Development of a dynamic housed windrow composting system:

Performance testing and review of potential use of end products

Executive Summary

Report for:

Canford Environmental
Dorset

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ORGANIC RESOURCE AGENCY LTD

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1 INTRODUCTION

In 2000 W.H.White Plc applied for planning permission to develop a 6,000m^2 building complex, located in Poole's Green Belt, in which to undertake composting of Municipal Solid Waste (MSW: plate 1) and commercial waste. Permission was granted in 2002. Part of the permitted building complex (2000m^2) was constructed in 2003 and was made available by W.H.White Plc for Canford Environmental Ltd to undertake trials on the New Earth Technology into composting of mixed household waste due to the unavailability locally of source separated kitchen organic waste. Canford Environmental received funding via ENTRUST and the DEFRA Legacy Fund.

Canford Environmental employed the Organic Resource Agency Ltd. (ORA) to advise on the trials and carry out the assessment of the technology and products from the facility.

The trials were carried out on batches 13 to 20 and have provided the basis for the development of the design and operation of the facility to a point where it successfully passed three months of rigorous testing to gain State Veterinary Service (SVS) approval for the composting of catering waste (21 December 2004, reference 11/273/0074/ABP/CMP) as defined in the UK Animal By-Products Regulations. The trials have been on processed municipal solid waste (MSW) supplied by Bournemouth Borough Council at an average rate of 500 tonnes per month. The large scale of the trials means that the systems tested and results obtained are directly relevant to the commercial scale operation of the facility.

The technology employed at the plant is fully enclosed and the exhaust air is passed via a biofilter fitted with a scrubber to remove ammonia (Plate 1).

Plate 1 New Earth Technology showing biofilter and scrubber in foreground and composting hall in the background with the windrow turner emerging from the hall.

The raw material is received into the enclosed reception and pre treatment hall where the material is shredded and can also be screened to remove the over-size fraction.

This is followed by a biological treatment phase where the material enters a second enclosed hall. Here it is formed into three windrows, which are approximately 4 m wide at the base and 2 -2.5 m in height at the apex. Air is drawn through the windrows under negative pressure via ducting at the centre of the base of the each windrow. The exhaust air is passed via a scrubber and a biofilter before being emitted to the environment.

The windrows are turned with a specialist windrow turner fitted with an advanced air filtration system for air entering the cab (Plate 2). The turner inverts the material, including the base layer, to ensure that the material which was once on the outside of the windrow is put to the centre. The turning frequency and duration in the hall has been adjusted in the various trials which have taken place.

Plate2: Windrow turner (Sandberger UNI 4001) used in enclosed composting hall

The final step of the process is screening and wind-sifting. This process produces a range of products of different particle size and can separate the light fraction, including plastics, from the process.

2 COMPOSTING PERFORMANCE TESTS

During spring 2004 the composting process monitored in detail:

- Batch 18, All of the waste was shredded and screened. The material which was less than 70 mm was formed into a windrow for composting. The material was aerated and turned for 9 weeks. It was then matured for a further 3 weeks at an un-aerated windrow without any further turning.

- Batch 20, The waste was shredded only once and screened to 70 mm. Only the material of less than 70 mm (which consisted of 67 % of the waste input), was composted. The material greater than 70mm which typically includes the high energy material such as plastic film, paper and wood was therefore effectively excluded from the composting process. Aerated composting took place over 6 weeks followed by another 6 weeks for maturation in an un-aerated and unturned windrow.

Samples were taken during the trials to assess the rate of degradation and stabilization of the organic matter. The temperature in the windrows was recorded in order to assess the progress of the composting process and to determine whether the time temperature profile was sufficient to kill pathogens. The gases produced by the windrow were analysed regularly to assess the performance of the aerobic degradation process. The aeration system was then adjusted to optimise the composting process.

2.1 MASS BALANCE, FRESH MATTER, DRY MATTER, BIODEGRADABLE ORGANIC DRY MATTER

In order to optimise the design and operation of the facility it is essential to understand the mass balance of inputs and outputs that are achieved under different process management regimes.

