Douglas Partners
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REPORT
on
INDEPENDENT TECHNICAL REVIEW

ARROWBIO® SOLID WASTE TREATMENT PROCESS

Prepared for
WASTE SERVICE NSW / ANZ INVESTMENT BANKING

Project 37387
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EXECUTIVE SUMMARY

Douglas Partners Pty Ltd (DP) has been commissioned by Waste Service NSW and ANZ Investment Bank as the Independent Technical Expert to undertake a due diligence technical evaluation of a proposed mechanical-biological waste processing system for the treatment of Municipal Solid Waste (MSW).

The Waste Treatment technology under review comprises a two stage process namely:

- An initial water based separation which removes the recyclable materials and prepares the organic stream for treatment;
- Biological treatment of the organic fraction resulting in the production of stabilized compost and biogas.

The treatment process is being considered by Waste Service NSW for installation at its Belrose Waste Management Centre.

The scope of the independent technical review comprised:

- A review of current relevant issues relating to management and processing of Municipal Solid Waste;
- A review of available technical information regarding the process plant operated by Arrow Ecology Ltd in Tel Aviv, Israel;
- An inspection of the waste facility at Tel Aviv. This plant is similar to the one proposed for Belrose even though the detailed design of the proposed Belrose plant is not available at this stage.

The plant operated by Arrow Ecology Ltd in Tel Aviv is designed to cater for approximately 70,000 tonnes of Municipal Solid Waste per annum. The waste is delivered between about 6 am and 2 pm daily and is processed by a small number of highly trained technical personnel using a purposed designed process control system that allows intervention at any stage of the treatment. The plant proposed for Belrose will be similar in most respects to that already operating in Tel Aviv except that it will have a number of parallel processing streams to cater for the treatment of 100,000 tonnes of Municipal Solid Waste per annum.

The basic concept of the ArrowBio process comprises an integration of well proven water based mechanical and biological waste treatment units. The waste is dumped directly onto a walking floor which progressively moves the material to a large flotation tank. Heavy material such as glass and metal settle to the bottom of the tank whereas plastics and other light materials float to the top whilst organics remain in suspension. The heavy fraction is removed from the bottom of the flotation tank for further mechanical screening and separation. A trommel screen is used to split open plastic bags and magnetic and eddy currents remove ferrous and non-ferrous metals into different streams. The light fractions are removed from the flotation tank through a paddle wheel where it is then shredded and passes through an inclined trommel screen to separate the plastic components for recycling. The final processing occurs in a high pressure hydo crusher where water is used to shear the organics into small fragments in preparation for biological treatment. Once the preprocessing is completed the materials are then in readiness for acetogenic and methanogenic anaerobic biological treatment which essentially produces a fluid stream which is recycled into the process and biogas which can be utilized to generate power and compost.

The ArrowBio system has a number of innovative concepts which have been integrated into a mature waste treatment process. The system is modular in design and simple in concept as well as in operation. The modular nature of the plant means that it can be easily duplicated to allow treatment of any volume of waste. The system allows for the intake of unsegregated Municipal Solid Waste with highly variable solid waste contents. The operation of the system is thus not depended upon the waste input having to meet certain specified waste composition criteria. Whilst the full details of the mechanical pretreatment facilities for Belrose is still to be finalised, it would appear that no presorting by hand will be necessary. In general, the mechanical material separation/recovery facility relies on simple screening by flotation and thus provides a reliable, initial segregation process to recover the majority of recoverable materials for recycling. Bulk waste materials that are not suitable for direct feed into the biological treatment system are removed by hand after initial inundation in the separation tank. The biodegradable fraction of the waste is degraded gradually into various fractions. The most soluble and easily biodegradable organic portion is degraded into biogas whereas the solid organic waste which is not readily biodegradable is retrieved as compost. The entire biological treatment process is closed and therefore there are no odour problems associated with the treatment of the organic rich water. The waste process system based upon the ArrowBio technology is flexible and yet relatively simple to operate. The process design provides for the systematic segregation of wastes of different treatability. As a result various waste fractions can be treated separately in an optimized manner.

The ArrowBio process has been well proved through approximately two years of commercial scale operations. Prior to that, a smaller pilot plant was tested at Hadera in Israel for 1½ years.

Douglas Partners supports the proposed technology as a suitable means of waste treatment based upon the information obtained from Arrow Ecology Ltd and observations made during a visit to Tel Aviv. In general, the following conclusions are made:

- Arrow Ecology Ltd has the relevant experience and credentials;
- The technology selected is well proven with good operational records;
- The selected integrated system has good and efficient system design;
- The operational technical plant at Tel Aviv aptly demonstrates the technical feasibility of the selected integrated system;
- The reliability of the system is supported by good operational records of the Tel Aviv facility;
- The proposed process is essentially an innovative means of getting all organics in an easily digestible form and then utilizes standard wastewater treatment technology to reduce the organic waste to methane for use in power generations;
- In overall terms the technical and financial risk is low.

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INDEPENDENT TECHNICAL REVIEW
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1. INTRODUCTION

This report presents the results of an independent technical review of an innovative, integrated waste treatment process for Municipal Solid Waste (MSW).

The waste treatment technology under review comprises a two stage process namely:

- an initial water based separation technology developed by Arrow Ecology Ltd under the patented name ArrowBio®, whereby clean recyclables such as glass, metals and plastic are separated from the waste intake, and
- follow-on biological treatment of the lighter organic stream (anaerobic digestion) whereby biogas, stabilised compost (fertilizer) and irrigation grade water are produced.

The process has been selected by Waste Service NSW as a feasible alternative waste treatment technology to landfilling. It is to be adopted as part of the environmentally sustainable waste treatment solutions for the Waste Service Facility at Belrose.

Douglas Partners Pty Ltd (DP) has been commissioned by Waste Service NSW and ANZ Investment Bank as the Independent Technical Expert (ITE) to undertake a due diligence technical evaluation of the nominated Mechanical Biological Treatment (MBT) process. The MBT is an integrated system of waste treatment that avoids many of the limitations of other treatment current technologies by using well established techniques for treatment of the organic fraction of the waste stream as operated by Arrow Ecology Ltd in their Tel Aviv plant in Israel (the Selected Integrated System). The objective of the evaluation is to assess whether the proposed MBT facility is a technically sustainable waste management option for NSW.

2. BACKGROUND

2.1 General

The rate at which Municipal Sold Waste (MSW) is being generated in Australia has been continually rising in a similar manner to other developed countries. In view of the trend of increasing MSW generation, an integrated solid waste management hierarchy has been adopted by NSW, as stipulated under the Waste Avoidance and Resource Recovery Act 2001 [1]. The hierarchy calls for:

- avoidance of unnecessary resource consumption;
- maximum/optimum resource recovery including the beneficial use of waste materials and energy recovery;
- the ultimate reduction for direct landfill disposal of solid waste.

A graphic representation of the integrated solid waste management hierarchy is presented in Figure 1 in Appendix A.

The Waste Recycling & Processing Corporation of New South Wales (Trading as Waste Service NSW) commenced operation as a State Owned Corporation on 1 September 2001 to implement the integrated solid waste management hierarchy. As part of their statutory functions defined under the Waste Recycling and Processing Corporation Act 2001, Waste Service NSW is required to pro-actively “research, develop and implement alternative technologies for managing waste” with a view to implementing a sustainable waste management system in NSW.

Waste Service NSW propose to develop an integrated municipal waste processing facility based on MBT technology. The proposed facility, with a planned capacity of 100,000 tonnes per annum, is to be developed at Belrose. The current technical review focuses on the technical feasibility of the Selected Integrated System in NSW in general, although some specific comments are also made on the proposed project at Belrose.

2.2 Waste Management in NSW

Despite all efforts to implement waste avoidance and resource recovery, it is generally forecasted that the municipal solid waste (MSW) will steadily increase in the foreseeable future. On the other hand, approvals for new MSW landfills are becoming more and more difficult and time consuming. The community is therefore faced with increasing amounts of waste and steadily decreasing landfill capacity.

Some of the typical problems associated with new landfills include:-

- The basic need to acquire a site that is the correct size and has the right combination of hydrogeological, geographical, socio-economic and infrastructure features.
- Environmental legislation has become increasingly restrictive due to technical, political and emotional considerations and the statutory requirements and procedures for new landfill approval are becoming increasingly onerous, lengthy and complex.
- Environmental controls measures at MSW landfills are rapidly becoming more and more stringent, typically resulting in further delays and additional cost in the implementation of the controls; and
- Difficulties in obtaining support/endorsement for new landfill sites from the local communities or local authorities. One major factor being the “Not In My Back Yard” (NIMBY) syndrome.

Given the difficulties and long lead time in acquiring approvals for new landfills and the rapid rate of depletion of the existing landfill capacity, it is obvious that appropriate alternative waste management technologies are required in NSW, in order to:-

- Maximise reuse of resources;
- Minimise the quantity of waste requiring landfill disposal so as to extend the life of the existing landfills; and
- Minimise long-term environmental (and financial) liability of landfills.

In view of the limited capacities of existing waste treatment/disposal facilities, a strong demand for appropriate alternative waste technologies exists.

3. PROJECT BRIEF

In the light of the rate of generation of municipal solid waste (MSW) in NSW and the rapid depletion of the capacity of the limited, existing landfills in the foreseeable future, Waste Service NSW is committed to identify, develop, construct and ultimately operate waste facilities based on alternative sustainable technologies. One of the pivotal sustainable technologies identified is integrated Mechanical Biological Treatment (MBT) for MSW. It is intended that an MSW processing plant based on the Selected Integrated System, be designed, constructed, commissioned and operated by Waste Service NSW. At the time of the review, it is intended that the proposed plant be constructed in the Waste Service Depot at Belrose, NSW.

Whilst the proposed MBT is to be developed at Belrose, the justifications for the waste facility equally applies to other areas in NSW.

The independent technical review is required as part of the due diligence process of the proposed development of the integrated MSW processing plant. The scope of the independent review comprised the following:-

- A review of current, relevant issues related to the management and processing of municipal solid waste, from both an international as well as the NSW perspective;
- A review of available technical and factual information regarding the selected Integrated System;
- An inspection of an existing, operational waste facility at Tel Aviv, Israel (the “Tel Aviv Facility”), which has been designed and constructed in a similar, comparable manner to the proposed plant, with a view to evaluate its likely technical feasibility and viability.

The main issues to be addressed by the Independent Technical Expert include, inter alia, the following:-

- The environmental and regulatory status of the Selected Integrated System (SIS), including environmental compliance issues relevant to the NSW;
- The technical feasibility of the SIS, including the design and construction of the waste collection and separation systems, the recovery of the inorganic fractions, the robustness and sustainability of the light biological fraction for anaerobic digestion, the efficiency of the biogas processing system;
- The suitability of the Operator's management and supervision systems, maintenance regime and performance, including spare part management; and
- A review of the available gas recovery information on the Tel Aviv Facility, including the composition of the gas produced and the likely rate of gas generation. On the basis of the available information, evaluate whether the expected quantity and quality of biogas produced from the plant will meet the project objectives;
- A review of the operational and maintenance records of the Tel Aviv Facility with a view to identify the main issues of concern and to suggest effective control/management measures.

4. WASTE POLICIES AND MSW PROCESSING

4.1 General Overview

It has been well established internationally that MSW should be managed in accordance with the established priorities as defined in the following Hierarchy of Integrated Solid Waste Management (ISWM) (See Figure 1) [1, 7].

It should be noted that, whilst the order of priority of the various element of waste management options are established, in practice, all elements of the above-mentioned hierarchy will required to be in place so as to provide comprehensive, integrated management of MSW.

In summary, preference is given to technologies that will result in the avoidance, reduction or reuse of waste (Front End Technologies), over “end of pipe” technologies such as waste treatment and disposal.

