REPORT

ASSESSMENT OF FOOD DISPOSAL OPTIONS IN MULTI-UNIT DWELLINGS IN SYDNEY

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In-Sink-Erator

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The study was overseen by a steering committee which consisted of representatives from the NSW Environmental Protection Authority (EPA), Sydney Water, the NSW Waste Boards, Nature Conservation Council, Local Government and Shires Association and In-Sink-Erator. The project definition and methodology, together with the wording in this report, were developed in consultation with the committee, however this report does not necessarily represent the endorsed view of any of these organisations.

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2 Investigators

Dr Ron Wainberg
Program Manager, Solid Waste Management
CRC for Waste Management and Pollution Control Limited
Project Manager

Dr Jeppe Nielsen,
Director
Nielsen Environmental Pty Ltd
Sub-investigation 1: Operational Impacts of the Food Waste Disposal System.
Sub-investigation 3: Economic Assessment of the Disposal System Options.

Dr Sven Lundie
CRC Senior Research Fellow
University of New South Wales
Sub-investigation 2: A Life Cycle Assessment Comparison of the Environmental Impacts of the Disposal System Options.
Sub-investigation 3: Economic Assessment of the Disposal System Options.

Dr Gregory Peters
Researcher
University of New South Wales
Sub-investigation 2: A Life Cycle Assessment Comparison of the Environmental Impacts of the Disposal System Options.
Sub-investigation 3: Economic Assessment of the Disposal System Options.

Associate Professor Nick Ashbolt
Deputy Director, Centre for Water and Waste Technology
University of New South Wales
Sub-investigation 4: Microbial Risk Assessment of the Disposal System Options.

Associate Professor David Russell
Head of the Social Ecology Research Centre
University of Western Sydney
Sub-investigation 5: Social Impacts of the Disposal System Options.

Claire Jankelson
Researcher
University of Western Sydney
Sub-investigation 5: Social Impacts of the Disposal System Options.

3 Executive Summary

Food Waste Processor (FWP) units are mainly used to dispose of waste generated in the kitchen during the preparation of food. Their use is limited by legislation to domestic and existing hospital use only (in NSW). The highest per capita installation of FWP units appears to be in apartment blocks.

In-Sink-Erator has approached the Cooperative Research Centre for Waste Management and Pollution Control (CRC for Waste Management & Pollution Control Limited) to investigate the environmental, technical, economic and social impacts of their product. In-Sink-Erator is the leading supplier of residential, sewer-based food waste disposal systems.

The research was undertaken as five separate but interlinked studies examining the technical/operational, environmental, economic, social acceptance and microbial risk impacts of FWPs. The In-Sink-Erator unit was taken as representative of FWP units.

The study was restricted to the Waverley Local Government (Council) Area in the eastern suburbs of Sydney. Within the limitations provided in the specific reports, the results are believed to be representative of this area.

The procedures for this study are believed to be generic for analysis of these types of impacts. Such procedures should be able to be transferred to other situations, for FWP use in both multi – unit and other dwellings.

The results may not be transferable or applied to other areas without using new or verified data sets. The general conclusions are expected to follow those reported here for similar situations, but care must be taken to verify and document the basis on which the assumptions are based.

The following FWP scenarios were adopted:

- The current situation. Available data indicate that 3% to 5% of households in the Waverley area have FWP units. A value of 5% has been adopted for this investigation.
- The future situation. Using the market penetrations of 15%, 25% and 50%, the 50% market penetration in this study is considered to be an extreme case. It was assumed that all FWPs are used every day for each of the adopted market penetrations - an extreme situation.

The five studies and their results are outlined below.

Sub-investigation 1: Operational Impacts of the Food Waste Disposal System.

The aims of the analysis of the operational impacts investigation were:

- To determine current and anticipated future loads on the sewerage system from the use of FWP units; and
- To determine the positive and negative macro environmental impacts from the use of FWP units in terms of impacts on:

  (a) the occurrence of sewage overflows;
  (b) the sewage treatment process;
  (c) biosolids reuse;
  (d) the marine environment in disposal of uncaptured portion of food wastes; and
  (e) energy consumption required in sewage transport, treatment and biosolids processing.

- To provide data to evaluate capital and operating costs of the food disposal options.

Data was both generated through a laboratory investigation using a FWP unit and also obtained from In-Sink-Erator, Sydney Water and other relevant sources. The specific water usage used in this investigation for each FWP unit was 6.2 Liters per household per day or 2.95 Liters per person per day. These values are higher than the values obtained from the laboratory investigation, midway between other referenced studies and lower than those used in overseas investigations.

Several assumptions were made for this investigation in consultation with the steering committee:

- All of the FWPs were assumed to operate together every day for each of the adopted market penetrations.
- The current market penetration was assumed to be 5%.
- It was assumed that the latest available local data as used in this study will not change in the future.
- Pollutant load increases of less than 10% for all pollutants at Bondi STP were considered to be within the design and operational capabilities of the plant and would not result in operational problems or need capital upgrades.
- Sewage quality into Bondi STP was assumed to be the same as in the Waverley-Bondi Eastern Slopes Intercepting Sewer.
- The results from the laboratory investigation were assumed to be representative of the Waverley Catchment.