For both batch 18 and 20 the greatest loss in dry matter occurred in the aerated phase. Both batches resulted in a decrease in dry matter of more than 50% over the total period of composting, with batch 18 showing a marginally greater loss than batch 20 (figure 1).

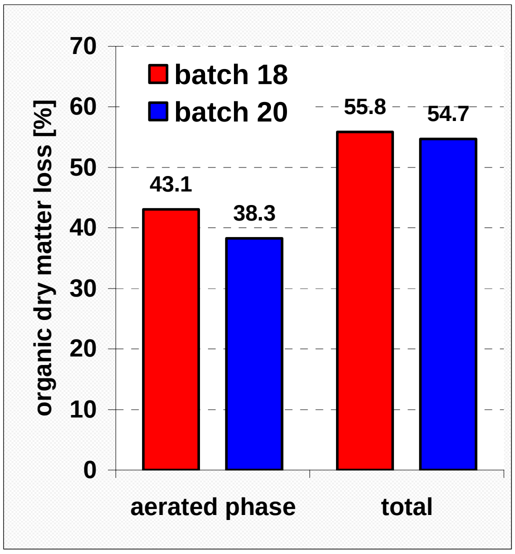

Figure 1. Loss of dry matter of MSW during the aerated phase of the composting process and for the aerated and maturation phase as a whole.

2.2 ASSESSMENT OF THE STABILIZATION OF THE ORGANIC MATTER IN ORDER TO DETERMINE LIKELY BEHAVIOUR IN THE LANDFILL

Composting provides a method of treating household waste in a way that, coupled with subsequent disposal of the waste, prevents serious impacts on the environment that are related to the disposal of untreated wastes. Negative impacts are particularly dependant on the release of climate affecting gases into the atmosphere and of organically and chemically loaded leachate to land. Waste is stabilised through the degradation of organic components. The extent of biological stabilisation through composting can be assessed using biological parameters, and the reduction of leachate by chemical analyses.

2.2.1 Biological test method

Various test methods have been used to determine the degradability, or the degree of stabilisation, of the organic matter. Organic matter with low respiration rate has a lower level of biodegradability and is therefore more biologically stable than organic matter with a higher respiration rate.

During the composting process, degradation starts with the easily degradable components and progresses to the components of the organic matter that are harder to degrade. Respiration activity can be measured and used to determine the extent to which the degradation process has proceeded. Organic matter with low respiration activity is biologically the most stable. When stabilised organic matter is landfilled, no significant emissions of methane will occur. In addition, there will be no significant settlement of the landfill site when stabilised wastes are deposited and compressed.

Figure 2 shows the reduction in biodegradability over time resulted in a fall in respiration activity as measured by static respiration index (SRI). This shows that at the end of the composting process the material in batches 18 and 20 had been stabilised sufficiently to conform with the German requirements for stabilised waste (5 g O_2/ kg DM) which can legally be sent to landfill. It is also interesting to note that the most rapid fall in biodegradability (i.e. increase in stability) occurs in the first 6 weeks of the composting process, this coincides with the fastest rate of loss in terms of dry and fresh weight.

