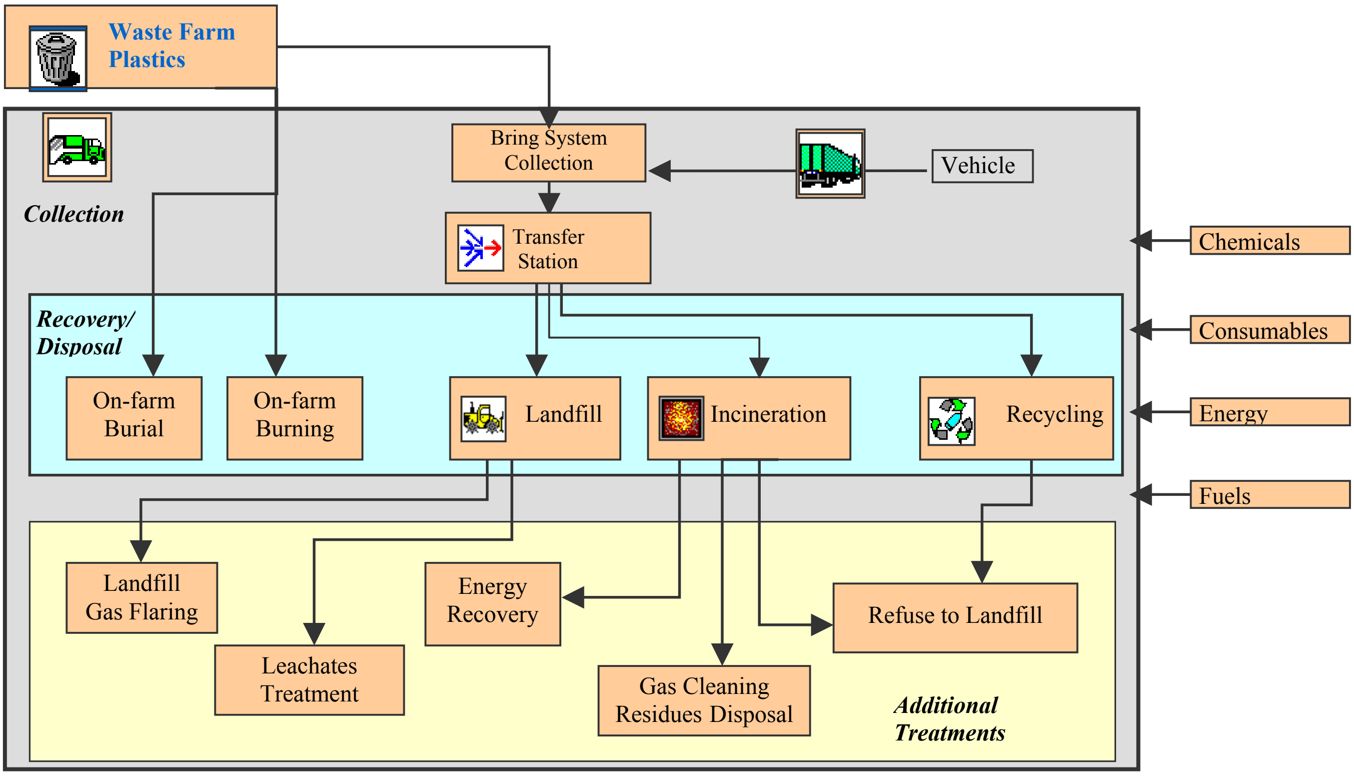
The system boundaries employed for the assessment of management scenarios for waste farm plastics start at the point of waste arising. That is, after the plastics have been used for their intended purpose and are of no further use to the farmer.

Raw material, energy and other inputs, as well as environmental burdens resulting from raw material extraction, processing, product manufacture, distribution and use are not considered. This is because the farm plastics have a common history in terms of production, distribution and use for all scenarios. Including these processes in the assessment would not assist in comparison of different scenarios.

Washing and/or collection/bundling of waste plastics on the farm are also not considered as this is assumed to be the same for all scenarios compared.

The system boundaries for the project are shown in Figure 2.

Figure 2 System Boundaries



The management of waste farm plastics is divided into two major sections:

- collection; and
- recovery/disposal.

Collection

The following elements are taken into account:

- the use of vehicles to take plastics to collection facilities and from collection facilities to treatment/disposal facilities;
- production/construction, operating requirements (for example, oil, fuel etc.), maintenance, use and end of useful life of vehicles;
- collection at a collection site (transfer station). The construction, maintenance and operation (for example, site vehicles and utilities) and demolition of the facility are taken into account.