There were major differences in concentrations and loads of pollutants in FWP effluent between this investigation and those used by other investigators. In particular, the mean NFR,

BOD_5 and COD concentration from this investigation differed by up to three times when compared to literature values.

Only this study and two others are based on local monitoring data. The others are based on monitoring sewers for small differences of irregular flows. Results from the other investigations cited in this report are based on generic literature values or theoretical calculations.

The overall results of the operational impacts of the food waste disposal study show:

- increases in sewage flows from FWPs at any of the adopted market penetrations are very small;
- FWPs contribute less than 0.1% flow to the Instantaneous Maximum Flow in the sewer at a market penetration of 50%;
- impact on the sewage treatment process from the hydraulic loading attributable to FWPs is small. Even for 50 % market penetration, FWPs would only contribute an extra 0.5% to the Mean Average Daily Flows which are attributable to the area studied through the sewage treatment plant;
- impacts from additional pollutant loads on the sewage treatment process as a result of FWP usage is also small: a market penetration of up to 15% should not cause operational problems in terms of BOD_5, Oil and Grease and NFR. (It should be noted that the mean annual effluent concentration for Oil and Grease at Bondi STP was closer to the EPA licence limit than for the other pollutants for 1999. An increase of 10% Oil and Grease could increase effluent concentrations by about 2 mg/L, resulting in a mean average effluent concentration of about 25 mg/L, if the rate of chemical dosing for the chemically assisted sedimentation process is not varied. This slightly increased effluent concentration is about 15% less than the EPA licence limit of 30 mg/L.)
- FWPs would not adversely affect sludge digesters, dewatering centrifuges and biosolids trucking movements up to a market penetration of 25%;
- FWPs at any market penetration studied are unlikely to affect biosolids reuse, the marine environment or energy consumption.
- The use of FWPs would result in additional hydrogen sulphide generation within the sewerage system and while this is associated with corrosion and odour problems, it is not possible to quantify the effects or to estimate an upper FWP market penetration that could be sustained by the existing system.

Sub-investigation 2. Environmental Profiles of the Food Disposal Options

The aim of investigating the environmental profiles of food waste disposal options was to assess FWPs on the holistic basis of the ISO14040 standards using *Life Cycle Assessment* (LCA) and compare them to home composting, co-disposal of food with municipal waste and centralised composting of food and garden waste.

The functional unit ("fu") adopted for the LCA was the average amount of food waste produced by a household for disposal in one year, 182 kg (wet).

The LCA was based on several assumptions made in consultation with the Steering Committee:

- The beneficial use of by-products, such as compost and biosolids (avoided products), was not part of the study.
- The FWPs are operated correctly and require no maintenance over a 12 year lifespan.
- The home composting unit is made of polyethylene that lasts for 12 years.
- Home composting is correctly operated, and food waste degrades under aerobic conditions.
- A Centralised Composting system for food and garden waste was assumed to run in parallel with the existing MSW system, at a capacity of 50,000 tpa.

The disposal of food waste with municipal waste is common practice. No major assumptions were made concerning the collection of waste. The amount of recovered energy is uncertain should the biogas generated be used for energy recovery. This was treated by a sensitivity analysis.

The LCA gave the following results for the impact categories studied:

- Home composting had the smallest environmental impacts in all impact categories studied;
- The FWP unit ranked second in terms of energy consumption, global warming potential and acidification, but fourth in terms of human, aquatic and terrestrial toxicity potential and eutrophication;
- Co-disposal received the second highest ranking in the categories of toxicity potential and eutrophication potential, ranked only slightly behind FWP for energy consumption and acidification and had the lowest ranking for global warming potential; and
- Centralised composting had a relatively poor environmental performance due to its energy intense collection activities, ranking fourth for energy and acidification and third in the remaining categories.

Normalization of the results to an emission per capita basis (without weightings), showed eutrophication from the FWP to have the largest relative potential impact for all the food waste disposal options (of the impact categories considered), followed by centralized composting. Co-disposal made significant contributions only to global warming and eutrophication potential. The energy consumption and acidification potential of all food waste disposal options were smaller relative to the annual average per capita impact.

Sub-investigation 3: Cost Comparison of the Food Disposal Options.

The results of this study show home composting is the least expensive option for the residents of multi-unit dwellings, while the FWP is the most expensive. The cost to the resident of co-disposal and centralized composting are in between these two extremes, with centralized composting being marginally the cheaper.

From a system-cost point of view, FWD appears again to be the most expensive option, and this cost increases beyond the 25% market penetration level in the study area as additional capital expenditure may be required at the sewage treatment plant.

The Codisposal system option would not necessitate additional capital investment (within limitations imposed by the existing landfill capacity) as this is the waste management option presently in place, whereas implementation of the Centralised Composting system option would necessitate capital expenditure since such a system suitable for food wastes does not exist within the Sydney area.

Sub-investigation 4 Additional Health Risks of the Food Disposal Options.

The aims of this part of the investigation were to evaluate:

- Microbial risks associated with sewer overflows caused by FWP units;
- Relative microbial risks between the four processing options; and
- Risks associated with disease vectors.

