Ministry for the Environment

Manatū Mō Te Taiao

Review of Odour Management in New Zealand

Air Quality Technical Report No. 24

Technical Report

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Foreword by the Ministry

This report contains an extensive review of how odorous discharges are assessed and managed in New Zealand in accordance with the Resource Management Act 1991. It also recommends some new and innovative approaches to assessing and managing odours based on international and national experience and research. This technical background report has been used to develop the new draft national guide on managing odour discharges under the Resource Management Act 1991.

The authors, Tracy Freeman and Roger Cudmore (Aurora Pacific Limited), have also examined the application and usefulness of the Ministry's first guide to *Odour Management under the Resource Management Act* (1995) and sought input from practitioners on the requirements for improved national guidance on odour management.

If you wish to comment on any of the advice or information raised in this technical background report, please do so within the your submission on the draft revised Good Practice Guide for Odour Management.

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Executive Summary

Aurora Environmental Ltd and Freeman Environmental Solutions Ltd (now Aurora Pacific Ltd) were engaged by the Ministry for the Environment to prepare a technical document that would provide the background information for developing an updated odour assessment and management guideline for New Zealand. This report contains a detailed summary of background information on odour effects, followed by a discussion of the various assessment tools and how these can be effectively utilised.

Based on our own experience and the feedback from the survey of New Zealand air quality practitioners, we have concluded that there are a number of key issues that limit the effective and consistent assessment of industrial odours in New Zealand, including:

- the subjective definition of what may be deemed to be an objectionable and offensive odour
- the selection of the most appropriate odour assessment tools and how these can be most effectively implemented to assess the extent of adverse odour effects
- the restrictive common interpretation of what constitutes an adverse odour effect, and the dearth of case law that considers adverse effects due to chronic (low-intensity, long-term) odour exposure
- the absence of objective criteria for indicating when significant adverse odour effects are likely to occur, beyond the use of odour complaints monitoring
- the need for a common basis for linking different odour assessment and monitoring tools objectively
- the development of useful odour-modelling concentration guidelines that are effects-based and appropriate to differing circumstances.

To help resolve the above issues, we have recommended a general approach for odour impact assessment and monitoring that includes:

- focusing on the methods and criteria for determining when significant ‘adverse effects’ are being caused, and defining ‘objectionable and offensive odours’ as those that cause adverse effects
- formally recognising the need to manage both long-term (chronic) and short-term (acute) odour exposures, and to implement appropriate regulatory responses and assessment tools for each type of odour effect

- the use of standardised 'population annoyance' surveys as the main monitoring and research tool for investigating the level of adverse odour effects within New Zealand communities, and the specification of an interim guideline for population annoyance criterion of 20% 'at-least annoyed'
- the specification of interim odour-modelling guidelines that are based on current case study and theory, with the requirement that future revision of odour-modelling guidelines be linked to population annoyance criteria
- the use of odour diaries in circumstances where surveys are not viable, with evaluation of results to be based on FIDOL factors and with reference to modelling concentration guideline values
- the specification of differing protocols for detailed versus informal odour complaint investigations by council officers, with guidance provided on the different uses of complaint data for situations of acute versus chronic odour effects
- providing guidance on the content and style of odour management plans for controlling odour emissions from industrial sites.

It is worth commenting on two of these points in particular. First, the recommendation to underpin odour assessment tools by the use of 'population annoyance' as the fundamental indicator of the psychological stress induced in populations exposed to industrial odours. This approach forms the basis of objective odour policy and assessment standards in Germany and the Netherlands, and we consider it to represent the best practice for managing odour impacts in an effects-based way.

The use of a population annoyance indicator to make odour impact assessments more effective does not rule out the use of complaints monitoring, site investigations, modelling and other tools. However, using these methods appropriately requires more detailed consideration to ensure consistency and certainty in odour regulation approaches.

Regarding the subjective definition of when odour(s) may be deemed to be 'objectionable or offensive', we have recommended that this be resolved by effects-based arguments; in particular, by the consideration of whether adverse effects are likely to occur. This is consistent with New Zealand's environmental legislation. The report recommends that the terms 'adverse odour effects' and 'objectionable and offensive odour effects' be viewed as the same. Therefore, rather than entering into lengthy debates over what may be deemed to be objectionable and/or offensive, the approach recommended reduces this to the question of whether or not adverse effects are occurring.

Another significant feature of the recommended approach is the formal acknowledgement that odours can cause adverse effects by chronic exposure as well as short-term impacts, and that these often cause different types of adverse effect and require different assessment tools and management responses. In the past, regulatory compliance monitoring methods and actions have not given enough attention to the adverse effects due to chronic exposure to odours. We believe that the definitions of ‘acute’ and ‘chronic’ odour effects given in this document are an important step towards ensuring that this situation is gradually rectified.

Finally, we have addressed important issues associated with odour modelling. For a start, we do not consider that the prescriptive modelling approach proposed for some states of Australia is appropriate for New Zealand. Instead, we have recommended the use of modelling in limited circumstances, and that this should not be relied on as the sole assessment tool. Some interim guidelines have been proposed, which draw on theoretical derivations as well as empirical case studies linked to population annoyance survey data. Importantly, this report recommends a process for the future refinement of these interim modelling guidelines, linked to population annoyance.

Contents

1. Introduction

The Ministry for the Environment commissioned this report to provide detailed background and technical information and recommendations for its review of *Odour Management under the Resource Management Act* (Ministry for the Environment, 1995). The aim is for this report to become the primary reference document for the revised odour guide. It has been prepared with the requirements of the Resource Management Act 1991 (RMA) in mind, particularly the occurrence of 'offensive or objectionable' odour effects and the evaluation of whether such effects do, or may, occur.

Odour Management under the Resource Management Act (the 1995 odour guide) is the only current national guidance available to regulators, consultants and practitioners on odour management and evaluation practices. Development of the 1995 odour guide began in 1992, and culminated in the production of a discussion document in 1994 entitled *Odour Measurement and Management Discussion Document*. This was used to stimulate debate on possible odour measurement and management guidelines for New Zealand. The responses received significantly influenced the content of the 1995 odour guide.

An initial draft of the present report was circulated to interested parties in June 2001, and a workshop was held on 26 June 2001 in Wellington. The draft report was also formally peer reviewed. Feedback from the workshop, the peer review, and the Ministry was incorporated into this final draft.

1.1 Why do we need a new odour guide?

The 1995 odour guide needs to be revised to reflect advances in odour assessment and management techniques made during the last seven years, and to promote consistent practice among odour management practitioners and regulators in New Zealand. For example, a joint New Zealand/Australian standard for olfactometric measurements is close to being finalised, but the appropriate use of measurement technology is not adequately covered by the existing guideline. In addition, more guidance needs to be given on selecting appropriate odour concentration criteria to encourage consistent modelling evaluations and decisions.

There have been substantial debates and investigations into the issue of odour concentration guidelines, with guidelines being recommended by two reports:

- *Analysis of Options for Odour Evaluation*, prepared by CH2M Beca Ltd for Auckland Regional Council, published November 1999
- *Environmental Standards for Industrial Odour Effects*, prepared by Aurora Environmental Ltd (the Aurora Report), first published in 1998, with the latest revision dated June 2000.[1]

[1] This report was funded by a group of New Zealand industries from around New Zealand.

Much of the discussion on modelling in the 1995 odour guide is out of step with the recommendations in these reports. For example, there is no longer any debate between yes/no and forced-choice olfactometry, the agreed concentration averaging time is now 1 hour (as opposed to three minutes), and the type of odour concentration threshold is now different from that used in 1995.

Since the 1995 odour guide was published, there have been improvements in the use of odour annoyance surveys and how the information from these can be used to develop odour management policies and guidelines to support an assessment of whether an odour will have an objectionable or offensive effect. There has also been substantial development in understanding how adverse odour effects arise (for example, a low-concentration odour occurring over a long period of time can cause adverse effects, as can a high-concentration odour occurring over a short period of time), and this has implications for appropriate management and odour assessment tools.

Finally, members of New Zealand's industry sector have been represented at various New Zealand odour workshops in recent years and they have expressed concerns about the uncertainty surrounding current odour assessment practices and their ability to plan for the future. This review attempts to address these concerns by providing clear direction in the use of odour assessment tools, and the evaluation and reporting of the information gained.

1.2 Feedback on the 1995 odour guide

As part of this review, in December 2000 a questionnaire on the 1995 odour guide was distributed to over 100 people involved in odour management in New Zealand across all sectors. Twenty-four responses were received, from regional councils (10 responses), consultants (6), city councils (3), lawyers (2), industry (2), and one health officer. The respondents were asked to rate the 1995 odour guide from poor to very good in seven specific topic areas. The responses are summarised in Appendix 1. Basically, the respondents wanted more information to be provided on most topics.

Respondents were also invited to make generalised comments, and a large number were received. A full analysis of the feedback is also attached in Appendix 1.

This feedback has shaped the development of the current document, and we have included information on most of the areas where more detail was sought.

2. Properties of Odour

2.1 What is odour?

Odour is a sensory response to the inhalation of air containing chemicals. When the sensory receptors in the nose come into contact with odorous chemicals, they send a signal to the brain, which interprets the signal as an odour. The olfactory nerve cells in humans are highly sensitive instruments, capable of detecting extremely low concentrations of a wide range of odorous chemicals. The type and amount (or intensity) of odour are both important in processing the signal sent to the brain. Most odours are a complex mixture of many odorous compounds.

'Fresh' air is usually perceived as not containing any contaminants that could cause harm, and it smells 'clean'. Fresh air may contain some chemicals with an associated odour, but these odours will usually be perceived as pleasant, such as the smell of mown grass or sea spray. But not everyone likes the smell of mown grass. Because our sense of odour and our emotional response to it are synthesised by our brain, different life experiences and natural variation in the population can result in people having different sensations and emotional responses to the same odorous compounds.

Other sensory information – such as sight and taste – can influence the particular sensation of odour our brain creates, even when chemical stimuli are not present. For example, visual screening of an odour source can reduce the number of complaints about it.

