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Evaluation of the odour reduction potential of alternative cover materials at a commercial landfill

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Abstract

The availability of virgin soils and traditional landfill covers are not only costly and increasingly becoming scarce, but they also reduce the storage capacity of landfill. The problem can be overcome by the utilisation of certain suitable waste streams as alternative landfill covers. The objective of this study was to assess the suitability of Construction & Demolition fines (C&D), Commercial & Industrial fines (C&I) and woodchip (WC) as potential landfill cover materials in terms of odour control. Background odour analysis was conducted to determine if any residual odour was emitted from the cover types. It was deemed negligible for the three materials. The odour reduction performance of each of the materials was also examined on an area of an active landfill site. A range of intermediate cover compositions were also studied to assess their performance. Odour emissions were sampled using a Jiang hood and analysed. Results indicate that the 200 mm deep combination layer of C&D and wood chip used on-site is adequate for odour abatement. The application of daily cover was found to result in effective reduction allowing for the background odour of woodchip.

Keywords: C&D; C&I; Woodchip; Daily landfill cover; odour

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Introduction

Odours are considered to be the greatest nuisance associated with landfills (Drew et al., 2007) and can cause considerable annoyance and impact both on the environment and amenities in proximity to such sites (Sarkar et al., 2003). Consequently the issue of odour control has become increasingly more important in terms of regulation and design of landfills (Hurst et al., 2005). Daily landfill cover is the material spread over deposited waste at the end of each working day and assists in the control of odour as well as other nuisances such as windblown litter, vermin, flies and birds. (EPA, 1997) Plaza et al. (2007) proved that a cover layer can act as a barrier, reducing the diffusion of gas and odour through the cover layer.

The fact that some odours only require to be present at very low concentrations before they are perceived means that it is not easy to either analyse an odour nuisance situation or find effective cost efficient remedies. Similarly for this reason adequate containment and abatement is both difficult and expensive. Despite this, it is usually possible to achieve an economically tolerable solution to an odour problem (Valentin, 1980).

The use of landfill cover, although a necessity, reduces the landfill void space available for the deposition of compacted waste (Milke, 1997). This problem can be overcome if the material being used to perform as a daily landfill cover is sourced from within the waste stream, reducing the landfill void space occupied by virgin soils (Querio and Lundell, 1992) or non waste material. In recent years, much research has been done into finding alternative daily cover (ADC) material, now that traditional materials such as topsoil are not as readily available (Ait-Benichou *et al.*, 2008; Carson, 1992; Querio and Lundell, 1992).

The use of ADC can significantly reduce the quantity of cover soil required. The volume taken up by soil cover in a typical landfill is in the region of 20 to 25% of the

fill capacity. By converting from soil daily cover to ADC, this volume can be reduced to as little as 9 to 13% of the fill capacity. This can amount to a considerable and significant volume gain depending on a landfill's remaining fill capacity (Haughey, 2001).

Fill capacity is a precious commodity and modern landfills are specifically engineered to maximise their potential storage capability. The use of alternative landfill covers instead of the traditional soil cover is one such method for increasing the fill capacity. One advantage of using alternative cover over traditional methods includes the preservation of void space and soil material. The objective of the study was to evaluate the odour reduction potential of alternative cover materials for both intermediate and daily landfill cover uses. Tests were carried out on fines materials (both C&D and C&I) and woodchip, from two different material recovery facilities (MRFs).

Materials and Methods

Residual background odour

Representative samples from the two fines materials and woodchip (WC) were sourced in two MRFs (Fassaroe and Millennium Park) near Dublin and spread out in an even layer on a laboratory floor to form a blanket covering of an area larger than the footprint of the Jiang hood (400 x 800 mm). A depth of 5-10 mm of sample material was chosen to ensure an adequate blanket layer.