A formal quantitative microbial risk assessment (QMRA) approach was undertaken at a screening level to compare risk between the various options under consideration. To compare pathogen risks, each of the four possible pathogen groups was represented by an index organism; *viz*: a virus (rotavirus), a bacterium (*Salmonella typhimurium*), a parasitic protozoan (*Giardia lamblia*) and a helminth (*Ascaris lumbricoides*).

Overall the study identified that:

- Risks from overflows from raw sewage would be unacceptable, however, FWP units may only marginally increase the rate of sewer overflows during periods when the sewer is already flowing at 100% (such as during storm events);
- Domestic composting, without the addition of pet faecal wastes or meat products, was predicted to result in acceptably low infection rates for all the pathogen groups;
- Commercial composting (including human faecal wastes) appeared satisfactory from the point of view of no significant pathogen risks;
- Overall vector-based diseases were not considered significantly different due to the operation of FWP units and on-site domestic composting in approved containers.

Sub-investigation 5: Social Impacts of the Food Disposal Options.

The relative merits (social factors) of the four food waste disposal options in multi-unit dwellings within the study area were compared through two focus group discussions. The options were assessed across four criteria: consumer choice, accessibility of the option, space requirements, and consumer uptake.

Disposal of food with municipal waste (the dominant current practice) was judged as being the least satisfactory of all the options. Individual garden composting, while environmentally ideal, was judged to be impractical for multi-unit dwellings.

FWPs and the separate food waste collection with centralised composting were evaluated as being much more appropriate (across the four criteria) than the mixing of food and other waste. This assessment, however, was provisional on the availability of a level of treatment that would enable re-use of the waste material.

Overall conclusions.

Up to a market penetration of about 15 % of households, the use of FWP in multi-unit dwellings would have small impacts on the sewage treatment and transport systems. Beyond this figure there are increasing impacts, and at 50% market usage some may become significant.

The study indicates that Home Composting is the least expensive option for the residents of multi-unit dwellings, while the FWP is the most expensive. The cost to the resident of Co-disposal and Centralised Composting are in between these two extremes, with that of Centralised Composting being marginally the cheaper.

For the householder, FWP appears to be the most expensive option. Overall, costs increases beyond the 25% market penetration level in the study area may be incurred as additional capital expenditure may be required at the sewage treatment plant.

The Co-disposal system option would not necessitate additional capital investment (within limitations imposed by the existing landfill capacity) as this is the waste management option presently in place, whereas implementation of the Centralised Composting system option would necessitate capital expenditure since such a system suitable for food wastes does not exist within the Sydney area

From an environmental viewpoint well controlled and managed home composting is the most favoured option across all impact categories. FWP ranks approximately equal second across three categories but fourth across four categories of impact potential.

None of the options, when correctly operated, posed a significant additional risk to health.

While the focus groups preferred FWP or centralised composting for food disposal in multi-unit dwellings, for convenience and perceived health benefits, they are sensitive to the impact arising from the disposal of the waste materials. Thus FWP and Centralised Composting would appear to have a high acceptance rate if the biosolids or compost are reused in a way that has acceptable minimal impacts on the environment.

For up to 15% market penetration in the study area, the use of FWP in multi-unit dwellings would be expected to have a small impacts on the sewage treatment system. If their adoption and use became more widespread, there would appear to be a need for additional investment in the sewage treatment system, however this is unlikely to be in the near future given the presently low market penetration of these units. Environmentally, correctly implemented Home Composting is the preferred option, however this may not be acceptable to residents of multi-unit dwellings for whom the FWP offers a practical, but much more expensive, alternative. The environmental cost of adopting this alternative would present a trade-off: The Energy, Global Warming and Acidification impacts are less than or equal to those of the Co-disposal or Centralised Composting options, however the Toxicity and Eutrophication impacts are higher.

4 Background

Food Waste Processor (FWP) units are mainly used to dispose of waste generated in the kitchen during the preparation of food. Their use is limited by legislation to domestic and existing hospital use only (in NSW). The highest per capita installation of FWP units appears to be in apartment blocks.

In-Sink-Erator has approached the Cooperative Research Centre for Waste Management and Pollution Control (CRC for Waste Management & Pollution Control Limited) to investigate the environmental, technical, economic and social impacts of their product. In-Sink-Erator is the leading supplier of residential, sewer-based food waste disposal systems.

The research was undertaken as five separate but interlinked studies examining the technical/operational, environmental, economic, social acceptance and microbial risk impacts of FWPs. The In-Sink-Erator unit was taken as representative of FWP units.

This research assessed the environmental, technical, economic and social impacts in in-sink food waste disposal units. The main objectives were to:

(a) *To establish and quantify:*

- *The positive and negative environmental impacts*
- *The infrastructure provision and operating costs*

resulting from current and possible future use of in-sink food disposal units in multi dwelling developments to assess the impacts on the water and wastewater management system, as well as impacts avoided in the solid waste management system, in "likely" and "worst case" scenarios, depending on disposer market penetration.