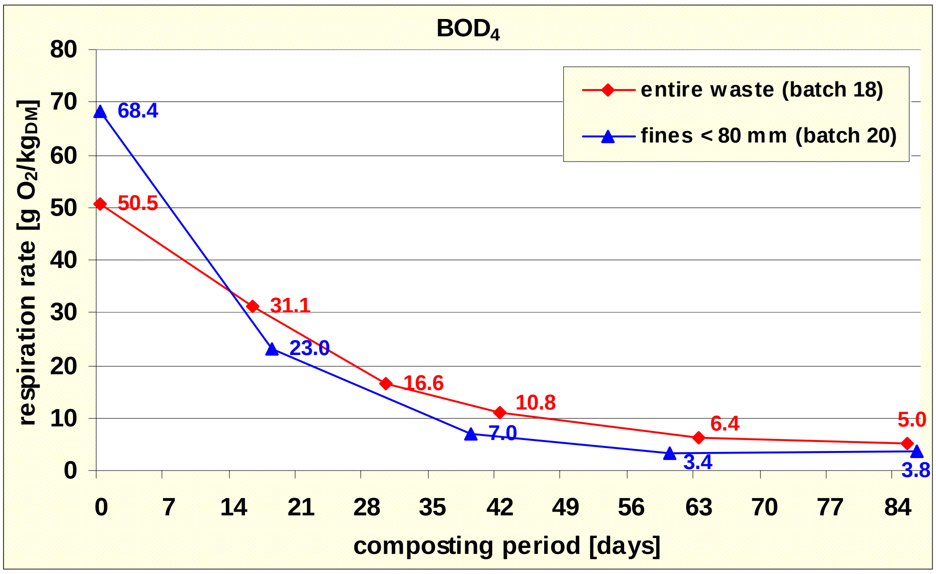

Figure 2: Change in respiration rate (using SRI, BOD_4) during the composting of MSW using New Earth Composting Technology.

Other biological test methods including dynamic respiration index (DRI) and gas formation rate GFR_{21} as well as the chemical parameter TOC_{eluate} showed a similar pattern as found using SRI, i.e. they could be reduced by 90 to 96 % within the 12 weeks of composting period (Figure 3).

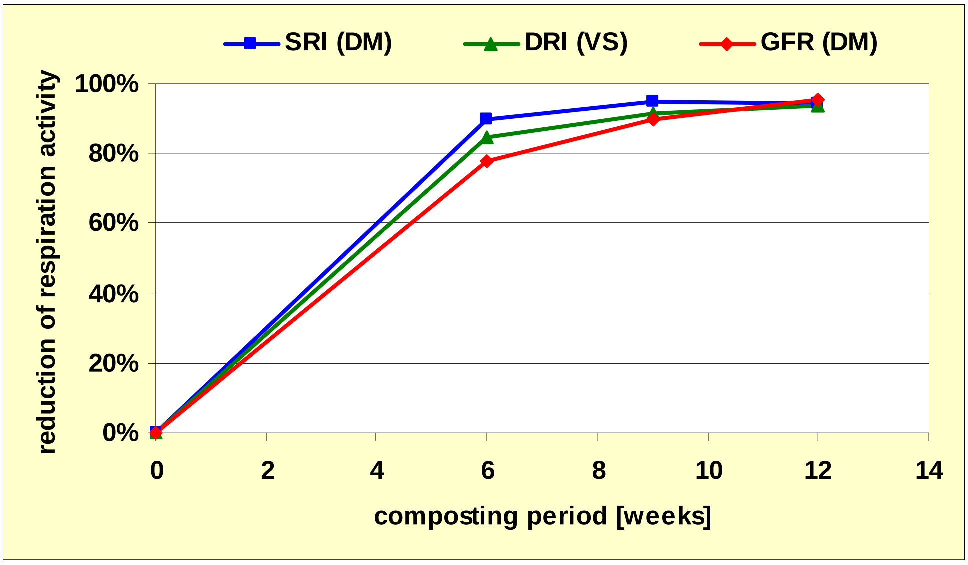

Figure 3. Reduction different measure of biodegradability (using SRI, BOD_4) during the composting of MSW using New Earth Composting Technology.

2.3 SANITISATION

Three different methods were used in order to assess the ability of the technology to sanitise the product :

- Indirect assessment of pathogen control according to the UK Animal By-Products Regulations (ABPR) 2003 for meat-included catering waste
- Direct assessment of the control of indicator organisms according to the German Biowaste Ordinance
- Placement of a large quantity of tomato seeds in the margin of the windrow to assess the efficiency of mixing the material, by determining the reduction in the germination rate of the tomato seeds due to heat exposure.

The evaluation of the time temperature profiles required under the UK ABPR, found that for the composting batches tested, a high level of sanitisation was achieved in the core and base zone of the windrow. The edges of the windrow also contributed considerably to the sanitisation effect. Meeting the ABPR requirements (two sanitisation cycles each with 4 periods of at least 2 days at a temperature of > 60 °C and 3 intermediate turning operations), is not an easy task. However, it was demonstrated that even within a 4 week intensive composting period, complete sanitisation can be reached if there is careful management of the turning dates. In practice this means immediate turning after the conditions for a sanitisation cycle (2 days > 60°C) are reached in the relevant zones of the windrow.