Recovery/Disposal

The following options and elements are taken into account:

- the construction, maintenance and operation (e.g. site vehicles, utilities, liner and cover materials) of landfills;
- the construction, maintenance and operation of incineration facilities and energy recovery, with resultant avoided environmental burdens;

- recycling processes and avoided burdens associated with replacement of virgin materials.

QUANTITATIVE ASSESSMENT

Quantitative assessments were undertaken for both on-farm and off-farm waste plastics management scenarios. For scenarios involving on-farm management practices, published input and emissions data was used. For scenarios involving off-farm management processes the WISARD (Waste Integrated Systems Assessment for Recovery and Disposal) Life Cycle Assessment software tool was used.

WISARD takes account of the environmental effects from transport, infrastructure development and operation, recycling processes, landfilling and incineration, energy recovery and avoided burdens (where applicable).

The quantitative assessment was based on the farm and horticultural unit numbers and plastics quantities detailed in Table I.

Table I Farm Numbers and Plastics Quantities

Region	Farms	Horticultural Units	HDPE Chemical Containers (tonnes)	LDPE Film (tonnes)
Hawke's Bay	2,991	1,491	188	227
Canterbury	10,581	1,755	519	791

METHODOLOGY AND ASSUMPTIONS

Project Assumptions

In undertaking any modelling exercise it was necessary to work within a framework of assumptions in order to define and compare different scenarios. It is recognised that the assumptions provide for idealised scenarios. However, every effort was made to ensure that assumptions are the best approximation to a real world situation.

Assumptions included:

- off-farm scenarios (recycling, landfill disposal and incineration) involve farmers delivering waste plastics to the nearest existing transfer station for consolidation prior to transport to the recycling facility, or transport directly to an existing landfill or specified incinerator location;
- single trip delivery of plastics by farmers using a diesel powered ute, or light truck, possibly using a trailer;
- each of the specified options will be used by 100 percent of farmers;
- farmers will follow instructions in respect of chemical container cleaning (that is, containers will be triple rinsed as per best practice, in accordance with NZS 8409:1999, Code of Practice for the Management of Agrichemicals) and the majority of contamination will be removed from plastic films.

Scenario Specific Assumptions

Existing Situation

The existing situation in respect of waste HDPE and LDPE management practices was assumed to be as detailed in "The Storage and Disposal of Unwanted Agrichemicals and Agrichemical Containers in New Zealand Kiwifruit Orchards", 2001, a Massey University Master of Science thesis by Callum Passey.

On-farm Burial

The following scenario specific assumptions were made:

- the breakdown of plastics will be very slow and, therefore, discharges to the air and water from the burial pit due to the plastic itself will be negligible;
- one hour of bulldozer, digger or tractor operation will be required per farm or horticultural unit for the burial of the total annual waste plastic quantities (half an hour for HDPE and half an hour for LDPE). Fuel consumption was assumed to be 10 litres of diesel per hour.

On-farm Burning

The following scenario specific assumptions were made:

- all waste farm plastics will be burned once a year, either in open pits or piles above the ground, with no forced aeration;
- one litre of diesel will be used as an accelerant for burning of HDPE and one litre of diesel will be used as an accelerant for LDPE;
- emissions from the burning of LDPE are the same as those from HDPE.

Drop-off at Collection Facility (Transfer Station or Landfill) for Recycling

The following scenario specific assumptions were made:

- each farmer will make an average of one trip per year to recycle both HDPE agrichemical containers and LDPE film;
- inputs for construction and operation of the drop-off recycling facilities were assumed to be those specified in WISARD for a small transfer station;
- plastics will be transported to a larger collection facility, consolidated and then transported to a recycling facility in the lower North Island;
- 15 percent of collected plastic is rejected at the consolidation facility, due to contamination, and disposed of to the nearest landfill;
- the average weight of plastic (both HDPE and LDPE) transported on a transfer vehicle is 10 tonnes;
- collected plastic will be recycled only once.

Most recycling scenarios assumed that the collected plastics would replace virgin plastic (a non-renewable resource) when recycled into new products. An additional scenario was run, for LDPE collected in Hawke's Bay, whereby the collected plastic is used to replace wood (a renewable resource) in the manufacture of transport pallets.