(b) To compare the benefits and disadvantages of the FWP with the following food waste management options:

- *Individual garden composting,*
- *Disposal of food with municipal waste (Co-disposal),*
- *Separate organic waste collection with centralised composting.*

5 Aims of the Investigation

The specific aims of the investigation were to:

- determine current and anticipated future loads on the sewerage system and sewage treatment system from the use of FWP units;
- determine the positive and negative macro environmental impacts from the use of FWP units in terms of impacts on:
  - the occurrence of sewage overflows;
  - the sewage treatment process;

- biosolids reuse;
- the marine environment in disposal of uncaptured portion of food wastes;
- energy consumption required in sewage transport, treatment and biosolids processing.

- determine loads diverted from municipal solid waste collection as a result of using FWP units and the associated environmental and economic consequences;
- determine environmental profiles of the food disposal options;
- evaluate capital and operating costs of the food disposal options;
- evaluate the social implications of the food disposal options;
- compare the overall benefits and disadvantages of the food disposal options.

6 Report Structure

The aims of this study were addressed through five separate sub-investigations, the results of which form the basis for the overall comparison of the benefits and disadvantages of the food disposal options.

These sub-investigations were:

- An operational analysis approach to assess impacts on the sewerage system of FWP units;
- A Life Cycle Assessment approach to compare the environmental impacts of the disposal system options;
- A cost comparison of the disposal system options;
- A microbial risk assessment (MRA) conducted to estimate additional health risks;
- A broad assessment of the social aspects of each food waste disposal option through focus groups;

Following a literature review, the sub-investigations are presented in detail in the following sections 8 to 12 of this report and then the overall comparison of the food disposal options is presented through the conclusions in section 13.

7 Literature Review

A review of the available literature revealed the following references which describe earlier investigations to evaluate impacts of FWPs on sewerage systems:

Sinclair Knight (April 1990) undertook a study for Sydney using market penetrations of 5% to 100%. The authors concluded that FWPs would have a minimal effect on the volumes of sewage flow and could result in significant increases in pollutant loads in Sydney sewerage systems, although impacts would be dependent on the extent to which FWPs were used. At the estimated market penetration rate at the time of the study (10%), FWPs were concluded to have a minimal effect on the sewerage system. The results from this investigation were based on generic literature values, not on local sampling data.

Griffith University (August 1994) collected kitchen organic waste from 10 households in the Ashmore suburb of Gold Coast City, ground the waste through a FWP unit and analysed the resultant wastewater. Impacts on the Ashmore sewerage system (75,000 households) were evaluated assuming 100% market penetration of FWPs.

The results indicated that the incremental increase in the sewage hydraulic load would be negligible, increases in solids and BOD_5 loads would be less than 20% and nutrient loads would increase by less than 5%. Furthermore, STP aeration tanks would have to be increased in size by about 16%, based on the most pessimistic circumstance that STPs were at full load capacity. It was concluded that FWPs do not present an unmanageable load on the existing sewage treatment facilities. FWP market penetration in the area at the time of the study was approximately 20%, however this was not considered by the investigators.

de Koning, J and van der Graaf, JHJM (1996) investigated impacts of FWPs on the Dutch sewerage system using the theoretical chemical composition of food waste. Food composition data were obtained from investigations undertaken in different countries. It was concluded that impacts of FWPs on sewer systems and wastewater treatment plants was minimal and that adverse effects were negligible at a FWP market penetration of 10%.

NYC (Late 1990s) monitored sewers for 21 months at three study locations to determine impacts of FWPs. The data were used to predict impacts on sewers to the year 2035 assuming a worst case scenario of 1% increase in the number of households using FWPs annually. This rate of increase would mean that more than one third of households in New York City would have FWPs installed by the year 2035, a market penetration which was considered to be unlikely.

The results indicated that although FWP units may cause increases in Suspended Solids and Oil & Grease in the sewerage system, incremental increases in sewer maintenance costs, water consumption and STP operating costs would be minimal. It was recommended that a ban on the introduction of FWPs in combined sewer areas of New York City should be lifted.

There is a scarcity of published literature on Life Cycle Assessment (LCA) for food waste processors (FWP), whereas more LCA studies are available for municipal solid waste (MSW). Four studies have been found which address the environmental impacts of FWP units.

The most relevant work was carried out by Diggelman & Ham (1998). Basically, this study compares food waste management in the MSW system (default system) with the FWP system. Five alternative options are compared in the United States: 1) FWP and on-site systems, 2) FWP and municipal wastewater systems, 3) MSW collection and composting, 4) MSW collection and Waste-to-Energy and 5) MSW collection and landfill. Life Cycle Inventories (LCI) were provided for each option, and they included the production and operation of capital equipment. The five systems were ranked for twelve inventory indicators: land use, total system materials, water, total system energy, total system costs, air emissions, acid gases, greenhouse gases, wastewater, waterborne waste, solid wastes and system food waste byproducts (sludge, septage, compost, ash, landfill residues). The five systems were ranked simply from high to low impacts for each inventory indicator.

Waste Board (2000) and Partl *et* al (1999) have investigated alternative kitchen organics collection systems in the greater Sydney region. The two collection systems studied were 1) regular kerbside collection system of garden organics with kitchen waste and 2) domestic in-sink disposal of kitchen organics. However, these studies provide only a qualitative assessment of environmental impacts and a quantitative evaluation of associated costs.