The work on the direct assessment of the performance of the process found that during a four-week period, the indicator organisms used for sanitization tests under the German Biowaste Ordinance, were killed in all zones of the windrow, i.e. tomato seeds and tobacco mosaic virus.

The results of the tomato seed test revealed that the material on the edges of the windrow were well mixed into the windrow core by windrow turning machine. After 5 turning operations (equivalent to 6 sanitization periods) no viable seeds were been found.

The tomato seed study also found that sanitization could also be achieved in shorter time than 2-day intervals between turnings if temperatures are higher (e.g. >70 °C). The sanitization effect under these conditions should be at least as effective despite the shorter reaction time since the rate of pathogen destruction increases exponentially with linear increases in temperature. In consequence, with significantly higher temperatures than 60°C it would be reasonable to correspondingly reduce the time period at which the higher temperatures have to be maintained.

2.4 Compost quality

A wide range of chemical and physical analysis were carried out on the composted material (Table 1). In general the level of nitrogen was found to be high for a composted product. The C:N ratios were low, which suggest that the nitrogen will be relatively available to plants. Heavy metals in the screened material were generally higher than would be expected than for material produced from a source segregated raw material. Levels of zinc, lead and cadmium were often found to be higher than the PAS 100 standard.

Unit	Batch 2 Green waste fully processed	Batch 3 Mixed Household waste 3 weeks processed	Batch 4 Mixed Household waste 12 weeks processed	Batch 8 Mixed Household waste 12 weeks processed < 10 mm	Batch 8 < 10-40 mm	Batch 8 > 40 mm	PAS 100 Potentially Toxic Elements Upper Limits
Dry Matter (DM) [%]	60.7	83.8	81.6	69.5	71.4	76.6	
Total Nitrogen [% of DM]	1.02	1.95	1.71	1.75	0.82	0.29	
Total Phosphorus [% of DM]	0.136	0.268	0.55				
Total Potassium [% of DM]	0.429	0.674	0.25				
Total Carbon [% of DM]	15.4	24.1	20.1	18.7	8.32	23.7	
C : N Ratio	15:1	12:1	11.7:1	11:1	10:1	82:1	
Total Zinc [mg/kg DM]	162	387	435	503	232	122	400
Total Copper [mg/kg DM]	26.2	132	155	159	56.3	40	200
Total Lead [mg/kg DM]	84.2	686	606	433	109	46	200
Total Nickel [mg/kg DM]	5.0	16.5	27.5	29.8	14.4	5.7	50
Total Chromium [mg/kg DM]	7.8	18.1	31.7	30.0	14.4	5.05	100
Total Mercury [mg/kg DM]	0.16	0.13	0.45	0.70	1.97	0.60	1
Total Cadmium [mg/kg DM]	0.29	1.15	3.49	1.68	0.53	0.29	1.5
PH	7.61	7.26	8.3	7.5			
Conductivity [Mmhos]	0.78	1.35					

Table 1 Chemical analysis of composted material

A batch of material which was screened to 10mm was also assessed according to the method used in the PAS 100 standards. It should be noted that PAS 100 does not apply to materials derived from a mixed waste source. However, Canford Environmental wanted to measure the performance of the product from the process as a means of determining how it might perform if source segregated material was to become available.
The analysis found that he sample from Batch 4 complied with PAS 100 in terms of human pathogens and weed propagules. The material failed to meet the standard in terms of phytotoxins.

The level of physical contamination was too high to comply with PAS 100 standards in terms of the content of glass and plastics. The particle size of the glass was less than 8mm and the plastic content was 0.8% of the total weight (table 2). However, it should be noted that the level of physical contamination is a direct result of the raw material being mixed municipal solid waste, which contained plastic and glass. If a source segregated waste stream was used then the level of glass and plastics would be expected to significantly lower.