Drop-off at Transfer Station for Landfill Disposal

The following scenario specific assumptions were made:

- each farmer will make an average of one trip per year to dispose of both HDPE agrichemical containers and LDPE film;
- inputs for construction and operation of the transfer station are assumed to be those specified in WISARD for facilities approximating those used;
- where the collection site is a landfill with public access, it is assumed that there is an on-site transfer station;
- the average weight of plastic (both HDPE and LDPE) transported on a transfer vehicle is 10 tonnes;
- plastics would be landfilled in the existing landfill to which waste from the transfer station is normally transported, with the landfill characteristics taken into account in the assessment;
- leachate and landfill gas discharges from plastic breakdown in the landfill are negligible.

Drop-off at Collection Facility for Incineration with Energy Recovery

The following scenario specific assumptions were made:

- each farmer would make an average of one trip per year to dispose of both HDPE agrichemical containers and LDPE film;
- inputs for construction and operation of the transfer station are assumed to be those specified in WISARD for facilities approximating those used;
- the average weight of plastic (both HDPE and LDPE) transported on a transfer vehicle is 10 tonnes;
- plastics would be transported to a single municipal solid waste incineration facility in each region, at the largest population centre (Christchurch in Canterbury and Hastings in Hawke's Bay);
- flue gas clean-up is by a wet system;
- energy recovery is by cogeneration;
- bottom ash resulting from the burning of plastics is assumed to be negligible.

Inputs and emissions from the incineration facility in WISARD were adjusted to reflect the chemical composition and energy content of HDPE and LDPE plastic.

(It is noted that no such incineration facility exists in New Zealand, or is likely to be developed in the foreseeable future. However, this scenario provides a comparison with on-farm burning and enables the extent of potential benefits of energy recovery to be estimated.)

Travel Distance Assumptions and Calculations

The following assumptions were made in order to determine average travel distances for farmers dropping plastics at transfer stations, for recycling or disposal.

- farms and horticultural units are evenly distributed in those areas where the activities occur;
- farmers will take waste farm plastics to the nearest transfer station;
- where the distance to two transfer stations is approximately the same, farmers will use the transfer station in the larger population centre;

- the cost to dispose of waste is sufficiently similar between any two disposal facilities that it will not skew users towards one facility;
- fuel consumption is based on vehicles travelling in rural areas (that is vehicle emissions are estimated using a rural fuel consumption cycle).

Each transfer station, and landfill which is typically open to general public, was allocated a catchment of contributing farms and horticultural units. The catchment boundaries were determined by the boundary of the study region and, where possible, intersected roads where it was considered that farmers would travel to different transfer stations.

Within each catchment an effective area was calculated to encapsulate those areas of primary pasture and horticulture, as indicated on MAF Pastoral Land-use and Forest Cover maps. Primary pasture and horticulture were separately encapsulated to allow separate calculation.

The numbers of farms and horticultural units in each catchment were estimated.

Travel distances were estimated by measuring distances along roads within each catchment using scale maps.

RESULTS

Indices Assessment

A number of environmental indices use equivalency factors to transpose quantified environmental inputs and outputs (for example, energy consumption, emissions to air and water) into specific measures of the same environmental concern, such as global warming or depletion of non-renewable resources.

Coefficients obtained through scientific research by organisations (as listed with the index) provide relative weighting for each flow within the particular impact assessment category being considered. For instance, in the case of greenhouse effect, global warming potentials (GWPs) are used to take account of the relative contributions that different greenhouse gases make to global warming. For example, methane has a GWP of 24, over 100 years, compared to carbon dioxide, which has a GWP of 1. In this way the effects of materials or processes that emit more methane can be compared against others that emit more carbon dioxide.

Assessment of Scenarios

The following indices were used in assessing the comparative impacts of both on-farm and off-farm scenarios:

- air acidification – (University of Leiden – CML);
- human toxicity – (University of Leiden – CML);
- greenhouse effect, direct (100 years) – (Intergovernmental Panel on Climate Change – IPCC).

It should be noted that the calculation of the indices assessments in respect of on-farm scenarios involves a limited number of flows and, therefore, are likely to be conservative.

In addition, the following indices are also used in assessing the comparative impacts of off-farm scenarios:

- eutrophication of water – (University of Leiden – CML);

- non-renewable resource depletion (remaining years of use) – (Ecobilan Group).

Eutrophication of water is not applicable to the on-farm scenarios as no leachate discharges from the burial or burning of plastic are assumed.

There was insufficient information available with which to calculate non-renewable resource depletion as a result of burial or burning of plastics.