2.2 Quantifying odour

Is it possible to construct devices that register odour? Dynamic dilution olfactometry (DDO), electronic noses and specific chemicals can be used (with varying success) to indicate the relative amount of odorous chemicals present in the air. The most commonly used odour measurement technique is DDO. This and other techniques for odour measurement are described in detail in section 7.3.

Briefly, DDO measures odour concentration in terms of how much a given sample needs to be diluted with odour-free air so that 50% of a panel of human 'sniffers' cannot distinguish the odour from odourless air. This is called the 'dilution to threshold' concentration.

The information obtained from odour measurements does not directly tell us the likely effect of the odour, in terms of its perceived intensity, pleasantness or potential to cause annoyance in the long term. However, an understanding of the various relationships between different odour-related factors can allow laboratory data to be used indirectly to assess potential odour effects. Just what these factors and relationships are is the subject of much of this document.

2.3 The psychometric properties of odour

2.3.1 How odour intensity changes with dilution

The intensity (or sensation) of odour as measured by the human nose is actually related to the logarithm of the odour concentration:

$$Intensity = fn \times \log(concentration) \qquad \text{.................................Eqn. (i)}$$

This is referred to as a 'psychometric' property of odour. The relationship is commonly known as Steven's Law, and it is also found with other human senses, such as noise and light. What it means is if the relative concentration of an odour is increased tenfold, then it will be perceived to increase in intensity by a much smaller amount. This runs against the common belief that the change in odour intensity between consecutive dilutions is nearly equal.

Steven's Law is illustrated in 0, which shows the relationship between odour concentration (the mass of odorous chemicals, determined by DDO) and the actual odour intensity (the perceived strength of the original odour) of the discharge. In the example shown, anm odour source discharges odour at a concentration of 10,000 OU/m^3 (odour units per cubic metre), as determined by DDO. Although the emission concentration is 10,000 times higher than the dilution to threshold concentration for the combination of chemicals in the odorous gas, the actual odour intensity of the emission will be substantially less than 10,000 times as intense.

Equation (i) above may have different coefficients for different types of odour. This occurs because most odours occurring in the environment are a mixture of odorous compounds. As the odorous compounds dilute as they are dispersed through the atmosphere, odorants that smell stronger than others at emission concentrations may decrease in intensity at a faster rate than others in the mixture. At some dilution level, a crossover may even occur, such that the initially weaker odour becomes dominant.

Take, for example, the odorous emission resulting from the dehydration of partially decomposed cow manure. Within about 50 m the odour typically has a strong ammonia smell. However, at a distance of 1 km or more the odour is putrid and no ammonia can be detected (Water Environment Federation, 1995). Similar effects have been observed downwind of stockpiled treated sewage sludge in New Zealand.

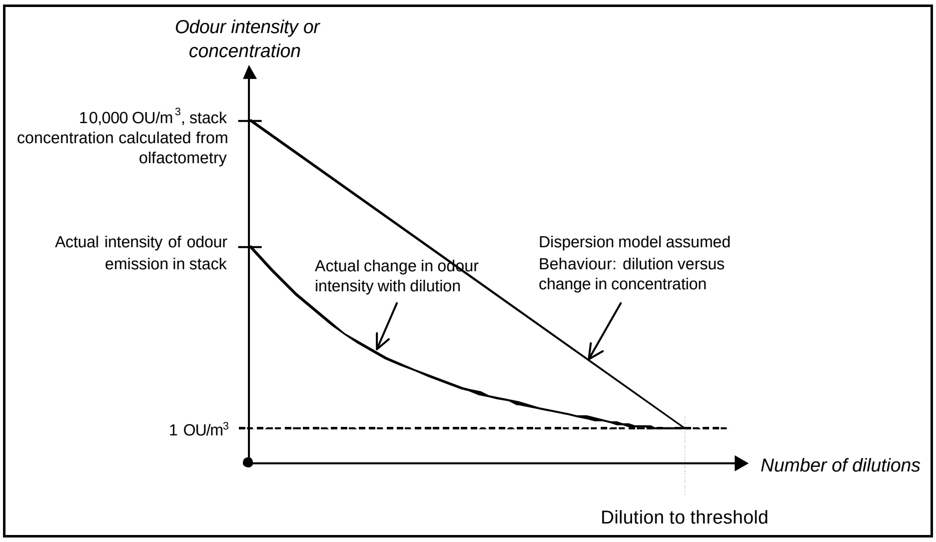


Figure 1. Odour intensity versus odour dilution

2.3.2 Synergistic effects and masking

An extension of the psychometric property described in the previous section is the phenomenon of masking, whereby the presence of one odorant can disguise, or mask, the presence of a second. The different odorants may also interact, with the type of interaction changing as the concentrations of the individual components vary. This can cause interactive or 'synergistic' effects, such that the odour intensity of the sum of the odorants is either greater than or less than the intensity of the component odours.

In practice, odours from significantly different sources and with different characters are usually neither additive nor synergistic, but instead one source tends to dominate and mask the presence of another source. This effect has been shown with the interaction of kraft pulp mill odours and geothermal odour.

2.4 Nose desensitisation

If an odorous chemical is constantly present in the air, the human nose can become desensitised to the point where the air does not have any obvious odour. This is sometimes referred to as 'odour fatigue', and it explains why people working at or very close to a persistent source of odorous discharge are often not even aware of its presence, or the perceived strength of odour experienced by those further away from the source. Nose desensitisation is also the reason why odour panellists participating in olfactometry tests must rest for specified times between samples and breathe odour-free air in the waiting area.

As a result, when conducting odour investigations for a particular industrial or trade site it is essential that observations on the odour character and strength are first made *beyond* the boundary of the source at the point where the odour is weakest. If observers first visit the source of the odour where it is strongest, desensitisation of their noses can render subsequent observations unreliable.

Chapter 2: Recommendations

Observations on an odour's character and strength should first be made beyond the boundary of the source, at the point where the odour is weakest, before visiting the source of the odour where it is strongest.

3. Effects of odour

3.1 Health effects

The main effect of environmental odour is nuisance, but in more serious cases it may lead to feelings of nausea and headache, and other symptoms that appear to be related to stress. It has been postulated that the mechanism of 'environmental worry' (see section 3.2.2) helps to explain the occurrence of physiological effects in people exposed to odorous substances at concentrations much lower than might be expected to lead to actual toxic effects (Shusterman et al., 1991).

Many odorous compounds are indeed toxic at high concentrations, and in extreme cases of acute exposure toxic effects such as skin, eye or nose irritation can occur. But such effects are most likely to occur as the result of industrial accidents, such as the rupture of tanks containing toxic compounds or severe upset conditions in chemical or combustion processes.

Repeated exposure to odour can lead to a high level of annoyance, and the receiver may become particularly sensitive to the odour. Complaints are most likely to come from individuals who are either physiologically or psychologically sensitive to the odour, and certainly a combination of both types of sensitivity will increase the likelihood of complaint. The individual components of an odour necessary to cause an adverse reaction from people are usually present in very low concentrations – far less than will cause adverse effects on physical health or impacts on any other part of the environment.

To illustrate this, Table 1 compares odour threshold data for ethyl mercaptan, hydrogen sulphide and methyl mercaptan with ambient air-quality criteria. The selected criteria are one-thirtieth of the New Zealand Workplace Exposure Standards (WES) for the individual compounds.[2] The odour threshold values are the reported detection thresholds for these compounds (the concentration at which these chemicals can be smelled).

The odour threshold values for these three chemicals are several orders of magnitude less than the WES/30 values. This means that the chemicals can be smelled at much lower concentrations than those causing adverse effects on health. Therefore, if present in sufficient quantities, these compounds would create an odour problem at much lower concentrations than would be needed to create a public health problem.

Despite these examples it should not be assumed that odour thresholds will *always* be much lower than toxicological thresholds. The potential for significant adverse

[2] WES/30 values are commonly used in New Zealand to define ambient air-quality criteria when no national ambient air-quality guidelines are available, as is the case with these compounds.

effects on public health from chemicals in odorous discharges should be considered on a case-by-case basis.

Table 1. Odour threshold values for selected compounds

Compound	WES/30 value ($\mu g/m^3$)	Odour threshold ($\mu g/m^3$)
Ethyl mercaptan	43	0. 075–2.5
Hydrogen sulphide	470	0.7–7
Methyl mercaptan	33	0.04–4
Reference source	OSH and Department of Labour, 1994	NZWWA, 1999

Very little information is available about the physiological effects of odour nuisance on humans. However, it is known that prolonged exposure to environmental odours can generate undesirable reactions in people such as unease, irritation, discomfort, anger, depression, nausea, headaches or vomiting. In our experience, other effects reported by people subjected to environmental odours can include:

- difficulty breathing
- frustration, stress and tearfulness
- reduced appetite and pleasure in eating, and difficulty preparing food
- reduced comfort at night (the need to close bedroom windows on hot nights, and being woken in the night by the odour)
- embarrassment when visitors experience the odours
- reduced business due to prospective customers being affected by the odour
- odour invading the house and washing
- reduced amenity due to the need to keep windows closed and avoid outdoor activities such as gardening.

3.2 Causes of adverse odour effects

3.2.1 The FIDOL factors

The FIDOL factors (frequency, intensity, duration, offensiveness and location) encompass the pattern of odour impacts and the receiving environment where these occur. These are the factors that influence the extent to which odours adversely affect individuals, and this information can be utilised to assist with odour investigation and assessment.

Frequency, intensity and duration

The *frequency* of the odour occurrence is how often an individual is exposed to odour in the ambient environment. Frequency is influenced by the odour emission source and characteristics, the prevailing wind conditions, the location of the source in relation to the individual affected, and the topography of the area. The frequency of odour exposure is generally greatest in areas that are most often downwind of an odour source, especially under stable conditions with low wind speeds (provided that the odour is not emitted at a significant height above the ground).

The *intensity* of odour refers to an individual's perception of its strength. This is different from the odour's character, or quality. The relationship between the perceived strength (or intensity) of an odour and the overall mass concentration of the combined chemical compounds ($\mu g/m^3$) was discussed in section 2.3.1.

Finally, the *duration* of exposure to the odour is related to the type of odour source, the local meteorology and the location of the odour source.