Notwithstanding the establishment of the above-mentioned Hierarchy of ISWM, its general recognition by waste authorities world-wide and the continual efforts by governments and non-government organisations to implement waste avoidance, reduction and recycling programmes, the rates of MSW generation has continued to increase in most areas.

On the other hand, as a result of both practical and political considerations, approvals for new landfills has been difficult and, even if ultimately successful, require very long lead time whilst the existing, available landfill capacities are being rapidly depleted. As a result of the actual and/or expected (ultimate) shortfall in landfill capacities, a number of waste management policies and measures have been introduced in recent years by various authorities over the world. A general review of the current situation is summarised in the following section.

4.2 International Practices

4.2.1 EU Countries

Despite all efforts to implement “Front End Technologies” for the management of MSW, landfilling remains the predominant waste management option in many European countries. With a view to alter the trend, and to conserve the limited landfill capacity, EU has issued a “European Landfill Directive”. The Directive aims at progressively lowering the limits on the organic contents of landfilled materials, and introduces outright bans on the landfilling of specific wastes. The Directive states that “all waste that is sent to landfill must be treated, unless the waste is inert, or treatment does not contribute to the objective of the Directive by reducing the quantity of the waste or hazards to human health or the environment.” [2, 3, 10]

A number of target dates have been set, as follows:-

- By 2006, reduce biodegradable municipal waste landfilled to 75 percent of that produced in 1995;
- By 2009, reduce biodegradable municipal waste landfilled to 50 percent of that produced in 1995; and
- By 2016, reduce biodegradable municipal waste landfilled to 35 percent of that produced in 1995.

In particular, a number of countries with more advanced waste management infrastructure (including Denmark, Germany, the Netherlands, Sweden and Switzerland) have set even higher targets or earlier implementation timetables for the Directive. As an example, in Germany landfilling of biodegradable waste will not be permitted beyond 2005.

As a result of the imposed restrictions on the disposal of solid waste at landfills, new technologies are required to process the biodegradable portion of the municipal waste. Traditionally, municipal wastes (either in its raw form, or more recent cases, portion of the waste after various degrees of waste segregation and reduction of moisture) are incinerated for energy recovery. However, waste incineration is an unpopular treatment option due to public objection and political pressures. It also has serious implications for greenhouse gas emissions, and is particularly prone to poor air emission quality because of failures of the dust extractors.

As a result of the quest for alternative technology to adequately handle the organic waste portion, mechanical-biological treatment (MBT) systems have developed, along with novel thermal treatment technologies such as gasification and pyrolysis.

MBT processes offer a simple, effective, flexible and yet relatively low cost, reliable and politically acceptable options to tackle the waste problem (as compared with thermal technologies). MBT processes typically involve the simple combination of proven technologies such as various forms of mechanical waste preparation and separation, followed by an aerobic or anaerobic treatment process. The separation can be by pneumatic and/or hydromechanical methods and the biological treatment will result in various forms of stabilised process products and a reusable energy source such as biogas.

In terms of greenhouse gas impacts, the European Commission Environment Directorate General has commissioned AEA Technology (AEA) to undertake a study on the climate change impacts of various waste management options. The findings are detailed in the AEA report titled "Waste Management Options and Climate Change: Final Report" (Report Number ED21158R4.1, dated July 2001) [3]. The study reviewed a number of management options for municipal solid wastes, viz. landfilling, incineration and mechanical-biological treatment (MBT). The report concluded, that:-

"For mainstream options for dealing with bulk MSW as pre-treatment for landfill, the option producing the lowest greenhouse gas flux (a negative flux of some 340 kg CO_2 eq/tonne MSW) is MBT…"

"The performance of MBT with landfilling of rejects is further improved as higher standards of landfill gas control are implemented, relative to mass-burn incineration, provided the contribution from carbon sequestration is included."

There are currently over 100 operational waste processing facilities in Europe incorporating some form of MBT technology. The capacity of MBT plants ranges from very small facilities with waste throughput of less than 10,000 tonnes per annum, to large scale integrated facilities with over 200,000 tonnes per annum capacity [Heermann]. The information demonstrates the high adaptability of the MBT system from a technical application standpoint. It should, however, be noted that the optimal size of a MBT system will be dependent upon a number of factors including, overall operational efficiency and system flexibility [which typically improves with increased system size]; economics consideration [cost-effectiveness]; and system affordability/sustainability. In general, economies of scale apply, such that larger, regional scale facility will be technically more efficient to run as well as economically more viable.

4.2.2 USA

One of the major Federal legislation on solid waste management and resource recovery is the Resource Conservation and Recovery Act, 1976 (RCRA). The legislation had a profound effect on solid waste management. The RCRA legislation provided the legal basis for implementation of guidelines and standards for solid waste storage, treatment and disposal.

RCRA has been amended and reauthorised many times over the years, although the main emphasis has been on hazardous waste.

In addition to the statutory provisions of the RCRA, the management and control of municipal solid waste was also supplemented in the USA by the development of general environmental guidelines promulgated by the USEPA.

Apart from the Federal Legislation, there are also State laws promulgating the detailed management requirements for municipal solid waste in the various states.

There is no similar restriction and timetable laid down for landfill disposal as in the case of EU countries. Most of the actions are spearheaded by the private sector. Pro-active government action to implement the waste hierarchy is relatively limited to environmental regulations in USA which are continuously revised and amended such that more and more emphasis is placed on recycling and resource recovery.

It has, nevertheless, been recognised in USA that the hierarchy of integrated solid waste management must be enforced in a manner that is practicable. It has, further been recognised that the cost of solid waste management will continue to increase, and more restrictive regulations and controls will be applied to waste management facilities.

4.2.3 New South Wales

Before 1995, New South Wales (NSW) waste legislation was primarily concerned with waste disposal. In view of the increasing quantities of municipal solid waste generated daily, the Waste Minimisation and Management Act (WMM Act) was enacted in 1995 [4], providing the first statewide framework for waste minimisation.

As part of the provisions of the WMM Act, a review of the act was conducted in 2000. To provide input to the planned review, an Alternative Waste Management Technologies and Practices Inquiry (the "Waste Inquiry") was commissioned in August 1999 by the New South Wales Government through the Ministry for the Environment.

Findings of the Waste Inquiry were presented in the document titled "Report of the Alternative Waste Management Technologies and Practices Inquiry" dated April 2000 (The Waste Inquiry Report 2000) [5]. The Waste Inquiry reviewed the situation in waste management in NSW and issues confronting the Government, business and citizens; examined management practices and technologies overseas and in other parts of Australia, with a view to identifying and evaluating appropriate technology classes and types, and assessing appropriate management practices. The Waste Inquiry focused on municipal waste, commercial and industrial waste and construction and demolition waste.

In summary, the Waste Inquiry concluded that "*in waste management, choices of State or regional technologies, practices and strategy are inextricably linked*", and urged the Government to "*adopt this triple manifesto as the defining framework for waste management and recommends that the Government move forward with its intended review of State waste management legislation and strategic policy framework, moving from waste disposal toward resource management.*"

As a result of the planned review, the Waste Avoidance and Resource Recovery Act 2001 (the "WARR Act") commenced on 8 October 2001 [1].

The objectives of the WARR Act are:-

- To encourage the most efficient use of resources;
- To reduce environmental harm;
- To ensure that resource management options are considered against a hierarchy of the following order:-
    - avoidance of unnecessary resource consumption;
    - resource recovery (including reuse, reprocessing, recycling and energy recovery); and
    - disposal.
- To provide for the continual reduction in waste generation;
- To minimise the consumption of natural resources and the final disposal of waste by encouraging the avoidance of waste and the reuse and recycling of waste;
- To ensure that industry shares with the community the responsibility for reducing and dealing with waste;
- To ensure the efficient funding of waste and resource management planning, programmes and service delivery;
- To achieve integrated waste and resource management planning, programme and service delivery on a State-wide basis; and

- To assist in the achievement of the objectives of the WARR Act.

As part of effort to implement the integrated solid waste management hierarchy, the Waste Recycling & Processing Corporation of New South Wales (Trading as Waste Service NSW) commenced operation as a State Owned Corporation on 1 September 2001. The constitution of Waste Service NSW has been clearly defined, under the Waste Recycling and Processing Corporation Act 2001 [6], to:-

- establish, maintain and operate waste processing facilities, secondary resource facilities and related facilities;
- conduct business or provide services relating to waste, and secondary resource recovery;
- provide waste management services, secondary resource management services and related services;
- research, develop and implement alternative technologies for managing waste; and
- to trade in waste and secondary resources.

Whilst the future direction of municipal solid waste management in NSW is not as well defined as in EU countries, NSW has a reasonably well established "statutory" management infrastructure for the processing and disposal of municipal solid waste, such that shortfalls and deficiencies of the current resources can be dealt with reasonably efficiently through the provision of alternative waste facilities. Mechanisms for supportive actions from government authorities are also in place with the necessary legal basis provided by the existing legislation.

4.3 Alternative Waste Strategy for NSW

Like most European countries and the USA, a certain degree of success has been achieved in waste separation and recycling in NSW. However unlike some European countries, the majority of MSW generated in NSW is disposed of at the various solid waste landfills without any treatment.

Currently, waste disposed of at the various municipal solid waste landfills typically has high organic contents. As an illustration, Figure 2 in Appendix A presents the typical MSW composition for the catchment of the Eastern Creek Waste Management Centre [8]. The results are summarised in Table 1 along with comparative values for the Tel Aviv facility operated by Arrow Ecology.

Table 1 – Comparative Waste Streams Operated by Arrow Ecology Ltd

Waste Categories	NSW Θ	Tel Aviv #	Bin Waste Φ
Green Waste	28	4.0	15.3
Food Waste	27	37.8	22.2
Mixed Paper	11	22.4	13.9
Cardboard	3	22.4	8.8
Textile	4	3.3	3.2
Various forms of Plastic	8	13.9	8.8
Ferrous Metals	3	1.5	3.4
Aluminium	1	1.8	2.9
Glass	3	3.3	8.4
Nappies	3	4.3	2.4
Wood	1	1.7	3.0
Hazardous Waste	2	0.3	-
Inert Waste	3	5.6	3.7
Others	3	0.1	4.0

Θ from Eastern Creek # provided by Arrow Ecology Φ from Reference g

As shown in the Table 1, only a low fraction of the municipal solid waste is classified as "inert materials". The rest of the waste categories may contain, to varying degrees, materials that can be degraded, stabilised or selectively extracted for reuse. Upon appropriate treatment/processing, these non-inert materials may be converted as useful resources or rendered inert for long term disposal, with a substantial reduction in the ultimate waste quantities.

In particular, the municipal solid waste in NSW contains well over 50% organic components comprising, food waste, paper waste and green waste. Whilst a substantial part of the organic portion of waste is potentially bio-degradable (eg food waste), a good portion of the organic waste materials are less biodegradable. A typical example of the less biodegradable organic material is the "green waste". It has been well documented that vegetation waste (especially wood based materials) contains stable chemical compounds such as tannin which will not be readily broken down by biological activities. The bulk of these materials is relatively stable biochemically and yet possesses high calorific value. As a result, these less biodegradable materials may either be biologically stabilised for use as fill for landfill rehabilitation, disposed of as stabilised residue or processed to retain their calorific values and produce Refuse Derived Fuel (RDF).

The characteristics of the waste streams in NSW and for the Tel Aviv facility operated by Arrow Ecology are slightly different probably because the sources of materials are not identical. For example, many councils in Sydney now have green waste recycling which has reduced the amount of green waste included in MSW. No such recycling exists in Tel Aviv so all green waste is disposed of with MSW. Similarly there are substantial differences in housing accommodation with most of Sydney residents living in single unit homes with garden whereas in Tel Aviv a large proportion of the population lives in apartments with only limited gardens. The green waste proportions at the source may therefore be different. Notwithstanding these slight differences there is a large proportion of each waste stream which is potentially biodegradable. All this means that a large percentage can be prepared by the wet treatment technology for biodegradation whilst the other non biodegradable elements can be easily and efficiently separated for recycling or disposal.