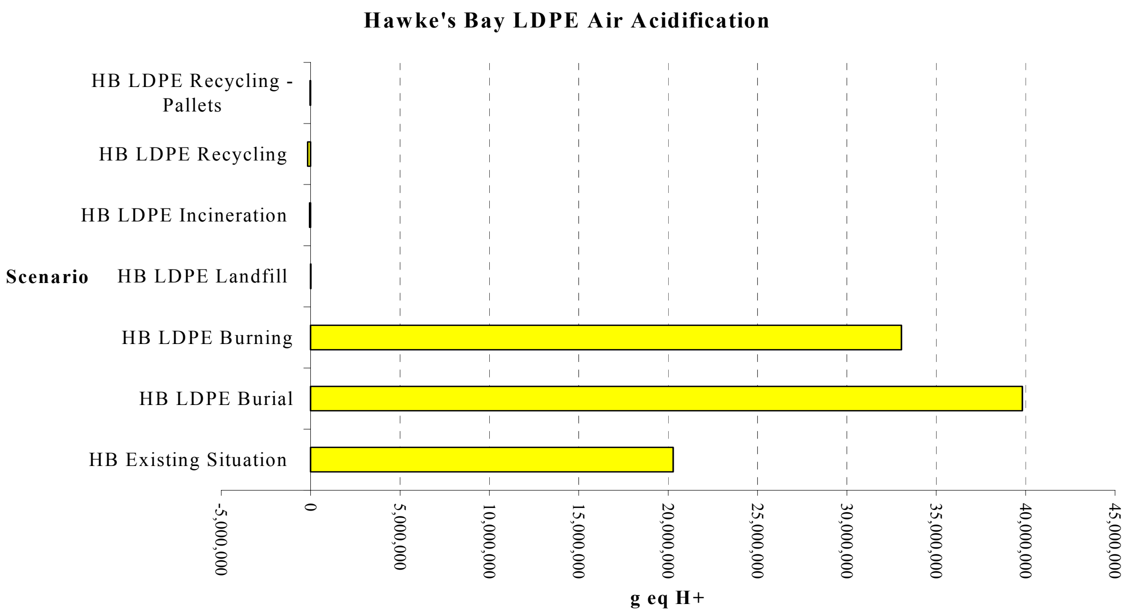
Tables AI to A IV, in Appendix A, detail the indices assessment results for different scenarios for the management of waste farm plastics in Hawke's Bay and Canterbury.

Table A II also contains results for the recycling of LDPE into transport pallets, as a replacement for wood.

Discussion of Quantitative Results

Figures 3 to 7 provide a graphical comparison of the effects of Hawke's Bay scenarios for the management of waste LDPE. These results are also representative of the comparative effects of scenarios for the management of waste HDPE in Hawke's Bay and the management of waste HDPE and LDPE in Canterbury.

Figure 3 Hawke's Bay LDPE Air Acidification



The on farm-burial and on-farm burning of plastics result in greater effects in respect of air acidification (Figure 3) and airborne human toxicity (Figure 4) than other scenarios.

It should be noted that the emissions from the burial of plastics arise entirely from the estimated emissions of farm machinery used in the burial process. The degree of effects could, therefore, change significantly in accordance with a different assumption in respect of farm machinery usage.

