CASE STUDIES IN THE USE OF SOURCE SPECIFIC ODOUR MODELLING GUIDELINES

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ABSTRACT

Two case studies are compared where source specific odour modelling guidelines have been used: odour emissions from a new brewery and odour from stabilised wastewater biosolids proposed for use in a quarry rehabilitation. In the case of brewery odour, two odour modelling guidelines were used to assess the effects of the proposed brewery operation on a green-field site: 8 OU/m³ at the 99.5th percentile and 6 OU/m³ at the 98th percentile. These guidelines were selected based on published guidance in the United Kingdom which demonstrates that industries with more offensive odour have a different odour exposure criteria than those with lower offensiveness. For an assessment of digested, stabilised biosolids covered with topsoil, a modelling guideline of 6 OU/m³ at the 99.5th percentile was proposed, based on a dispersion modelling calibration and field observations of a similar existing operation. The two case studies show that there is no single odour standard or guideline that will fit all processes and types of odours. The "one size fits all" threshold which assumes all odours have the same nuisance threshold is shown to have limitations, in particular, when assessing effects of odours which may not normally be considered offensive.

KEYWORDS

Dispersion modelling, hedonic tone, modelling guidelines, odour, offensiveness

1 INTRODUCTION

Odour annoyance has become a major environmental issue among neighborhood communities, councils and national governments around the world. The effects of odour emissions are assessed for a number of reasons, including the investigation of odour complaints and in resource consent applications. For a new activity in a new location, an assessment of effects must be based on either dispersion modelling results or past experience with the same activity in other locations. For existing activities, dispersion modelling predictions of odour impact are less useful and data from the community such as complaints history or odour surveys is more relevant.

Odour is described using odour units (OU) and is measured through olfactometry, which expresses the intensity of an odour as a concentration in odour units (OU/m³). One of the most common odour impact assessment techniques use measurements of source odour emission rates (based on dynamic olfactometry), simulation of local meteorological conditions and dispersion modelling, to estimate odour impacts. Dispersion modelling enables predictions of how far and at what concentration air quality contaminants, in this case odour, travel and disperse. Having determined the predicted ground level concentrations at a location or sensitive receptor, this is then compared to a numerical guideline, called an odour modelling guideline, to assess whether the level predicted is acceptable or not.

For regulatory purposes in New Zealand, there are two general types of atmospheric dispersion models used:

- Steady state Gaussian-plume models such as AUSPLUME, ISCST3.
- Advanced models such as CALPUFF and The Air Pollution Model (TAPM).

The most easily used dispersion models are the Gaussian models, although the trend is increasingly towards the use of the advanced models. The use of advanced models avoids most of the limitations of the steady state models (MfE, 2004).

1.1 WHAT IS AN ODOUR MODELLING GUIDELINE?

Odour modelling guidelines are the threshold against which dispersion model results are compared to determine whether adverse effects are likely. Odour modelling guidelines usually contain two components; a concentration, and a percentage compliance (for example, 'odour concentration shall not exceed X OU/m^3 for more than Z% of the meteorological conditions'). The values of X and Z are determined for each individual situation, and are set to represent the qualitative standard of 'no offensive or objectionable odour'. The percentile frequencies most commonly used in New Zealand are 99.5 and 99.9.

The dispersion model calculates odour concentrations at every receptor on the modelling domain for every hour of the meteorological data. In the case of a 12-month meteorological data set, the model stores 8,760 concentration data records for each receptor. If the 99.9th percentile results are required, the model calculates the 99.9th percentile of the hourly concentration data at each receptor point (i.e. the 9th highest concentration at each point), and this is the output concentration for that receptor. Similarly, if the 99.5th percentile results are required, the 44th highest concentrations are extracted.

The potential for adverse effects from exposure to odour depends not only on the very highest odour predictions (i.e. the 99.5th or 99.9th percentile) but also on the frequency of occurrence of lower intensity odours. This can drive the potential for an odour to cause a chronic effect due to long term odour exposure. The assessment is further complicated by the influence of odour offensiveness and the time of day when the odour occurs.

1.2 NEW ZEALAND GUIDANCE ON ODOUR MODELLING GUIDELINES

The first odour modelling guidelines used in New Zealand were developed in the early 1990s. At that time, a level of 2 OU/m^3 (99.5th percentile) was widely regarded as the threshold for odour nuisance effects for wastewater treatment plants, using Gaussian dispersion models. Subsequently, there was considerable debate in the late 1990s regarding appropriate modelling guidelines, which resulted in the Ministry for the Environment (MfE) developing the Good Practice Guide for Assessing and Managing Odour in New Zealand (MfE 2003). These guidelines have in turn been adopted by some Regional Councils.

The guidance document (MfE 2003) gives general guidance for odour modelling guidelines, as summarised in Table 1.

Table 1: Odour modelling guidelines recommended in MfE, 2003.

Sensitivity of the receiving environment	Concentration	Percentile not exceeding concentration
High	2 OU	99.9% and 99.5%
Moderate	5 OU	99.9% and 99.5%
Low	5-10 OU	99.5%

The concentrations in Table 1 are intended to be used as design ground-level concentrations for one hour modelling averages. The percentile factor in the right-hand column of Table 1 allows for a small level of exceedance of the predictions, to account for worst-case meteorological conditions at which objectionable effects are unlikely because the conditions occur infrequently.