A small sample of the material was collected and weighed to determine the moisture content. The Jiang hood was then placed over the material to ensure that it formed a flush fit with the surface of the material. The fan was then activated and the generated airflow ($0.0045 \text{ m}^3\text{s}^{-1}$ at the exhaust port) was allowed pass through the hood and over the sample material for a period of ten minutes before a sampling device was attached to the exhaust port on the hood and two samples were retrieved. Odour samples were collected using a vacuum sampler (Hurst *et al.*, 2005; Li *et al.*, 1998; Sheridan *et*

al., 2003). The sample bag (c. 20 litres) took approximately five minutes to fill. The procedure was repeated, until a set of three different moisture contents had been investigated.

The samples from both MRFs were tested over a range of moisture contents to simulate the natural wetting and drying of stockpiles on site and to determine if this would be a factor in contributing to the potential odour generation. The tests were conducted in two formats, one was to progressively increase the moisture content of the sample material and test the odour generated. The second format involved odour sampling of the material at its original moisture content, before completely saturating the material and repeating the process. The third sample was not collected until the material had been given considerable time to dry out to a moisture content greater than the first test but less than the second test.

All the samples were analysed in the University College Dublin (UCD) olfactometry laboratory within 24 hours of collection using the ECOMA TO7 Yes/No olfactometer (ECOMA, Honigsee, Germany), and the operating procedures complied with the European olfactometry standard (CEN, 2003). The samples were divided into two groups of three (A and B samples from the three moisture contents). Separate teams of (*four*) panellists were used to analyse the A and B samples, and the geomean of the results were calculated. The procedure was replicated on two separate occasions with samples from the two different source locations.

Cover composition trial

An isolated inactive section of a commercial landfill was chosen to conduct the odour reduction trials. The site which formed the sixth lift in one of the landfill phases was subject to active gas extraction. A series of six plots 4.5 m x 4.5 m, separated from each other by a buffer strip of 2 m, were marked out using marking tape and pegs. The

existing cover material (C&D and woodchip) was removed and deposited elsewhere in the landfill. The marked plots were stripped down to the raw compacted waste before being covered with various material compositions (Table 1) using an excavator by the exact same means as was normally done on the active cell.

The C&D was added first by the excavator gently shaking its bucket before the weight of the machine was used to good effect by “tracking” it in. The process observed was the exact same as that used by the excavator operator when applying cover material on the working face. The same process was then repeated with the woodchip layer. Both materials were obtained from the on-site stockpiles, which originated in the Millennium Park MRF.

The Jiang hood was placed in the centre of each plot to facilitate air sample collection. A section of unused geotextile membrane material was used to cover the exposed plot following testing each day as it would be in breach of Irish Environmental Protection Agency (EPA) guidelines to leave the waste exposed continuously throughout the course of the trial. The collected air samples were returned to the olfactometry laboratory to determine the odour concentrations and consequently, the odour emission rates from the site. This method was similar to that used by other researchers (Drew et al., 2007; Nicolas et al., 2006; Sironi et al., 2005).

At the end of the first week of the trial, it was decided to change the methodology and focus on less cover compositions but to study them in greater detail. Therefore, plots two, three and four were subsequently no longer used and, duplicate samples were collected from plots one, five and E1 (Exposed). These samples were analysed as before using olfactometry and a geomean ascertained from the findings to provide more representative emission rates. As a result of unexpectedly low odour readings from the exposed plot (E1), it was decided to open a new exposed plot (E2) and to fill the original exposed plot with clay, a typical landfill cover material. The clay

covered plot was filled in the same manner as the other plots and was referred to as plot 6 in the results. The amended plot layout can be seen in Table 1. Moisture samples were collected from both woodchip and clay cover and brought back to the laboratory for analysis.

Pre-cover versus post cover analysis

Duplicate odour samples were collected on two randomly selected sites on the working face on the raw waste, after which the sample equipment was removed from the working area until the deposition of waste had ceased and the daily cover had been placed. At the end of the day, a number of geotextile covers were placed on the sloped working face, while C&D fines (50 mm) followed by a woodchip layer (150 mm) were placed on the completed horizontal section. The post-cover samples were taken on this recently deposited daily cover material. As with the pre-cover sampling, two sites were randomly selected and duplicate samples collected at each. The samples were analysed in the laboratory by dynamic olfactometry using two different sets of panellists to improve the accuracy of the results. The geometric mean of the odour concentrations were used to determine the odour emission rate for both pre- and post-cover sections of the landfill.

