ODOUR IMPACT AND CONTROL AT A LANDFILL SITE IN HONG KONG

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Abstract

In Hong Kong, landfill dumping has been a main approach for municipal solid wastes disposal and will be continued in the near future. However, gaseous emission from municipal waste may causes offensive odours and disturbs the neighbours around landfill sites. Usually there are not enough buffer zones between landfill sites and the nearest sensitive receptors due to a land restriction in Hong Kong. In this study, a comprehensive investigation about odour pollution impact from a local landfill site was performed, in which a local landfill site was selected as an odour emission source to study its odour pollution impact to the surrounding areas and also identify its major characteristics. The investigation was conducted with three approaches of olfactometry with a dispersion modelling, odour patrol monitoring, and application of an e-nose technique. The odour pollution impact with reference to the criteria proposed by the Hong Kong Government was assessed based on the results of grap sampling and the previous 5 years weather data. A "Factor of Two" method is recommended to assess the odour impact based on the olfactometry results. Electronic nose analysis indicates that the odour in the boundary area of the landfill site has a similar nature to municipal wastes including the waste sludge from conventional biological treatment processes, municipal refuse from residential areas and construction wastes, but a different nature to some chemical wastes including the sludge from a chemically enhanced precipitation process, and some industrial wastes

Introduction

Odour effects from a variety of sources are causing a growing number of public complaints and concerns throughout the world. Whilst the community has always had to live with odours, it appears that many people have been becoming more sensitive to the issue, and requiring greater controls and mitigation measures on odour sources (1, 2). In Hong Kong two main reasons include the maturing of the regulation in odour pollution control and the high awareness of environmental quality, a feature of the Hong Kong environment which is of high social and economic value. However quantitative assessment of odour effects remains a significant problem. Despite world-wide efforts, it is still remarkably difficult to: (i) measure odour, (ii) determine its transport in air, and (iii) predict any effects. This is particularly a problem when trying to license a new development site which may produce odours. In Hong Kong, landfill dumping has been a main approach for municipal solid wastes disposal and will be continued in the near future. However, gaseous emissions from municipal waste cause offensive odours and affect the neighbours around the landfill sites. Usually there are not enough buffer zones between landfill sites and the nearest sensitive receptors due to a land restriction in Hong Kong. In this study, a comprehensive investigation about odour pollution impact from a local landfill site was performed by applying olfactometry analysis with dispersion modelling, odour patrol and also an electronic-nose (E-nose) technique. The final assessment of the predicted odour concentrations was carried out with reference to the criteria proposed by the Environmental Protection Department (EPD) of Hong Kong Government.

Olfactometry for odour measurement

So far, olfactometry remains the most practical technique for auditing and process optimization, and will continue to be needed for odour impact assessment and design of odour treatment systems. A local landfill site was selected as an odour emission source to study its odour pollution impact to the surrounding areas and also identify its major characteristics. The investigation was conducted with three approaches of olfactometry, dispersion modelling, and application of an E-nose technique. Three main tipping areas within the landfill site were identified as main odour emission sources and odour gas samples were collected during a dumping operation period by using an odour sampling system, which includes a battery-operated air pump, a sampling vessel, and nalophane^{NATM} odour bags. About 60 L of foul gas was collected for each of odour samples. A wind tunnel was also employed in this sampling work and the collected odour samples were analyzed by an olfactometer (Olfactomat-n1) which follows a new European Standard Method (EN13725) to determine odour concentration. Three odour samples collected from the three tipping areas of the landfill site were transported to our odour research laboratory and analyzed by the olfactometry method on the same day, in which 6 qualified panellists participated in the odour testing session, who were previously selected through screening tests by using a 50 ppm of certified n-butanol gas as a standard odour material. The results of odour concentrations are shown in Table 1.