The guidance document (MfE 2003) recommends using the 99.5th percentile as the baseline percentile for odour assessment, although for sensitive receiving environments the 99.9th percentile should also be used to assist in the evaluation of model results. In addition, MfE (2002) recommends that the use of the 99.9th percentile would be better than the 99.5th percentile when the source operates intermittently and less than 50% of the time, because the infrequent peak impacts of odour in such cases can be the main driver of nuisance.

1.3 SOURCE SPECIFIC MODELLING GUIDELINES

Use of source-specific odour modelling guidelines is an approach accepted in the guidance (MfE, 2003), where it is recommended that other guideline values can be used on a case-by-case basis where they are justified for specific odour sources. The use of a source-specific guideline may be appropriate in the following cases:

- when the hedonic tone of the odour is rated as pleasant or neutral
- when emission rates are high and preliminary modelling results indicate a level of effect that intuitively seems overly conservative
- when the sensitivity of the receiving environment is rated as moderate or low.

2 ODOUR ANNOYANCE

2.1 HOW DOES AN ODOUR CAUSE ADVERSE EFFECTS?

Under the Resource Management Act 1991, the main concern with odour is its ability to cause an effect that could be considered offensive or objectionable. However, not all odours have the same potential to cause annoyance. The offensiveness or hedonic tone of an odour is a subjective or qualitative aspect that relates to its pleasantness or unpleasantness.

The main factors that influence whether a person finds a particular odour a nuisance or an annoyance are the well known "FIDOL" factors of odour:

- Frequency (F): how often does the person experience the odour either as detectable, recognisable or annoying?
- Intensity (I): how strong a response in an individual/community will the odour invoke?
- Duration (D): how long does the odour last within a short time period?
- Offensiveness/character (O): how pleasant or unpleasant is the odour to an observer or community (i.e. the hedonic tone).
- Location (L): where was the person when the odour was observed?

The "L" factor accounts for the type of activity the person is engaged in, and the sensitivity of the receiving environment. These aspects determine the likelihood of a person being adversely affected to the point where they find an odour to be offensive or objectionable.

Essentially, for a person to be adversely affected by odour, the odour must occur frequently enough, for long enough, and at sufficient intensity and unpleasant character, so that the odour is offensive or objectionable.

Different combinations of these factors are significant when assessing adverse effects. Depending on the severity of the odour event, one single occurrence may be significantly adverse and this is known as an "acute" odour effect. However, in other situations, where there is a higher frequency of odorous events the threshold odour level would be lower. This longer term impact is known as a "chronic" odour effect.

2.2 ODOUR OFFENSIVENESS

Offensiveness or "hedonic tone" is a subjective or qualitative aspect of an odour, relating to its pleasantness or unpleasantness. The differentiation between an odour being "pleasant" or "unpleasant" (i.e. the hedonic tone) is not incorporated into environmental standards or guidelines in New Zealand. In the United Kingdom for example, installation-specific odour guidelines have been developed which are based on a number of factors, including the relative hedonic tone. This United Kingdom guidance is discussed in more detail in the first case study (section 3).

Research has also been carried out in Europe over the last 20 years to quantify the quality of an odour and to compare different odorants according to their hedonic tone. The VDI (Verein Deutscher Ingenieure), also known as the Association of German Engineers, developed methodology standards for the quantification of the intensity of an odour, and the hedonic tone of an odour. Hedonic tone measurement is defined in VDI 3882(II) (VDI, 1994). This gives an expression of the relative pleasantness or unpleasantness of different odour samples, at predetermined concentrations. The scale used is given in Table 2.

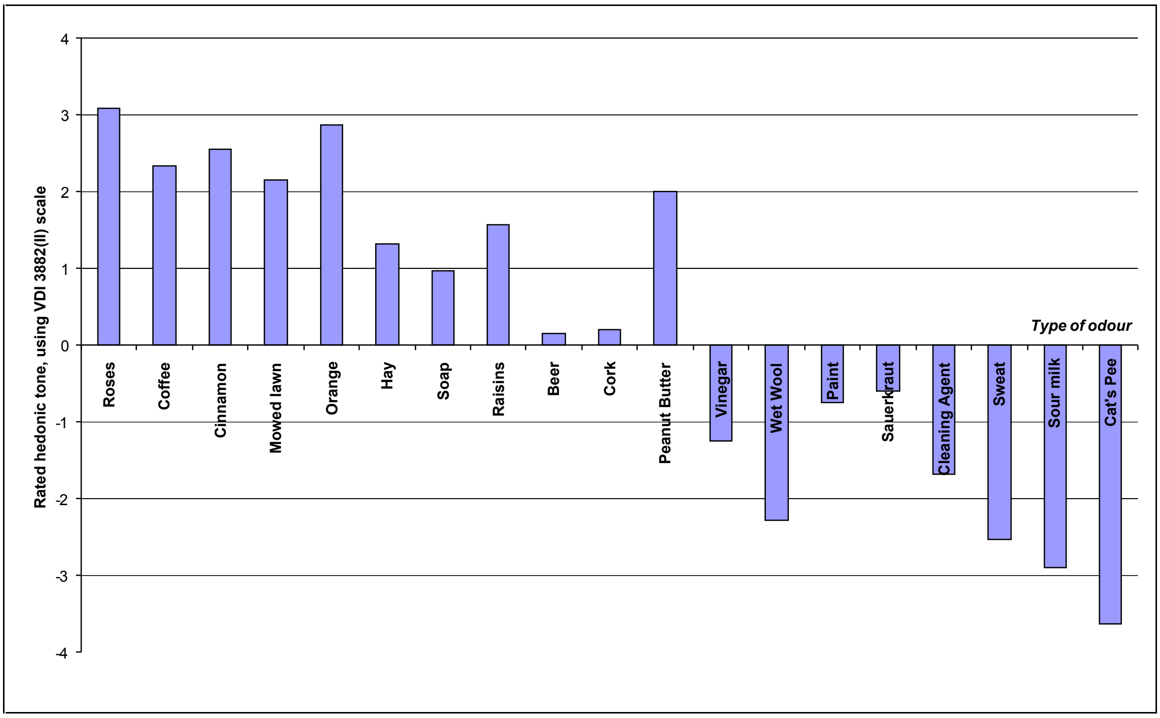
Table 2: Scale for odour hedonic tone (VDI, 1994)