Hardin *et al* (1999) analysed three disposal options for putrescible (kitchen and garden) waste, ie. kerbside collection and landfill, home composting/worm farming and disposal with FWP. According to the authors, the environmental impacts from the three options were difficult to assess, and as a consequence, the study does not quantify environmental impacts, although it provides a qualitative assessment for the Brisbane area.

None of the previous studies quantify environmental impacts in terms of impact categories for FWP and the alternative waste treatment options in the greater Sydney region. A comparative, quantitative LCA of the four options (ie. FWP, MSW and landfill, home composting and centralised composting) is not available. The LCA investigation performed in this study goes beyond the LCI study from Diggelman & Ham (1998) by addressing the environmental indicators and impact categories of energy consumption, Global Warming, Human- and Eco-toxicity, Acidification and Eutrophication Potential qualitatively and odour qualitatively. Moreover, the potential environmental impacts are based on Sydney specific conditions.

8 Investigation of Operational Impacts

Sub-investigation 1

Operational Impacts of the Food Waste Disposal System.

9 Environmental Profiles of the Food Disposal Options

Sub-investigation 2

A Life Cycle Assessment Comparison of the Environmental Impacts of the Disposal System Options.

10 Capital and Operating Costs of the Food Disposal Options.

Sub-investigation 3

Cost Comparison of the Disposal System Options.

11 Additional Health Risks of the Food Disposal Options.

Sub-investigation 4

Microbial Risk Assessment of the Disposal System Options.

12 The Social Implications of the Food Disposal Options.

Sub-investigation 5

Social Impacts of the Disposal System Options.

13 Conclusions

The five investigations carried out in the course of this study have sought to evaluate the technical, environmental, economic, health and social aspects of the in-sink food waste disposal unit. The aim has been to quantify the positive and negative environmental impacts as well as the marginal infrastructure costs which would result from different levels of market penetration (5%, 15%, 25% & 50%).

The study has intentionally focused on multi-unit dwellings in the Waverley – Bondi area of Sydney, NSW, Australia.

The study has further sought to compare the FWP system with three other food waste management options (Home Composting, Co-disposal with MSW, and separate organic waste collection with Centralised Composting).

The salient outcomes from the five investigations are summarised below:

Technical Aspects of the FWP.

Sewerage systems differ from place to place, depending on factors such as age and the level of technology implemented. Undertaking a technical evaluation of the impact FWPs have on the sewerage system will necessitate defining the characteristics of the sewerage system in question, because the FWPs impact will be relative to the quantity of sewage and quality of treatment. The outcomes described in this study are relevant for the *Waverley/Bondi Eastern Slopes Intercepting Sewer*. While the methodology can be applied to other systems, care should be taken in transporting the results of the present study.

The additional hydraulic load resulting from the use of FWPs is very small. For the catchment area studied this load was calculated to be 0.007% of the *Instantaneous Maximum Flow* within the sewerage system, at 5% market penetration, rising to 0.07% at the 50% penetration level. This low additional load is not likely to increase the risk of sewer overflows, although if the sewer is running at full capacity during wet weather overflows may be experienced as a result of the total load.

The same applies to the hydraulic load on the STP: the additional flow contributed by FWPs in the study area at all market penetration levels examined is calculated to be very small compared to the flow treated at the Bondi STP attributable to the study area (the "scaled-down Bondi STP"): at 50% market penetration, FWP units would only contribute an extra 0.5% to the Mean Average Daily Flow. From a hydraulic load perspective, the STP would be able to cope with the additional load except when the plant is running at full capacity during wet weather when any additional load, including FWPs, will lead to an overflow situation.

The situation is different when considering the additional pollutant load on the STP. A 25% market penetration would lead to the production of 7% additional biosolids. Beyond this level, the performance of sludge digesters, dewatering centrifuges and biosolids trucking movements may be adversely affected.

The results for BOD_5 and Oil & Grease are more restrictive and indicate for a FWP market penetration of up to only 15% would operational problems not be expected at Bondi STP, while the NFR results would indicate a level of 20% (interpolated value) would be acceptable.

It follows from the biosolid, BOD_5, Oil & Grease and NFR results that for the area studied, an FWP market penetration of up to 15% will have no significant effects on the hydraulic load, capacity and performance of the sewerage system and the sewage treatment plant.

This must be tempered by the observation that increased levels of hydrogen sulphide generation would accompany any increased BOD_5 levels and this could lead to increased (but unquantified) corrosion and odour problems.

From the technical point of view, FWPs are not expected to have an impact on biosolids reuse, the marine environment or energy consumption associated with sewage treatment at the market penetrations studied.

Environmental Aspects of the Four Options.

The environmental profiles of the four disposal options are summarised in the following table:

Rank	Energy	Global warming	Human toxicity	Aquatic eco-toxicity	Terrestrial eco-toxicity	Acidifi-cation	Eutrophication
1	HC	HC	HC	HC	HC	HC	HC
2	FWP	FWP	CD	CD	CD	FWP	CD
3	CD	CC	CC	CC	CC	CD	CC
4	CC	CD	FWP	FWP	FWP	CC	FWP

FWP FWP
HC Home composting
CD Co-disposal
CC Centralised composting

The options have been ranked within each impact category but not across the categories as an overall impact assessment.

From an environmental point of view, well managed and controlled Home Composting is the most favoured option across all impact categories.