Table 1. Odour Strength at the Tipping Areas of the Landfill Site

Sample	Odour concentration (ou/m^3)
Tipping Area 1	949
Tipping Area 2	367
Tipping Area 3	262
Geometric Mean	450

The source odour emission rate (SOER) at this area source can be calculated as follows:

$$\text{SOER} = \frac{\text{Odour concentration (ou/m}^3\text{) x Wind speed (m/s) x Cross section area (m}^2\text{)}}{\text{Covered surface area (m}^2\text{)}}$$

$$= (450\ \text{ou/m}^3) \times (0.23\ \text{m/s}) \times (0.405\text{m} \times 0.25\ \text{m}) / (0.79\ \text{m} \times 0.405\ \text{m}) = 32.7\ \text{ou/m}^2\text{/s}$$

The effective area of the whole tipping area in operation was estimated to be 20,727 m^2. The US-ISCST complex model was applied to predict the odour dispersion at the surrounding area of the landfill site. In the meantime, 5-year weather records were obtained from the nearest HK Observatory Station. Based on the odour measurement results and weather data, the dispersion contour of odour concentration around the landfill area was calculated by a US-ISCST complex dispersion model to predicate the worst case during a year. Based on the results of modelling work, the odour contour maps with different time intervals are shown in Fig. 1 and the odour pollution at the surrounding area was evaluated against the EPD criteria of 5 ou/m^3.

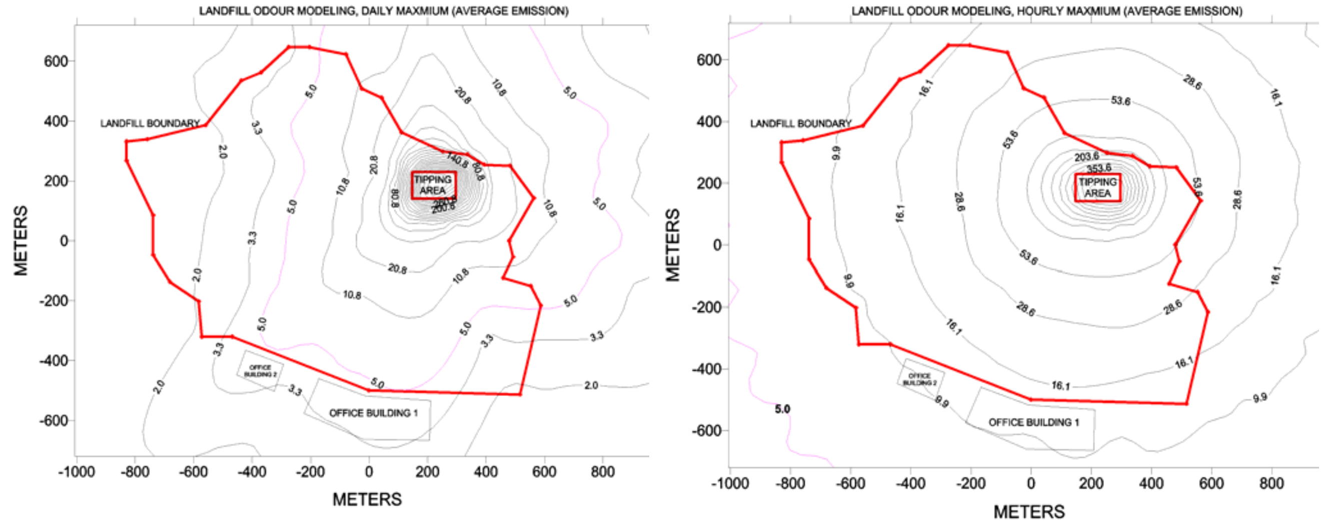
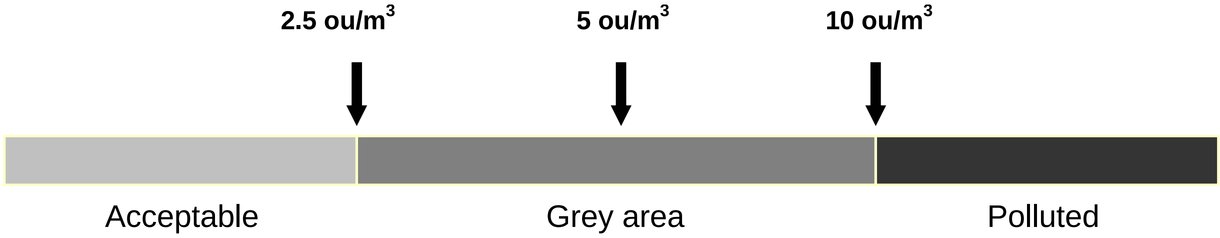