Odour	Hedonic Tone Rating
Extremely unpleasant	-4
	-3
	-2
	-1
Neither pleasant nor unpleasant	0
	+1
	+2
	+3
Extremely pleasant	+4

These scales serve to illustrate the widely recognised issue of the intensity and hedonic tone of an odour and the importance of these factors in assessing the risk that an odour will cause a nuisance downwind.

As an example of hedonic tone ratings in practice, Figure 1 shows a comparison of the hedonic tone of various odour sources, from an Integrated Pollution Prevention and Control (IPPC) guidance document from the United Kingdom (Environment Agency, 2002a). In this report, emissions from the brewing of beer for example were found to have a hedonic tone rating of 0.14 and can therefore be regarded as a neither pleasant nor unpleasant odour.

Figure 1: Hedonic rating of odours. Source: Environment Agency (2002a)



3 CASE STUDY 1: ODOUR EMISSIONS FROM BEER BREWING

3.1 BACKGROUND

NZ Breweries Ltd (Lion) is developing a new integrated beverage manufacturing facility comprising the relocation of three existing operations: the Khyber Pass brewery in Newmarket, offsite warehousing and the Contract Bottling Company, to a new single "green field" site, presently undeveloped, in Manukau. The new site is scheduled for completion prior to the Rugby World Cup in 2011.

On behalf of Lion, the authors of this paper carried out the assessment of the air quality impacts of the proposed new facility in support of the resource consent application to discharge contaminants to air. The air discharge consent was granted in March 2009.

The assessment of potential odour effects at the new site was able to draw upon the significant history of operation at the existing Khyber Pass Road site as well as two other brewery sites. The Khyber Pass site had been in operation for more than 100 years in a part of central Auckland that has become a densely populated mixture of commercial and residential land uses.

3.2 ODOUR FROM THE BREWING PROCESS

3.2.1 PROCESSES LEADING TO ODOUR EMISSIONS

There are a number of processes at a brewery which have the potential to be a source of odour however the largest and most significant source is the evaporation of volatile organic compounds from the brewing activities. Odour discharged from the wort kettle during the brewing process was considered to be the most significant source of odour from the site.

The wort boiling stage is when a dissolved sugar and water mix (known as wort) is boiled in the kettle to develop colour and flavour, in a process that takes approximately 60 minutes. It takes approximately thirty minutes to heat the wort to boiling temperature, after which, hops are added for flavour and aroma which adds to the odorous properties of emissions. The kettle is vented via a stack discharging from the top of the brewhouse building. The brew kettle that will be installed at the new site will have a vapour condenser for heat recovery. Wort boiling is the largest single heat consuming process in a brewery and recovering heat from wort kettles saves energy by condensing nominally 95% of this vapour. This also reduces odour emissions because condensable odorous vapours are removed from the air exhaust. The vapour emission occurs for only a period of 3-5 minutes during each batch, with approximately ten batches processed per day.

3.2.2 CHARACTERISING THE ODOUR EMISSIONS

In order to define the odour concentration and emission characteristics of the future wort boiler emissions, odour monitoring was undertaken at the Khyber Pass site in January 2008. The discharge at this site is not condensed, and emissions occur over a period of about 60 minutes for each batch. Emission data collected included exit gas composition, volumetric flow rate, exit velocity, exit temperature and odour concentration. Three odour samples were collected after hops addition, when the odour emissions from the wort boiler are expected to be highest. Emissions from the Khyber Pass Road wort kettle are diluted with air prior to discharge which meant that concentration had to be corrected to account for undiluted vapour only. As the same beer will be brewed in a similar manner at the new site, the nature (e.g. hedonic tone) and intensity of odour emissions are expected to be similar. A key difference however, will be the significantly shorter duration of the odour discharge due to vapour recovery (3 – 5 minutes at the new site, compared to 60 minutes at the existing site).

3.3 SENSITIVITY OF THE RECEIVING ENVIRONMENT

The area immediately surrounding the new site comprises a mix of commercial and light industrial development. The closest residential properties were approximately 500 metres away. Potentially sensitive areas (e.g. schools and nearest residential properties) were identified and nominated as discrete receptors in the dispersion model.