These three factors should be considered concurrently. Odours may occur in frequent short bursts or for longer less-frequent periods. However, all of these odour patterns can cause a significant adverse effect, although an odour of high intensity (concentration) occurring for a short period of time is likely to cause a *different* type of adverse effect to a low-intensity odour occurring almost constantly.

Offensiveness

Offensiveness, or 'hedonic tone', is the subjective rating of pleasantness or unpleasantness of an odour. This double meaning can be confusing: on the one hand offensiveness is one of the FIDOL factors and can be used in relation to a pleasant odour; on the other hand we use the RMA definition of 'offensive or objectionable odours', where offensive means unpleasant. It may help to remember that the RMA definition has a much broader meaning, which encapsulates the combined effect of all the FIDOL factors.

The hedonic tone should be considered separately from intensity, and to be a useful parameter it needs to indicate the inherent character of the odour.

When assessing the extent of adverse effects, the physical effects of the odour on the affected people should be considered here (as described in chapter 3.1). The odour source and its associated characteristics (such as dispersion, and impregnation onto surfaces such as skin or washing) also influence how offensive an odour may be to an individual.

Location

Location is an essential factor when assessing the likelihood of adverse effects from odours. It accounts for the type of area in which a potentially affected person lives, the type of activity they are engaged in, and the sensitivity of the receiving environment. These factors determine the likelihood of a person being adversely affected to the point where they find an odour to be offensive or objectionable. The absence or presence of background odours (see section 3.2.2) also has a significant effect.

The sensitivity of the receiving environment can generally be categorised according to land use. For example, odours occurring in an industrial area are less likely to be considered offensive by people working on neighbouring industrial premises, and if the odours occur at night they are unlikely to have any effect at all unless people are working night shifts. In addition, people who are more likely to be sensitive to odour effects may not be present in such environments (see section 3.2.2 below).

Conversely, odours occurring in the evenings in residential areas (particularly in summer) could have a significant adverse effect on residents using their backyards for outdoor dining and entertaining, or trying to sleep with windows open. People coming to a place for (say) recreation who are not familiar with the odours in the area are also more likely to be adversely affected.

People living in and visiting rural areas generally have a high tolerance for rural-type odours, such as from silage or decomposing cow manure, which are acceptable to most rural people and fit the description of a rural odour in a rural area. Some types of odour are quite different to the normally expected rural odours, however, and much less acceptable; for example, odours from rendering plants, wastewater treatment and large-scale intensive factory farms.

Further discussion on the sensitivity of the receiving environment is provided in section 3.2.4.

3.2.2 Other factors influencing adverse effects

In addition to the FIDOL factors, other background odours, perception, cultural issues, and even a person's mental and physical state may need to be considered in assessing the degree of adverse effects.

Cultural issues

In some cases, such as with human sewage treatment, it is the knowledge of the activity generating the odour that causes an offensive reaction in the people smelling the odour. If the people know it is there, and find the activity itself to be offensive, they are more likely to find the odour itself offensive even if the FIDOL factors would indicate otherwise.

Perception

If a person who is exposed to an odour associates it with a natural occurrence, such as mudflats, seaweed, or some rural activities, they often do not consider the odour to be offensive or objectionable, so a significant adverse effect is less likely to occur even if the true source of the odour is an industrial activity. Conversely, if the odour is associated with an activity such as wastewater treatment, landfilling, composting, industrial production or factory farming, the same odour is more likely to cause an adverse response in people (see 3.2.3 for further discussion).

Background odours

Some environments have a high level of background odours contributing to the overall ambient air; for example, silage and cow manure in rural areas, algae decomposition on the Manukau Harbour mudflats, hydrogen sulphide from geothermal activity in the Rotorua district, and commercial smells from traffic and restaurants. If a person lives in such an environment, they can become desensitised to these odours, and the addition of other similar odours may not be noticed (unless the odour is strong enough to dominate the background odours).

Similarly, in a community dominated by one or two industries, and where most of the community is employed by that industry, the people who live there are likely to find the odours more tolerable than individuals whose livelihood is not directly or indirectly related to the local industry. Problems can then arise in these situations when visitors or new residents come into an area and they are not conditioned to the background odours, or when a small community begins to grow and become populated by residents with no association with the dominant industry.

3.2.3 Odour impacts in sensitised communities

It is becoming increasingly clear that certain communities can become sensitised to odours. Triggers for such sensitisation include one-off or rare but highly adverse events that permanently change people's perceptions about the odour. When a community displays signs of sensitisation, common features are a high level of complaints over the long term, and a general mistrust of those responsible for the perceived source of the odour.

To better understand the nature of an individual's response to odours it is helpful to understand two processes that occur in all sensory systems: adaptation and sensitisation.

Adaptation is a reduction in responsiveness (a decrease in perceived odour intensity) during or following repeated exposure. Adaptation can occur on either a short-term or long-term basis. Short-term adaptation primarily occurs as a result of olfactory fatigue (see section 2.4). Long-term adaptation results in a more persistent reduction in response, which can be measured in hours or even days following exposure and can account for situations where people who work in odorous environments cannot comprehend complaints from neighbours who only receive intermittent odours (Schiffman, 1998).

Conversely, *sensitisation* results in increased responsiveness during or after exposure. Individuals who may not be particularly sensitive to odours may become sensitised through acute exposure events, or as a result of repeated exposure to nuisance levels of odours. Often symptoms such as headaches, nausea, throat irritations and sleeplessness are reported at exposure levels barely exceeding the odour threshold.

Schusterman et al. (1991) suggest a link between environmental odours and ‘environmental worry’, which may help to explain apparent physiological symptoms reported in populations exposed to concentrations well below levels at which toxicology predicts any irritation or adverse health effect. This effect may be explained by mechanisms such as biologically intrinsic odour aversions (the idea of a predictable, inherent odour response to certain stimulus), exacerbation of underlying medical conditions (such as asthma or morning sickness), or conditioned responses (known as behavioural sensitisation).

Behavioural sensitisation is well documented for cases of acute over-exposure to odorous substances in the workplace. The odour may be well tolerated before acute exposure, but may then act as a trigger for recurrent anxiety or hyperventilation symptoms afterwards. In some cases, similar involuntary responses may be triggered by odours from other chemicals to which no known aversive conditioning has occurred.

Schusterman et al. (1988) concluded that far from being a neurotic process, behavioural sensitisation to odours is an adaptive or protective response with minimal, if any, voluntary or personality component. Similar response mechanisms have been observed within communities strongly opposed to, or affected by, the siting of municipal, industrial or agricultural odour sources.

Dalton (1996; 1997) has reported that beliefs about the safety of an odour can have an effect on its perception. In Dalton’s clinical studies, groups of people were exposed to odours in a test chamber. One-third of test subjects (the positive group) were told that the odour was a natural extract used by aromatherapists; another third (the negative group) were told the odorant was an industrial chemical that purportedly caused health effects after long exposure; while the remaining third (the neutral group) were told the stimulant was a common, approved stimulus for olfactometry experiments.

The positive group showed normal adaptation over the test period, with the perceived intensity decreasing over time. However, the negative group rated the strength of the odour as increasingly greater after an exposure of 10 minutes, which was illusory as it actually remained constant over time. Overall, the negative bias group found the odours to be more irritating and had the greatest number and intensity of health symptoms, including nose, throat and eye irritation as well as light-headedness.

Symptomatic response to perceived health risks has also been examined by Knasko et al. (1990) in a study of the behaviour, physical wellbeing and emotional state of persons in a room that supposedly contained odour but really did not. People who were told the room contained a malodour reported a more negative mood and more symptoms of discomfort than people told that the feigned odour was pleasant. This study, like those of Dalton, showed that cognitive expectations about odour and irritation can influence sensory perception.

A number of studies conducted in communities surrounding municipal, agricultural and industrial odour sources, such as those reported by Schusterman (1992), confirm that community odour impacts can extend beyond mere nuisance and annoyance effects, producing a range of physiological symptoms including headache, nausea, eye and throat irritation, and sleep disturbance. A common feature of many of these studies is that measured or modelled exposures to airborne toxicants report levels well below those known to cause acute symptoms by recognised toxicological mechanisms. The available evidence suggests that enhanced odour recognition can occur as a result of remembered or 'learned' experiences.

The degree to which individual sensitisation can be influenced by community interactions (or group processes) is not well understood. However, it is postulated that community sensitisation may be 'transmitted' via normal or extraordinary communication processes. These communications may be either internal (between community members) or external (such as via media reports). Negative images (those that transmit messages of concern, dismay, distrust, adverse health impacts, etc.) are likely to be more influential in increasing adverse reactions in the receiver. Thus community interactions may help to explain the occurrence of localised hotspots in which the occurrence of sensitised individuals may exceed the expected probability.

3.2.4 Sensitivity of the receiving environment

Many different types of land use and location can occur in immediate proximity to an odorous activity. These can be grouped into three main categories depending on the degree of sensitivity. This is shown in Table 2.

