Evaluating odour impacts from a landfilling and composting site: involving citizens in the monitoring

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Abstract The City of Montreal operates a large sanitary landfill site within a densely populated urban area. Adjacent to the landfill site is a yard waste composting facility that processes 10,000 metric tons per year using the windrow technique. Over the years, numerous complaints have been received from citizens in the surrounding area regarding odours, particularly during the fall period. Aware of this nuisance, the City of Montreal wanted to identify odour sources, management operations leading to odours, and weather conditions accentuating odours, as well as to quantify actual odour impact. Forty-three (43) citizens living adjacent to this site were recruited and trained to make odour observations during the fall of 2000. This paper presents the methodology used to select and train the citizens chosen to make odour observations, to quantify and to identify odours. It also presents the main results of the study.

Keywords Field olfactory; landfills; odour impact; odour monitoring

Introduction
The sanitary landfill and composting yard utilized for this case study is located within an abandoned limestone quarry situated on the Island of Montreal (Figure 1). It is surrounded by a densely populated urban area, containing 4,500 persons/km². The landfilling activities commenced in 1968; to date, some 75 ha have been utilized for refuse disposal (Figure 2). It is estimated that 36 million metric tons of refuse have been landfilled at this site, with depths ranging to 80 metres. Since the beginning of 2000, only dry solid waste from industrial or commercial sources is accepted at this site. The City of Montreal acquired the site in 1988 to improve environmental security and to ensure progressive closure.

As the site is located in an urban environment, an extensive gas collection system of 350 wells has been installed. Approximately 160 Mm³ of landfill gas (LFG) are recovered annually and conveyed to an on-site 25 MW power plant. The recovery rate represents approximately 90% of the estimated LFG production (Nastev, 1998). There is also an extensive leachate collection system leading to an on-site treatment facility. The treated wastewater is then pumped into the public sewer.

Along the west side of the landfill facility, City authorities have constructed a composting site (Figure 2). Every year, 10,000 metric tons of leaves and yard wastes are composted here. Of this, some 7,000 metric tons originate from the public domain (parks and roads) and are transported in bulk to this composting facility. The remaining 3,000 tons come from private property, citizens’ backyards, and are brought into the composting site in plastic bags. The peak period for arrival of this organic material is from mid-October through to the end of November.

The composting pad, with its crushed and compacted gravel surface, measures 80 metres by 540 metres long. Compost is made by the open air windrow technique. Windrows are turned frequently, using a tow-behind mechanical windrow turner. Prior to January
2000, the windrows were turned using a 3 m$^3$ front-end loader; as a result windrows were turned infrequently and this led to a problem of anaerobic conditions.

To handle leaves and other yard waste arriving in plastic bags, a debagging plant was constructed. This came on-line in January 2000. This plant processes 15 metric tons per hour, using a hammer-mill shredder followed by a manual sort to remove plastic and other impurities from the organic matter. Prior to the establishment of the debagging plant, bags were hand-opened in a long and labour-intensive operation. As a consequence of the time delay between bag arrival and opening, anaerobic conditions often prevail in the bags resulting in strong odours. Odour events were accentuated by the infrequent turning of the windrows. These conditions caused citizen complaints. This was noted especially during the last quarter of the year, when leaves are brought to the site and composting activities commenced.
For the landfill managers, it was obvious that the prime odour source was composting activities. It was felt that the implementation of the debagging plant along with the mechanical windrow turner would considerably reduce odour emissions. However, based on the information at hand, it was difficult to predict the odour potential and impact related to the composting site. Area residents had real fears that the level of odours would remain at the same level or escalate. Moreover, contrary to the landfill managers, a large proportion of citizens considered the source of odours to be the landfill itself (LFG, leachate treatment basin, landfill front, etc.).

Aware of citizen concerns, City administrators asked for odour monitoring. The main goals of this monitoring study were:
• to quantify real odour impacts of the composting facility when compost is made in accordance with established practices;
• to identify the various odour sources at the site;
• to identify the source, operation and/or atmospheric condition responsible for odour emissions.

This paper presents the methodology used to select and train the citizens to make odour observations to quantify and to identify odours. It also presents the main results from the study.

Selection of observers
There were specific objectives in selecting and training the volunteers:
• to draw a representative sample of the local population, being neither insensitive nor hypersensitive to the target odours;
• to involve citizens in the project and the main aspects of it;
• to explain the importance of their conscientious participation;
• to develop the observers’ capability to clearly distinguishing different odours, and particularly the key odours associated with the project;
• to help the observers to discriminate objectively different odour intensity levels, and to properly characterize the odour episodes.