Figure 4 Hawke's Bay LDPE Human Toxicity

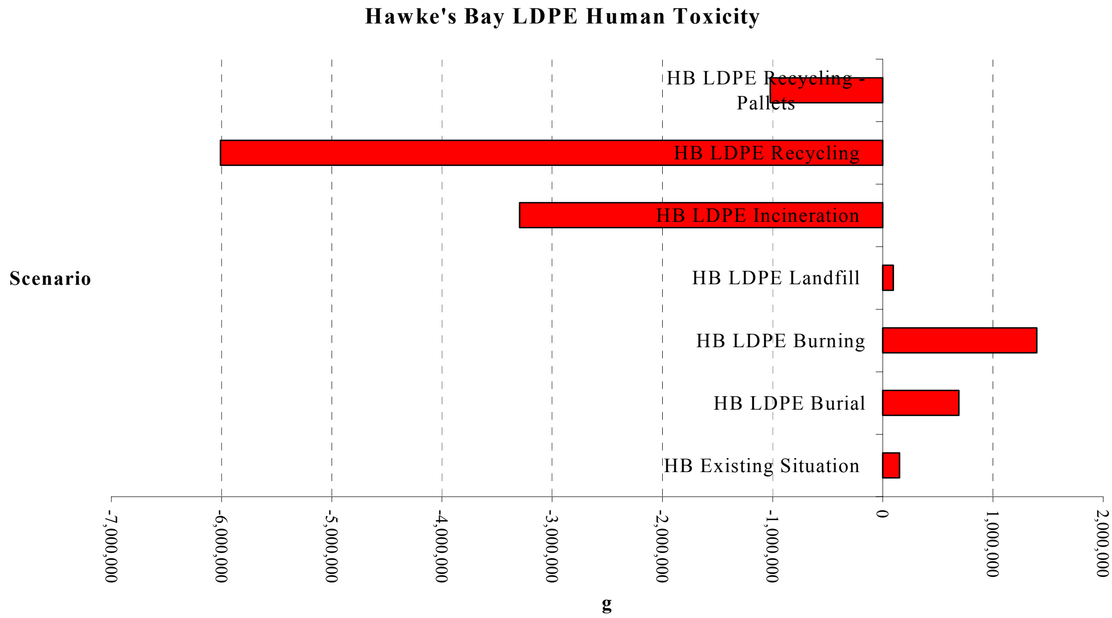
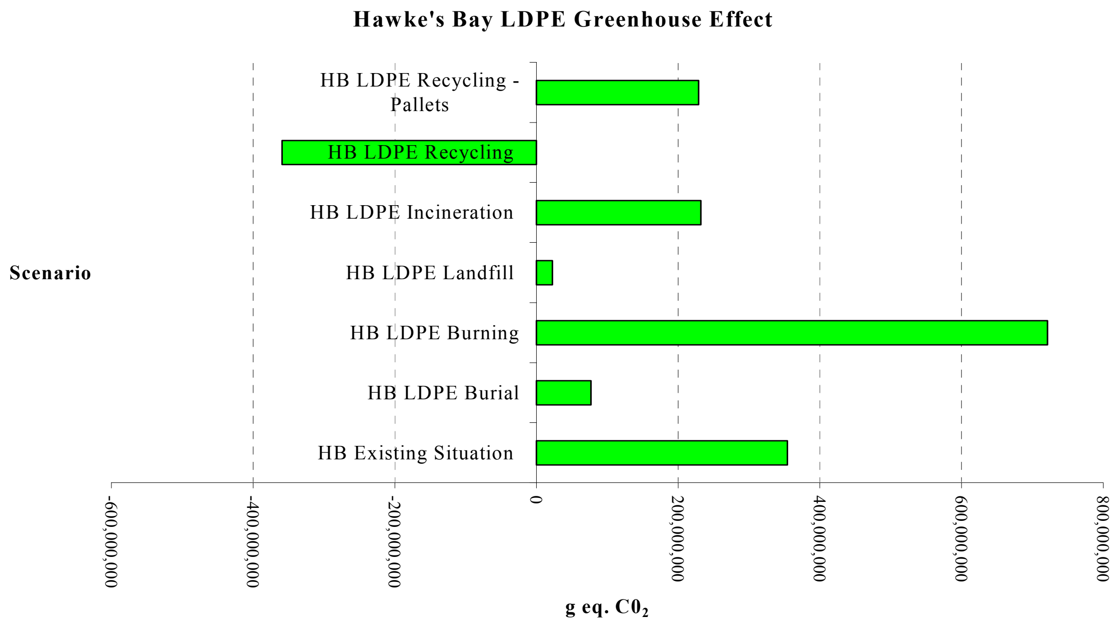


Figure 5 Hawke's Bay LDPE Greenhouse Effect



The approximate contributions of the use of diesel as an accelerant on each effects index total is given in Table II.

Table II Contribution of Diesel to Index Total for On-farm Burning Scenarios (%)

	Hawke's Bay HDPE	Hawke's Bay LDPE	Canterbury HDPE	Canterbury LDPE
Air Acidification	38	32	38	25
Human Toxicity	13	11	13	9
Greenhouse Effect	3	2	3	2

As the majority of effects result from the emissions from the burning of plastic, rather than the emissions from the accelerant, the comparative effects (when compared to other scenarios) do not change significantly if a different assumption was made in respect of the use of an accelerant, or the type and quantity of accelerant.