The available information, therefore, clearly indicates that there is substantial potential for alternative MSW management technologies to operate successfully in NSW. The success of the MSW facility can be measured by the following benchmarks:-

- The overall reduction in unstable waste going to landfill;
- The stabilisation of waste to be landfilled so that common environmental issues related to landfill disposal (such as the uncontrolled generation of landfill gas and leachate can be alleviated;
- With respect to the process water, the potential for recovery of the natural moisture held within the organic waste and for the water produced by biodegradation as a valuable resource for such things as irrigation;
- The conversion of biodegradable waste into useful forms of energy such as biogas, refuse derived fuel (RDF), stabilized solids or into marketable materials such as fertilizers;
- The production of a stablised waste which has a higher compacted density and thereby a low space requirement in the landfill;
- A stabilized waste which has a lower volume compressibility and therefore a much lower potential for ongoing settlement once compacted into the landfill. This greater volume stability will result in much lower maintenance cost for the landfill owner and will enable

the use of the landfill area for recreation purposes much quicker than is presently possible.

As stated in Section 4.2.3, the community has a strong commitment to sustainable waste management. In response to this demand the New South Wales Government, through the Minister for the Environment, established the Waste Inquiry in August 1999 [Ref 5]. The Waste Inquiry made a number of recommendations to the government. These include:-

- The Government should adopt the "triple manisfesto" of waste management, viz. technologies, practices and strategy;
- The Government should move the emphasis from waste disposal toward resource management;
- The Government should lead actions to stimulate and facilitate the establishment of a market for recycled materials. This can be achieved by various means including facilitating innovative commercial linkages between markets, technologies and practices; and ensure a consistent policy and regulatory philosophy with a view to build up confidence in recycled products;
- Government policy and management initiatives should be organised to encourage development of waste technologies through economic instruments or financial assistance, voluntary industry agreements and regulations, so that "*each waste streams is treated to best advantage*"; and
- The Government should adopt integrated waste management as part of the strategic policy framework for waste management in NSW.

A number of waste management technologies were reviewed in the Waste Inquiry and it was recommended that "*purpose-specific emerging technologies should be adopted into waste management operations in the municipal, commercial and industrial, and construction and demolition sectors on a planned commercial basis with private funding, but with general facilities as necessary by Government through economic and regulatory instruments, financial incentives and institutional arrangements*".

In summary, therefore, the essential elements for the establishment of a market for alternative waste management technologies exists in NSW through favourable waste generation pattern, community support for sustainable waste management and government policy for the adoption of an integrated waste management hierarchy.

5. GENERAL TECHNOLOGY REVIEW

5.1 General

The common issues faced by most developed countries are the need to handle large quantities of municipal waste generated daily, and the sustainability of the limited waste disposal capacity available to handle the waste generated.

Currently, the majority of MSW disposed of at landfills is untreated and/or unstabilised. The continued disposal of untreated waste will result in a number of environmental and health issues, including:-

- Untreated wastes (comprising both the degradable as well as the non-degradable fractions) occupies much higher volumes and hence takes up unnecessarily the already limited landfill capacity.
- Subsequent to their disposal and burial at the landfills, untreated wastes will undergo anaerobic degradation in an uncontrolled, or difficult to control manner, resulting in the sporadic generation of landfill gases and leachate with elevated levels of dissolved solids. Control of landfill gas and treatment of leachate are two of the long-term costly items of all municipal waste landfills.
- Whilst the landfill gas may theoretically be collected and reused, control over the rate and quality of the landfill gas generated is limited. Typically, even for a well managed landfill with an effective landfill gas (LFG) collection system, only 60 - 70% of LFG generated is captured. The quality of the LFG collected in this way varies according to many uncontrollable factors such as climatic condition, the type of waste, the permeability of the landfill cap, and rainfall, the density achieved in the landfill, the type of daily cover employed, temperature and the specific operational conditions at individual landfills. In summary, the cost-effectiveness of recovery of landfill gas from the buried waste is typically low.

As a result of the daily generation and disposal of large quantities of untreated MSW at the landfill, the pressing problems faced by the waste authority are:-

- how to maintain a sustainable management system for MSW, and;
- how to prolong the life of existing landfills and to maintain adequate landfill capacity in the long run, given the limited available landfill space and the difficulties in obtaining approval for new landfills.

Whilst waste avoidance and recycling may contribute in alleviating the above issues, the effectiveness of these options is limited to the reusable/recyclable part of MSW. In particular, the direction and extent of recycling activities is market driven and is typically limited only to certain, higher grade fractions of plastic, paper and metal wastes.

With regard to the organic portion of the municipal waste which constitute the bulk of MSW, specific waste processing facilities are required to ensure these wastes may also be subject to suitable resource recovery/treatment/stabilisation, such that the ongoing effectiveness of the waste management services can be maintained. In other words, there is good potential for alternative waste management technologies.

5.2 Alternative Technologies

Currently, a number of alternative technologies are available to further process MSW, with a view to achieving volume reduction and/or resource/energy recovery. These are broadly categorised into biological technologies and thermal technologies. Both technologies may integrate with other pre or post treatment processes which may be mechanical based.

The characteristics of these technologies are summarised as follows [2, 3, 5, 7, 8, 9]:-

- **Thermal technologies -** These rely on heating the waste to produce energy, either directly or indirectly.
- **Mechanical - Biological technologies -** The mechanical processes in these technologies typically segregate the MSW into various fractions, such that the waste feed sent into the biological process vessels are well sorted for the subsequent biological treatment. The biological processes make use of controlled atmosphere conditions to

optimise organic waste decomposition. The stabilised organic material can be used for landfill rehabilitation and as daily cover in landfill operations. In addition, anaerobic digestion systems produce a gaseous fuel for energy production.

5.2.1 Thermal

In general, thermal processing of municipal solid waste will convert the waste into gaseous, liquid, and solid products, typically with the concurrent or subsequent release of heat energy. Thermal processes can be further categorised on the basis of their air requirements. In general, the basic categories of thermal technologies include combustion, gasification/pyrolysis.

5.2.1.1 Combustion

Combustion (basically incineration) involves the complete oxidation of the combustible fraction of solid waste into carbon dioxide and water. The processes are initially energy intensive because they require intensive fuel intake in addition to municipal solid waste to attain the required temperature. Process control, corrosion and emission of air pollutants (including SO_2, NOx, suspended particulates and dioxin) are critical issues.

The heat generated from the combustion process may be converted into steam and ultimately to electrical power. Both capital and operation costs of combustion plants are high.

5.2.1.2 Gasification/Pyrolysis

Gasification and Pyrolysis are actually two broadly similar, but different processes.

One of the principal differences between the two processes is that pyrolysis processes use external source of heat to drive the endothermic (heat absorbing) pyrolysis reactions in an oxygen free environment, whilst gasification processes can theoretically be broadly self-sustaining (depending on the heat contents of the MSW) and use limited (but controlled) quantities of air and oxygen for the partial combustion and breakdown of solid waste.

The fuel generated in the gasification or pyrolysis processes can, in turn, be used to power industrial engines coupled to generators. Alternatively, the pyrolysis oil can be heated to a high temperature, converting the carbon-rich material to a gaseous form. This gas, which is rich in carbon monoxide, can be used as a fuel. The resulting electricity can be used to power the system and return a portion to the electricity grid.

Pyrolysis processes are energy intensive because they require high fuel intake in addition to municipal solid waste to attain and maintain the required temperature. Both Pyrolysis and Gasification involve operations at elevated temperatures and pressures. They produce a highly corrosion atmosphere in the sealed process chambers. In addition air pollutants such as SO_2, NOx, suspended particulates and dioxin have to be dealt with before the process is terminated and the solidified waste dispensed of to landfill.

Both processes have been well established in the petrochemical industry. The application of pyrolysis and gasification to the treatment of municipal solid waste is, however, relatively recent. The technologies have been used at small-scale for agricultural waste processing for several decades and at the current state, both technologies require further research.

The capital and operational costs for both systems are assessed to be high.

5.2.2 Mechanical - Biological

The mechanical - biological treatment (MBT) processes typically comprises a mechanical pre-treatment/separation/waste preparation process at the front end to sort and remove the various over-sized or unsuitable wastes for the subsequent biological treatment. The main purpose of the mechanical processes is to provide a preliminary classification and separation of the incoming municipal solid waste, and to prepare the waste feed into a form best suited for the subsequent biological process. Under most circumstances, the pre-treatment/separation/waste preparation processes involve the use of mechanical devices such as shredders, mills, screens and magnetic separators in tandem or in various combinations. Specific pneumatic or water-based systems may also be used in an effective manner to achieve the same purposes.

The biological part of the process may comprise various types of MSW treatment technologies including simple composting or rotting to aerobic and/or anaerobic digestion.

Composting technologies facilitate decomposition of organic wastes through microbial activities. The schemes usually involve some form of pre-treatment to separate and recover organic waste and commence biological degradation. The composting process typically comprise an initial decomposition stage where the organic materials in the waste feed will be decomposed in controlled aerated conditions to enhance the microbiological activities. This is followed by a second, maturation stage in which full stabilisation of the organic material is achieved. Enclosed composting systems make use of a variety of drum, trommel or silo devices to provide aeration and odour containment.

Anaerobic digestion systems bring about biological degradation of the biodegradable portion of the organic wastes through microbial activity in low oxygen conditions. Pre-treatment separation systems are used to extract any inorganic materials and prepare the organic material for digestion. In the core process, methane-rich gas is recovered, and a nutrient-rich organic digestate is available for use as landfill rehabilitation material. The gas can be used for energy production, and the digestate can be further stabilised using an aerobic composting process.

As stated in Section 4.3, anaerobic digestion has limited application on material which is difficult to biodegrade, especially “woody materials”. Application of the anaerobic digestion technology on the bulk of MSW may not, therefore, be effective. On the other hand, application of the anaerobic digestion technology to segregated, easily biodegradable fraction of MSW will be very effective, especially if the segregated waste fraction is in aqueous form.

The various individual unit process technologies adopted in MBT systems are typically well proven in the field of MSW processing as well as in wastewater treatment. The concepts are relatively simple and the operations typically reliable, as demonstrated by the day to day operations of many of the existing solid and liquid waste treatment plants worldwide.

The expected capital and operational fees for MBT systems are relatively low when compared with thermal technologies.

In this regard, a number of technical reviews of the MBT technology has been conducted by various organisations/independent workers, including, notably, a comprehensive technical review of the MBT technologies has been conducted by Eunomia and TBU and published by Greenpeace Environment Trust [9]. In the conclusion of the Greenpeace study, it was stated that:-

"Relative to both an incinerator or a landfill, the direct emissions to the atmosphere are low. Once one accounts for the avoided emissions associated with materials and energy recovery, the net benefits relative to incineration in respect of, for example, CO_2 emissions appear significant irrespective of the source of energy which one assumes is displaced by energy from waste technologies. Further analysis would need to be undertaken to ascertain the full impacts (in absolute and comparative terms) of the plant as designed here.

However, we believe that [MBT technology] exhibits considerable potential in that it offers to local authorities a treatment which is-:

- *A high performer in environmental terms;*
- *Shows limited visual disamenity;*
- *Able to function at relatively small-scales without significant diseconomies of small scale; and*
- *Competitively costed given the low atmospheric emissions and positive environmental features.*

This type of treatment should be of significant interest to authorities who recognise the potential for public disquiet arising from conventional incineration and other thermal treatment technologies and who are concerned to ensure that technologies used are environmentally sound and relatively flexible in terms of their ability to operate using different waste mixes.

An interesting aspect of the [proposed MBT technology] is that it is compatible for use with other waste inputs such as sewage sludge and other commercial and industrial wastes. As such, changes in throughput and composition could also be made through changing the mix of input materials, though always with the prior aim of ensuring that materials do not need to be sent to the facility in the first place."