Table 2. Types of land use/location, and sensitivity of the receiving environment

Type of land use/location	Sensitivity classification			Comments and reasons for classification
	High	Mod.	Low	
Residential/ living (high-density residential)	v			• People of high sensitivity to odours can be exposed. • People can be present at all times of day and night, both indoors and outdoors. • Visitors to homes in the area are unfamiliar with the odours, and are more likely to be adversely affected (this can cause embarrassment to residents and raise awareness of the problem).
Rural residential (low-density residential, say minimum property size 1 ha)		v	v	• Because the population density is lower, the opportunity to be adversely affected is lower. However, people of high sensitivity to odours can be exposed at all times of day and night. • Rural residential areas are often subjected to rural-type background odours, but a lower intensity would be considered acceptable than in a true rural zone. • A trend becoming more common is for residents in rural residential areas to work in the cities and return to their homes at night or in the weekends. As a result, they are not desensitised to the rural-type background odours. • Overall, rural residential areas would be considered to be of either moderate or low sensitivity, depending on the circumstances of the particular area.
Rural	v		v	• A low population density means that the opportunities for sensitive people to be exposed to odours is lower. • People living in and visiting rural areas generally have a high tolerance for rural-type odours. Some odours such as silage are offensive to some people and pleasant to others. Although these people can be desensitised to rural-type odours, they can still be sensitive to different types of odour (such as an industrial odour). • Rural communities may be more tolerant of rural-type odours but may be highly sensitive to non-rural-type odours (e.g. rural residents are not likely to be any more tolerant of rendering plant or landfill odours than those living in large metropolitan areas).
Heavy industrial			v	• A mix of odours is generally tolerated in industrial zones, as long as the intensity is not severe. • People who occupy these areas tend to be adult, and in good physical condition. They are more likely to tolerate some odour without finding it offensive or objectionable, particularly since the odour is associated with their employment (and source of income). • Many odours are emitted from sources located at or close to ground level, and tend to produce the greatest downwind odour effects at night during stable atmospheric conditions. Therefore, if the occupancy of an

Type of land use/location	**Sensitivity classification**			**Comments and reasons for classification**
	High	**Mod.**	**Low**	
				industrial zone is low or nil at night, the potential for adverse effects from odours during that period is low.
Light industrial		v		• This tends to be a mix of small industrial premises and commercial/retail/food industry activities. The latter are incompatible with industrial odour effects, so the sensitivity is described as moderate (i.e. greater than heavy industrial but lower than residential), even though occupation is likely to be low at night.
Light commercial / retail / business / education / institutional	v			• This land use is similar in sensitivity to the high-density residential area, as people of all ages and nasal sensitivity can use the area. • Some land uses (e.g. hospitals and schools) tend to be where people expect better than average air quality. • Depending on the mix of development in the area, human occupation may be low at night. This can moderate the sensitivity slightly.
Open space / recreational	v			• These areas are used by people for outdoor activities and exercise – where people tend to be more aware of the quality of air they are breathing, so their sensitivity is heightened. • People of all ages, physical condition and nasal sensitivity can be present. • People are more likely to be present during the day, but they could also be present at night (e.g. at a floodlit sportsground). • People often visit these areas from other parts of the city or country, and are more likely to be adversely affected by odours than those living in the area because they are not used to the exposure. • Some disagreement was expressed during consultation on the classification of sports fields as having high sensitivity. This may need to be considered on a case-by-case basis, depending on the type and frequency of use of the sports fields, and the number of visitors coming to watch sporting events.
Tourist / conservation / cultural / marae	v			• These areas are generally considered to have high environmental value, and therefore adverse odour effects are unlikely to be tolerated.
Public roads			v	• This is particularly applicable to the situation where a public road runs through the middle of a large odorous site, or through a buffer distance around a site. • Roads are generally considered to have a low sensitivity because people using them are only exposed to an odour (if present) for a short time.

We can group the land uses described in Table 2 into three degrees of sensitivity:

1. High sensitivity:

- residential/living (high-density residential)
- light commercial/retail/business/education/institutional
- open space/recreational
- tourist/conservation/cultural/marae

2. Moderate sensitivity:

- rural residential (low-density residential)
- light industrial

3. Low sensitivity:

- rural land
- heavy industrial.

These categories should be regarded as guidelines only, as there will always be exceptions. In particular, they should be used in accordance with amenity values defined in district plans for various land-use zones.

As we have already mentioned, the sensitivity of the receiving environment is also dependent on the offensiveness of the odour relative to the location in question, particularly if that odour is new to the area. For example, an odorous industrial chemical in a rural environment could turn that environment into a sensitive receiving environment, simply because it is unacceptable even to the very few people living in the area. People living and working in an industrial environment might not be so sensitive to that same chemical. Generally, the sensitivity of the receiving environment is dependent on the experiences and expectations of the people already in that environment, and the odours they are currently experiencing.

3.3 Short-term versus accumulated adverse effects

The FIDOL factors discussed in section 3.2.1 and the other factors discussed in 3.2.2 are commonly used by regulators in New Zealand to determine whether an odour is offensive or objectionable to the extent that it causes an *adverse effect*. Adverse effects can be caused by odours of low intensity and offensiveness occurring frequently over a long period, or by odours of high intensity and offensiveness occurring infrequently. We consider these two types of odour to cause different types of adverse effect, although both are important and both are defined by the FIDOL factors.

Odours of *low intensity* and *high frequency* can cause chronic effects (see section 3.3.1), and odours of *high intensity* and *low or high frequency* can cause acute effects (see section 3.3.2). Odours of *low intensity* and *low frequency* may cause chronic effects, or may be infrequent enough that no adverse effect is registered by the community.

The terms 'chronic' and 'acute' define the two extremes of adverse effect caused by odour. In reality, odour impacts are often caused by a mixture of the two, or by chronic effects that are mistaken for acute effects because of the intensity of the odour. Generally one type tends to be more dominant for a particular situation. The ability to identify which mechanism is dominant for a specific case is an important odour management skill, for which this report provides guidance.

The pattern of a particular industry's odour impacts can theoretically fall anywhere within the ranges of frequency, intensity and duration and can therefore be capable of causing both chronic and acute adverse effects. However, similar types of industry tend to produce similar types of emissions, resulting in one of these types of adverse effect being prominent. For example, continuous processing plants tend to generate continuous emissions that cause chronic adverse effects. Alternatively, a number of industry types generate little odour when operating normally, but specific incidents have the potential to cause acute adverse effects.

A more extended explanation of these two types of effects is provided next.

3.3.1 Chronic odour effects

By a chronic odour effect we mean the psychological stress caused by recurring odour impacts on neighbours of an industrial site, which is the primary type of odour effect caused by many processing and manufacturing industries. The main odour discharge in such cases is normally due to the continuous or semi-continuous emissions from defined and consistent processes, such as the drying of a food product or rendered animal by-products. The main feature of such emissions is that they are often controlled and quantifiable.

The most important aspect of chronic odour exposure is that significant (chronic) adverse effects can be caused irrespective of whether any individual odour event may be considered offensive or objectionable by a council enforcement officer. It is the repeated nature and accumulated effect of the odour events that cause the problem. The environmental significance of chronic odour effects is a function of the FIDOL factors discussed above; for example, the predominant wind patterns, including local/regional air drainage flow patterns at a specific site, greatly influence the extent of potential adverse effects at different locations surrounding the source.

The concept of chronic adverse odour effects and recent understanding of their importance has forced the definition of 'objectionable or offensive' to extend beyond the assessment of whether a single odour event can be deemed to be objectionable or offensive. For chronic odour effects a longer-term assessment is required, taking account of all the FIDOL factors.

Consequently, it is often impractical to determine how well a site is complying with the duty to avoid causing adverse odour effects by having regulatory enforcement officers make observations at or beyond the site boundary. When reports of such one-off assessments are used as evidence of non-compliance, the adverse effect being described is almost always related to an acute odour effect (see 3.3.2 below). To demonstrate non-compliance due to chronic odour effects, it is necessary to undertake an assessment of the accumulated effects over a period of at least several months.

3.3.2 Acute odour effects

The term 'acute odour effect' relates to the adverse effect due to the short-term exposure to odours that are sufficiently intense to be considered objectionable or offensive on a single occasion, irrespective of how often they may occur. This is the primary type of odour effect caused by activities with occasional discharges of odour. Such circumstances typically arise from abnormal process emissions, or infrequent activities that emit a large quantity of odour for a limited period of time. Examples include the 'crashing' of an aerobic waste-water treatment pond's dissolved oxygen levels, or the discharge of gas when re-opening old areas at a landfill site. The significance of these temporary sources of odour is often related to the quality of the management practices in place.

However, acute effects are not restricted to temporary or abnormal process emissions, but could occur on a regular basis as part of the normal operation of a factory. Acute odour impacts are also associated with highly variable and/or uncontrolled discharges of contaminants to the atmosphere that are typically difficult to quantify in a way that allows for reliable dispersion model calculations (see section 8).

Other examples of activities that can create acute effects but that can be substantially minimised by good management practice include some wastewater desludging operations, wastewater or sludge disposal to land, spraying of crops with agri-chemicals, and composting of waste solids.

Unlike chronic odour effects, when enforcing compliance if acute effects are involved, reports from a council officer of specific odour events beyond a site boundary can be effectively used as evidence of an adverse effect being caused.

3.3.3 The regulatory definition of 'adverse effect'

What is an 'adverse effect'? Section 17 of the 1991 RMA states: "Every person has a duty to avoid, remedy, or mitigate any adverse effect on the environment arising from an activity". Subsection 3 provides that this duty can be enforced by enforcement orders and abatement notices requiring a person to "cease, or prohibit a person from commencing, anything that … is or is likely to be noxious, dangerous, offensive or objectionable to such an extent that it is likely to have an adverse effect on the environment".

In relation to odour, the terms 'noxious', 'offensive' and 'objectionable' are all appropriate. In some cases the chemicals that make up the odour may be toxic, and the meaning of 'dangerous' will have to be considered, although the chemicals causing an odour will usually be present in much smaller concentrations than is required to cause an adverse effect on health (see section 3.1).

Regional air plans often refer to 'objectionable or offensive effects' as being the potential adverse effect of odour discharges predominantly from industrial or trade premises. A useful interpretation of 'offensive or objectionable effects' as applied to odour is given in the Gisborne Regional Air Plan[3] and the Proposed Bay of Plenty Regional Air Plan[4]:

> *'Offensive' is defined as '...giving or meant to give offence... disgusting, foul smelling, nauseous, repulsive...'. 'Objectionable' is defined as 'open to objection, unpleasant, offensive'. Case law has established that what may be offensive or objectionable under the Resource Management Act 1991 cannot be defined or prescribed except in the most general of terms. Each case will depend upon its own circumstances. Key considerations include:*
>
> *a) Location of an activity and sensitivity of the receiving environment: What may be considered offensive or objectionable in an urban area, may not necessarily be considered offensive or objectionable in a rural area;*
>
> *b) Reasonableness: Whether or not an activity is offensive or objectionable should be determined by an ordinary person who is representative of the community at large and neither hypersensitive nor insensitive, deciding whether the activity is disgusting, nauseous, repulsive or otherwise objectionable.*

This interpretation tallies with the definition of acute effects, but less so with that for chronic effects. Chronic effects may not give offence, nor be disgusting, foul smelling, nauseous, repulsive, nor even unpleasant (for example, the smell of coffee over a coffee shop). They still may be objectionable for those people who are repeatedly subjected to the odours over time, and therefore may still cause significant adverse effects such as stress, depression and even physical effects where people become sensitised to a specific odour.