3.4 SELECTION OF A SOURCE SPECIFIC MODELLING GUIDELINE

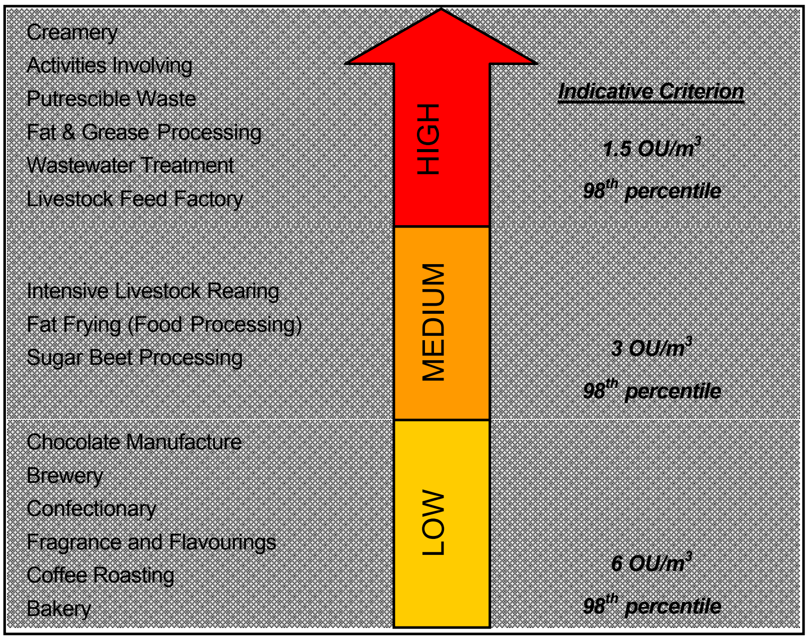
3.4.1 PUBLISHED GUIDELINES

Section 1.2 described the generic odour modelling guidelines approach in the MfE Odour Guide. In this project however, a source-specific odour modelling guideline was proposed based on the low offensiveness of the odour.

At the time this work was being undertaken, industry-specific modelling guidelines had been proposed in the Draft United Kingdom IPPC Horizontal Guidance for Odour document (Environment Agency, 2002), as shown in Figure 2. This document has since been revised and re-released for consultation in the United Kingdom (Environment Agency, 2009). The indicative criteria for different activities remain as recommended "benchmark levels" for dispersion modelling assessments in this revised document.

These criteria give some indication of relative offensiveness of industrial odours. Odours have been categorised as having a 'low', 'medium' or 'high' offensiveness with an exposure criteria assigned to each category. Environment Agency (2002) categorises odour from a brewery as having an indicative odour threshold criteria of 6.0 OU/m^3 at the 98th percentile.

Figure 2: Indicative odour exposure criteria for ground level concentration of mixtures of odorants, from Environment Agency (2002a)



Environment Agency (2002a) specifies that once these indicative criteria have been adjusted to reflect local factors (such as a sensitised local community, or adjustment to match local complaints records) the indicative criteria indicate the exposure that a particular environment can tolerate "without reasonable cause for annoyance". There were no relevant local factors to incorporate in the case of the proposed brewery site. The definition of "without reasonable cause for annoyance" as follows:

' "no reasonable cause for annoyance" describes a point where the majority of the exposed population (90%) report that they are not annoyed, i.e. they find exposure at that level is acceptable. The 10% "annoyed" point is reckoned to be a lower limit of detection for the assessment methodology, i.e. the point at which we can show with good statistical confidence that the result is "real" and does not arise from the methodology used in the survey. Beyond this point, according to our current understanding, it is considered likely that there may be reasonable cause for annoyance.' (Environment Agency, 2002a).

If this is compared with the "at least annoyed" response considered to be acceptable in New Zealand from community odour annoyance surveys of 20%, it is likely that the "no reasonable cause for annoyance" threshold in the IPPC report represents a similar amenity standard to "no offensive/objectionable odour" in New Zealand.

In terms of applying the IPPC indicative odour exposure acceptability criteria to industry proposals, the IPPC report states that *'the installation-specific odour exposure acceptability criterion can be used as a basis (benchmark) for determining the appropriate maximum odour emission rate that equates to "no reasonable cause for annoyance", and the operator should go as far as possible towards achieving this by the application of best available techniques (BAT).'*

3.4.2 COMPARISON OF IPPC MODELLING GUIDELINES WITH NEW ZEALAND GUIDELINES

The applicability of the IPPC odour exposure acceptability criteria with New Zealand odour modelling guidelines was evaluated. The following comments are noted:

- The IPPC definition of "no reasonable cause for annoyance" seems similar to "no objectionable/offensive odour" in New Zealand; however no direct comparison studies have been done.
- The IPPC definition of "no reasonable cause for annoyance" by measuring odour annoyance in communities may overlook small sections of the community that are annoyed by odour due to their proximity to the site. Again, no direct assessments of the determination of "no reasonable cause for annoyance" in practice have been made.
- The IPPC criteria use the 98^{th} percentile of modelling results. New Zealand guidelines typically use the 99.5^{th} percentile. As shown below, there is a ratio of about 4 between the 98^{th} percentile and the 99.5^{th} percentile at the residential discrete receptors around the proposed brewery site. If the proposed plant discharged offensive odours such as those from a rendering plant, then the applicable IPPC criteria would have been 1.5 OU/m^3 at the 98^{th} percentile, which correlates to 6 OU/m^3 (1.5 × 4) at the 99.5^{th} percentile for the receiving environment around the proposed brewery site. This would indicate that the IPPC criteria are less stringent than the New Zealand guidance criteria (MfE 2003), which recommends 2 OU/m^3 for the 99.5^{th} percentile. Therefore it could be argued that the IPPC criteria of 6 OU/m^3 for odours of low offensiveness needs to be reduced by a factor of 3 (6 ÷ 2) – making the resulting odour modelling guideline for a brewery odour in New Zealand 2 OU/m^3 at the 99.5^{th} percentile, which is the same as the recommendation in the guidance (MfE, 2003) for an offensive odour. Subjectively however, this odour modelling concentration seems very low for an odour of known and demonstrated low offensiveness.
- Conversely, the IPPC criteria can be regarded in a different way. The ratio between the criteria concentration for an odour of high offensiveness and an odour of low offensiveness is 4 (6 ÷ 1.5). Therefore, applying this ratio to the New Zealand recommended guidelines, the odour modelling guideline for a brewery odour in New Zealand could be taken as 8 OU/m^3 at the 99.5^{th} percentile (2 × 4).