Figure 1: Odour dispersion contour at the surrounding area of the landfill site

Odour impact assessment

The odour impact in this study was assessed based on the results of olfactometry and the previous 5-year weather data. It can be indicated that odour concentration at the nearest air sensitive receivers (Office Buildings 1 and 2) of the landfill site is always below 5 ou/m^3 with a chance of 99.99% based on the yearly, monthly and daily average weather data, and odour concentration at the boundary of the landfill site is higher than 5 ou/m^3 with a chance of more than 0.01%, based on the hourly average weather data. However, it may not be a good approach by simply applying the “pass” and “fail” attitude in the practice of odour impact assessment. The concentration component of the odour modelling guideline gives the indicative level of odour nuisance, but that any concentration predicted by the model within a factor of two of the boardline may not indicate whether adverse effects will occur. For example, the concentration component of the odour modeling guideline in Hong Kong is 5 ou/m^3. If the model results were less than 2.5 ou/m^3, then it could be concluded with more confidence that no significant adverse effects would occur. Similarly, if the model results were greater than 10 ou/m^3, then it could be concluded that significant effects were more likely to occur (subject to assessment of the sensitivity and conservatism in model results). However, if the model results fell into the “grey area” range between 2.5 and 10 ou/m^3, then the evaluation process would need to rely more heavily on a subjective assessment of the model results, and other methods in the evaluation “toolbox” to assess the potential for adverse effects.

It should be noted that the “factor of two” proposed above has been selected somewhat arbitrarily based on the authors’ experience, and that it is the philosophy of the approach, rather than the actual definition of the “grey area” range. Some case studies have been examined using this approach and the factor of two appears to be appropriate. However, as this methodology is implemented, the factor of two may be modified to fit with further case study information as it becomes available.



When interpreting dispersion model results as described above, the sensitivity of the model results to changes in the input data assumptions, and the amount of conservatism in that input data should be considered. Aspects include: (i) odour emission rate data used – source of data, use of variable or worst-case emissions, offensiveness of odour type; (ii) land use and occupation where adverse effects are predicted to occur – population density, sensitivity of receiving environment, time of day when adverse effects occur; (iii) model algorithm assumptions – dispersion coefficients, use of surface roughness factors, other model settings; and (iv) meteorological file used – use of appropriate site-specific files, influence of calm conditions. By considering these factors, a judgment of whether the model results indicate any adverse effects can then be made. Any significant uncertainty in the input factors will be reflected as uncertainties in the modelling outputs. This should be considered in determining if a modelling approach is appropriate to any particular application.

Odour patrol monitoring

An odour patrol monitoring program was carried out at the boundary of the landfill site, in which 6 monitoring locations on the boundary were identified and three qualified panelists from PolyU conducted the field inspection on a daily basis for 30 days. The panelist needs to assess the odour intensity around the boundary of landfill site at 5 different levels from 0 to 4 in accordance with the EPD criteria as follows:

0	Not detected	No odour perceived or an odour so week that it can not be easily characterised or described
1	Slight	Identifiable odour, slight
2	Moderate	Identifiable odour, moderate
3	Strong	Identifiable, strong
4	Extreme	Severe odour

The panellists had their average individual n-butanol thresholds in the acceptable range of 20 to 80 ppb/v. One of the panellists conducted the on-site assessment each day alternatively at a time randomly scheduled between 9:00 - 17:00 for a month. During each odour assessment, weather conditions were also recorded as relevant information. The odour patrol monitoring results are expressed in Tables 2 and 3. The results indicate that odour intensity at all the monitoring locations were not higher than Level 2, unless only once the odour intensity at Location 3 was between 2 and 3 with a low percentile of 3.3.