Greenpeace then commented that:-

"The [MBT] plant and the principles behind it, give some insight as to how (and why) it makes sense to consider options beyond the 'off-the-shelf' techniques such as mass-burn incineration. We ought to be entering a period of 'post-Fordist' residual waste management. In this period, residual waste technologies would not be selected for mass treatment of all

waste in one process, but increasingly residual waste will be split into constituent parts for more tailor made treatments. Such treatments will not supplant source separation approaches. Source separation will ensure quality of materials recovered (especially the major fractions, biowaste and paper), and enable the introduction of incentive measures, such as charging, which encourage both minimisation and source separation."

"…waste management technologies like MBT should complement source separation approaches and, in doing so, reduce the environmental impact of residual waste treatments, and the demand for primary resources."

The opinion outlined above is generally in agreement with DP's evaluation of the technology as detailed below.

5.3 The Selected MBT Technologies

The selected water-based integrated MSW treatment system has been identified by Waste Service, NSW as a pivotal technology for the processing of the organic fraction of MSW.

A general schematic of the process is presented in Figure 3 in Appendix A.

The bulk of the broadly unsorted municipal solid waste intake is essentially kept submerged in the process water which is used as the medium for the waste separation process through gravitational settling, screening and dissolution. The heavier fraction, comprising inorganic materials such as metals, glass and plastics are separated from the light fraction which comprises mainly the organic fraction. By using flotation, breaking or crushing of potentially hazardous materials, such as batteries, can be avoided, alleviating the risk of chemical contamination of the MSW input to the system. The light fraction are then subject to hydro-mechanically shredding of the organic solids. The organic rich, light fraction will then be subject to anaerobic digestion in aqueous phase for production of methane gas.

Upon segregation of the easily biodegradable fraction into the aqueous phase, anaerobic digestion is conducted on an organic rich liquid, rather than with bulk solid waste. This results in more effective process control due to consistent feed into the anaerobic digestion system, as well as substantial reduction in the potential for odour problems. By applying the anaerobic digestion technology to the organic rich fluid, the system is similar to the well proven and long practiced anaerobic digestion treatment processes for wastewater.

In summary, the early use of water will have the benefit of:

- Effective odour control right from the start of the waste handling process;
- No presorting required or minimal presorting to remove unsuitable materials such as furniture, carpet, etc;
- Effective separation through gravitational settling;
- Maintain soluble light fraction components (light organics) in dissolved/dispersed phase for effective biological action;
- Enhance the performance of the hydro-crusher used to optimise the size of the light fraction for the subsequent acetogenic and methanogenic reactors.

Biogas of consistent quality is produced as part of the byproducts of the anaerobic digestion.

Notwithstanding the recent interest in the application of Mechanical-Biological Treatment (MBT) technologies to MSW processing, and the innovative, integrated concept of the MBT systems, the unit processes involved in the ArrowBio system are actually well established and proven technologies. The typical operation issues associated with the various units are well documented and the effective solutions to the issues well established. The overall uncertainties associated with the technology is therefore limited and are generally classifiable as "nuisance issues". This is in contrast to fundamental problems with high degree of uncertainties, which are typically associated with newly developed innovative technologies, as opposed to the innovative integration of mature technologies.

Given the proven technologies involved and the relative simplicity, cost-effectiveness and demonstrated reliability of the system components, it is considered that the proposed MBT is a suitable alternative technology from a technical standpoint.

The selected integrated system patented by Arrow Ecology Ltd under the name of ArrowBio is a relatively simple method for treating MSW using well proven equipment and clearly understood techniques. The integration of various well established processes into a single system for treating MSW is an innovative way of utilizing long established and well researched methods for a new application. The innovation is in the integration of waste handling and wastewater treatment to achieve a substantial improvement in waste reduction and energy recovery from MSW without any serious environmental drawbacks.

The short description of the selected process given above is simply to put the MBT of Arrow Ecology into the general review of available treatment technologies. A broader more detailed description is provided in Section 6 below.

6. REVIEW OF THE SELECTED INTEGRATED SYSTEM

At the time of the current technical review, the detailed design, layout and actual configuration of the proposed MBT facility for Belrose has not been finalised. Given the preliminary nature of the proposed development the review is therefore necessarily restricted to a conceptual technical evaluation.

Whilst the detailed design of the proposed MBT facility at Belrose has not, at this stage, been finalised, it is understood that the facility will be based on similar configuration of the existing facility at Tel Aviv, Israel, except that it will have a number of parallel processing streams to cater for the treatment of 100,000 tonnes of MSW per annum.

In order to provide a comprehensive review of the conceptual evaluation of the technical feasibility of the proposed facility, the following elements are taken into consideration:-

- The technical capability of the designer and supplier of the main treatment process, Arrow Ecology Ltd;
- The technical basis of main waste processing technologies, focusing in particular the design/operational concept of the ArrowBio® process at Tel Aviv (The “Tel Aviv Facility”); and
- Onsite observations made at the Tel Aviv Facility and associated information regarding the operation/maintenance of the facility.

The overall technical assessment of the proposed MBT facility at Belrose will therefore be based on an evaluation of the following elements of concern:-

- Credentials, Experience, Track Records of Provider – This will be an indicator of the technical capability of the Technology Provider;
- Technological consideration – to assess whether the processes involved are technologically proven and mature;
- Operational Records of the Tel Aviv Facility - Good performance records will demonstrate the efficiency and reliability of the proposed MBT facility;
- Flexibility - Applicability of the proposed technology to NSW;
- Environmental Performance – Assess the waste output of the system, and the overall sustainability of the MBT system; and
- Cost Effectiveness of the MBT system.

In summary, the onsite evaluation component of the independent assessment comprised an initial review of the available technical information on the ArrowBio® technology and the process information of the Tel Aviv Facility. This was followed by an inspection of the Tel Aviv Facility, which was conducted by the writer between 20 – 25 August 2004.

Discussions were also held with technical personnel of Arrow Ecology Ltd on issues associated with the design, construction, operations and maintenance of the Tel Aviv Facility. DP note that part of the information inspected/discussed may contain proprietary information that cannot be disclosed. Under such circumstances, a summarised technical opinion is given by DP.

6.1 Experience of Arrow Ecology Ltd

Arrow Ecology Ltd is an environmental management company based in Israel. The company formerly operated under the name of Hydro Power Ltd (since 1975). The name of the company was changed to Arrow Ecology Ltd in 1991. Arrow Ecology Ltd specializes in the following types of projects:

- Bio-Technological and Physico-Chemical Treatment of wastewater and sludge.

- Hydro-mechanical systems.
- Environmental consulting/planning/laboratory services.

The technical information provided by Arrow Ecology Ltd and discussions held with Mr Yair Zadik indicate that Arrow Ecology Ltd is involved in the design, develop, manufacture and, in many cases, operation of various high-tech heavy industrial plant and plant components, including:-

- Cleaning and Oil Recycling of crude oil tanks;
- Design and construction of wastewater treatment plants (WWTP) for various sites for Israel Oil Refineries and Israeli Military Industries;
- Onsite Treatment of PCB;
- Recycling of solvents and polypropylene from sludge;
- Marine oil spill treatment; and
- ArrowBio Facility at Tel Aviv.

Based on the information provided, the following are some of the major clients of Arrow Ecology Ltd:

- Israeli Oil Refineries;
- Ministry of the Environment;
- Israel Electrical Co.,
- Delek Oil Co.

The information publicly available from Arrow Ecology Ltd indicates that many of the above are long term clients. Arrow Ecology is also involved in a number of international projects, with overseas offices set up in USA and Canada.

The development, construction and management of many of the above-mentioned plant or plant components requires high technical skills and expertise in the relevant specialist engineering. In particular, the following points are noted:-

- Arrow Ecology Ltd has demonstrated extensive experience in both MSW treatment as well as wastewater processing. This experience is relevant in the development the proposed MBT facility because the proposed process is essentially a waste treatment after separation of the organic fraction from the MSW;

- Arrow Ecology Ltd demonstrated through the records of previous projects that they possess relevant capability extending from design to construction and commissioning, operation and maintenance of waste facilities. In particular, Arrow Ecology Ltd have been involved in various biological treatment facility design/upgrading projects. From a practical standpoint, possession of experience in both the design (relatively more theoretical) as well as the construction and the operation (putting concept into practice) of waste facilities is invaluable and will substantially reduce the risk or uncertainties of the proposed development;
- In particular, Arrow Ecology Ltd have been responsible for the design, construction and operation of the Tel Aviv MBT plant, which will form the basis of the proposed MBT facility at Belrose. This provides crucial, "hands on" experience that will be directly relevant to the successful development of the proposed MBT facility; and
- Arrow Ecology Ltd have been involved in complex hazardous waste/chemical treatment projects including onsite treatment of PCB contaminated water and site remediation of petroleum hydrocarbon contamination. These projects typically require high levels of technical expertise.

In summary, based on the professional and project experience provided, it is considered that Arrow Ecololgy Ltd have demonstrated that they possess appropriate and relevant technical/professional expertise in the design, development and operation of the proposed MBT facility.

6.2 ArrowBio Process

The basic concept of the ArrowBio® Process is shown in Figure 3. The system comprises an integration of a number of well proven water based mechanical and biological waste treatment unit processes. The Tel Aviv Facility has a waste processing capacity of 70,000 tonnes per annum and is designed, constructed and operated on a commercial scale by Arrow Ecology Ltd.

The conceptual review outlined in this section is based on information presented in the patent document, along with the information on the layout of the Tel Aviv Facility. It comes from extensive discussions with the following Arrow Ecology Ltd personnel:

- Yair Zadik – Joint CEO;
- Israel Feig – Managing Director;
- Amir Assa – Biotechnologist;
- Lior Zaid – Design Engineer.

It is understood that the proposed ArrowBio® based facility at Belrose, NSW is an integrated Mechanical-Biological Treatment (MBT) process based on the Tel Aviv model. The proposed facility will comprise the following unit processes:-

- Waste pre-screening – This is to facilitate removal of obvious hazardous materials from the system.
- Fluidized/Mechanical Pretreatment and Segregation of MSW – The broadly screened (but otherwise unsorted) MSW is deposited on a walking floor and then directly into a large flotation tank, filled with water. Heavy materials such as glass and metals settle to the bottom of the tank whereas plastics and other light materials float to the top, whilst organics remain in suspension. The heavy fraction is removed from the bottom of the flotation tank for further mechanical screening/separation. A trommel screen is used to split open plastic bags and magnetic and eddy current separators remove ferrous and non ferrous metals in different streams. The light fraction is moved from the flotation tank through a paddle wheel, shredded and then pass through a inclined trommel screen to separate the plastic components (for recycling) from the organic fraction, which will be sent for further "pulverization" prior to anaerobic digestion.
- Biological process. This is undertaken in two phases:
  - The initial Acidogenic Stage. This is a continuous acid forming process where fresh organic slurry is pumped continually into a fermentation tank for facultative anaerobic digestion of the organics whilst fermented liquid is retrieved to the second stage. Naturally occurring micro-organisms initiate the fermentation process and transform complex organic molecules such as carbohydrates into simpler compounds such as fatty acids and sugars. The reaction rate is controlled through maintaining the correct pH, organic material concentrations in the slurry, as well as controlling the proper liquid circulation and hydraulic retention time of the reaction.
  - The Second, Anaerobic Methanogenic Fermentation Stage. The exit fluid from the initial stage contain high level of organic materials in the form of organic acids. The liquid is heated to approximately 40°C and pumped into a second bioreactor for

anaerobic degradation during which naturally occurring micro-organisms perform the degradation process and transform the organics into biogas (approx. 70% methane and 20% carbon dioxide), and biomass. Like the Acidogenic stage, the process is similarly controlled by pH, organic contents, proper solids concentrations in the liquid and correct circulation and hydraulic retention time. The process is also continuous.