Sieve Fraction	**<1mm**	**1-2mm**	**2-4mm**	**4-8mm**	**8-16mm**	**16-31.5mm**	**>31.5m**	**Category Total**
Mass of material in each sieve	106	27.4	37.5	19.6	2.3	0.0	0.0	**192.8**
Mass of contamination >2mm								
Glass			5.6	7.5	0.0	0.0	0.0	13.1
Metal			0.0	0.0	0.0	0.0	0.0	0.0
Plastic			1.0	0.5	0.0	0.0	0.0	1.5
Glass, metal and plastic contamination subtotal			**6.6**	**8.0**	**0.0**	**0.0**	**0.0**	**14.6**
Stones and other consolidated mineral contaminants			3.3	3.0	0.0	0.0	0.0	6.3
Other			0.0	0.0	0.0	0.0	0.0	0.0
Contamination total			**9.9**	**11.0**	**0.0**	**0.0**	**0.0**	**20.9**

Table 2 Physical contaminants in Batch 4 screened to 10mm

A process of gaining exemptions (under the environmental protection act) for the application of screened material to land for the production of oilseed rape for bio-fuel is currently underway. This process will take account of the potential for agricultural benefit and environmental improvement to result from the application of the composted material. It is this site specific approval from the Environment Agency which will provide the ultimate test for the suitability of the material for application to land.

3 CONTROL OF EMMISSIONS

3.1 EXHAUST AIR CLEANING

The New Earth Technology facility is equipped with a biofilter and a primary acidulous scrubber. The performance of the biofilter system was assessed for different parameters via comparison of untreated gas and exhaust air concentration.

Figure 4 shows the performance of the air cleaning system for various parameters.

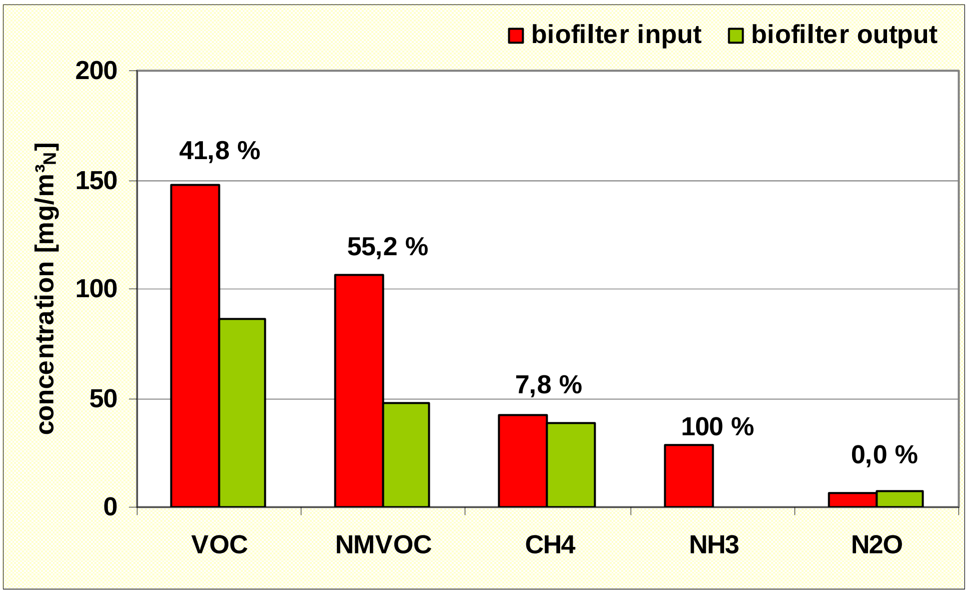

Figure 4: Concentration of different substances before and after the exhaust air treatment system; the numbers describe the level of cleaning in relation to the starting concentration

During the measurements, high VOC concentrations (mostly in the form of methane) were found in the air drawn from the windrows. This situation was successfully addressed by changing the aeration system from alternate to continuous (aeration rates see Table 3). After three days the VOC-levels were reduced to only 5.5% of the original level.