Therefore, the general requirement imposed by regional air plans and in many air discharge consents to not cause objectionable or offensive odours is consistent with the general duties imposed by Section 17(3)(a) of the Act if the focus is on

[3] Proposed Regional Air Quality Management Plan for the Gisborne Region (August 2000), section 6.2.4.

[4] Proposed Bay of Plenty Regional Air Plan (July 2000), section 6.6.4(a).

both acute *and* chronic adverse effects on the community, rather than subjective interpretations of the meaning of 'objectionable and offensive' odour.

3.3.4 Sensitivity to odour and adverse effects

The High Court in *Zdrahal* v *Wellington CC* [5] in its test for what may be offensive or objectionable referred to the issue of sensitivity:

There are two ways to define sensitivity to odour:

1. *In any cross-section of the population, some individuals have a more sensitive sense of smell than others. Therefore, some people would be described as having a 'hypersensitive' sense of smell, and others would be described as having an 'insensitive' sense of smell, and the rest of the population would have an 'average' sense of smell.*

2. *The other type of 'sensitivity' is where a person has been subjected to an odour over time and becomes increasingly distressed and intolerant of its ongoing presence. This person is said to become 'sensitised'.*

In communities that have been subjected to odours for a period of time, the latter type of sensitivity described above may occur with some of the people. Although it may be difficult to find evidence to support or refute this for individuals, it would be more practical to demonstrate when the general community has become sensitised to a particular source of odour (see section 3.2.3).

One needs to be careful in the use of concepts such as 'hypersensitive people' and 'sensitised communities'. For example, the former type of individual may be considered not to reflect the average reasonable person in a community. However, the sensitisation of a general community (for example, via adverse conditioning processes) is not an indication that this community is unreasonable, or not suffering genuine adverse effects. The sensitisation to an odour source and the consequent distress is an adverse effect that can be experienced by the average, reasonable person and not just those who may be classed as being hypersensitive and/or unreasonable.

3.4 Where should the adverse effects be investigated?

For most of the 1990s consent conditions relating to odour tended to take the form 'no offensive or objectionable odour at or beyond the boundary of the site'. Theoretically, then, an enforcement officer could visit a site to monitor compliance with such a resource consent condition, and could observe odours that met this criterion at the boundary and take enforcement action against the owner – even if no one is actually adversely affected by the odour due to the separation

[5] [1995] 1 NZLR 700

distance between the site and the nearest sensitive receptors (for example, houses or recreational grounds). We therefore recommend that a local authority should not take enforcement action in such a situation.

There are two related issues here: 'internalisation' and 'reverse sensitivity'. The principal of internalisation is that those who create adverse effects must internalise them rather than force the rest of society to bear the burden of dealing with them. 'Reverse sensitivity' refers to the effects of the existence of sensitive activities on other nearby activities that have lower sensitivities, particularly by leading to restraints in carrying out those other activities[6]. (See Appendix 2 for case law on these two issues.)

Investigations of odour problems should be made at a place where the adverse effect is being felt, which in some cases will be some distance *beyond* the boundary of the offending activity and not necessarily *at* the boundary. Investigating officers should not monitor odours detected at the boundary of the site in the absence of any adverse effects further out in the neighbouring community.

However, when formulating consent conditions there are two arguments in favour of retaining the wording 'at or beyond the boundary of the site' even in situations where there are no sensitive receptors immediately beyond the boundary.

- The owner/operator of an activity that discharges odours does not have the right to use neighbouring land that he/she does not own as a mixing zone or buffer distance for dilution and dispersion of the odours, unless the land is zoned appropriately (such as a buffer zone or designation around a waste-water treatment plant), or consent is given by the owner of that land.

- The neighbouring land, which may have been unoccupied at the time of granting the consent, may be developed at a later time for a more sensitive land use.

Generally, if the FIDOL and other factors in sections 3.2.1 and 3.2.2 above are used to consider whether offensive or objectionable odour effects have occurred, then the sensitivity of the receiving environment will be automatically taken into account. For the reasons listed above, we recommend that the condition wording 'at or beyond the boundary of the site' be retained in resource consents, except in cases where a buffer distance is warranted or agreed to. In the latter case an alternative wording could be used, such as 'within [x] metres of a residential property boundary or public place'.

However, because of the requirement to demonstrate and monitor any adverse effects, such conditions should not be used by council enforcement staff as a reason to monitor effects anywhere except at the location of public complaint. As noted in 3.5.3, whether something is offensive or objectionable has to be linked to

[6] *Auckland RC* v *Auckland CC* [1997] NZRMA 205; (1997) 3 ELRNZ 54 (EnvC)

whether it is of such an extent that it has or is likely to have an adverse effect on the environment. (Guidance on complaint monitoring and enforcement is given in chapter 5.)

3.5 The legal perspective on adverse effects from odour

3.5.1 Is odour a contaminant?

There has been some debate over whether odour constitutes a contaminant under the RMA. Section 2 of the Act provides a definition of contaminant as follows:

> *'Contaminant' includes any substance (including gases, liquids, solids, and micro-organisms) or energy (excluding noise) or heat, that either by itself or in combination with the same, similar, or other substances, energy, or heat–*
>
> *(a) When discharged into water, changes or is likely to change the physical, chemical, or biological condition of water; or*
>
> *(b) When discharged onto or into land or into air, changes or is likely to change the physical, chemical, or biological condition of the land or air onto or into which it is discharged.*

The definition specifically refers to the discharge of the chemicals. As noted in section 2.1, odorous compounds are chemicals. Therefore, odour is a 'contaminant' as defined in the RMA.

3.5.2 Chronic and acute effects

'Effect' is defined in section 3 of the RMA as:

> *In this Act, unless the context otherwise requires, the term 'effect' … includes–*
>
> *(a) Any positive or adverse effect; and*
>
> *(b) Any temporary or permanent effect; and*
>
> *(c) Any past, present, or future effect; and*
>
> *(d) Any cumulative effect which arises over time or in combination with other effects–*
>
> *regardless of the scale, intensity, duration, or frequency of the effect, and also includes–*
>
> *(e) Any potential effect of high probability; and*
>
> *(f) Any potential effect of low probability which has a high potential impact.*

This definition covers both acute and chronic effects, as defined in section 3.3. Both types of effect come within sections 3(d) and 3(e) of the Act. Acute effects could also be considered under 3(f).

Two cases, *Te Aroha Air Quality Protection Appeal Group* v *Waikato RC*[7] and *RC Vosper & Sons Ltd* v *New Plymouth DC*,[8] consider the issue of acute odour effects, although the Planning Tribunal did not use that term, but instead referred to (f) in section 3 of the RMA. A summary of the conclusions from these two cases is as follows (see Appendix 2 for further detail).

Te Aroha Air Quality Protection Appeal Group v *Waikato RC*

This case related to appeals against land-use consent and air-discharge permits granted for a new by-products rendering plant located next to an export beef plant. On appeal the Tribunal refused consent, concluding that the potential high impact that might result from the low-probability occurrence of an emission from the proposed rendering plant was not an acceptable risk under the RMA. The Tribunal found that the escape of objectionable odours would adversely affect people and the social, economic, aesthetic and cultural conditions, and amenity values, and would have a potentially high impact on local businesses.

RC Vosper & Sons Ltd v *New Plymouth DC*

This case addressed an appeal against the district council's refusal to grant consent to install a cremator unit and modify part of an existing building as a crematory in New Plymouth. The Tribunal found that "the potential impact could not be compared with the breadth of impact apprehended in the Te Aroha Air Quality Protection Appeal Group case". The anticipated potential effects were not significant enough to warrant refusing the consent. (Although the Tribunal found in favour of the applicant in relation to the odour issue, it refused consent for other reasons.)

3.5.3 Case law – 'offensive or objectionable'

Whether something is noxious, dangerous, offensive or objectionable has to be linked to whether it is of such an extent that it has or is likely to have an adverse effect on the environment. The High Court in *Zdrahal* v *Wellington CC*[9] held that the correct test for what may be offensive or objectionable under the RMA must be objective; that is, if reasonable ordinary people – neither hypersensitive nor insensitive – would be offended or find it objectionable.

The Court of Appeal in *Watercare Services Ltd* v *Minhinnick*[10] confirmed and adopted the approach in *Zdrahal*, and set out four steps for establishing whether

[7] (No 2) (1993) 2 NZRMA 574 (PT)
[8] [1994] NZRMA 324 (PT)
[9] [1995] 1 NZLR 700
[10] CA221/97

an enforcement order should be made under section 314(1)(a)(ii); that is, whether an activity is noxious, dangerous, offensive or objectionable. In summary these are:

1. The Court must be satisfied that the applicant's assertion is honestly made.

2. The subject matter of the application is or is likely to be noxious, dangerous, offensive or objectionable.

3. If it is, it is of such an extent that it is likely to have an adverse effect on the environment.

4. If the first three steps are established, the Court's discretion should be exercised in favour of making the enforcement order.

The Court held that at the second and third steps the Court is acting as the representative of the community at large. It must weigh all the relevant competing considerations and ultimately make a value judgement on behalf of the community as a whole.[11]

Chapter 3: Recommendations

1. When assessing offensiveness (factor "O" in the FIDOL factors), the inherent character and cultural associations of the odour should be assessed. The more subjective rating of the odour's hedonic tone can also be provided, but is insufficient on its own to establish offensiveness in the context of a FIDOL factor analysis.

2. When assessing the significance of adverse odour effects, observation by council enforcement officers should be undertaken from the location(s) of neighbouring sensitive land-use areas. Observations of odour effects that are adjacent to the property boundary of an activity should only be undertaken in circumstances where sensitive receptors or land uses are also situated close to the property boundary.

3. The condition wording 'at or beyond the boundary of the site' should be retained in resource consents, except in cases where a buffer distance is warranted or agreed to.

[11] For further consideration of the case law, see Appendix 2.