In order to attain these objectives, the following methodology was developed.
• In a previous study, an atmospheric dispersion model for odours was used to determine an impact radius of 1,500 m as the most likely zone of critical exposure (Figure 2). This was confirmed using the global facility odour emission rate, whereby odours were evaluated using odour flux chamber sampling and olfactometric measurements.
• An invitation to a general information meeting was sent to some 20,000 residents living within the delineated 1,500 metre radius of the composting site.
• Presented at this meeting was the historical, contextual and operational information relating to the site. Similarly, the objectives and methodology of the study were clearly defined, as were the potential management ramifications of the findings on the future operations of the site. Volunteer assessors were solicited.
• At a training session for potential volunteer assessors, the general concepts relating to odour perception and weather conditions were discussed. Tests were conducted to eliminate insensitive or hypersensitive potential volunteer assessors. A detailed training session was conducted for the chosen volunteers with an olfactometer, to define the source and parameters of the different key odours involved. A ranking scale was introduced for odour intensity levels.

Care was taken with the selection of the volunteer assessors so as to obtain consistent and representative test results within the study area. The first preoccupation was to obtain an even distribution of volunteers within the area, as well as a representative population.
Time constraints imposed on volunteer selection and training lead to an odour perception threshold evaluation based on $n$-butanol to estimate odour sensitivity. The most convenient method was to use a static scale of butanol. The preparation and presentation of the $n$-butanol solutions were made in accordance to standard ASTM E 544 – 75. Ten $n$-butanol samples were presented to each volunteer. These sample series included two blanks of distilled water. Solution sample intensity of $n$-butanol ranged from 0.1 to 40 ppm in mixed order. The volunteer assessors had to correctly identify the samples in which the butanol was perceived.

Only the volunteer assessors perceiving a threshold between 0.5 and 30 ppm were selected for the next stage of evaluation. This range of acceptance was based on the prEN13725 recommendations for normal odour threshold to $n$-butanol (0.21 to 0.84 ppm equivalent in solution). However, the range of acceptance was wider than prEN13725 instructions indicated, due to the fact that: (a) static dilution was used in place of dynamic dilution, and (b) the volunteer assessors were not fully trained as yet. For most of the assessors, this was their first experience with olfactometry. Usually, odour perception of butanol in a static dilution method is higher than for a dynamic dilution method, due to the accuracy of the technique and the efficiency of presentation. For example, the ASTM E 544 – 75 states that the odour threshold for $n$-butanol in static scale is 2.5 ppm in solution.

The volunteers accepted at the stage of the perception threshold test went on to the intensity discrimination level test. This test was conducted to eliminate those unable to discriminate different intensity levels. This test was largely extracted from the section related to static scale presentation method within the ASTM E 544 – 75 standard. Ten samples of $n$-butanol solution were presented in an increasing order of a step factor of 2, doubled from 20 to 5,120 ppm. The volunteer assessors had to determine the corresponding odour intensity of two unknowns from the samples. A deviation of one rank in the scale was tolerated to accept potential volunteers.

The observers were then taught to recognize different odours: compost, biogas, rotten eggs, and MSW. Subsequent training utilized an olfactometer. Intensity evaluations of these specific odours were based on a scale of 0 to 5. As the study parameters were implemented for compost odour, the volunteer assessors were exposed to different dilutions of compost odour in specific decreasing sequence levels. The evaluation of the volunteers’ sensitivity to compost odour was made twice. Before their training, they were asked to refrain from smoking, chewing gum, eating spicy food, or drinking coffee or alcohol for at least 30 minutes prior to their tests. Of all the volunteers examined, 64% succeeded in both tests, and were qualified as observers.

**Odour observation and data management**

The time frame of this study was established to coincide with the influx of organic matter, leaves and yard waste, between mid-October and December 22, 2000. This time frame is important, as both composting activities and the majority of the odour complaints received occur within the last quarter of the year. Observers were required to make odour observations twice a day, between 6:00 and 9:00, and from 16:00 to 19:00, five days a week. These daily observation periods were chosen for their propensity to present the highest probability of obtaining stable weather conditions which are favourable for odour detection. The time periods were also chosen for the availability of most of the citizens at their residence before and after their work day.

During both daily observation times, observers were obliged to go out of their home to make their observations. Observations were taken at ground level, and always at the same place. An observation card with the following data was required to be completed:

- observer’s number;
- date;
• specific observation time;
• weather conditions;
• general health condition;
• odor intensity (0 = nothing, 1 = just perceivable, 2 = low, 3 = medium, 4 = strong and 5 = intolerable);
• type of odour (compost, landfill gas, MSW, rotten eggs, sewer, other “to be specified by the observer”).

There were three types of observation cards: a white one for the morning; a blue one for the evening; and a yellow one for special observations. If the observers detected strong odours at times outside the scheduled observation times, then they had opportunities to let the City know by use of the yellow card. This card differed from the others in the fact that the intensity scale had only the upper three ranks. If questions arose, then the observers could call a special telephone number listed on the cards. All questions were answered within a day.

The observation cards were post-paid and to be mailed. Hoarding of completed observation cards was discouraged, and it was requested that they be sent daily, or at least twice a week.

The time lag between dates of observation and receiving the cards was verified before the data was compiled and entered in the database. It was used to identify those who were not conscientious about their commitment. Only one observer had to be contacted to be reminded. All cards were received within ten days of the observation.