Results and discussion

Residual background odour

Results from the residual background odour trials (Table 2) indicated a negligible passive odour from the possible cover materials at various moisture contents. The odour emission rates for the three sample materials were found to be low enough to be deemed negligible (Figure 1 and Figure 2).

There was no considerable difference observed in the odour produced from the samples from either of the material recovery facilities (MRFs). This would indicate that

there is no difference in odour generation from the materials as a result of varying source location. This is not surprising, particularly when considering the woodchip product, as this material is not influenced by its source location in the same way as the fines materials. The fines could potentially be influenced to a greater extent due to the fact that they contain constituent material which originates from its source location, soil for example. This creates the possibility for the source location to influence the behaviour of the material.

The results are positive for the use of these materials as daily landfill cover, as unlike other covers such as compost which can contribute to odour generation (Fischer et al., 2008; Nicolas et al., 2006; Sironi et al., 2007), these materials are relatively odourless in that regard. The results imply that there should be no issue either using or storing these materials on-site. While the moisture did have a minor effect on the materials, it seemed to be a positive one. The wetter the material got, the less odour produced. This would suggest that there should be no odour issues involved with the outdoor stock piling of the materials. It was noted that the woodchip odour emissions seemed to increase while it was left to air dry following saturation (Figure 2 in particular). However, the values recorded are still very low and not worthy of concern.

Cover composition trial

After reviewing the first week of results (Figure 3), it was decided to change the focus and the remit of the study. The trial focused on two particular cover compositions, that of pure woodchip, and combined C&D and woodchip layers. The main reason for this was to facilitate the collection of duplicate samples for improved accuracy. It was clear from the early results that, although the expected high value for the exposed plot bench mark failed to emerge, the odour emitted from the other plots was relatively low. This indicated that all cover compositions performed adequately at the applied depths,

which would support the EPA guidelines recommending a minimum cover of 300 mm for intermediate landfill cover (EPA, 2000).

From studying Figure 3 and Figure 4, it becomes apparent that apart from the odour peaks experienced on days eight and ten of the trial, the odour concentration values were emission rate of approximately $6 \text{ ou m}^{-2} \text{ s}^{-1}$. This is a very positive result for the site operator as it seems to suggest that the landfill is emitting little or no odour through its intermediate cover. The geomean odour emission rate calculated using these odour concentrations was $1.35 \text{ ou m}^{-2} \text{ s}^{-1}$. Although this is not solely attributable to the intermediate cover and its barrier effect, with gas extraction being another possible contributing factor, it does play an important role in the abatement of the landfill odour.

Plot 6 represents the plot which was filled in with a clay cover. Its performance in relation to the other plots can be seen from day eight to day fourteen in Figure 4. Clay is a traditional landfill cover and can also be used as a good bench mark for the performance of the possible alternative cover materials. From the aforementioned graph it can be seen that the clay plot (6) returned relatively low odour values. While the clay values seem to be lower than those from the other plots the difference is only marginal and proves that the alternative materials perform adequately well when compared to a traditional cover material. Samples collected to determine the moisture content (MC) of the materials on-site revealed WC and clay had average values of 60% and 20% (MC) respectively. The woodchip had the highest moisture content, which is not surprising considering its absorbent nature.

From examining Figure 4, it is clear that on occasions the exposed plot returned odour emission rates lower than that from the covered waste, which was the extreme opposite to what was expected. There are a number of possible reasons for these unusual results. Firstly, the low exposed waste reading could be a direct consequence of efficient extraction of the odorous gases from the test area by the landfill gas collection

system. The gas extraction system was under negative pressure drawing gas from the nearby well heads. Another possible explanation for the low exposed odour values could lie with the nature of the waste in the test area. From examination of the exposed area, it was evident that the waste present was mainly plastic, or other inert material, with little or no sign of putrescibles. Considering that this part of the landfill was not in active use during the trial, it is reasonable to expect that any putrescibles and organics which may have been present in the waste originally would have decomposed leaving the more inert material.