Of the other three options, the FWP was ranked approximately equal second with Co-disposal from the point of view of energy and acidification and equal second with Centralised Composting when considering global warming potential. It ranked fourth for the remaining categories of toxicity and eutrophication.

→ STP does not have sec treatment (BOD and nutrient removal)

From these results the FWP is considered to represent a viable food waste disposal option with equivalent or smaller adverse impacts on energy consumption, global warming and acidification compared to co-disposal and centralised composting. When considering toxicity and eutrophication however, co-disposal is to be preferred over centralised composting and the FWP.

These impacts can be put into a wider perspective and compared with annual per capita emissions, where data is available:

Option	Energy consumption	GWP	Acidification potential	Eutrophication potential
Home composting	0.00%	0.14%	0.00%	0.07%
FWP	0.05%	0.16%	0.03%	1.22%
Co-disposal	0.05%	0.37%	0.04%	0.35%
Centralised composting	0.17%	0.24%	0.16%	0.72%

The results indicate that the FWP option has the greatest potential relative impact on eutrophication at 1.2%. This is followed by centralised composting at 0.7% and co-disposal at 0.4%. Relative impacts of all options on acidification and energy consumption are relatively minor, while for global warming potential of co-disposal and centralised composting are the highest.

These impacts relate to the "functional unit" defined for this study: the quantity of the food waste produced by a household in one year, that is 182 kg of wet food waste per annum. Accordingly, the impact ranking is independent of market penetration.

The environmental impact of the FWP compared to co-disposal of food waste was estimated as a function of market penetration. A market penetration of 50% would cause a reduction of greenhouse gases (-28%), energy consumption (-5%) and acidification (-7%). However, environmental impacts of the other categories assessed would rise dramatically due to the intense extraction and production of materials for the FWP unit and the additional loads of nutrients to water: increase of human toxicity by a factor of 6, aquatic eco-toxicity by a factor of 2, terrestrial eco-toxicity by a factor of 5 and eutrophication by a factor of 2. The overall energy consumption and acidification would remain the same.

Economic Aspects of the Four Options.

The study indicates that Home Composting is the least expensive option for the residents of multi-unit dwellings, while the FWP is the most expensive. The cost to the resident of Co-disposal and Centralised Composting are in between these two extremes, with that of Centralised Composting being marginally the cheaper.

From a system point of view, FWP appears again to be the most expensive option, and this cost increases beyond the 25% market penetration level in the study area as additional capital expenditure may be required at the sewage treatment plant. Pollutant load considerations are however likely to necessitate capital expenditure at a lower market penetration level (see above).

The Co-disposal system option would not necessitate additional capital investment (within limitations imposed by the existing landfill capacity) as this is the waste management option presently in place, whereas implementation of the Centralised Composting system option would necessitate capital expenditure since such a system suitable for food wastes does not exist within the Sydney area.

Health Aspects of the Four Options.

Assessment of the likelihood of ingestion of food waste from any of the four waste management options is beyond the scope of this study. It was possible however to evaluate the risk of infection in the event of ingestion occurring.

In the event of ingestion of raw sewage, the risk of infection was judged to be unacceptably high, however this risk was not attributable to level of FWP market penetration. As discussed above, the low additional load on the sewerage system attributable to FWPs is not likely to increase the risk of sewer overflows, although if the sewer is running at full capacity during wet weather overflows may be experienced as a result of the total load.

Of the remaining options, only home composting exhibit an increased risk in the event of ingestion occurring. This was of potential salmonellae infections from accidental ingestion of raw food wastes, but was judged to be at an acceptable level. Risk from the other microbial groups were very low from exposure to raw food wastes.

None of the options when operated correctly were judge to pose an additional risk of disease vectors.

Social Aspects of the Four Options.

From a social point of view, the Focus Group studies have shown that environmentally conscious occupiers of multi-unit dwellings, while conscious of the impact of waste management practices, are aware of the need for a trade off between easily managed and environmentally beneficial practices. In this context, the FWP and centralised composting system options are the most preferred and practical of the four options, but this is predicated on the requirement that the end product produced from the food waste (the biosolids or the compost) must be reused in an environmentally acceptable manner.

The selection of any waste management option for a particular waste stream will generally involve a trade-off because of the inherent difficulties in satisfying all selection criteria which are established. Informed decision-making therefore requires a transparent presentation of the relevant data so that the overall costs and benefits of the final decision can be understood. This study does not attempt to "sum" the various factors evaluated for the four food waste disposal options studied, or to score them relative to each other. Rather, the aim has been to assess the four options in terms of the given criteria so that impact of subsequent waste management decisions are quantified. as far as possible.

The following tables summarise the main points from the five investigations in terms of the six primary aims of this project:

AIM	Option 1 FWP
Current & future additional sewer load for the study area.	0.004 ML (5% penetration) to 0.037 ML (50% penetration) per day
Positive and negative macro environmental impacts from the use of FWPs:	
1. Occurrence of sewage overflows	Unlikely to impact.
2. Sewage treatment process	Little impact up to 15% market penetration. Some additional H_2S generation.
3. Biosolids reuse	Unlikely to impact.
4. Marine environment	Negligible impact.
5. Energy consumption	Negligible impact.
Food Waste loads diverted through FWP.	At 5% penetration, 109 tpa diverted, offset by 31 tpa additional biosolids.