4. Overview of Assessment Techniques

This chapter summarises the range of odour assessment tools discussed and recommended in this report. Detailed discussion of each assessment tool is then given in chapters 5 to 9.

4.1 Types of odour assessments

An assessment of odours in the environment may need to be carried out for a variety of reasons, including:

(a) preparing or evaluating resource consent applications, section 128 reviews (review of consent conditions), or impact assessments, for three separate categories:

- category (i): renewing an existing activity
- category (ii): proposed modifications to an existing activity (mitigation or process change)
- category (iii): proposed new activity

(b) monitoring compliance with resource consent conditions

(c) investigating odour complaints to determine if an offensive or objectionable odour is present.

The methods used to assess the odours will depend on the type of situation. A number of different techniques for odour assessment are available, and together these form a 'toolbox' of odour assessment techniques. The best tools to use for an odour assessment partly depend on whether the assessment is an evaluation or a compliance issue. This has been a source of confusion in the regulation of air discharges. The confusion most commonly arises in the resource consent process, where an application is evaluated against appropriate criteria before a decision is made.

Evaluation involves assessing the actual and potential effects of an activity to determine whether significant adverse environmental effects will occur. If the consent is granted, the consent holder is then required to *comply* with (and be able to demonstrate compliance with) any conditions imposed as part of that consent. These two processes for evaluation and compliance are quite separate, and often the evaluation criteria are different to the criteria imposed as conditions of consent.

4.2 Introducing the toolbox

The odour assessment toolbox includes the following techniques.

Table 3. The odour assessment toolbox

Technique	Description
1. *History of complaints regarding the discharge*.	Procedures for investigating complaints and using them to assess patterns of odour nuisance are discussed in chapter 5 .
2. *Experiences of the applicant or regional council with the discharge, and information regarding past compliance.*	This will obviously vary on a case-by-case basis. Section 35(5)(i) of the Act requires local authorities to keep a summary of all written complaints received by it during the preceding 5 years concerning alleged breaches of the Act or plan, and information on how it dealt with each such complaint. Experience can also include the collation of field observations of odour impacts via either informal methods, or when following standardised VDI procedures for completing field observations (chapter 5).
3. *Information from community consultation undertaken by the discharger*.	Some general guidelines on consultation are discussed in chapter 6.
4. *Information from odour diaries, community surveys, and other surveying tools such as field investigations undertaken by the discharger*.	Methods for developing, undertaking, and using the results of diaries and surveys are discussed in chapter 6. The Court has imposed resource consent conditions requiring the consent holder to conduct community surveys and odour diary programmes[12]. For examples of conditions, see Appendix 2.

[12] *Broomfield v Otago RC* W45/97. Appeal against discharge permits with respect to a landfill. The Court imposed a condition that required the consent holder to maintain a record of complaints relating to odour emissions, including the location where odour was detected, date and time, description of wind speed and direction, most likely cause, and any corrective action undertaken. The consent holder was also required to implement a community odour diary programme where odour nuisance complaints occurred more than once a week over a month period, and to correlate the information. The conditions are included in the examples in Appendix 2.

Hicks v Canterbury RC C58/95. Appeal against consents for sewage treatment and disposal system. The Court imposed conditions, which required records to be kept of all odour complaints in which the complainant considers the odours result from the sewage operation. The records were to include the location, time, and wind speed and direction, and any corrective action taken.

5.	*Dynamic dilution olfactometry measurements and dispersion modelling results.*	Measurement techniques are discussed further in chapter 7. Dispersion modelling techniques and the development of odour-modelling guidelines to interpret the model's results are discussed in chapter 8.
6.	*Review of site management and contingency plans*.	Is the best practicable option (BPO) being applied for the discharge? BPO and other management and mitigation practices will be briefly discussed in the final odour management guide.
7.	*Review of process controls and design, and records of emission control improvements undertaken and those proposed for the future*.	This also includes engineering risk assessment (e.g. frequency of pond crashes).
8.	*Analysis of site-specific wind and topographical features*.	This is discussed in section 8.4.
9.	*Past experiences and knowledge of the odour effects generated from existing sites of a similar nature and scale*.	This can be useful in assessing whether adverse effects are likely, but requires expert analysis to account for the site in question having different topographical, meteorological or odour emission properties.

Deciding which of these evaluation techniques is most appropriate will depend on the type of application and the particular activity and location. Often a number of techniques will be used in combination. An overview of the various assessment tools, their advantages, disadvantages and applications is given in Table 4. This includes tools not recommended for assessing odour effects, but which can be used for internal monitoring of performance.

Table 4. Overview of potential assessment tools

Tool	**Advantages**	**Disadvantages**	**Situations where tool is useful**	**Situations where tool is less useful or inappropriate**
Council officer investigations in response to complaints	• Independent verification of occurrence of adverse effect • Confirmation of source and cause of odour	• Odour-causing adverse effect may have disappeared before officer can investigate • Officer may not be able to confirm significant adverse effect if odour is of low intensity (and contributing to overall long-term chronic effect)	• Acute effects – single odour-causing events that are of high odour intensity • Where there is some confusion or doubt regarding the source of the odour • To eliminate vexatious complaints	• Chronic effects – where no single event is offensive
Odour annoyance surveys	• Accounts for real effects and interactions of physical and social factors A simple and cost-effective approach for assessing the relative extent of nuisance being caused within a community Can also help to rank different industrial facilities according to their contribution to the overall cumulative stress or annoyance within a specific community	• Can only be implemented for urban or semi -urban population densities to ensure statistical significance • Requires specialist design for each case to ensure results relate to a particular level of impact	• Measurement of degree of adverse effect in terms of annoyance, in urban or semi-urban areas • Where odour is being contributed by a number of sources of varying character • To quantify the zone of influence from a specific odour source	• Rural or isolated areas where population density is low

Tool	Advantages	Disadvantages	Situations where tool is useful	Situations where tool is less useful or inappropriate
Odour diary	• Provides a method of obtaining information from the community on odour impact patterns • Gives exposure pattern information, such as frequency of strong, moderate or weak odour impacts at various locations, over a defined period of time • Diarists can record adverse effects as they happen (e.g. ‘had to shut windows, felt nauseous’)	• Difficult to conduct in a way that provides useful data unless diarists are well motivated • Considerable diligence and effort are required from all parties to sustain diary entries over a long period • Less straightforward to evaluate the significance of results compared to annoyance survey data, as the information is not a direct measure of adverse effects being caused	• Rural or isolated areas where population density is low • When the major type of effect is either chronic (frequent, low intensity impacts) or due to short-term acute impacts. • Measuring odour occurrence patterns (e.g. frequency, duration) • Confirming whether a particular industrial or trade site is causing occasional odour impacts	• Can be used in most situations, but is less effective than surveys for establishing effects in densely populated communities
Community consultation	• Gives a measure of the sensitivity of the receiving environment in terms of community receptiveness to odour • Gives a qualitative measure of the degree of adverse effect being experienced • May indicate community feeling towards allowing odour when the cause of odour is the dominant industry (and revenue earner) for a community	• Few if any disadvantages	• Obtaining community feedback regarding odour effects • Obtaining community feeling towards a proposed new development.	• None

Tool	Advantages	Disadvantages	Situations where tool is useful	Situations where tool is less useful or inappropriate
Individual field observations of odour using employed sniffer	• Provides daily feedback to company managers on the relative level of odour present beyond the boundary	• Information is obtained in a relatively informal way, which is not considered suitable as a tool for establishing the significance of actual odour effects	• Providing feedback to company staff to indicate the likely level of odour being created beyond the site boundary on a particular day, and trends over the longer term	• Use as evidence of either significant or minor adverse odour effects caused in a community
Individual field observations of intensity versus time (VDI method – see 5.3.1)	• Can be used to collate a data base of odour intensity versus time patterns for different weather conditions • Provides detailed FIDOL information over relatively short time periods • Does not require emotive judgements of odour character or effects • Results can be linked to existing intensity versus odour concentration relationships, and used to infer odour exposure levels and peak-to-mean ratios in the environment	• As with odour diaries, the information indicates the exposure pattern and is not a direct measure of adverse effects being caused • Requires detailed procedures and training of assessors to ensure consistent results • Only suitable for existing activities, although this experience may be transferable to other sites when allowing for changing meteorology and emission control technology	• Confirming the character of existing impacts of odour • Investigating odour complaints • Self-monitoring of odour impacts beyond the site boundary • Providing further supporting information to odour diary or survey programmes	• None
Assessment of site-specific meteorology and terrain features	• Essential to ensure that areas affected by worst-case weather conditions are identified, as well as areas that will be most frequently impacted due to terrain	• None	• All situations	• Often requires expert micro-meteorological knowledge to complete a reliable assessment

Tool	Advantages	Disadvantages	Situations where tool is useful	Situations where tool is less useful or inappropriate
	effects and/or regional weather patterns. Also necessary when transferring experience from other sites.			
Industry/council experience and records	• The council can judge the reliability of the owner/operator to follow a management plan, etc. • Apply typical buffer distances • Draw on knowledge of the nature of the emissions, including variability and character • Know what works in terms of practical mitigation options	• When comparing two similar industries, if there is some variable that creates the potential for a different odour annoyance between the two; e.g. sensitivity of receiving environment, meteorological influences, quality of raw materials or on-site management practices	• Establishing a new industry when there are similar industries already present in the region • Assessing the likely effect of proposed mitigation options	• None
Source monitoring and dispersion modelling	• Allows prediction of changes in adverse effects • Allows investigation of the contribution of individual sources to overall odour level • Allows investigation of the effect of potential mitigation options, and identification of priorities for mitigation of various odour sources within a site • Allows identification of	• Adequate monitoring can be expensive, and may not capture the worst conditions for odour emission • Of little use where acute odour impacts create the main potential for adverse effects. • Modelling predictions are often unreliable because of paucity of emission data and/or complex drainage flow patterns	• When changes are proposed to an existing activity, such as expansion or mitigation • When a new activity is proposed	• Existing activities, unless for assessing the potential effect of proposed plant changes, confirming actual emission rate changes, or distinguishing activity from other similar activities. Occasional or periodic releases of odour, unless emission rate is known (often will not be).