The exceptionally high odour emission rate (Figure 4) recorded for the second exposed plot (E2) on its first day of testing could be explained by the fact that this odorous gas had been trapped underneath the impermeable intermediate cover layer and was released when the cover material had been removed. Despite this unusual feedback, it was still obvious that the cover combinations tested were adequate as cover materials with very low odour emissions rates observed in general.

Pre-cover versus post cover analysis

From evaluating Figure 5, the beneficial effect to the application of daily cover with regards to odour abatement is quite evident. On average the total odour reduction due to the application of daily landfill cover on the working face is in excess of 50%. The application of daily cover significantly (P -value ≤ 0.05) reduces the odour emission. When the residual background odour generated by the woodchip is taken into account, then it is conceivable that the actual raw odour reduction is much higher and somewhere in the region of 100%. There was no significant difference between the woodchip background odour and that of post cover application. A similar Italian study (Sironi *et al.*, 2005) recorded a total odour reduction of approximately 80%. However, there are no reported results on the actual residual background odour from the clay cover material

used, which means that the actual raw waste odour reduction could in fact be much higher.

The unusually high spike in the pre-cover results could be due in part to a significantly higher presence of putrescibles in the waste being landfilled on that particular day. Normally, there was a reasonably low putrescible presence evident in the landfill waste. A similar situation was observed by Drew *et al.* (2007). Despite this peak, the post cover odour values seem to have been affected very little.

Conclusion

The background odour emissions from C&D, C&I and woodchip were considered negligible, even when moisture content was varied, suggesting the materials would not pose odour nuisance problems either in application or when stock piled. No significant difference was observed between materials from different locations, thus source location was not an issue either.

All intermediate cover compositions performed sufficiently in terms of odour abatement. Total odour reduction following application of daily landfill cover (50 mm C&D fines followed by 150 mm of woodchip) on the working face was in excess of 50% and virtually 100% when background odour was considered.

Acknowledgements

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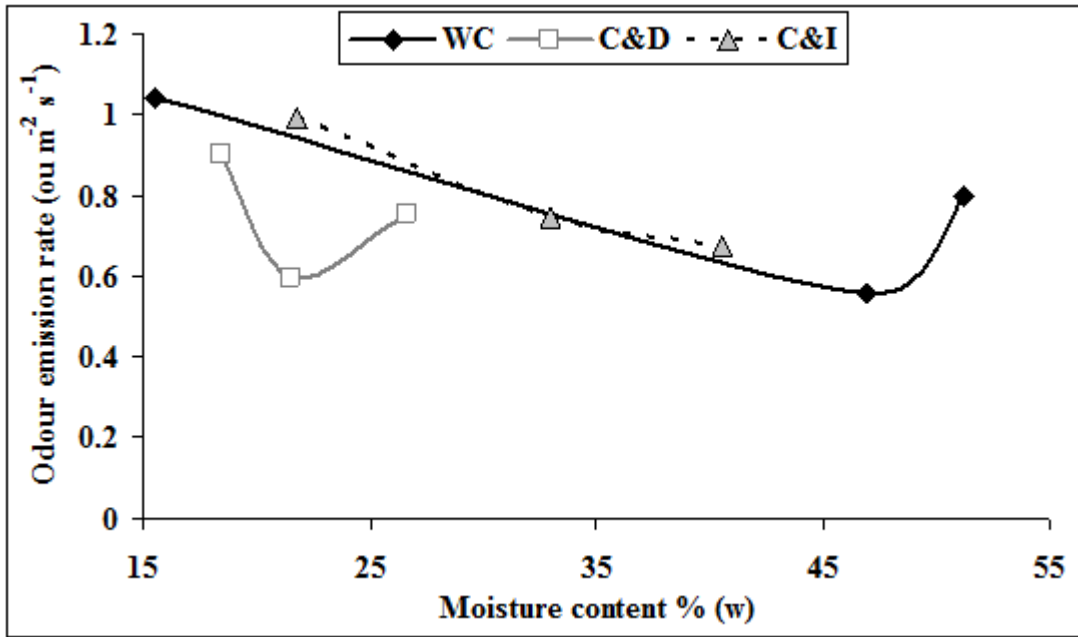