Overall, it was considered appropriate to use the IPPC criteria for brewery odour as a surrogate for "no offensive/objectionable odour" for the proposed Lion brewery – i.e. 6 OU/m^3 at the 98th percentile. However, model results were also assessed at the 99.5th and 99.9th percentile using an odour guideline concentration of 8 OU/m^3, and other contributing factors from the FIDOL factors were also considered, particularly through the frequency of odour occurrence.

3.4.3 MODELLING ASSESSMENT

The potential effects of discharge to air from the wort kettle proposed brewing operation at the new site were modelled using the CALPUFF dispersion model.

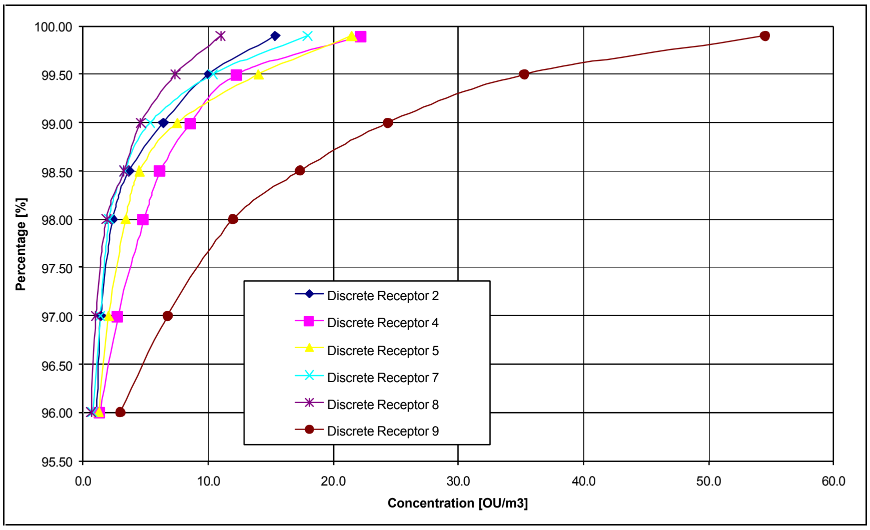
Table 3 displays the ground level concentrations predicted by the model for each discrete receptor for a range of percentiles. These predictions are also shown graphically in Figure 3. The table also shows the ratio between the various percentiles and the 99.5th percentile. The ratio is specific to each location due to wind patterns and individual separation distances. There is approximately a factor of 2.5 to 5, with an average of 3.9, between the 98th percentile and the 99.5th percentile for the residential receptors around the site.

The maximum 98th percentile concentration predicted to occur in a residential area around the proposed brewery is about 4 OU/m^3, which is less than the guideline of 6 OU/m^3 recommended in the Environment Agency (2002) report.

Table 3: Ground level concentrations at discrete receptors for various percentiles

Percentile	Predicted odour concentration (OU/m^3) at each discrete receptor					
	2	4	5	7	8	9
99.9	15.4	22.2	21.5	17.9	11.0	54.5
99.5	10.0	12.3	14.0	10.4	7.4	35.3
99	6.4	8.6	7.5	5.4	4.6	24.4
98.5	3.7	6.2	4.5	3.3	3.3	17.3
98	2.4	4.9	3.4	2.1	1.9	12.0
97	1.4	2.8	2.1	1.4	1.0	6.8
96	1.1	1.4	1.3	0.8	0.7	3.0
Ratio 99.5 to 98 percentiles	4.2	2.5	4.1	5.0	3.9	2.9
Type of receptor	Residential	Residential	Commercial	Residential	Residential	Commercial

Figure 3: Ground-level concentrations for odour dispersion from brewhouse kettle stack for various percentile factors



The modelling results showed that the 99.5th percentile guideline of 8 OU/m^3 could be exceeded at some sensitive receptors, although this modelling assumed that odour emissions occur for 60 minutes every three hours, rather than the actual emission frequency which is for 3-5 minutes, ten times per day. The modelling results also showed that the 98th percentile guideline of 6 OU/m^3 is not likely to be exceeded at any of the receptors regarded as having a high sensitivity to odour emissions, despite the model's conservative assumed odour emission duration.

These factors all lower the potential for any odour noticed in the receiving environment to cause adverse effects. When these factors are coupled with the low frequency of occurrence of odours that exceed modelling guidelines, it was concluded that odour emissions from the proposed brewery are unlikely to cause adverse effects on the surrounding environment.

4 CASE STUDY 2: REHABILITATION USING BIOSOLIDS

4.1 BACKGROUND

Watercare Services Ltd (Watercare) is the owner and operator of the Mangere Wastewater Treatment Plant (WWTP) in Auckland, located on the coastline of the Manukau Harbour. Watercare commissioned an assessment of potential adverse effects of odour emissions from the proposed rehabilitation of a vacated quarry on nearby Puketutu Island using biosolids. The concept design for the proposed rehabilitation was for biosolids placed as a series of layers and contained within a perimeter embankment to create an elevated central landform adjacent to existing volcanic cones.