Figure 6   Hawke's Bay LDPE Eutrophication

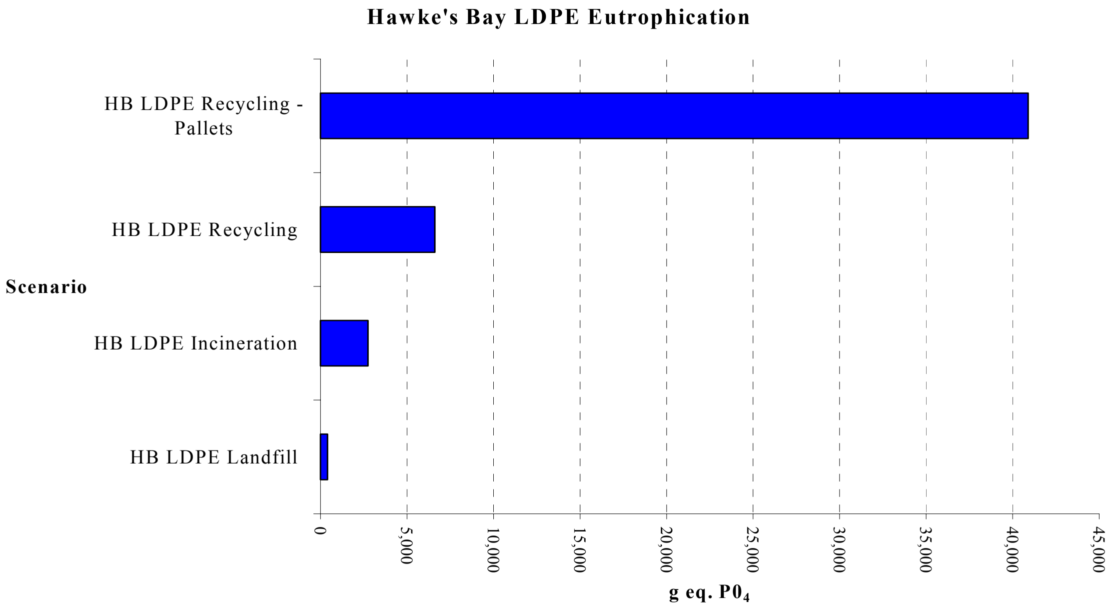
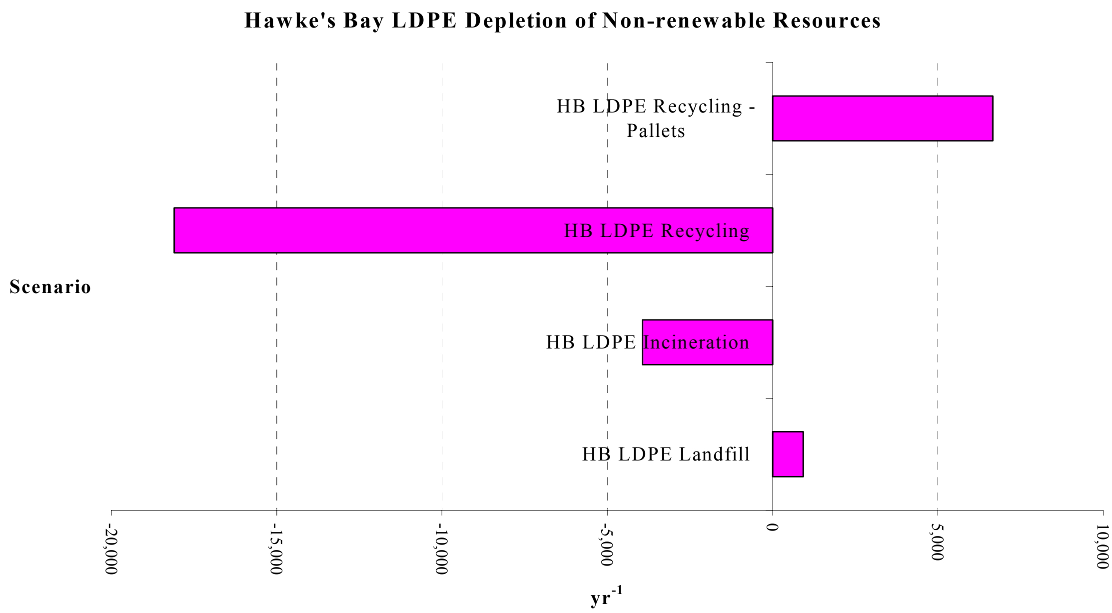


Figure 7   Hawke's Bay LDPE Depletion of Non Renewable Resources



The indices assessment indicates that the landfilling of waste farm plastics, using existing transfer stations and landfills has less effect on the environment than on-farm disposal scenarios, for those indices compared (Figures 3, 4 and 5). The emissions from the landfill scenario are due only to the transport of plastics and the construction and operation of transfer stations and landfills.

The recycling of plastics (as a replacement for virgin plastic) results in net avoided burdens for the air acidification, human toxicity, greenhouse effect and depletion of non renewable resources indices (Figures 3, 4, 5 and 7).