- Collection of the biogas generated. The system allows the recircuclation of the biogas through the bottom section of the bioreactor. This achieves a permanent agitation of the process without the need for mechanical devices.
- Treatment of final product from the biological sludge. The biological sludge in the two bioreactors is drawn off at pre-set periods, dictated by the process control. The sludge, termed ArrowBio compost, contains high nutrient contents (such as ammonia and phorphorus in readily available forms), can be dewatered and sold as a high value soil conditioning agent. The ArrowBio compost can be further processed and sold in a pelletized form. Given the long solid retention time in the two bioreactors, the product is fully stabilised and free of pathogens.
- The liquid from the dewatering process of the ArrowBio compost is partly reused for shredding and dissolving the incoming waste. Excess water is stored in a separate tank and may be discharged into the sewerage system or treated through a biological treatment plant.

The ArrowBio® based facility has a number of innovative concepts in the integration of mature waste treatment processes, including:-

- The system is modular in design and simple in concept as well as operation. The modular nature of the plant design means it can be easily duplicated to allow treatment of any volume of waste;
- The system allows for the intake of unsegregated municipal solid waste with highly variable solid waste contents. The operation of the system is thus not dependent upon the waste input having to meet a certain specified range of waste composition;
- Whilst the full details of the mechanical pre-treatment facility is still to be finalised, it would appear that no presorting by hand will be necessary. In general, the mechanical material separation/recovery facility relies on simple screening by flotation and thus provides a reliable initial segregation process to recover the majority of recoverable materials (eg metal cans) for recycling. Bulky waste materials that are not suitable for

direct feed into the biological treatment system are removed by hand after initial inundation in the separation bath;

- A continued water based process in two stages, during which the biodegradable fractions of the waste are degraded gradually into various fractions. The most soluble and easily biodegradable (odouriferous) organic portions are degraded into biogas, whereas the solid waste are retrieved as compost;
- The operational conditions for the degradation of the organic rich fractions can be maximised through various operational techniques, thus achieving optimal overall process performance;
- The entire process is enclosed and thus the most odouriferous treatment process, viz. anaerobic digestion, can be conducted on the organic rich water in fully enclosed anaerobic digestion tanks. The technology is well established (similar to conventional wastewater treatment) and can be effectively controlled;
- Better consistency can be attained through the application of anaerobic digestion on organic rich wastewater (rather than solid waste), and thus the quality of the biogas generated is more consistent. In addition, more complete biodegradation occurs resulting in high methane production;
- The bulk of the inert fraction will be removed initially. These heavy fraction materials can be removed and separated using various mechanical devices for subsequent recycling and/or disposal. The early removal of the solids will therefore reduce the potential for system failure due to wear and tear, and will improve the overall life span of system components.

In view of the available information, therefore, the waste processing system based on the ArrowBio® technology is flexible and yet relatively simple to operate. The process design provides for the systematic segregation of wastes of different treatability. As a result the various waste fractions can be treated separately in an optimised manner.

Moreover, the entire process is enclosed and the odouriferous fraction are dissolved in the process water throughout the entire process. In this way, the potential for the common odour problems associated with MSW plants can be minimised. The water phase digestion will also enhance the quality and consistency of the generated biogas.

6.3 The Tel Aviv Facility

An inspection of the Tel Aviv Facility was conducted between 20 and 25 August 2004 by Michael Thom of DP, accompanied by Mohan Selvaraj and John Sheen of Waste Service NSW and Yair Zadik of Arrow Ecology Ltd.

The Tel Aviv Facility matches closely with the information provided in the technical information package on the ArrowBio process (see Appendix C) [11].

6.3.1 General Comments

Generally, the Tel Aviv Facility comprises the following:-

- A walking floor delivering imported municipal solid waste from the transport compactor vehicle to the immersion tank for primary separation
- A 6000 m^3 separation tank with conveyors for moving the heavy fractions to the mechanical/magnetic separators
- A mechanical shredder and hydro crusher for breaking the waste down into fine fractions for dissolution of the organics in preparation for treatment
- A rotating trommel to separate the organics and plastic bags
- Primary biodegester for acid organic anaerobic treatment of the waste water
- A secondary methanogenic reactor
- Generator(s) to generate electricity for running the plant and to supply surrounding industry
- Control room for complete computer aided automatic control of each unit including the ability to change feed rate for various units. The control room is staffed by professionally qualified persons with a clear understanding of the whole process.
- Fertilizer units for collecting the organics which cannot be easily degraded
- Residue hoppers for collection of solids for disposal to landfill
- Recycling hoppers to store the separated aluminium and steel.

Selected site photographs on the various plant components are presented in Appendix B.

At the time of inspection, the facility was fully operational with observed good standard of housekeeping. It is noted that the closest sensitive receivers including residential houses were located some kilometres from the boundary of the site. No discernible odours were noted at the site boundary, and very little odours within the plant could be detected.

Based on the review, therefore, it is considered that the MBT system at the Tel Aviv Facility is well designed, versatile and not sensitive to variations in MSW feed such that it is capable of handling and processing MSW that varies in composition. The organic fraction should be at least 30% to be viable but the facility can handle a wide variety of input MSW.

6.3.2 Reduction of Operational Risk

Adequate and appropriate control and checks have been built into the design and an appropriate operational protocol has been developed for the Tel Aviv Facility. This can be applied in a similar manner to the proposed facility in NSW. In particular, oversized and unsuitable materials are removed from the waste stream prior to their introduction into the bioreactor vessel.

The Selected Integrated System is versatile and robust. It is noted that the main and critical processes of the system are not highly sensitive to external conditions such as temperature and changes in waste composition. The reliability of the system has aptly been reflected by its operational records, which has adequately demonstrated the capability of the system to handle the constantly fluctuating composition of municipal solid wastes. On this basis the Selected Integrated System which is based on the Tel Aviv Facility should be capable of accommodating the MSW in NSW.

The effectiveness of the system operational control is further enhanced by a number of management practices, which are:-

- Inclusion of manual check points to ensure the final removal of any unsuitable materials that are not removed by the initial visual and mechanical screening;
- The overall operation of system is monitored and controlled in real time using a specifically developed computerised process information management system. The computerised monitoring and control of the process operations provides a further level of control and safeguard over the efficient operation of the system. It is understood that a similar computerised process information management system is to be installed at the proposed facility in NSW;

- Implementation of a routine preventive maintenance inspection and checking by which the main operational components are monitored;
- Appropriate training of the site personnel.

In overall terms, it is considered that the level of control and monitoring is appropriate and the risk of operational disruption has been properly managed. It is, however, recommended that the proposed facility in NSW be operated by staff with appropriate professional qualification/knowledge (eg. process engineers, biotechnologist, etc). The staff should receive proper "on the job" induction training for the plant operation.

6.3.3 Operational and Maintenance Records

It is noted that the environmental emission/discharge standards in Israel are, generally speaking, amongst the most stringent environmental standards in the world. It is, however, understood that there have been no known, reportable issues regarding the environmental compliance of the Tel Aviv Facility with the specified standards. This is supported by the onsite observations and verified by Arrow Ecology. On this basis, it is envisaged that the Selected Integrated System (based on the Tel Aviv Facility) would be able to meet the technical and environmental standards applicable to NSW.

A review of the operational information suggest that the Tel Aviv Facility has been operating practically continuously over a two year period. Whilst routine repair and maintenance were conducted, as per any operational plant, it is understood that the typical unit process maintenance down time has been in the order of several hours at any one time.

Main issues of concern would be similar to typical MSW facilities, namely:-

6.3.4 Unsuitable Materials

Whilst the potential for an oversized object or unsuitable material (eg a chemical container) to slip through the initial visual and mechanical screening exists, the probability is expected to be low, and can be further reduced with the inclusion of a final visual checking point at the start of the system.

Very few incidents of unsuitable materials such as oversized items, textiles or timber furniture have occurred in the past 2 years of operation, and the repair/maintenance time for these incidents is in the order of 2 - 3 hours, i.e. minimal impact.

With regard to the potential for inclusion of chemicals or hazardous wastes in the system feed, the current waste screening/checking system, particularly with a combination of mechanical screening and visual checking, would be able to alleviate this concern. Moreover, given the waste sources, it should be noted that the chemical/hazardous materials of concern would most likely be in the form of discarded household chemicals. The quantities involved will probably be small, and will be effectively attenuated through the ArrowBio process such that the overall impacts on the system would be insignificant.

Information provided by Mr Amir Assa (Biotechnologist) suggests that the maximum allowable concentration of oils, paints, etc is 100 mg/L. As the unit capacity of the separator tank at Tel Aviv is 6000 kL (6000 m^3) the maximum allowable flux into the system is 600 kg (or about 600 litres) of potentially hazardous materials for bioreaction. The probability of such a quantity of materials being delivered in domestic waste without detection by the preimary separation process is extremely low.

Operational records of the Tel Aviv Facility, further demonstrated that the facility is capable of handling a wide range of waste types without having any detrimental impacts on the plant operation.

On this issue, it is considered that with the construction of a larger size facility, the potential impacts on the plant availability due to dosing issues will be further reduced by both the increased operational flexibility (as a result of increased number of process units), and the increased buffer capacity due to larger vessels.

6.3.5 Breakdown of Plant Components

This is a common problem faced by all processing plants and equipment, and the risk associated with this issue is no different from that faced by other industrial plants in general. It is, nevertheless noted that a comprehensive preventive maintenance checklist/programme has been developed by Arrow Ecology Ltd which should be applicable and transferred to the proposed facility in NSW. It is considered that, through implementation of the preventive maintenance programme, the risk of plant disruption can be effectively managed.

It is further noted that:-

- The selection of plant material appears to be appropriate, which will further reduce the probability of “unplanned outages”; and
- most of the plant components are commonly available items that may be sourced locally. A few proprietary items would have to be sourced from Arrow Ecology Ltd. The issue can, however, be effectively managed through a system of keeping and maintaining essential spares.

The overall impacts due to breakdown of components can, thus, be effectively managed through pro-active management actions. Furthermore the facility planned for Belrose will comprise a number of parallel systems so that maintenance can be handled by periodic shutdowns of one processing stream only.

6.3.6 Line Blockages

Blockage of feed lines is a common but minor problem in technical plants. The problems caused are typically at “nuisance” levels and are not critical. Implementation of regular preventive maintenance checks will drastically reduced “unplanned outages”. Fixing line blockages involves simple operations with low downtime.

6.3.7 Undersized Anaerobic Digesters

Under certain circumstances, for example, if the external temperature is too low or if the organic portion of the MSW increases, then an undersized anaerobic digester may not be able to generate enough heat to sustain the biological reaction. According to Arrow Ecology Ltd, the critical (minimal) quantity of municipal solid waste intake for a viable/sustainable anaerobic digester is in the order of about 15,000 tpa. It should be noted that:

- The planned Facility would have a larger capacity than the Tel Aviv Facility;
- The ambient temperature of NSW is similar to that of Tel Aviv where no external heat sources have been necessary since initial plant start up;
- External heat can always be applied to maintain the biological activities.

The above concern is therefore considered to be not an issue for NSW, although DP concur that MBT facilities (and the associated anaerobic digester) should be reasonably sized to attain the economy of scale, system flexibility and sustainability.

6.3.8 Quality of Byproducts

A major byproduct of the Tel Aviv Facility is biogas. Available records and information show that the biogas generated by the Tel Aviv Facility has consistently achieved a methane concentration level of 70%.

It is considered that a potential market for the stabilised fertilizers exist in Australia.

6.3.9 Modularity

The Tel Aviv facility is designed as a simple continuous single processing stream which is suitable for treating about 200 tonnes of MSW per day or approximately 60,000 tonnes per annum. The plant however has been designed so that the waste processing streams can be easily duplicated to treat any required amount of MSW. This modular construction provides significant flexibility and enables the Selected Integrated System to be adapted to suit any waste stream. It should also be noted that the plant operates from 6 am to 2 pm only for six days per week. Therefore the opportunity exists for utilizing a number of shifts to increase the overall plant capacity.