	Aeration rate	
Type of aeration	$m^3_N/(h*Mg_{composting\ input})$	$M^3_N/(h*m^3_{composting\ input})$
Alternating	2.35	0.95
Permanent	4.73	1.89

Table 3: Aeration rates in relation to mass and volume of the composted material (batch 21)

Plate 3. Assessment of exhaust air going to the scrubber and biofilter

Plate 4. Preparation for capturing gaseous emissions from the biolfiter

3.2 ODOUR

Odours were assessed from various points within and around the facility.

The concentration of odour in the exhaust air from the biofilter is of particular importance. Its performance was good with approximately a 98% reduction in odour when a higher odour concentration was put into the biofilter and approximately a 94 % reduction when less polluted exhaust air was fed into the system. This performance was measured with a comparatively low load of 25 $m^3_{exh.\ air}/(h*m^3_{vol.\ biof.})$ in relation to the volume of the biofilter. A typical load on a biofilter in plants handling MSW, in relation to the biofilter volume, are between 50 and 150 $m^3_{exh.\ air}/(h*m^3_{vol.\ biof.})$.

Assuming an efficiency of 98 % the system with alternating aeration mode and an average blower operation time of about 9 hours per day was able to reduce a maximum odour concentration in the raw air of 23,500 odour units to 500 ou[1] in the cleaned exhaust air. A further reduction of the odour concentration can be achieved through increasing the windrow aeration. In the tests the increase of the blower operation time from 9 to 22 hours per day caused a reduction of the odour concentration of the windrow exhaust air by 75 %. At the same time the odour concentration of the cleaned air was reduced from 470 to 300 ou.

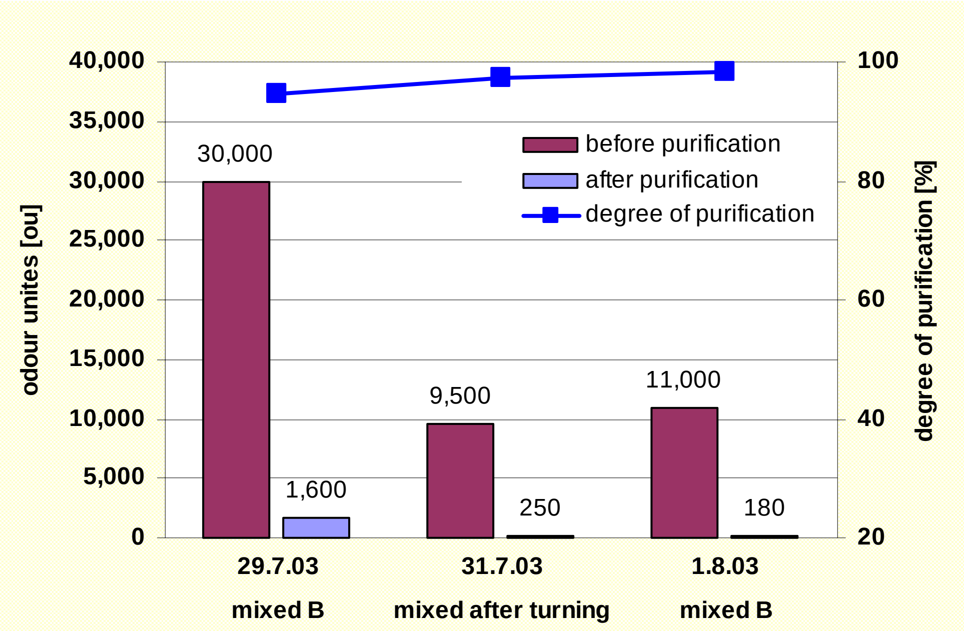

Figure 5: **Odour units recorded before and after purification by biofilter (sucked air mixed from 1 and 4-5 week old material))**

3.3 BIOAEROSOLS

Due to the lack of studies concerning fugitive dust emissions and bioaerosols from enclosed composting operations, it is difficult to draw any definitive conclusions regarding the risks to the surrounding population from such sites. However, research has outlined guidelines in terms of potential effects on health. Therefore, control measures can be implemented in the

[1] 500 ou = peak value for MBT plants according to German Air Regulation (TA Luft)

interim. Sites can measure their emissions and ensure that the health of potential sensitive receptors is protected. Lack of standards in this area should not necessarily preclude this precautionary approach.