An existing, similar rehabilitation activity at a site adjacent to the Mangere WWTP known as the Pond 2 Rehabilitation activity ("Pond 2") was used as a reference site for this assessment. Pond 2 has approximately the same surface area as that of the proposed rehabilitation and uses the same biosolids generated by the Mangere WWTP. This meant that odour emission rates from capping trials on Pond 2 could be used in the dispersion modelling assessment, and community feedback from the existing activity was used in the analysis to determine the threshold for offensive odour.

4.2 SENSITVITY OF THE RECEIVING ENVIRONMENT

Puketutu Island is located within the Manukau Harbour, joined via a causeway to the Auckland suburb of Mangere. A range of background odour sources are present in the vicinity of Puketutu Island, including both natural sources and those associated with Watercare's wastewater treatment operations.

On Puketutu Island, the most potentially odour-sensitive receptors were considered to be those where people are living or carrying out entertaining activities, followed by areas where members of the public may be exposed to odour during transitory activities such as recreation.

4.3 ODOUR CHARACTERISATION

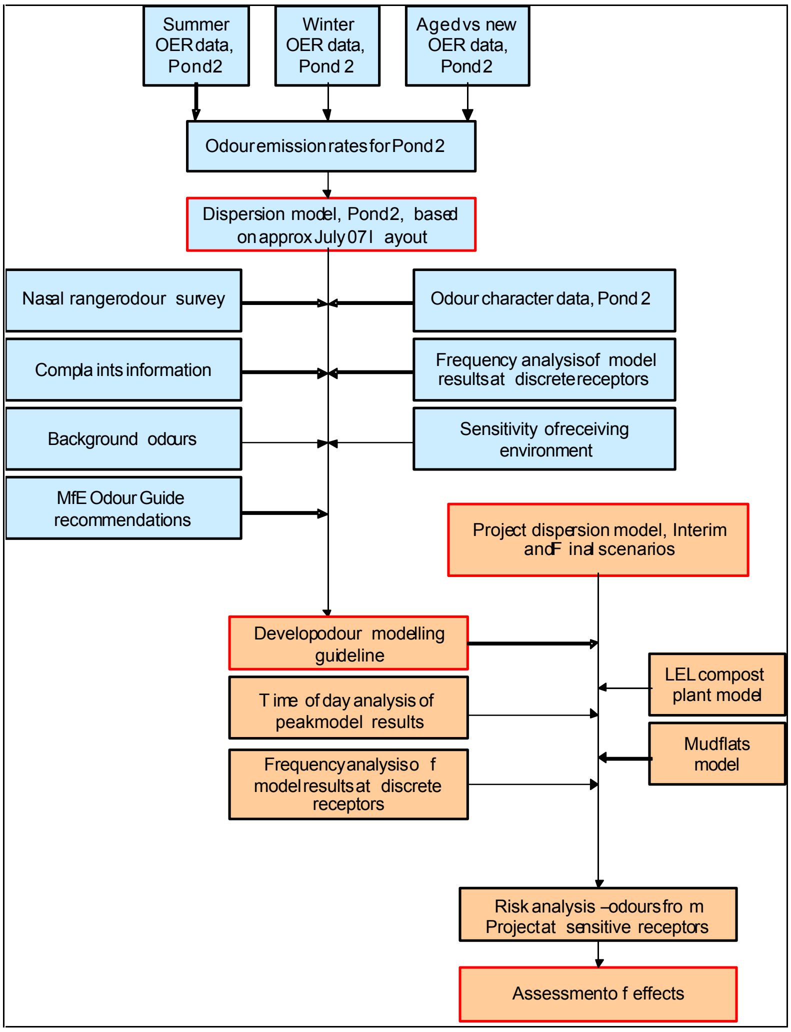
Biosolids are a biological material and will degrade to some extent, releasing odorous, volatile compounds such as hydrogen sulphide and mercaptans. Fresh biosolids can also generate an ammonia like odour due to the breakdown of the lime which is applied to stabilise the biosolids during dewatering. A monitoring survey of odour and methane emission rates measured the intensity and hedonic tone of odour emissions from the Pond 2 Rehabilitation during capping trials. In these trials of different cover materials, placement of cover material over the biosolids was shown to be effective in changing the hedonic tone of odour from the biosolids to a less offensive odour. Based on this data, the hedonic tone of the capped biosolids was expected to be close to the neutral range (+1 to -1) representing "neither pleasant nor unpleasant" (as per Table 2).

Odour emission rates from these trials were used as inputs to the dispersion modelling of the proposed rehabilitation activity.

4.4 DEVELOPMENT OF AN ODOUR MODELLING GUIDELINE

The proposed activity had a number of unique circumstances that meant that the standard NZ odour modelling guidelines were considered too conservative. For example, the receiving environment has a number of background odour sources, (in particular a very large expanse of tidal mudflats) which raised the question of whether the odour concentration represented by the 2 OU/m^3 modelling guideline in the MfE guidance (MfE 2003) would even be detected under typical conditions. Figure 4 outlines the process that was undertaken to develop an appropriate odour modelling guideline.