Tool	Advantages	Disadvantages	Situations where tool is useful	Situations where tool is less useful or inappropriate
	zones of greatest potential impact beyond a site	• Needs an appropriate odour-modelling guideline		

4.3 Selecting the appropriate evaluation tools

In this section we provide guidance for selecting the appropriate evaluation tools for each of the different types of assessment situation.

4.3.1 Preparing or evaluating an application to renew a resource consent

Category (i): existing activity

In this type of application the applicant seeks consent to continue with their current activity in the same manner, without any changes to the ways in which odours are generated and discharged. Odour monitoring and dispersion modelling are of little benefit in situations where community feedback and field investigations can be used to provide a more reliable assessment of the existing odour effects. Evaluation techniques that rely on assessing the degree of significant adverse effect experienced by people occupying land near the activity and a systematic field observation programme are more applicable.

When investigating *existing activities* that may be causing adverse effects, it is important to determine the type of adverse effect that is most likely to be occurring: whether they are chronic or acute odour effects, due to normal and controlled or uncontrolled releases of emissions to air, respectively. The correct identification of the type of adverse odour effects will help in the selection of the appropriate odour assessment tool.

Guidance on how to apply the appropriate tools for this situation is given in Figure 2, which indicates that if the person carrying out the evaluation considers that adverse effects cannot be suitably avoided, then the activity may be reclassified and evaluated as if it were a category (ii) activity.

The odour assessment tools in Figures 2 to 4 are given a priority, representing the typical weighting that is recommended for that tool in this assessment scenario.

Category (ii): proposed modifications to an existing activity

Resource consent applications are rarely as straightforward as in category (i), and the assessor must often evaluate the likely actual and potential effects of proposed changes to existing activities, or evaluate whether proposed odour emission control measures will be adequate to avoid, remedy or mitigate existing adverse effects. Although performance standards and proven control technology requirements can be used to minimise odour release, a greater reliance must be placed on dispersion modelling to consider the actual and potential effects. Application of the appropriate tools for this situation is shown in Figure 3.

In many cases the question of whether there is an adverse effect should be answered from the evidence of complaints, odour surveys or diaries, and consultation with neighbours. The dispersion model can then be calibrated to determine an appropriate odour-modelling guideline for assessing the results specific to the site. The role of dispersion modelling would then be to determine the degree of improvement offered by various mitigation options, rather than to prove the absence of an adverse effect.

If there are significant sources of background odour in the area around the site, this approach may not be possible, and the dispersion modelling approach described for category (iii) below may be required.

Category (iii): proposal for a new activity

This can be the most difficult type of application to prepare or evaluate. In this case there is no history of complaints, nor plant performance from which to determine the existing odour effects, and the regulator must rely heavily on dispersion model results or past experience with similar activities and proposed controls. The evaluation can be complicated if there is little information on which to select odour emission rates, and often a conservative approach to evaluation will be required. The dispersion modelling approaches described in section 8 should be applied. Application of the appropriate tools for this situation is shown in Figure 4.

(b) Monitoring compliance with resource consent conditions

This situation is similar to preparing or evaluating an application for a resource consent for an existing activity. The preferred assessment techniques will depend on the type of resource consent conditions being monitored. Odour monitoring may be carried out if discharge limits have been set on any odour sources within the site. However, the most important conditions will be those that require no offensive or objectionable odour effects beyond the boundary, or similar. Odour monitoring and dispersion modelling is of little use in this case, because it is generally less reliable than community feedback and field observations for establishing the true significance of existing odour effects.

Assessment techniques that rely on assessing the degree of significant adverse effect experienced by people occupying land near the activity are more useful, including complaint monitoring, community consultation, and odour diaries and surveys. However, some modelling may still be useful to distinguish between the odour contributions of neighbouring odorous activities.

(c) Investigating odour complaints to determine if offensive or objectionable odour effects are present

The range of assessment techniques used in this situation may vary from a simple subjective analysis of complaint records, to the use of odour diaries and surveys, to a full re-assessment of effects from the activity as if the site were applying for resource consents.

(i) Existing activities

Determine presence or absence of chronic effects

Assessment Tool	Priority	Comments
Complaint records	High	Complaints should be classified as validated by a council officer, or from wind-direction records, or as simply registered but not confirmed.
Industry/council experience	High	Experiences of the industry or regional council with the discharge.
Community consultation	High	Periodic meetings with community representatives from community associations. Look for anecdotal evidence of community feeling about odour effects.
Odour annoyance survey	High	Urban and semi-urban areas. Assess against percent at-least annoyed criteria.
Meteorology and terrain assessment	Moderate to high	Use to assess potential for downwind adverse effects as a result of poor dispersion around terrain features or in particular meteorological conditions.
Odour diaries and weather monitoring	Moderate	Isolated areas with low population densities. Assess the frequency, duration, and strength of odour impact events and associated experiences over 6 months, or a longer time period if necessary, to encompass a specific season.
Review of emission control system(s)	Moderate	Look for compliance with best practicable option (BPO), or industry codes of practice.
Olfactometry and modelling of odour sources	Moderate to low	Generally this tool is not recommended for existing activities unless for assessing the potential effect of proposed plant changes, confirming actual emission rate changes following new procedures and/or new plant commissioning etc, or distinguishing the activity in question from other similar activities in the region.

Are there any chronic effects?

Yes → Becomes a category (ii) activity

No

Determine acute adverse effects, either already present on occasion, or with the potential to occur

Assessment Tool	Priority	Comments
Complaint records	High	Have any complaints been attributed to acute events?
Industry/council experience and records	High	As for chronic effects.
Community consultation	High	As for chronic effects.
Review of odour management plan and contingency procedures	High	What is the level of acceptable risk for uncontrolled odour discharges? consider high-probability/low-impact events, and low-probability/high-impact events. Is BPO being utilised?
Odour annoyance survey	Low	If the acute effects are infrequent, surveys may not reflect the impact of the effect on the surrounding environment.
Odour diaries and weather monitoring	Low	If the acute effects are infrequent, diaries may not reflect the impact of the effect on the surrounding environment.
Olfactometry and dispersion modelling of odour sources	Low	Not recommended as an assessment tool for occasional or periodic releases of odour.

Are the acute effects adequately protected against?

No → Becomes a category (ii) activity

Yes

Evaluation completed

Figure 2. Selection of odour assessment tools for preparing or evaluating resource consents for an existing industrial or trade activity

(ii) Proposed modifications to existing activities

Determine presence or absence of chronic effects

Assessment Tool	Priority	Comments
Complaint records	High	Complaints should be classified as validated by a council officer, or from wind-direction records, or as simply registered but not confirmed. Assess how proposed changes will reduce level of complaint.
Industry/council experience	High	Experiences of the industry or regional council with this or other similar discharges.
Community consultation	High	Periodic meetings with community representatives from community associations. Look for a necdotal evidence of community feeling about odour effects.
Olfactometry and modelling of odour sources	High	Use results of complaints analysis, community consultation, and any surveys or diaries to identify the scale of problem, then use modelling to assess the effect of proposed plant changes.
Odour annoyance survey	High	Urban and semi-urban areas. Assess against percent at-least annoyed criteria. Assess how the proposed changes will reduce level of annoyance.
Meteorology and terrain assessment	Moderate to High	Use to assess the potential for downwind adverse effects as a result of poor dispersion around terrain features or in particular meteorological conditions.
Odour diaries	Moderate	Isolated areas with low population densities. Assess the frequency, duration, and strength of odour impact events and associated experiences over 6 months, or a longer time period if necessary, to encompass a specific season. Assess how the proposed changes will reduce level of annoyance.
Review of emission control system(s)	Moderate	Look for compliance with best practicable option (BPO), or industry codes of practice.

Are there any chronic effects?

Yes → Consider further mitigation and alternative options

No

Determine acute adverse effects, either already present on occasion, or with the potential to occur

Assessment Tool	Priority	Comments
Complaint records	High	Have any complaints been attributed to acute events? Assess how proposed changes will affect plant performance.
Industry/council experience and records	High	As for chronic effects.
Community consultation	High	As for chronic effects. Assess how the proposed changes will affect plant performance.
Review of odour management plan and contingency procedures	High	What is the level of acceptable risk for uncontrolled odour Discharges? consider high-probability/low-impact events, and low-probability/high-impact events. Is BPO being utilised? Assess how the proposed changes will affect plant performance.
Olfactometry and dispersion modelling of odour sources	Low	Not recommended as an assessment tool for occasional or periodic releases of odour.