Preliminary results
A total of 4,323 observation cards were received. From this, 4,076 were regular observations. This response represents a participation rate of 97%. The participation rate was considerably higher than anticipated. The remaining 247 observations include 61 made on the special yellow cards, and 186 control observations made by two employees of the City who were specifically trained.

Odour events
Considering the various sources and intensity of odours, the findings indicate that detectable odour was evident in 24% of the time. It is important to note that observers felt healthy during 99% of their observations. As shown in Table 1, 51.3% of odours were just perceivable and odour of intensity of three and higher represents only 14.3% of the observations.

Data also indicates that, regardless of intensity, 46% of the observations were associated with compost odour. Landfill gases were identified in 22% of the observations as the detectable odour. Other odour sources were responsible for the remaining 32%, as listed in Table 2.

The distribution of intensity, from one type of odors to others is quite proportionally distributed. Independent of the source, events of intensity 4 or 5 have occurred in only 3.5% of the observations and compost odour was responsible for only 2.2%.

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Distribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: just perceivable</td>
<td>51.3</td>
</tr>
<tr>
<td>2: low</td>
<td>32.4</td>
</tr>
<tr>
<td>3: medium</td>
<td>11.1</td>
</tr>
<tr>
<td>4: strong</td>
<td>3.1</td>
</tr>
<tr>
<td>5: intolerable</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Table 1 Distribution of intensity when odours are perceived
Spatial distribution

When the study was planned, the impact radius was estimated to extend 1,500 metres from the center of the composting area (Figure 2). As mentioned earlier, this estimation was based on odour dispersion modelling using input of various weather conditions and measured odour emission rates.

Observations by the observers confirm this impact radius. However, as shown in Figure 3, odour impacts are much more significant within 500 m of the site. Within this radius, compost odour was low, with intensity ratings of 1 (just perceivable) and 2 (low) most frequently observed (Table 1). In the same figure, the compost odour of intensity 1 (just perceivable) is distributed relatively uniformly over distance and does not show the decrease of the other intensity curves. It may be deduced that because of the low odour intensity level observed, it was difficult for the observers to correctly identify the specific odour source. Moreover, during the study period, there were leaves still on the ground within the area where the observations were taken. Every fall, this natural leaf decomposition odour from yards and streets undoubtedly impinged on the odour observations made, particularly in relation to detection of an ambient compost odour.

Except for landfill gases, other detectable odours did not necessarily originate from the study area. These miscellaneous odours were well distributed throughout the 1,500 impact radius.

Discussion

The results of this study are preliminary, but they permit us to achieve the initial goal: to quantify real odour impacts of the composting facilities during the fall, when the potential for odour emissions is the greatest. Results also confirm, as anticipated, that the composting site is the prime source of olfactory nuisances. A total of 46% of the odour events were associated with composting activities, while LFG was identified 22% of the time.

To meet the other initial goals, there is a need for further data interpretation. The global odour emission rate for each composting operation must be quantified. For example, does the debagging plant create more odour emissions than the windrow turning operations. Some surficial odour emissions flux, measured during the observation period, will be used to answer this type of question.

In order to be able to minimize odour impacts, there is a need to establish the link between operational actions like windrow turning, weather conditions and odour events as observed.

By focusing the data interpretation, there will be a much better understanding of where odour management efforts must be applied to successfully reduce composting odour incidents.

<table>
<thead>
<tr>
<th>Type of odor</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle exhaust gas</td>
<td>7.9</td>
</tr>
<tr>
<td>MSW</td>
<td>7.5</td>
</tr>
<tr>
<td>Wood stoves</td>
<td>6.0</td>
</tr>
<tr>
<td>Rotten eggs</td>
<td>1.7</td>
</tr>
<tr>
<td>Sewage</td>
<td>1.7</td>
</tr>
<tr>
<td>Cooking</td>
<td>1.3</td>
</tr>
<tr>
<td>Paint</td>
<td>0.9</td>
</tr>
<tr>
<td>Other or not determined</td>
<td>5.0</td>
</tr>
</tbody>
</table>
Conclusion

From mid-October to the end of December 2000, five days a week, twice a day, 43 citizens have made odour observations around the City of Montreal’s landfill and composting sites. This period of the year is the most critical for odour emissions related to compost activities. The observers were chosen following a rigorous approach based on their capacity to detect specific odours and recognize odour intensity. They all live at a maximum distance of 1,500 metres from the centre of the composting site. Although data interpretation is incomplete, the following conclusions can be drawn:

- the citizens’ participation rate was 97%;
- the composting site is the primary source of odours, with 46% of detectable odour observations, followed by LFG which was responsible for 22% of the incidents;
- the odours from sources other than the City’s landfill and composting sites were higher than anticipated;
- the odour nuisances were not as important as speculated. Independent of the source, events of intensity 4 or 5 have occurred in only 3.5% of the observations (compost odour was responsible for only 2.2%);
- the impacts from the composting site were significant within a radius of about 500 m.

With additional data analysis, it is expected that a better understanding of the link between weather conditions and operational actions will lead to odour management procedure for reducing the impact of the facility on the neighbouring residents.

References