Figure 1. Moisture versus odour concentration relationship, Fassaroe

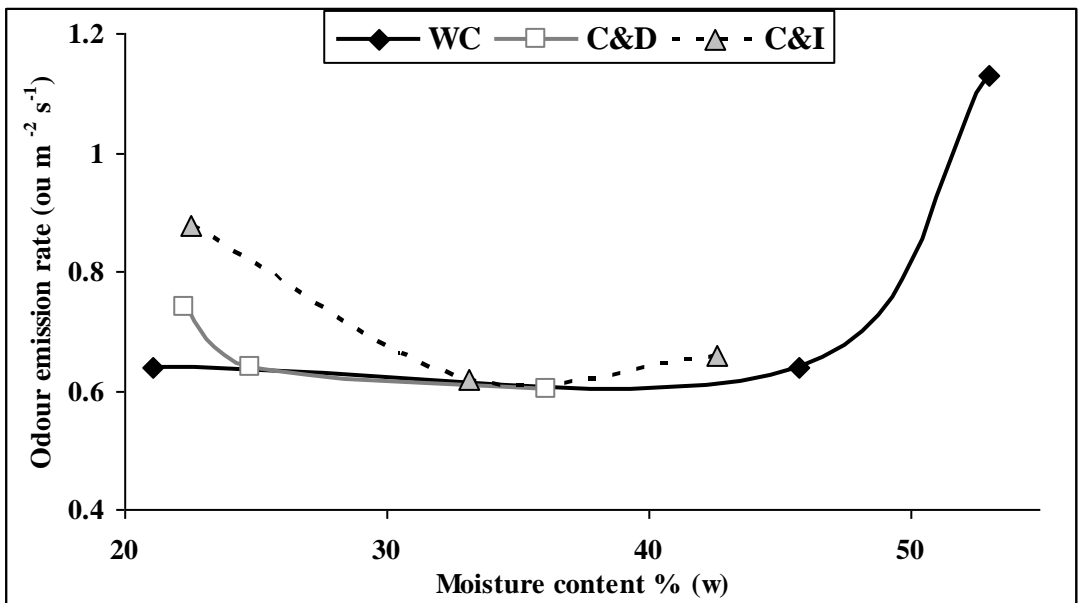


Figure 2. Moisture versus odour concentration relationship, Millennium Park

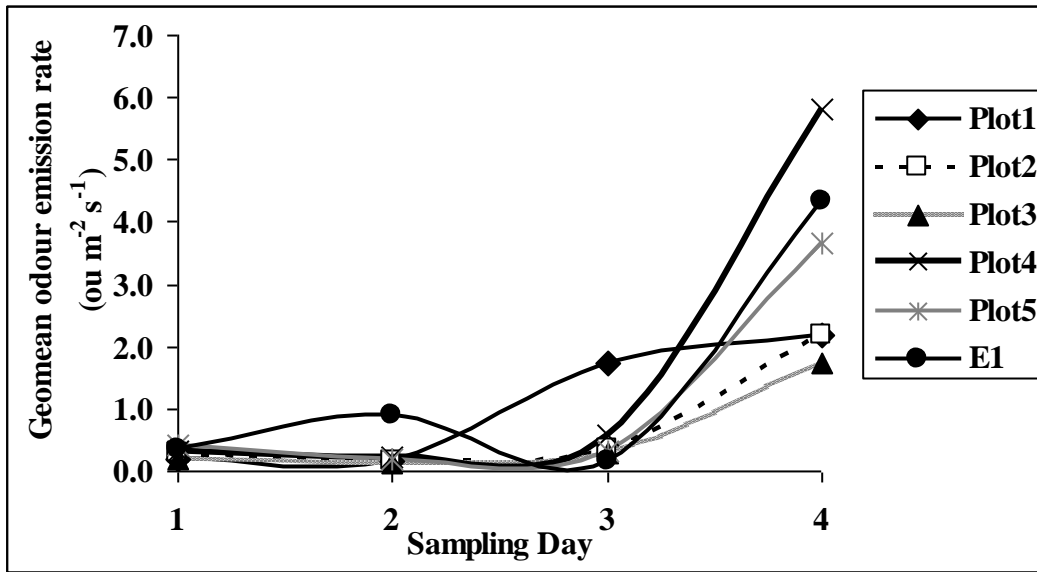


Figure 3. Odour emission rates for week one of cover composition trial

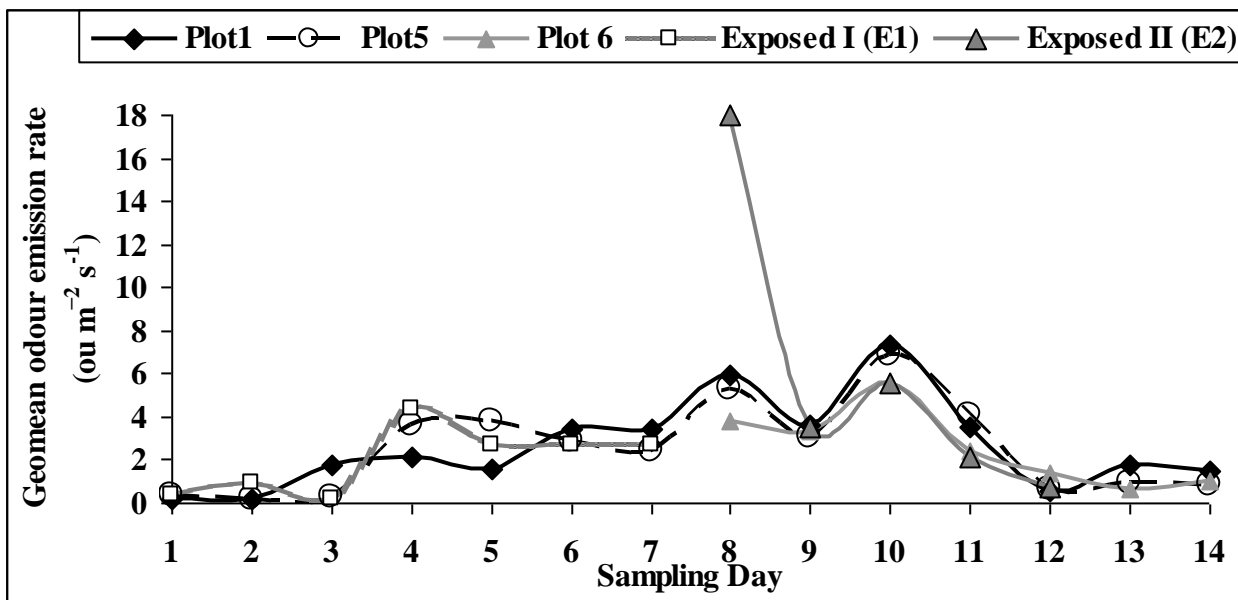


Figure 4. Geomean odour emission rates from the selected cover composition plots.

Table 1. Depth of cover material in trial plots

Plot	C&D (mm)	Woodchip (mm)	Clay (mm)	Total (mm)
1	0	300	0	300
2	50	150	0	200
3	50	200	0	250
4	100	200	0	300
5	50	250	0	300
6	0	0	300	300
E1	0	0	0	0
E2	0	0	0	0

Table 2. Residual background odour concentrations and emission rates (geomean)

Material	Source	Odour concentration (ou m⁻³)	Odour emission rate (ou m⁻² s⁻¹)
C&I	F.	52	0.79
	M.P.	46	0.71
C&D	F.	49	0.74
	M.P.	43	0.66
WC	F.	51	0.77
	M.P.	51	0.77

F. = Fassaro MRF

M.P. = Millennium Park MRF