Table 2 Average odour intensity during 3 April – 2 May 2003

Location	Monitoring period	Range of odour Intensity	Mean of odour intensity
1	3 Apr. – 2 May 2003	0-1	0.13
2	3 Apr. – 2 May 2003	0-1	0.18
3	3 Apr. – 2 May 2003	0-3	0.23
4	3 Apr. – 2 May 2003	0-1	0.28
5	3 Apr. – 2 May 2003	0-2	0.52
6	3 Apr. – 2 May 2003	0-2	0.53

Table 3 Percentile of odour intensity (%) during 3 April – 2 May 2003

Location	Range of odour intensity				
	0 and above	1 and above	2 and above	3 and above	4 and above
1	100	3.3	0	0	0
2	100	0	0	0	0
3	100	3.3	3.3	0	0
4	100	6.6	0	0	0
5	100	30	0		0
6	100	33	0	0	0

Electronic nose for odour measurement

Recently, so-called electronic nose or artificial nose has been introduced to the odour research, which was originally applied in food industries to identify the quality of food products. The main principle of these technique is to use an array of solid state sensors combined with neural network software to analyse the signals. To identify the characteristics of different odour sources, odour samples were collected from different incoming vehicles to the landfill site, respectively, which represent different odour sources such as sludge from sewage treatment works, municipal wastes and construction wastes. The samples from known sources were first analyzed by an e-nose (Alpha MOS - FOX4000) to record their odour characteristics as finger prints. Some odour samples collected at the boundary of the landfill sites as unknown samples were also analyzed by the e-nose. The odour patterns between individual known samples and unknown samples were statistically recognized by comparing their similarity index (SI) with a purpose of identifying the major odour emission sources which contribute to the odour pollution.

Table 4 Odour Samples Collected from Different Waste Sources

ID of samples	Waste sources
B1, B2, B3, B4, and B5	Boundary of the landfill site
S1	Biological sludge wastes from a sewage treatment works
S2	Domestic refuse from residential districts
S3	Chemical sludge wastes from a primary treatment works
S4	Industrial refuse from private sectors
S5	Feces wastes
S6	Construction wastes
T1, T2 and T3	Tipping areas

While 5 odour samples were collected at the boundary of the landfill site, 9 odour samples were also collected from the incoming waste vehicles which came from different waste sources including the sludge from sewage treatment works, municipal wastes, construction wastes and also at the tipping areas of landfill site, respectively. A total of 14 samples are summarized in Table 4.

Table 5 Summary of SI between Boundary Samples

No. of boundary sample	No. of boundary sample	SI	Averages
1	2	15	14.25
	3	26	
	4	11	
	5	5	
2	1	15	22.25
	3	40	
	4	23	
	5	11	
3	1	26	29.75
	2	40	
	4	22	
	5	31	
4	1	11	17.5
	2	23	
	3	22	
	5	14	
5	1	5	15.25
	2	11	
	3	31	
	4	14	