AIM	Option 1 FWP	Option 2 Home Composting	Option 3 Co-disposal	Option 4 Centralised Composting
Environmental profiles	Ranked 2nd for Energy, Global Warming and Acidification, 4th for Toxicity & Eutrophication.	Preferred option across all impact categories.	Ranked 2nd for Toxicity and Eutrophication impact, 3rd for Energy and Acidification and 4th for Global Warming.	Ranked 3rd for Global Warming, Toxicity and Eutrophication, 4th for Energy and Acidification impacts.
Costs	**Private costs:** Most expensive option. **Public costs:** Low additional operating and capital cost.	**Private costs:** Cheapest option. **Public costs:** Not applicable.	**Private costs:** Mid-range. **Public costs:** No additional cost as the infrastructure exists.	**Private costs:** Mid-range. **Public costs:** High initial system cost.
Social implications	Preferred option in multi-unit dwellings.	Least practical option in multi-unit dwellings.	Least preferred option in multi-unit dwellings.	Equally preferred option in multi-unit dwellings.

The table demonstrates that for up to 15% market penetration in the study area, the use of FWP in multi-unit dwellings would be expected to have small impacts on the sewage treatment system. If their adoption and use became more widespread, there would appear to be a need for additional investment in the sewage treatment system, however this is likely to be some time in the future given the presently low market penetration of these units.

Environmentally, correctly implemented Home Composting is the preferred option, however this may not be acceptable to residents of multi-unit dwellings for whom the FWP offers a practical, but much more expensive, alternative. The environmental cost of adopting this alternative would present a trade-off: the Energy, Global Warming and Acidification impacts are less than or equal to those of the Co-disposal or Centralised Composting options, however the Toxicity and Eutrophication impacts are higher.

ANNEX A. Summary of Results from the Sub-investigations

The conclusions from this study are presented below in terms of the stated aims of the investigation given in section 3. Conclusions reached with regard to the operational aspects of the sewerage system apply only to the *Waverley/Bondi Eastern Slopes Intercepting Sewer* and its contribution to the load on the Bondi STP. The methodology used in this study may be applied to other systems, however because of site specific design and construction criteria, care should be exercised in transporting all the results from Sub-investigation 1 to other sewerage systems.

Current and Anticipated Future Loads on the Sewerage System and Sewage Treatment System from the Use of FWP Units

- Conservatively, the specific daily water usage by each FWP unit is 6.2 liters per household, equivalent to 2.95 liters per person for the study area.
- For the study area, the marginal hydraulic load on the sewerage system is 0.004 ML per day at a FWP market penetration of 5%. This would rise proportionally to 0.037ML per day at 50% penetration.
- For the study area, FWP units will contribute 0.007% of the *Instantaneous Maximum Flow* within the sewerage system at 5% market penetration, rising to 0.07% at 50% penetration.

Positive and negative macro environmental impacts from the use of FWP units

The Occurrence of Sewage Overflows

- Flows contributed by FWP units in the study area would be very small compared to wet weather flows in the Waverley-Bondi Eastern Slopes Intercepting Sewer. At the highest market penetration level of 50%, the contribution would be less than 0.1% of the *Instantaneous Maximum Flow* in the sewer.
- While in principal FWPs could result in sewage overflows during wet weather if the sewer is flowing at full or very nearly full capacity, flows from FWP units at all market penetrations evaluated are extremely small compared with the increase in sewage flows that can result during wet weather.
- Problems with solids deposition or clogging in the sewer would not be expected at any of the FWP market penetrations examined.

The Sewage Treatment Process

Hydraulic Impacts

- The use of FWPs results in an additional water usage of 2.26 m^3 per household per year at the 5% market penetration level. This equates to approximately 1.3 ML per annum of additional water for study area.

- Flows contributed by FWP units in the study area at all market penetration levels examined would be very small compared to the flow treated at the Bondi STP which is attributable to the study area (the "scaled-down Bondi STP"): at 50% market penetration, FWP units would only contribute an extra 0.5% to the Mean Average Daily Flow.

- As with flow through the sewer, these small flow increases could in principal cause hydraulic capacities of the existing sewage treatment units and the allowable volume of treated sewage from discharged to the ocean to be exceeded. However, the flow increases caused by the operation of FWP units are extremely small compared to increases caused by wet weather.

Impacts of Pollutants

- The increased pollutant load on the Bondi STP resulting form FWPs should not cause operational problems for market penetrations of up to 15%.

- At a market penetration of 50%, FWP effluent would result in about 30% increase in hydrogen sulphide generation within the Waverley-Bondi Eastern Slopes Intercepting Sewer as a result of increased BOD_5, all else being equal. While lower increases in hydrogen sulphide generation would be expected at lower market penetrations, it is considered that any increase in hydrogen sulphide generation could lead to increased corrosion and odour problems, however this cannot be quantified.

Biosolids Reuse

- The small additional quantities of biosolids which would be produced by FWPs at any of the market penetrations studied are unlikely to affect the current contaminant grading or the reuse options for biosolids from Bondi STP.