The reason for the avoided burdens is that the recycling of plastic, as a replacement for virgin plastic, avoids environmental burdens associated with the transport and production of the virgin plastic, as indicated in Figures 5 (greenhouse gas effect) and 7 (depletion of non renewable resources).

The incineration of plastics in a municipal solid waste incinerator, with energy recovery, results in a net avoided burden for the air acidification, human toxicity and depletion of non renewable resources indices (Figures 3, 4 and 7). The reason for the avoided burdens is energy recovery from the incineration process, which in New Zealand would displace energy production using gas. However, these avoided burdens are not as great as those that result from recycling to replace virgin plastic.

Incineration of plastics results in a net adverse effect for the greenhouse effect index (Figure 5), due to carbon dioxide emissions from the burning of the plastic.

Recycling and incineration of plastics result in adverse effects due to eutrophication (Figure 6). In the case of recycling eutrophication effects are primarily due to the discharge of detergent used for washing plastic as part of the recycling process. In the case of incineration these effects are primarily due to the discharge of wastewater from the flue gas cleaning process.

Comparison of recycling of LDPE, to replace virgin plastic, in New Zealand and recycling of LDPE into transport pallets (replacing wood) indicates that the recycling of plastics into items that replace wood (a renewable resource) results in reduced avoided burdens for air acidification and human toxicity (Figures 3 and 4). It also indicates increased effects on the environment in respect of greenhouse effect, eutrophication and depletion of non-renewable resources (Figures 5, 6 and 7).

Qualitative Assessment

A qualitative assessment was undertaken to identify issues associated with the management of waste farm plastics that are not included in the quantitative waste management life cycle assessment.

Table VII summaries the issues and risks associated with the handling of items that may contain contaminants and the disposal of other materials with farm plastics in respect of both on-farm and off-farm scenarios.

It indicates that there are risks to the environment associated with inadequate rinsing of HDPE chemical containers, or cleaning of LDPE film for all management scenarios. There are also increased risks of leachate discharges if plastics are burned or buried with other waste materials.

The requirements for rinsing and cleaning of plastics to enable recycling could potentially affect participation rates for that management option.

Table III Summary of Qualitative Issues and Risks

Scenario \ Issue/Risk	Planning Instrument Non Compliance	Health and Safety - Fires	Contamination /Residual Chemicals	Low Participation	Leachate Discharges
On-farm Burial	✓		✓		✓
On-farm Burning	✓	✓	✓		✓
Landfill			✓		
Recycling			✓	✓	
Incineration			✓		

CONCLUSIONS

A comparative LCA of five scenarios for the management of two types of waste farm plastic (HDPE chemical containers and LDPE film), required a number of assumptions, in respect of plastic quantities on farms and horticultural units, machinery and vehicle usage, travel distances, behaviour of farmers, facilities used and recycling and disposal processes, in order to overcome information gaps and to standardise input parameters across management scenarios.

The results indicate that a program whereby farmers drop off waste plastics at transfer stations for recycling, into products as a replacement for virgin plastic, will have the least negative effect on the environment, when compared to other scenarios and the present situation.

This is due to avoided burdens in respect of air acidification, human toxicity, greenhouse effect and depletion of non renewable resources that result from the avoidance of extraction, processing and transport of virgin plastic raw materials.

On-farm disposal, by way of burning or burial results in greater adverse effects in respect of air acidification, human toxicity and greenhouse gas effects than off-farm management scenarios. On-farm burning has a greater negative effect than burial.

The landfilling of waste farm plastics, using existing transfer stations and landfills, has less adverse effects than on-farm burial.

It should be noted that the plastic waste streams assessed for the two regions were small, ranging in size from 188 tonnes to 791 tonnes. As a result the differences in environmental effects between the scenarios are small in absolute terms.

A qualitative assessment of issues and risks that are not addressed by the quantitative LCA indicates that poor management of on-farm disposal practices can result in a number of risks to people and the environment.

Off-farm management scenarios can also entail risks to people and the environment, if waste plastics are not properly rinsed or cleaned.

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BIBLIOGRAPHY

ALGA (Australian Local Government Association), Avcare (National Association for Crop Protection and Animal Health), NFF (National Farmers' Federation), and VMDA (Veterinary Manufacturers and Distributors Association), 2002. drumMUSTER, http://www.drummuster.com.au

Bloomer, D. Alternatives Needed for Agrichemical Container Disposal. Mafnet, Ministry of Agriculture and Forestry. http://www maf.govt.nz/mafnet/publications/rmupdate/rm6/rm6005.html.