Sampling at the New Earth Technology facility showed typical background particulate and bioaerosol concentrations. Sampling during operations showed very low concentrations of fungi, of the order of the background concentrations, and lower concentrations of bacteria than would be found on a windrow site.

- Prior to operations beginning, particulates were of the order of concentrations previously measured using the same equipment and protocols in other background studies, once vehicle movements were taken out of the sample.

- Prior to operations beginning, bacteria showed a small peak in the vicinity of the roadway but continued to fall after this disturbance (no further such peaks were sampled). During operations, bacteria peaked during unloading, but were also significantly higher at the weir. Further sampling is needed to confirm the source of bacteria at the weir as it is a considerable distance from the compost hall (270m);

- It is unlikely surrounding farmland and sensitive receptors will be affected by the site from dispersal of bioaerosols due to the low concentrations detected on-site;

- Water sprays on roadways proved to be very effective to prevent fugitive dusts becoming a nuisance from busy access routes throughout the year.

In conclusion a variety of studies have shown different dispersal distances and have used differing reference values for estimating effects on health to local populations. At this time no significant health effects have been reported in relation to an operational site in the UK. The results in this report indicate that the Canford Poole, site based on the information available to date, generates bacteria in the range of 10^3 cfu/m^3 and fungi below 100 cfu/m^3 on site. Therefore, the site presents no significant risk to sensitive receptors in its vicinity.

3.4 RISK TO STAFF

Particular attention was paid to ensure that the levels of micro organisms in the windrow turner and the front end loader were acceptable by the use of appropriate air filter, air conditioning and ensuring that the vehicles were kept clean and doors were not opened inside the enclosed composting areas. The study found that the levels were about 10 times lower than has been found on some other sites. No absolute values have been set, but the levels found in the cabs of the windrow turner were very low i.e. < 10^4 colony forming units (cfu).

4 CONCLUSIONS

An in depth technical assessment and optimisation of the New Earth Technology has found it to be capable of consistently performing to a high standard in terms of the following key parameters:

- Significant reduction in mass of MSW via a process of aerobic degradation (composting)

- Achievement of a high level of stability of the product as measured by respiration rate, gas formation rate and TOC in the eluate. This issue, and the mass reduction, are likely to have significant implications in terms of achieving targets for the diversion of biodegradable waste from landfill and compliance with the Landfill Allowance Trading Scheme.

- Low levels of emissions from the facility to air in terms of bioaerosols and odour by the effective operation of the biofilter system.

- Low levels of micro organisms in the vehicles used by staff in the composting hall if good practice is observed.

- Ability to achieve a high level of sanitisation which allows the facility to comply with the conditions of the UK ABPR whether derived from MSW or from source separated ABPR "catering waste".

There is scope for further improvement, which could be addressed by a continuous programme of development including:

- Improvement in the mechanical pre treatment to achieve higher levels of efficiency in terms of consistent particle size reduction and screening / sorting to increase the efficiency of separation of recyclable / recoverable materials and reduce the level of physical and chemical contamination in the end products.

- Further improvement of aeration system to optimise the control of the composting process

- Improvement of the guidance system for the windrow turner when operating in conditions of poor visibility due to high vapour concentration in the hall during turning.

The New Earth Technology at the facility in Poole offers the potential to be used as a resource to examine other issues which are fundamental to achieving diversion of biodegradable MSW from landfill with a view to complying with forthcoming regulations including:

- The ability of the dynamic aerobic composting processes to produce materials to the range of standards identified in the EU Working Document, Biological Treatment of Bio-Waste 2nd Draft; including stabilised waste for disposal in landfill through to material suitable for spreading to land.

- The potential to compost source segregated kitchen and garden waste, and similar commercial wastes, to produce a high quality compost.

- Identification of the source of heavy metals in mixed MSW

Based on the data and information gathered it would appear that New Earth Technology is robust and flexible in terms of how it can be operated to meet a wide range of important technical and regulatory criteria which govern the treatment of waste in the UK.