The Tel Aviv plant has one waste stream only and therefore must cease operations if blockages occur. By using a number of parallel processing streams any delays due to system breakdowns can be minimized with the plant still operating, even though at a reduced capacity. Furthermore routine preventative maintenance can be conducted without the need to divert the waste to other processing facilities. It is therefore better to have a number of modules as it improves the flexibility of the plant.

7. OVERVIEW AND CONCLUSION

It is noted that a single module, 70,000 tonne per annum Tel Aviv Facility has been successfully operational for approximately 2 years.

In other words, the compatibility of the ArrowBio® processes (and the other unit processes developed and utilised in the Tel Aviv plant) has been well proven through approximately 2 years of commercial scale operations. Prior to that, a smaller pilot plant was tested at Hadera in Israel for 1½ years.

The proposed NSW facility will be upscaled from 70,000 tonne per annum (tpa) capacity to 100,000 tpa capacity. This will be met by a combination of an overall increase in the number of modular units and a relatively small increase in the size of the individual units. In fact, the scale up factor is small and the proposed NSW facility is practically of the same order of magnitude in terms of operational capacity. The up-scaling philosophy is considered to be pragmatic and favourable. In this way, the overall risk associated with the up-scaling is low whereas the flexibility of the plant will be substantially increased.

In this regard, and taking into consideration the information obtained on the Tel Aviv Facility and MBT in general, the following points are noted:-

- The system provider has relevant experience and credentials;
- The technology selected is well proven with good operational records;
- The Selected Integrated System has good and efficient system design;
- The operational technical plant at Tel Aviv aptly demonstrates the technical feasibility of the Selected Integrated System;
- The reliability of the system is supported by the good operational records of the Tel Aviv Facility; and
- The proposed process is essentially an innovative means of getting all organics in an easily digestable form and then utilizes standard waste water treatment technology to reduce the organic waste to methane for use in power generation;
- In overall terms, the technical and financial risk is low.

On this basis, the Selected Integrated System is considered to be an appropriate technology suitable for NSW. The risk associated with the proposed plant in NSW is considered to be minimal.

Operational issues such as exhaust emissions from trucks will need to be dealt with in the final plant design but these are unconnected to the technical feasibility of the plant.

In summary, Douglas Partners supports the proposed technology as a suitable means of waste treatment based upon observations and information supplied.

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DOUGLAS PARTNERS PTY LTD Reviewed by:

Michael J Thom
Principal

Ronnie Tong
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NOTES RELATING TO THIS REPORT

Introduction

These notes have been provided to amplify the geotechnical report in regard to classification methods, specialist field procedures and certain matters relating to the Discussion and Comments section. Not all, of course, are necessarily relevant to all reports.

Geotechnical reports are based on information gained from limited subsurface test boring and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, Geotechnical Site Investigations Code. In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. sandy clay) on the following bases:

Soil Classification	Particle Size
Clay	less than 0.002 mm
Silt	0.002 to 0.06 mm
Sand	0.06 to 2.00 mm
Gravel	2.00 to 60.00 mm

Cohesive soils are classified on the basis of strength either by laboratory testing or engineering examination. The strength terms are defined as follows.

Classification	Undrained Shear Strength kPa
Very soft	less than 12
Soft	12—25
Firm	25—50
Stiff	50—100
Very stiff	100—200
Hard	Greater than 200

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration tests (SPT) or Dutch cone penetrometer tests (CPT) as below:

Relative Density	SPT "N" Value (blows/300 mm)	CPT Cone Value (q_c — MPa)
Very loose	less than 5	less than 2
Loose	5—10	2—5
Medium dense	10—30	5—15
Dense	30—50	15—25
Very dense	greater than 50	greater than 25

Rock types are classified by their geological names. Where relevant, further information regarding rock classification is given on the following sheet.

Sampling

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing with a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling are given in the report.

Drilling Methods.

The following is a brief summary of drilling methods currently adopted by the Company and some comments on their use and application.

Test Pits — these are excavated with a backhoe or a tracked excavator, allowing close examination of the in-situ soils if it is safe to descent into the pit. The depth of penetration is limited to about 3 m for a backhoe and up to 6 m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (eg. Pengo) — the hole is advanced by a rotating plate or short spiral auger, generally 300 mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling — the hole is advanced by pushing a 100 mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling in soils, since moisture content is unchanged and soil structure, strength, etc. is only marginally affected.

Continuous Spiral Flight Augers — the hole is advanced using 90—115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling — the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

Rotary Mud Drilling — similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. from SPT).

Continuous Core Drilling — a continuous core sample is obtained using a diamond-tipped core barrel, usually 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in very weak rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

Standard Penetration Tests

Standard penetration tests (abbreviated as SPT) are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" — Test 6.3.1.

The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150 mm of say 4, 6 and 7

  as 4, 6, 7
  N = 13

- In the case where the test is discontinued short of full penetration, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm

  as 15, 30/40 mm.

The results of the tests can be related empirically to the engineering properties of the soil.

Occasionally, the test method is used to obtain samples in 50 mm diameter thin walled sample tubes in clays. In such circumstances, the test results are shown on the borelogs in brackets.

Cone Penetrometer Testing and Interpretation

Cone penetrometer testing (sometimes referred to as Dutch cone — abbreviated as CPT) described in this report has been carried out using an electrical friction cone penetrometer. The test is described in Australian Standard 1289, Test 6.4.1.

In the tests, a 35 mm diameter rod with a cone-tipped end is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on a separate 130 mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected by electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20 mm per second) the information is plotted on a computer screen and at the end of the test is stored on the computer for later plotting of the results.

The information provided on the plotted results comprises: —

- Cone resistance — the actual end bearing force divided by the cross sectional area of the cone — expressed in MPa.
- Sleeve friction — the frictional force on the sleeve divided by the surface area — expressed in kPa.
- Friction ratio — the ratio of sleeve friction to cone resistance, expressed in percent.

There are two scales available for measurement of cone resistance. The lower scale (0—5 MPa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main scale (0—50 MPa) is less sensitive and is shown as a full line.

The ratios of the sleeve friction to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1%—2% are commonly encountered in sands and very soft clays rising to 4%—10% in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range:—

$$q_c \text{ (MPa)} = (0.4 \text{ to } 0.6) \text{ N (blows per 300 mm)}$$

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range:—

$$q_c = (12 \text{ to } 18)\ c_u$$

Interpretation of CPT values can also be made to allow estimation of modulus or compressibility values to allow calculation of foundation settlements.

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes, etc. This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

Hand Penetrometers

Hand penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150 mm increments of penetration. Normally, there is a depth limitation of 1.2 m but this may be extended in certain conditions by the use of extension rods.

Two relatively similar tests are used.

- Perth sand penetrometer — a 16 mm diameter flat-ended rod is driven with a 9 kg hammer, dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
- Cone penetrometer (sometimes known as the Scala Penetrometer) — a 16 mm rod with a 20 mm diameter cone end is driven with a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). The test was developed initially for pavement subgrade investigations, and published correlations of the test results with California bearing ratio have been published by various Road Authorities.

Laboratory Testing

Laboratory testing is carried out in accordance with Australian Standard 1289 "Methods of Testing Soil for Engineering Purposes". Details of the test procedure used are given on the individual report forms.

Bore Logs

The bore logs presented herein are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable, or possible to justify on economic grounds. In any case, the boreholes represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes, the frequency of sampling and the possibility of other than 'straight line' variations between the boreholes.

Ground Water

Where ground water levels are measured in boreholes, there are several potential problems;

- In low permeability soils, ground water although present, may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report.
- The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Engineering Reports

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. a three storey building), the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty storey building). If this happens, the Company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface condition, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- unexpected variations in ground conditions — the potential for this will depend partly on bore spacing and sampling frequency
- changes in policy or interpretation of policy by statutory authorities
- the actions of contractors responding to commercial pressures.

If these occur, the Company will be pleased to assist with investigation or advice to resolve the matter.

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some later stage, well after the event.

Reproduction of Information for Contractual Purposes

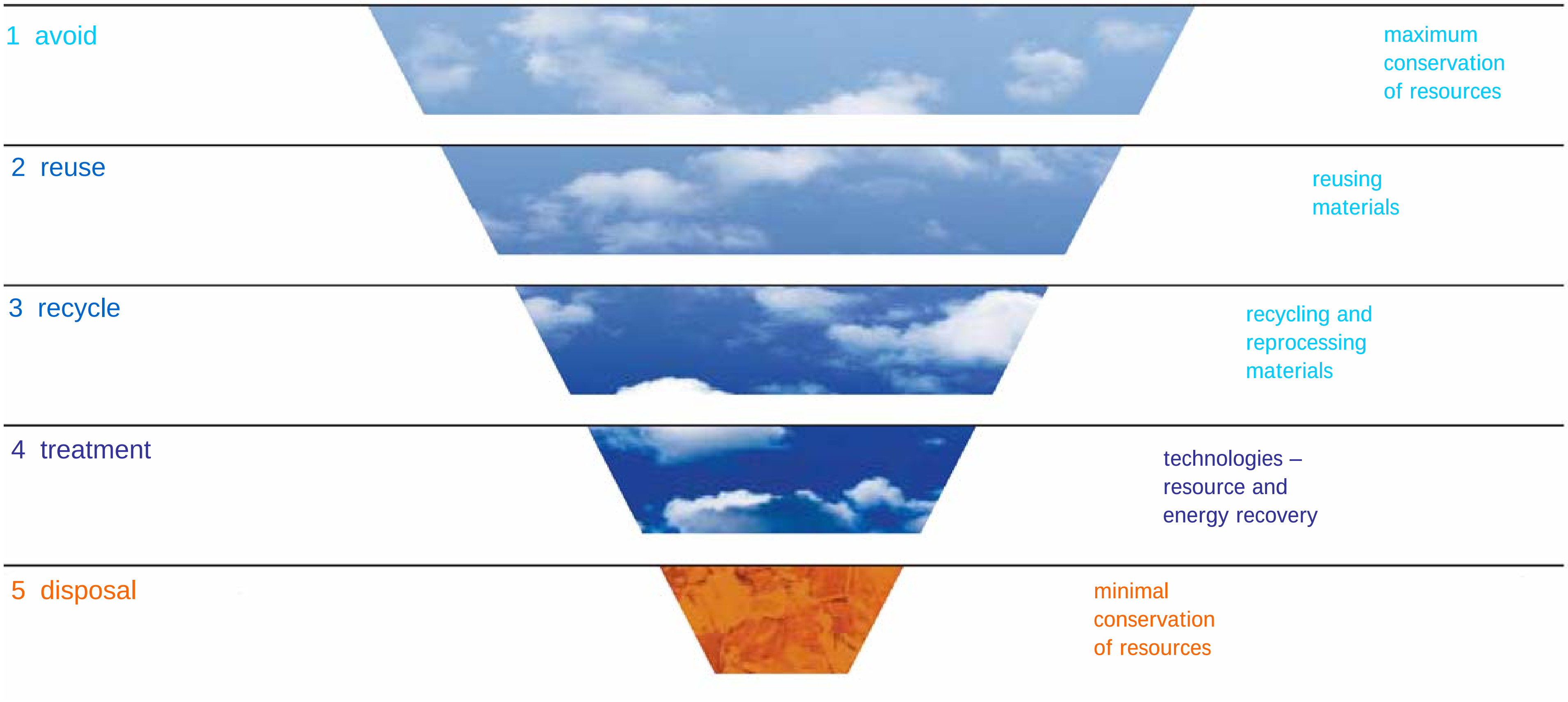
Attention is drawn to the document "Guidelines for the Provision of Geotechnical Information in Tender Documents", published by the Institution of Engineers, Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. The Company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