Dyer, R., 1998. The Safe Disposal of Clean Agrochemical Containers on Farm, Technical Note. United Kingdom Crop Protection Association.

Ecobilan Group, 2001. WISARD (Waste Integrated Systems Assessment for Recovery and Disposal) Version 3.7.r50.

Ecobilan Group, 2001. Lifecycle Tool for Waste Management in New Zealand – WISARD Reference Guide.

EuGeos Ltd., 2002. A Life-Cycle Assessment of Packaging Management Options for Crop Protection Products. (Prepared for the United Kingdom Crop Protection Association.)

MAF Statistics, Ministry of Agriculture and Forestry. http://www.maf.govt.nz/statistics/primaryindustries/land-use-and-farm-counts

Passey, C., 2001. The Storage and Disposal of Unwanted Agrichemicals and Agrichemical Containers in New Zealand Kiwifruit Orchards. Unpublished MSc. Thesis, Massey University, New Zealand.

Plastics New Zealand, 2002. Plastics Mass Balance Survey (2001 Production).

Standards New Zealand, 1999. NZS 8409:1999, Code of Practice for the Management of Agrichemicals.

APPENDIX A INDICES ASSESSMENT RESULTS

Table A I Indices Assessment for Hawke's Bay HDPE Scenarios

Scenario \ Theme	Air Acidification (g eq. H^+)	Eutrophication (water) (g eq. PO_4)	Human Toxicity (g)	Depletion of Non Renewable Resources (yr^{-1})	Greenhouse Effect (direct, 100 years) (g eq. CO_2)
Existing	18,013,153	696	141,188	-1,365	297,572,366
Burial	39,824,587		691,022		77,034,375
Burning	28,753,237		1,182,140		600,624,445
Landfill	1,992	383	8,874	903	21,376,384
Recycling	-130,012	5,426	-4,872,951	-14,539	-288,262,331
Incineration	-46,754	2,325	-2,722,719	-3,135	194,664,989

Note: Negative numbers represent avoided environmental burdens

Table A II Indices Assessment for Hawke's Bay LDPE Scenarios

Scenario \ Theme	Air Acidification (g eq. H^+)	Eutrophication (water) (g eq. PO_4)	Human Toxicity (g)	Depletion of Non Renewable Resources (yr^{-1})	Greenhouse Effect (direct, 100 years) (g eq. CO_2)
Existing	20,286,018	831	153,014	-1,749	354,158,936
Burial	39,824,587		691,022		77,034,375
Burning	33,047,797		1,397,801		721,521,755
Landfill	2,170	400	95,800	931	22,500,000
Recycling	-160,000	6,610	-6,010,000	-18,100	-359,000,000
Recycling - Pallets	-33,000	40,900	-1,020,000	6,660	229,000,000
Incineration	-56,585	2,751	-3,295,060	-3,937	231,996,861

Note: Negative numbers represent avoided environmental burdens

Table A III Indices Assessment for Canterbury HDPE Scenarios

Scenario \ Theme	Air Acidification (g eq. H^+)	Eutrophication (water) (g eq. PO_4)	Human Toxicity (g)	Depletion of Non Renewable Resources (yr^{-1})	Greenhouse Effect (direct, 100 years) (g eq. CO_2)
Existing	49,604,117	1,839	477,583	-3,789	818,881,416
Burial	109,708,651		1,903,624		212,214,063
Burning	79,173,090		3,254,734		1,653,578,173
Landfill	5,320	938	232,000	2,140	52,500,000
Recycling	-351,000	14,500	-13,100,000	-39,500	-782,000,000
Incineration	-129,000	6,310	-7,500,000	-8,960	531,000,000

Note: Negative numbers represent avoided environmental burdens

Table A IV Indices Assessment for Canterbury LDPE Scenarios

Scenario \ Theme	Air Acidification (g eq. H^+)	Eutrophication (water) (g eq. PO_4)	Human Toxicity (g)	Depletion of Non Renewable Resources (yr^{-1})	Greenhouse Effect (direct, 100 years) (g eq. CO_2)
Existing	65,519,735	2,797	401,541	-6,473	1,214,953,155
Burial	109,708,651		1,903,624		212,214,063
Burning	109,246,050		4,764,920		2,500,170,133
Landfill	6,780	1,070	288,000	2,350	60,800,000
Recycling	-564,000	22,900	-21,200,000	-64,400	-1,280,000,000
Incineration	-197,000	9,280	-11,500,000	-14,600	792,000,000

Note: Negative numbers represent avoided environmental burdens