Marine Environment in Disposal of Uncaptured Portion of Food Wastes

- Effluent from FWPs at all market penetrations evaluated would have negligible impact on effluent discharged to the ocean from Bondi STP in terms of the NSW EPA discharge criteria.

Energy Consumption

- Even at the maximum market penetration of 50%, transport and treatment of FWP effluent at Bondi STP would require only an additional 0.5% energy.

Loads diverted from municipal solid waste collection as a result of using FWP units.

- The use of FWP in the study area can be expected to divert 109 tonnes per annum of food waste from MSW collection system, at 5% market penetration.

- While this does represent a transport saving, this is partially offset by an additional 31 tonnes per annum of biosolids (at 5% market penetration) captured at Bondi STP requiring transport, an increase of 2.9%.

Environmental profiles of the food disposal options.

- *Energy consumption:* Home composting requires the least energy, FWP and co-disposal consume approximately the same and centralised composting has the highest energy demand.
- *Global Warming Potential*: Home composting generates the least CO_2-equivalents, followed by FWP, then centralised composting, with co-disposal the generating most.
- Energy recovery from biogas would have a marked positive effect.
- *Human toxicity, aquatic and terrestrial eco-toxicity*: Home composting is the best performing option, followed by co-disposal, centralised composting and then the FWP.
- *Acidification*: Home composting scores best, with FWP and co-disposal having higher impacts towards acidification and centralised composting the highest.
- *Eutrophication*: Home composting is the best performer, followed by co-disposal and then centralised composting. The largest contribution to eutrophication is caused by the FWP as a result of poor nutrient removal at the Bondi STP.
- On a normalized per capita basis, the energy consumption and acidification potential of the four options is a relatively small part of the annual average per capita contribution to these potential environmental effects, suggesting these impacts should be of lesser concern.
- A quantitative assessment of odour resulting from the four options is not possible. On a qualitative basis none of the options are expected to result in significant increases in odour, apart from increased (but not quantified) levels of hydrogen sulphide associated with the increased BOD_5 in the FWP effluent (see above).

Capital and operating costs of the food disposal options.

- The small flow increases resulting from FWPs at all market penetration levels would not require capital upgrades of the screens, grit tanks and the primary sedimentation tanks at Bondi STP.
- At a FWP market penetration in excess of 15%, additional chemical dosing may be required at Bondi STP to meet EPA discharge licence requirements.
- At a FWP market penetration in excess of 25%, the sludge digesters, dewatering centrifuges and biosolids handling and transport facilities at Bondi STP may require capital upgrades.

- FWPs in the study area would result in small increases in operating costs at Bondi STP, based on total operating costs. However, specific costs for individual process units could increase by up to about 30% at FWP market penetrations of 50%.

- Of the options studied, home composting is the least expensive for the householder.

- On the basis of either the total capital cost or the cost to the householder, the FWP option is the most expensive of the options studied.

- The co-disposal of waste does not involve additional capital expenditure as it is the system currently in place. The householder's cost for co-disposal is comparable with the high end of estimates for centralised composting.

The Social and Health Implications of the Food Disposal Options.

- There is a perceived need for a trade-off between a practice that is easily managed and one that is environmentally beneficial.

- For multi-unit dwellings, the two most attractive options are the FWP system and the separate food waste collection with centralised composting option.

- For both FWP and Centralised Composting, acceptance is based upon the level of waste processing planned and the ultimate re-use of the processed product.

- Provided there is an adequate level of waste treatment available for the FWP system, then it was judged to be 'ideal' for multi-unit dwellings, as it would preclude potential problems associated with localised storage of waste awaiting collection.

- Health risks associated with raw sewage overflows would be unacceptable, in the event of such overflows occurring.

- Potential salmonellae infections present the highest risks from the accidental ingestion of raw food wastes, but still at an acceptable level. Risk from the other microbial groups are very low from exposure to raw food wastes.

- Commercial composting does not appear to result in significant pathogen risks.

- Overall vector-based diseases were not considered significantly different due to the operation of FWP and on-site domestic composting in approved containers.

ANNEX B. Major Assumptions Made in This Investigation

Following is a list of the major assumptions made in this study.

- All of the FWPs were assumed to operate together every day for each of the adopted market penetrations.
- The current market penetration was assumed to be 5%.
- It was assumed that the latest available local data, as used in this study, will not change in the future.
- Pollutant load increases of less than 10% for pollutants at Bondi STP were assumed to be within the design and operational capabilities of the plant and would not result in operational problems or need capital upgrades.
- Sewage quality from Bondi STP was assumed to be the same as in the Waverley-Bondi Eastern Slopes Intercepting Sewer.
- The results from the laboratory investigation were assumed to be representative of the Waverley Catchment.
- The beneficial use of by-products, such as compost and biosolids (avoided products), was not considered within the LCA study.
- FWPs are operated correctly and require no maintenance over a 12 year lifespan.
- Home composting equipment is made from polyethylene and has a 12 year life.
- Home composting is correctly operated and maintained such that the food waste degrades under aerobic conditions.
- A Centralised Composting system for food and garden waste was assumed to run in parallel with the existing MSW system, at a capacity of 50,000 tpa.

Food waste was assumed to settle in Primary clarifiers at same rate as existing sewage (51% removal at Pri)