APPENDIX A
Figures

Waste Processing Hierarchy Highest Net Resource Value



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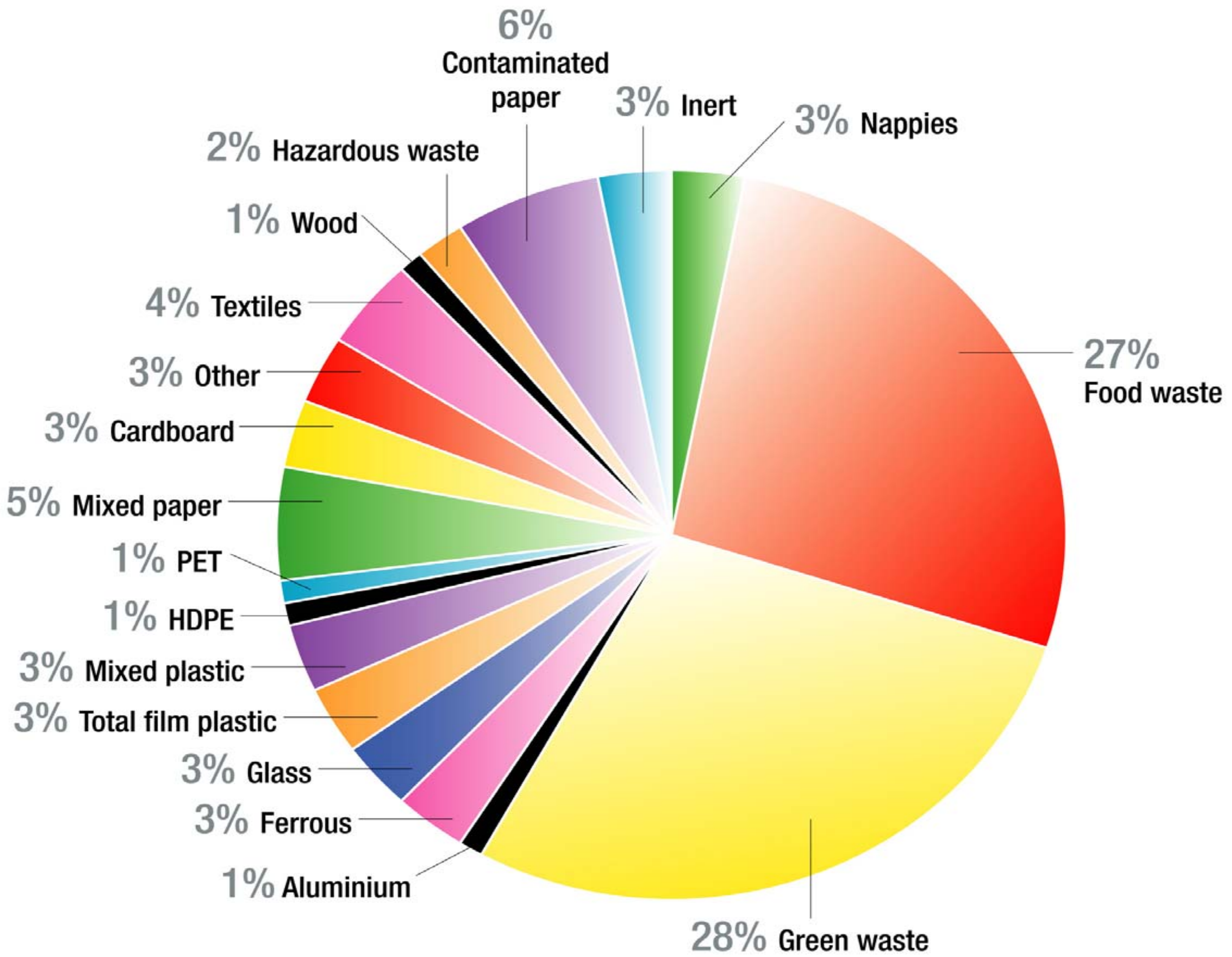
Hierarchy of Integrated Solid Waste Management
Figure 1



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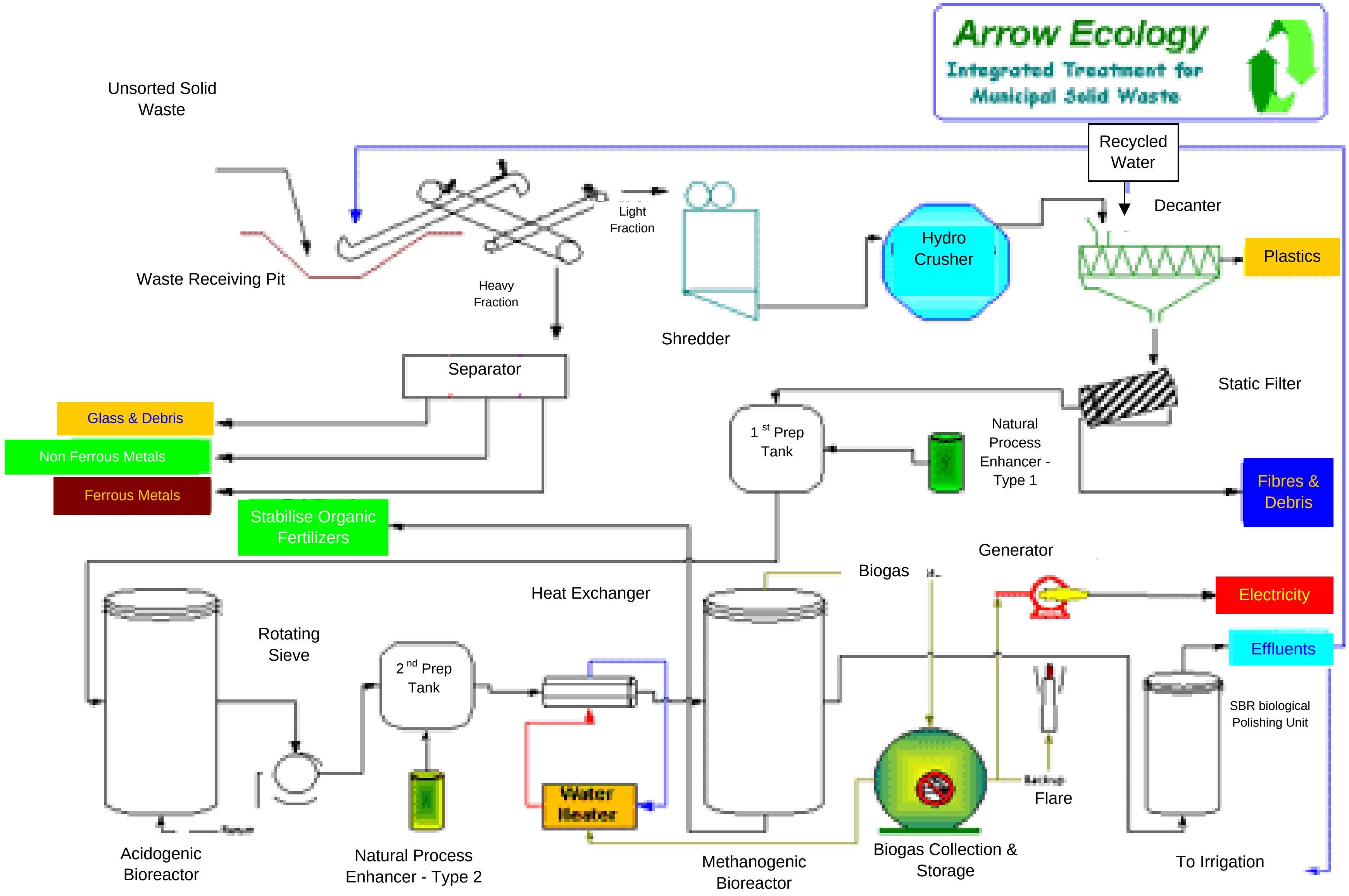
Waste Categories at Eastern Creek WMC, NSW
Figure 2



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Schematic Diagram of Selected Plant Process
Figure 3

APPENDIX B
Photographs of the Tel Aviv Facility

Photo 1: General view of various plant unit from process control room.

Photo 2: Magnetic and eddy current seperators for ferrous and non ferrous metals.

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Title	**Site Photographs** **Waste Treatment Technology Assessment** **Tel Aviv, Israel**		
Client: Waste Service NSW			**Office: Sydney**
Drawn by: MJT	**Scale: NTS**	**Project Number: 37387**	**Drawing No. 1**
Approved by:		**Date: 1 October 2004**	

Photo 3: Magnetic seperator for ferrous metals.

Photo 4: Primary material separation in flotation tank.

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Title **Site Photographs**
Waste Treatment Technology Assessment
Tel Aviv, Israel

Client: Waste Service NSW			**Office: Sydney**
Drawn by: MJT	**Scale: NTS**	**Project Number: 37387**	**Drawing No. 2**
Approved by:		**Date: 1 October 2004**	

Photo 5: Waste being dumped into the primary separation tank.

Photo 6: Trommel screen for separation of organics from plastic etc.

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Sydney, Newcastle, Brisbane, Wollongong, Campbelltown

Melbourne, Perth, Wyong, Townsville, Cairns, Darwin

Title Site Photographs
Waste Treatment Technology Assessment
Tel Aviv, Israel

Client: Waste Service NSW			**Office: Sydney**
Drawn by: MJT	**Scale: NTS**	**Project Number: 37387**	**Drawing No. 3**
Approved by:		**Date: 1 October 2004**	

Photo 7: Elevator taking waste to the metal separators.

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Melbourne, Perth, Wyong, Townsville, Cairns, Darwin

Title	**Site Photographs** **Waste Treatment Technology Assessment** **Tel Aviv, Israel**		
Client: Waste Service NSW			**Office: Sydney**
Drawn by: MJT	**Scale: NTS**	**Project Number: 37387**	**Drawing No. 4**
Approved by:		**Date: 1 October 2004**	

Photo 8: Primary elevator carrying waste from the flotation tank to the trommel for shredding plastic bags and waste separation.

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Melbourne, Perth, Wyong, Townsville, Cairns, Darwin

Title	**Site Photographs** **Waste Treatment Technology Assessment** **Tel Aviv, Israel**		
Client: Waste Service NSW			**Office: Sydney**
Drawn by: MJT	**Scale: NTS**	**Project Number: 37387**	**Drawing No. 5**
Approved by:		**Date: 1 October 2004**	

Photo 9: Movement of waste onto the primary elevator. Note the significant number of plastic bottles.

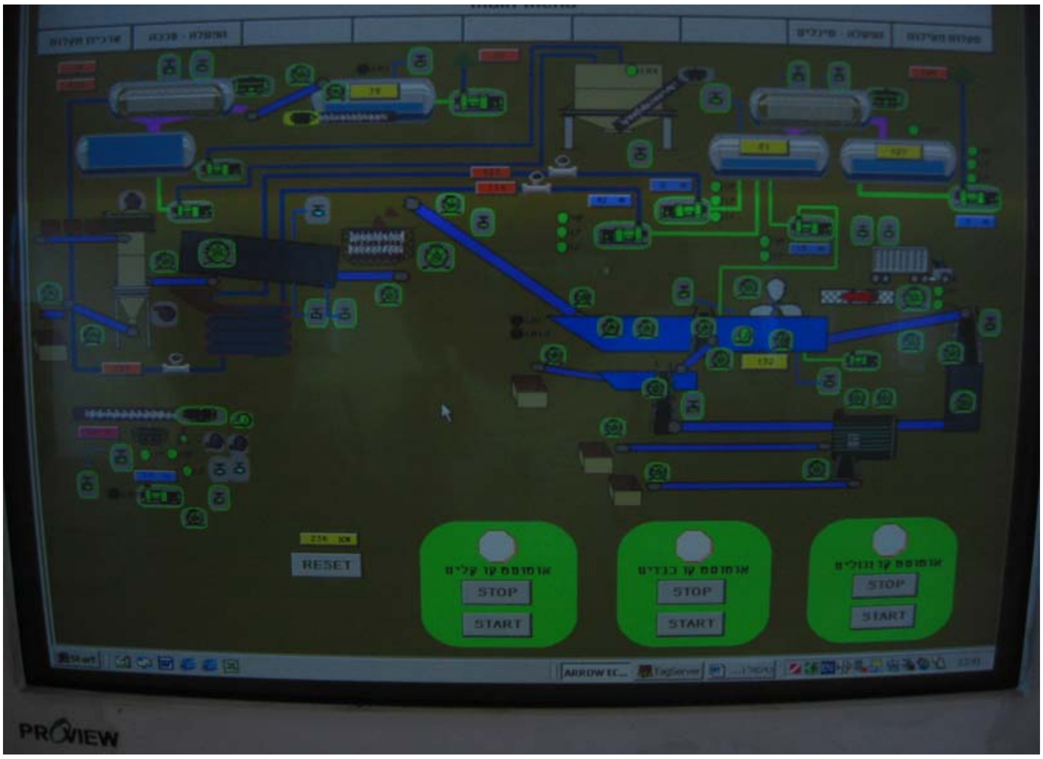

Photo 10: Individual process units are controlled is by touch screen technology.