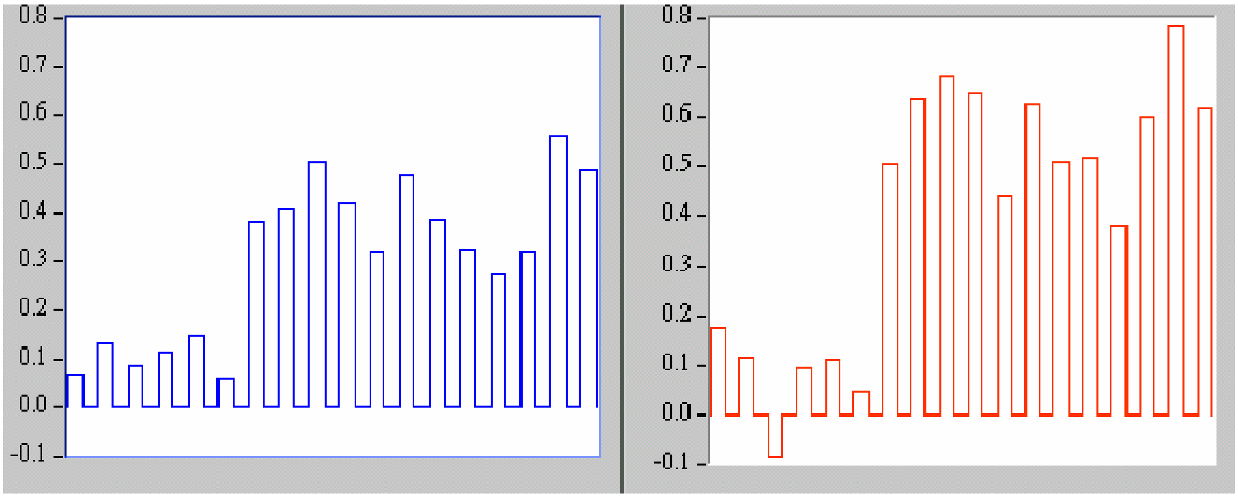


Figure 2: B1 vs. S2 (Domestic refuse from residential districts) (SI = 38)

All samples were analyzed by using the electronic nose to identify the odour patterns and a set of similarity index (SI) were figured out by the e-nose system software. The odour patterns and SI between background samples are shown in the following figures and also summarized in Table 5. The results indicate that all SI values are in the range of 5-40. The sample of Boundary 1 had the least average SI value of 14.25, which should be the most representative sample among the 5 boundary samples. To investigate the effects of different source wastes on the atmosphere in the boundary samples, the second set of similarity analyses was also carried out, in which Boundary 1 sample was used to be compared with other source samples. The results about the similarity analyses are shown in Figs 2 and 3, and also summarized in Table 6.

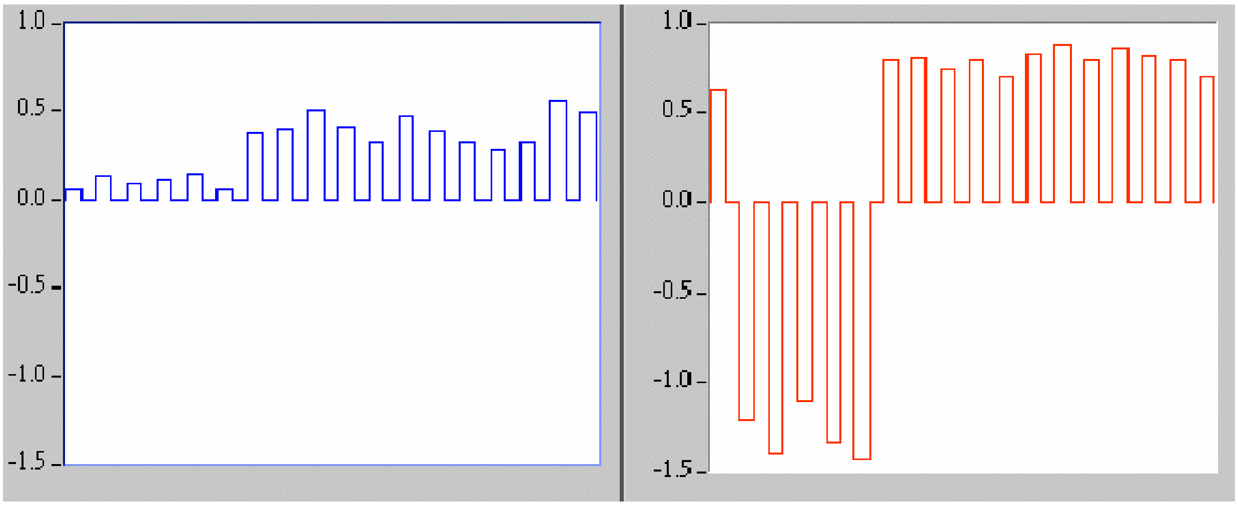


Figure 3: B1 vs. S4 (Industrial wastes from private sectors) (SI = 140)