Figure 4: Development of an Odour Modelling Guideline: Assessment Methodology Flowchart



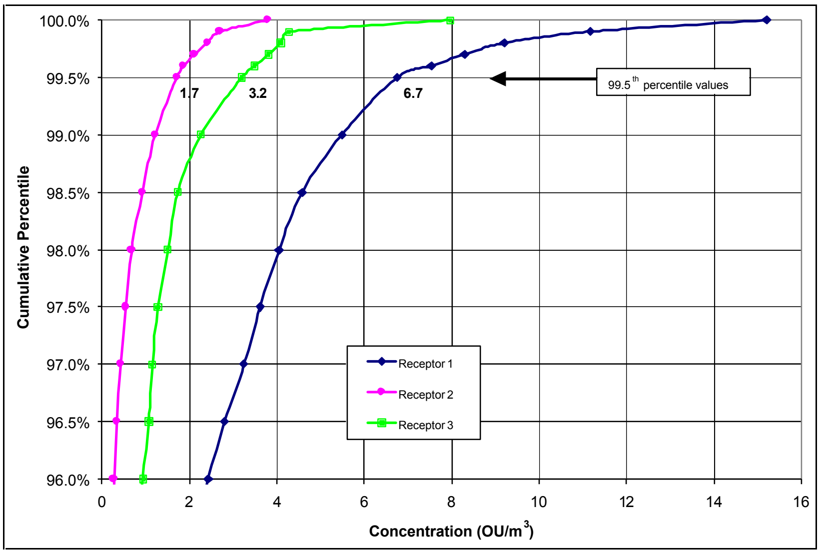
Note: OER: odour emission rate data

The development of an odour modelling guideline was based on the assumption (supported by community responses) that the steady state operation of Pond 2 (all covered biosolids excluding the working face) is not responsible for causing any odour nuisance beyond the Pond 2 boundary.

An odour survey programme was undertaken using a nasal ranger field olfactometer instrument at preset locations around the boundary of Pond 2 to monitor the intensity and nature of odour concentrations. The survey was carried out by Watercare employees over the summer of 2007/2008. Records were made of both background odours in the area when the observer was upwind of Pond 2, and when the observer was downwind of Pond 2. Most of the downwind observations did not include active placement of fresh biosolids, and therefore represented observations of odour from placed and covered biosolids (which represents the majority of the surface area of both the Pond 2 Rehabilitation and the proposed project on Puketutu Island). The survey found that the mudflats contribute a noticeable degree of background odour. This background odour is a similar intensity (as measured with the nasal ranger) to that which was observed with the nasal ranger when the observer was downwind of Pond 2 or the Mangere WWTP. These observations were also supported by anecdotal field observations by the authors of this paper.

Air emissions from Pond 2 were modelled in order to “calibrate” the dispersion model for this particular site and environmental conditions. This calibration was then used to develop a source specific odour modelling guideline for the dispersion modelling assessment. The calibration compared the modelled impact at the houses downwind of Pond 2 with community feedback data. Figure 5 shows the frequency of odour concentrations due to Pond 2 operations predicted at each of three discrete receptors.

Figure 5: Pond 2 Rehabilitation (July 2007 layout), odour exposure frequencies at discrete receptors.



The Pond 2 model results showed a 99.5 percentile odour concentration of 6.7 OU/m^3 at the closest residential location. Therefore, since the activity represented by this model was known not to be responsible for odour annoyance at these houses, the threshold for adverse effects at these locations due to the steady-state operation of Pond 2 was considered to be higher than 7 OU/m^3. To translate this threshold for adverse effects to Puketutu Island, two aspects were considered: the sensitivity of the receiving environment on Puketutu Island, and background odour sources on the Island. Other background odours on the Island such as the mudflats were considered to reduce the perceived sensitivity of the receiving environment.

Ordinarily, locations on the Island where residential-type activities are carried out would be expected to have a greater sensitivity to odour emissions compared to the houses near the Pond 2 operation, because of the current absence of odours from the WWTP on Puketutu Island. This would support using a lower odour modelling guideline than indicated from the Pond 2 modelling results. However, other background odours on the Island such as the mudflats and an independent greenwaste composting plant were expected to reduce the perceived sensitivity of the receiving environment.

Therefore, it was concluded that a suitable odour modelling guideline for the residential-type activities on the Island may be in the order of 6 OU/m^3 to avoid adverse odour effects. This is a lower guideline than indicated from the modelling of Pond 2, and it was acknowledged that there was some uncertainty over the exact value of this guideline. However, the 99.5th percentile model result was not the only way that potential adverse effects were assessed, so the uncertainty in this guideline was not considered to be critical to the assessment of environmental effects.

The potential for adverse effects from exposure to odour depends not only on the very highest odour predictions (ie the 99.5th percentile) but also on the frequency of occurrence of lower intensity odours (such as the exposure frequency curves shown in Figure 3). This may drive the potential for an odour to cause a chronic effect. The assessment is further complicated by the influence of odour offensiveness, contributions or masking from background odours, and the time of day when the odour occurs. These factors were all considered in the interpretation of the dispersion modelling results for the proposal on Puketutu Island.

4.5 MODELLING ASSESSMENT

CALPUFF was used to estimate the potential downwind concentrations of odour arising from the proposed rehabilitation site. Dispersion modelling of the proposed activity on Puketutu Island was used to assess the effects of two scenarios:

- The "Final Cover" scenario representing the situation in the future once the rehabilitation site is completed and fully covered with Final Cover material.
- The "Interim Worst Case" scenario represents the situation during the life of the Project when the greatest area of partially-filled site is exposed. In the Interim Worst Case scenario, parts of the surface would have final cover, some parts would have an intermediate cover, and some would be in an active filling phase.