Douglas Partners Geotechnics • Environment • Groundwater	*Sydney, Newcastle, Brisbane, Wollongong, Campbelltown* *Melbourne, Perth, Wyong, Townsville, Cairns, Darwin*

Title **Site Photographs**
Waste Treatment Technology Assessment
Tel Aviv, Israel

Client: Waste Service NSW			**Office: Sydney**
Drawn by: MJT	**Scale: NTS**	**Project Number: 37387**	**Drawing No. 6**
Approved by:		**Date: 1 October 2004**	

Photo 11: Removal of unsuitable materials is by trained operators after primary separation.

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Title **Site Photographs**
Waste Treatment Technology Assessment
Tel Aviv, Israel

Client: Waste Service NSW			**Office: Sydney**
Drawn by: MJT	**Scale: NTS**	**Project Number: 37387**	**Drawing No. 7**
Approved by:		**Date: 1 October 2004**	

Photo 12: Upflow clarifier which separates broken glass/sand from organic rich liquid.

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Title **Site Photographs**
Waste Treatment Technology Assessment
Tel Aviv, Israel

Client: Waste Service NSW			**Office: Sydney**
Drawn by: MJT	**Scale: NTS**	**Project Number: 37387**	**Drawing No. 8**
Approved by:		**Date: 1 October 2004**	

Photo 13: Automatic bailing of shredded plastic for recycling.

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Title	**Site Photographs** **Waste Treatment Technology Assessment** **Tel Aviv, Israel**		
Client: Waste Service NSW			**Office: Sydney**
Drawn by: MJT	**Scale: NTS**	**Project Number: 37387**	**Drawing No. 9**
Approved by:		**Date: 1 October 2004**	

APPENDIX C
Information Package from Arrow Ecology Ltd

The ArrowBio Process

The ***ArrowBio*** Process integrates an innovative, proven, liquid-based separation technology and high-rate anaerobic digestion - eliminating any need for prior separation or classification of mixed waste streams. The following types of wastes can be treated as-received:

- Municipal Solid Waste.
- Unsorted industrial waste from the paper (including recycled paper) and food processing industries.
- Manures and agricultural residues.
- Slaughterhouse wastes.
- Sludge from sewage and water treatment plants.
- Industrial settling tank sludge.
- Yard waste/garden trash with or without other household discards

Of these wastes, the most universal, and probably the most problematic, is Unsorted Municipal Solid Waste (MSW). It consists of a myriad of discards from households, businesses, and institutions managed in common. Thus MSW is extremely heterogeneous, seasonally variable, and differing in composition even among different collection routes within a given municipality. The organic and inorganic fractions pose very dissimilar problems, yet are received as a mixture in a single waste stream.

As a severe test of The ***ArrowBio*** Process, a realistic scale facility is in operation at the town of Hadera, Israel. Real unsorted MSW is received from that city and processed smoothly.

The fundamental advantage of the ***ArrowBio*** Process is two-fold. First, the MSW (or other waste stream) is processed directly as tipped from the collection truck. In the primary stage, organic and inorganic materials are separated through a unique, liquid-based, technology, involving gravitational settling, screening, and hydro-mechanical shredding of organic solids. Whereas ordinary separation schemes suffer from the wetness, or excessive dryness, of MSW, the ***ArrowBio*** Process frankly uses liquids to great effect.

The first stage end products are clean recyclables such as glass, metals, and plastic. Items such as batteries are removed gently, without breakage, thereby avoiding leakage of potentially toxic materials. Yet another, intermediary, product is an organic stream now ready for the next, biological, stage. The first stage thus performs two functions, separation and preparation, without additional machinery or effort.

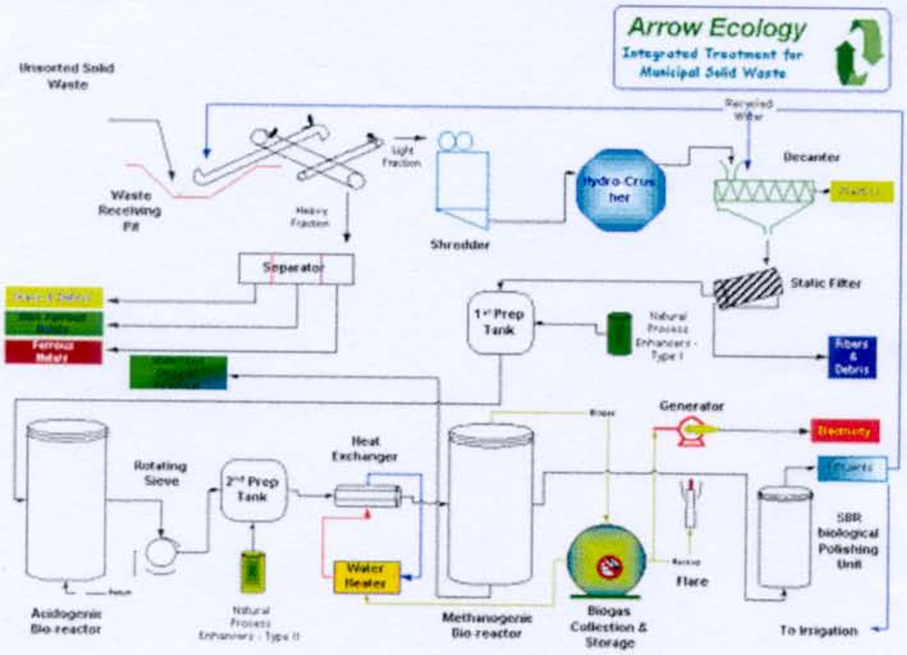
That is, in addition to removing inorganic and other non-biodegradable materials, the liquid-based separation simultaneously conditions the organic material for rapid biological action. This is accomplished by bringing the organic matter into solution or fine suspension (slurry). The solution/suspension is very rich, with a chemical oxygen demand (COD) in the tens of thousands of milligrams per liter. This supports the high-rate transformation of the organic wastes to methane (biogas) by naturally occurring microbial communities, in two highly controlled sequential reactors. Biogas production far exceeds in-house energy needs.

Excess biomass, discharged from the second reactor, is thoroughly stabilized and usable directly as an organic soil amendment ("compost"), or may be upgraded to a value-added product. Excess biologically generated water is either removed from the system (COD in the tens of milligrams per liter) or sent as makeup liquid to the up-front separation stage. Thus, with respect to energy and water, the system is autonomous.

Since it is consumed in producing energy for in-house use and/or export, emission of methane (potent greenhouse gas) to the atmosphere is entirely prevented.

Significant regional differences in MSW composition are noteworthy. In the Middle East and Asia, biodegradable organic matter may comprise 60 to 90% of the waste stream, with the remainder as biologically inert, mostly inorganic, materials. In contrast, European and North American MSW generally contains only 30 to 50% organics. Regardless of organic/inorganic proportion, unsorted MSWs are treatable by The ***ArrowBio*** Process.

The ***ArrowBio*** Process effortlessly accommodates the increasing tendency, mandated by national or local laws and regulations, to require source-separation of recyclable materials at the household, business, or institution of origin. Resultant shifts in MSW composition pose no problem in the process cycle. Rather, a given facility's capacity is effectively increased by this tendency. Moreover, perfect compliance with such mandates is neither expected nor achievable. Anyway, the function of conditioning the organics for high-rate methane production is indispensable.



Pre-Treatment and Preparation of the Waste

The waste is delivered by trucks into the preparation building. This building is equipped with exhaust fans and Bio-Filters, which assure that no smells escape into the environment. The waste is emptied directly into a reception chute and passed through a bag opening unit and a wet shredder. Water, essential for the shredding process, is re-circulated within the plant and no additional water needs to be added. From there the waste is transferred directly into the dissolving tank. Water is added and by imposing high shearing forces, the organic material is disintegrated down to fiber size, forming thin slurry so that it is separated from any inert material. Heavy components like broken glass, batteries, stones, metal parts etc. sink to the bottom and are separated from the slurry via a special discharge chamber.

1st Stage Acidogenic Fermentation
The organic slurry is pumped into the first Bio-Reactor or fermentation tank for facultative anaerobic digestion of the organic phase. Naturally occurring microorganisms start the fermentation process and transform the complex organic material into simpler compounds such as organic and fatty acids. Maintaining correct pH and organic material concentration in the reactor, together with proper liquor circulation and hydraulic retention time controls the process. This stage is a continuous process where fresh slurry is fed into the 1st reactor and fermented liquid is drawn off simultaneously and transferred to the 2nd stage.

2nd Stage Anaerobic Methanogenic Fermentation
The liquids leaving the 1st stage reactor are rich in organic material in the form of various organic acids. These liquids are being heated to ~40°C and pumped into the second Bio-Reactor for anaerobic degradation of the organic materials and the generation of biogas. Here too, naturally occurring microorganisms perform the degradation process and transform the organic material into biogas (~ 70% CH4 : 30% CO2) and biomass. This process is controlled by maintaining correct pH and organic material concentration in the reactor, together with proper solids concentration in the liquor and correct circulation and hydraulic retention time. This stage is also a continuous process where liquids from the 1st reactor are fed to the 2nd reactor and effluents are removed from the 2nd reactor. These effluents are being recycled within the system in order to maintain proper solids levels in the 1st reactor and for the initial stages of shredding of the incoming waste and the separation of inert material. Basically, no fresh water are added to the system.

The biogas, which is formed in the 2nd reactor, is being collected at the upper part of the reactor by means of a specially designed built-in compartment. This gas is re-circulated by a compressor and re-injected into the 2nd reactor close to its bottom, thus assuring a permanent agitation without mechanical devices. During routine operation, the biogas is also routed out of the system directly to energy generating units as steam boilers or electrical generators. The biogas can also be stored in simple inflating buffer tanks.

Treatment of final Products
The biological sludge formed in the 1st and 2nd reactors is drawn off at pre-set periods, dictated by the process control. This sludge contains many plant nutrients as ammonia and phosphorus in a readily available form to the plants. This fraction, called ***ArrowBio*** compost, can be dewatered rather simply and sold as a high value soil conditioning agent. Further processing such as pelletization of this product will increase the market potential and value of the ***ArrowBio*** compost. The long solid retention time in the 1st and 2nd reactors ensures a fully stabilized product which do not deplete the soil of nutrients due to intrinsic microbial activity and also is free of all pathogenic germs, bacteria, weed seeds, etc.

The biogas generated in the 2nd stage reactor is transported into a gas storage tank via filters which remove excess humidity and trace pollutants such as naturally formed H2S. The biogas is than used as a fuel for water heating, steam generation or electricity generation.

The liquid from the dewatering process of the ***ArrowBio*** compost is partly reused for shredding and dissolving the incoming waste. Excess water is stored in a separate tank and is being discharged directly into the public sewage system or into a simple biological treatment plant.

Materials Recovered From The ***ArrowBio*** Plant In Operation.

Aluminum

Fibers

Glass

Plastic