Table 6 Summary of IS between Boundary Samples and Sources Samples

Samples	SI	Comments
B1 vs. B2	15	Similar pattern
B1 vs. B3	26	Similar pattern
B1 vs. B4	11	Similar pattern
B1 vs. B5	5	Similar pattern
B1 vs. S1 (Biological sludge waste)	32	Similar pattern
B1 vs. S2 (Municipal residential refuse)	38	Similar pattern
B1 vs. S3 (Construction wastes)	23	Similar pattern
B1 vs. S4 (Chemical sludge waste)	165	Different pattern
B1 vs. S5 (Industrial wastes)	183	Different pattern
B1 vs. S6 (Feases wastes)	140	Different pattern
B1 vs. T1 (Tipping area 1)	64	Not defined
B1 vs. T2 (Tipping area 2)	37	Not defined
B1 vs. T3 (Tipping area 3)	73	Not defined

The above results may indicate that the odour in the boundary area of the landfill site has a similar nature to municipal wastes including the waste sludge from a conventional biological treatment process, municipal residential refuse and construction wastes, but a different pattern to some chemical wastes including the sludge from a chemically enhanced precipitation process and some industrial wastes.

Minimization of odour emission from landfill operation

As landfills become more sophisticated and take on the role of massive waste to energy bioreactors (methanogenic digesters), the demand for odour management will become more critical. The principles which need to be adopted are to minimize the number of sources of odour generation which exist on site; undertake direct management of those sources which can give rise to problems; ensure natural attenuation is available for those emanations which cannot be directly managed. The mitigation of odour can be achieved by the followings:

Appropriate Daily Cover

Daily cover is best comprised of mulched woody material (MWM) and earth mixtures in 50% by weight mixture. This material has been shown (3, 4) to be permeable but with some capacity to retain water; to be adequately traffic bearing, to be non combustible, heavy and abbrasive enough to prevent litter problems and to behave as a highly effective biofilter with respect to odour (50-70% reduction). This material is also readily available at landfill sites and 300mm thick layers adds to the gas generation potential and energy recovery value of the site long term. Some low permeability interim cover does need to be used to make gas harvesting close to the active face more efficient, but this material can be recovered from above the MWM/earth mixture for reuse quite readily.

Minimizing Fresh Waste Exposure

Current practices involve cover removal, followed by waste unloading, spreading and compaction using the smallest area possible. Inevitably “Bin Odours” are released in this process and odour flushing occurs due to gas release. These odour releases can be mitigated by progressively spreading mulched woody material/earth mixture and compacting it along with the waste, with a final top up at day end. In this way a biofilter is established rapidly which does not impede compaction on the face or spreading, but odour is mitigated.

Other Opportunities

Most other odour mitigation measures are common sense. They include: avoiding parking full waste vehicles on site overnight; providing vacuum venting on leachate sumps and drains; direct recycling leachate from sumps to sub cover reinfiltration in bioreactor landfills or to sewer; providing close monitoring and maintenance of gas harvesting systems and flares; avoiding excessively clayey final cap material or other material prone to dessication or settlement cracking, or provide for a moist biologically active attenuation capacity in the vegetation layer; washout of vehicles and their substructure to reduce on road vehicle odour; avoidance of odour masking agents which merely reinforce noticeable odour occurrence.

Conclusions

It is clear that any progress in odour control policy from a ‘no nuisance’ approach to a quantitative regulation needs a sound odour monitoring procedure with an acceptable compatibility between the odour police and measurements. The odour impact in this study was assessed based on the results of grap sampling and the previous 5 years weather data. Odour concentration at the nearest sensitive receivers of the landfill site is always below 5 ou/m^3 with a chance of 99.99% based on the yearly, monthly and daily average weather data. Odour concentration at the nearest sensitive receivers of the landfill site is higher than 5 ou/m^3 with a chance of more than 0.01%, based on the hourly average weather data. A "factor of two" method is recommended to assess the odour impact based on the olfactometry results. Electronic nose analysis indicates that the odour in the boundary area of the landfill site has a similar nature to municipal wastes including the waste sludge from conventional biological treatment processes, municipal refuse from residential areas and construction wastes, but a different pattern to some chemical wastes including the sludge from a chemically enhanced precipitation process, and some industrial wastes

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