The short duration, intermittent nature of the odour discharges from the biosolids application activity (i.e. the "working face") was not modelled.

Comparison of modelled odour exposure frequencies at receptors on Puketutu Island versus Pond 2 showed that the frequencies at all receptors on Puketutu Island are less than the frequencies at residences near to Pond 2, in some cases much less. This indicated that the potential for odour emissions from the proposed project to cause odour nuisance, even at sensitive receptors on the Island, would be less than that currently experienced at nearby residences.

5 DISCUSSION

The two case studies presented here demonstrate two methods that have been used for selecting a source specific odour modelling guideline. The first case study used published hedonic tone data which supported the assumption that brewery odour is known to be relatively inoffensive compared to commonly known offensive odour types, and draft guidance from the United Kingdom which proposes odour modelling guidelines specifically related to the activity, in this case a brewery.

In the second case study odour emission data from a similar activity at a different site was modelled and the results compared with real life observations. This calibration exercise allowed the estimation of a modeling threshold at which odour effects were likely to become offensive or objectionable. In turn, this threshold could be used as an odour modelling guideline for the new rehabilitation activity. This work was supported by a considerable amount of data, including an extensive emission rates sampling programme, olfactometry field surveys, and offensiveness testing. The offensiveness data was used to prove the hypothesis that the covered biosolids would have a different character and hedonic tone than fresh uncovered biosolids.

The MfE Odour Guide gives general guidance for selecting odour modelling guidelines which range from 1 OU/m^3 to 10 OU/m^3, depending on the sensitivity of the receiving environment and physical configuration of the source. However this Guide also advises that other guidelines can be used on a case-by case basis where they are justified for specific odour sources. Many guideline values in use today in New Zealand are based on an assumed odour annoyance modeling threshold of 2 or 5 OU/m^3. The odour annoyance threshold of 5 OU/m^3 is based both on research conducted in a controlled laboratory situation and site studies using Gaussian dispersion modeling, and is applicable to offensive odours. In reality, a person's perception of an odour is a complex reaction to the FIDOL factors, other background odours, and even their mental and physical state.

In the two cases highlighted in this paper, the reason for seeking alternatives to the standard and default guidelines recommended in the MfE Odour Guide was that there was data to support the presumption that the MfE's default thresholds may be too conservative for these cases. For example, the MfE guidance would have recommended the use of 2 OU/m^3 at the 99.9th percentile to assess the potential odour effects from the new brewery at the nearest houses. Despite the use of best practicable option in the form of vapour recovery to mitigate odour from the new site, the order of magnitude of odour emission rates from any wort kettle are sufficiently high to make it next to impossible to meet a standard of 2 OU/m^3 for 99.9 percent of the time using conventional modelling approaches. However these "one size fits all" default guidelines are not well suited to an activity such as brewing because of the low offensiveness of the odour and the intermittent, short duration pattern of the odour emissions.

A modelling guideline can take into account the intensity and frequency of odours, (the "I" and "F" of the FIDOL factors), but offensiveness cannot be assessed in modelling outputs and has to considered separately. One way to incorporate the relative offensiveness of an odour source is to develop a source specific modelling guideline, as demonstrated in the case studies presented here.

Odour modelling guidelines are not intended to be used as a "pass or fail" test and it is tempting to use them as such in regulatory assessment. Depending on the level of conservatism, a situation where guidelines values are predicted to be breached does not necessarily mean that adverse effects will occur. The potential for adverse effects from exposure to odour depends not only on the very highest odour predictions (i.e. the 99.5 percentile) but also on the frequency of occurrence of lower intensity odours. These assessments are further complicated by the influence of odour offensiveness, patterns of intermittent or short duration odour emissions, contributions or masking from background odours, and the time of day when the odour occurs. These factors all influence the likelihood that an odour emission would cause annoyance.

Both of the case studies presented here supported the odour assessments with detailed modeling and frequency analysis to assess how often and at what concentration odours might occur at different receptors.

6 CONCLUSIONS

The two case studies have shown evidence that there is no single odour standard or guideline that will fit all processes and types of odours. These case studies demonstrate that the current New Zealand odour modelling guidelines recommended in the MfE Odour Guide are very stringent for some types of odour emissions. The "one size fits all" default thresholds for different receiving environments assume that all odours have the same nuisance threshold. This approach has limitations, in particular, when assessing effects of odours which may not normally be considered offensive. For regulators the current approach is simple, and provides a degree of certainty that when new activities are consented the standards are sufficiently conservative to ensure no adverse effects. Conversely, for applicants engaged in the consenting process, the bar is set very high to be able to demonstrate no predicted adverse effects due to odour.

This presents a significant challenge for those involved in odour assessment, as each activity needs to be considered carefully on a source and site specific basis. Communication with regulators and potentially affected parties is needed to increase understanding that there is a quantitative method for grading different types of odours.

Two recommendations arise from the work on developing odour modeling guidelines described in this paper:

1. Further work should be undertaken to develop standardised approaches to incorporating different types of odours into the New Zealand guidelines that recognise that not all odours are the same.

2. A project should be carried out to determine whether for New Zealand conditions, the default 2 OU/m^3 odour modeling guideline that was developed in the 1990's with Gaussian plume models is still applicable with the advanced model CALPUFF that is now being used on a more frequent basis for odour assessments.

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