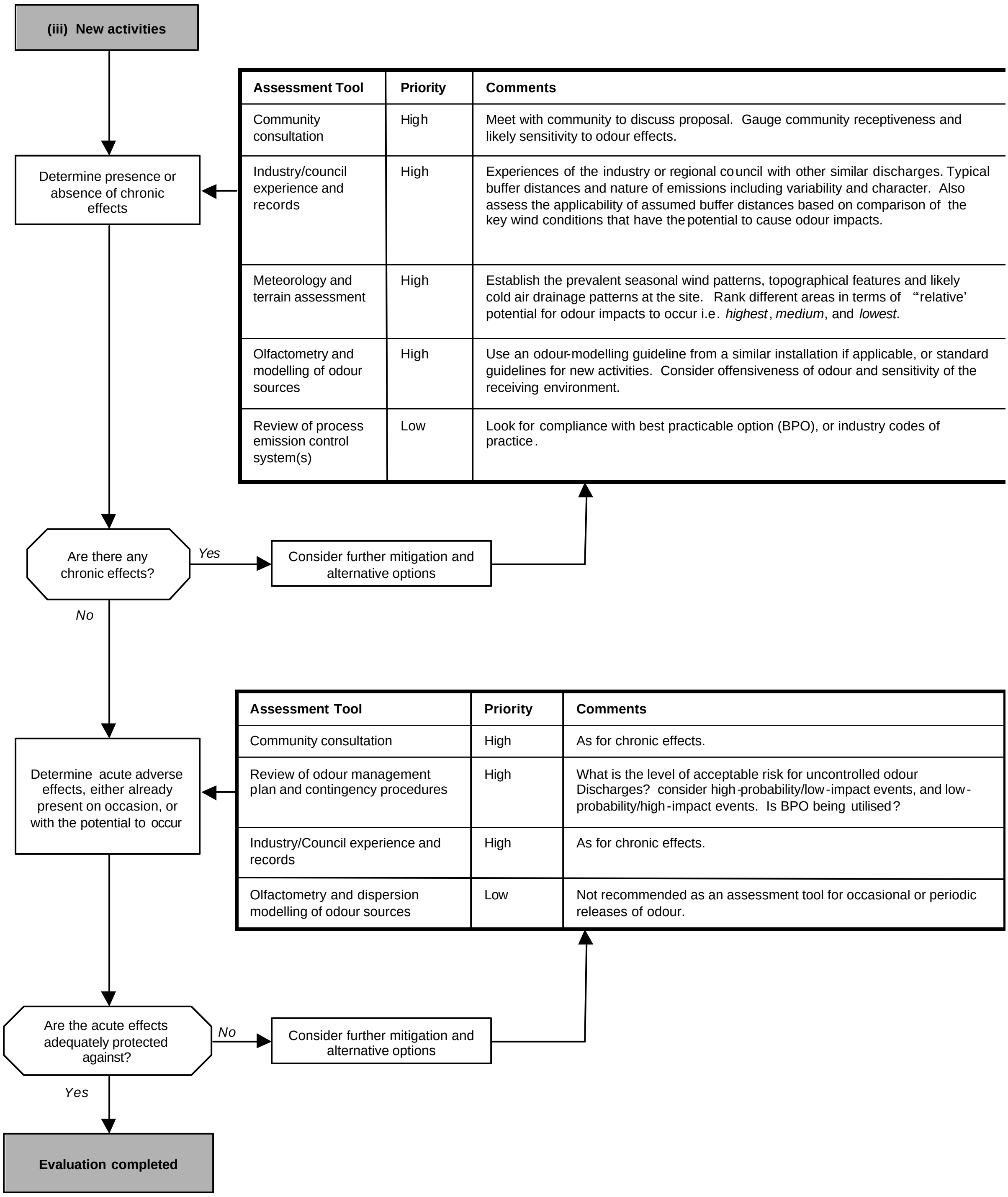
Are the acute effects adequately protected against?

No → Consider further mitigation and alternative options

Yes

Evaluation completed

Figure 3. Selecting odour assessment tools for preparing or evaluating resource consents for proposed modifications to an existing industrial or trade activity



Assessment Tool	Priority	Comments
Community consultation	High	Meet with community to discuss proposal. Gauge community receptiveness and likely sensitivity to odour effects.
Industry/council experience and records	High	Experiences of the industry or regional council with other similar discharges. Typical buffer distances and nature of emissions including variability and character. Also assess the applicability of assumed buffer distances based on comparison of the key wind conditions that have the potential to cause odour impacts.
Meteorology and terrain assessment	High	Establish the prevalent seasonal wind patterns, topographical features and likely cold air drainage patterns at the site. Rank different areas in terms of "relative' potential for odour impacts to occur i.e. *highest*, *medium*, and *lowest*.
Olfactometry and modelling of odour sources	High	Use an odour-modelling guideline from a similar installation if applicable, or standard guidelines for new activities. Consider offensiveness of odour and sensitivity of the receiving environment.
Review of process emission control system(s)	Low	Look for compliance with best practicable option (BPO), or industry codes of practice.

Assessment Tool	Priority	Comments
Community consultation	High	As for chronic effects.
Review of odour management plan and contingency procedures	High	What is the level of acceptable risk for uncontrolled odour Discharges? consider high-probability/low-impact events, and low-probability/high-impact events. Is BPO being utilised?
Industry/Council experience and records	High	As for chronic effects.
Olfactometry and dispersion modelling of odour sources	Low	Not recommended as an assessment tool for occasional or periodic releases of odour.

Figure 4. Selecting odour assessment tools for preparing or evaluating resource consents for a new industrial or trade activity

Having given a summary of the odour assessment tools available and the situations in which they are applicable, we now turn to look at each of these tools in more detail.

Chapter 4: Recommendations

1. Air-quality practitioners should undertake an evaluation of the odour assessment tools before commencing an odour assessment to ensure that the most effective strategy is being used for the specific case.

2. The evaluation of appropriate odour tools should be primarily influenced by the category the assessment applies to (category (i), (ii) or (iii) as discussed in section 4.3).

3. The second important consideration when evaluating appropriate odour assessment tools is whether the potential for adverse odour effects is likely to be dominated by continuous/semi-continuous process emissions, or by infrequent emissions events. This establishes whether chronic or acute odour effects are more relevant, or if both types are likely to be significant.

4. For any odour assessment category, (i), (ii) or (iii), the analysis of site-specific micro-meteorology, industry/council experience (which may include officer investigations and complaint records), and review of odour emission controls, in conjunction with community consultation, should be part of any assessment.

5. In addition to the fundamental assessment tools (recommendation 4 above), the appropriate selection of the other assessment tools – including odour annoyance surveys, odour diaries, field investigations, management plans/contingencies and odour modelling – should be considered with reference to the prevalent types of odour effect(s) and with the guidance provided in Table 4 and Figures 2, 3 or 4.

6. Odour annoyance surveys are strongly recommended for assessing and monitoring the significance of adverse odour effects when these can be practically implemented. For existing activities that have the potential to cause repeated odour impacts on urban residential areas, the use of a standard odour annoyance survey is recommended in preference to odour diaries, field investigations and odour modelling for establishing the significance of the existing odour effects.

7. Field investigations of odour and odour diary programmes to establish long-term FIDOL factors are recommended tools for providing supporting evidence to odour annoyance surveys, when the latter can be practically implemented. Where odour annoyance surveys are not practical, the use of field investigations and/or the completion of odour diary programmes becomes paramount.

8. When assessing the potential odour effects due to proposed modification or expansion of existing activities, it is important to assess the existing odour effects as recommended for existing activities (recommendations 6 and 7). This would then provide support for the improvements that may be derived by odour modelling, or from general experience.

9. For proposed new activities, odour modelling is recommended as a mandatory tool where the predominant odour effect is due to normal process discharges of odour that are continuous/semi-continuous and where reliable odour emission data is available.

5. Council Officer Observations and Complaint Investigations

5.1 Difficulties with complaints

Council officers often carry out site investigations in response to complaints from the community, which can sometimes be used as evidence to support enforcement action under the Act. If the complaints are to be used in this way, the completion of a rigorous and non-biased investigating procedure is essential, as the resulting evidence could be scrutinised by the Court.

In practice, many odour complaints are not investigated by a site investigation, but are simply recorded by the council or company who receives them. This is because odour incidents can often occur outside normal working hours – in the evenings, mornings, and during the night when atmosphere conditions are stable. Also, odours have often lessened or disappeared by the time staff from the council arrive to investigate a complaint. These characteristics of odour investigations are quite normal, and have a number of causes such as:

- the odour emissions from the activity are often highly variable, and must remain sufficiently high from the time of the complaint to the time of the investigation to result in it being recognised beyond the site boundary for the prevailing weather condition (wind speed and atmospheric stability)
- the wind direction is rarely constant for more than several minutes and often swings through an angle of 45 degrees, therefore varying at least 20 degrees either side of the hourly mean direction. For stable conditions this wind shift can be much greater. Such wind shifts can result in large changes in the odour intensity at any particular location
- the perception of odour following a wind shift can eventually dissipate as the nose becomes desensitised.

Validating complaints can also be difficult if:

- the site is located away from an urban base, such that an investigating officer cannot immediately verify complaints by a site visit
- the investigating officer is inexperienced with the type of activity causing the odour, or is unfamiliar with the local environment
- the investigating officer is particularly sensitive or insensitive to odours (see discussion on calibrated noses, section 5.5).
- there is a significant delay in receiving complaints from the time the odour event occurred.

Odour complaints that are not investigated can still provide a tool for assessing odour effects due to existing activities. In situations where specific complaints are a function of previous odour incidents (accumulated stress due to chronic odour exposure), the investigation of any specific incident by a council officer is not as important as the assessment of the cumulative effects of repeated incidents.

The complainant and the investigating officer may not always agree on the intensity of the odour. For example, the complainant may find the odour to have a higher degree of adverse effect because they are trying to carry out their day-to-day activities, such as cooking, sleeping or airing out the house. Or the complainant may have been subjected to frequent odour incidents over a long period, and may be stressed and frustrated by this, so their tolerance of the odour may have reduced to the point where they consider an odour to be of greater adverse effect than an investigating officer would

5.2 Verifying complaints

5.2.1 When should complaints be verified?

If someone registers a complaint by telephone, you should include the basic details of complaint *location, date and time* of incident, a description of the *odour character/strength/duration* of the event, and the *alleged source*. With this primary information, the *operating status* of the alleged source and *concurrent wind conditions* can be established at a latter date. It is then possible to at least confirm whether or not the complainant was likely to be downwind of known odour sources.

The procedures described below for investigating an odour complaint and reporting the findings may appear time-consuming and involved for routine site visits and investigations. However, when an investigation by a council officer is in response to an odour complaint and the aim is to confirm that the odour was likely to be causing objectionable or offensive effects, these detailed standard procedures are recommended.

Complaints have to be verified whenever enforcement action is being considered:

- to confirm that enforcement action is appropriate (for example, the council receives complaints but investigation establishes that the odour is from some other source[s])

- to identify which enforcement mechanism should be used (for example, the situation is not serious and it is appropriate to take low-level enforcement action and issue an infringement notice or abatement notice; or the situation is serious and it is appropriate to apply for an enforcement order or prosecute)

- to provide evidence for the enforcement action (for example, the council decides that it is appropriate to apply for an enforcement order, and evidence of the investigations is required to establish, on the balance of probability, that conditions of the consent have been breached and the odour is offensive and objectionable and has caused adverse effects to neighbours.

If the complaints are verified, council staff should discuss the complaints and the outcome of the investigation with the site operator/owner. This is informal enforcement action and may resolve the problem (note that there should also be discussion with the site operator/owner when each incident is investigated, as recommended in section 5.2.3).

5.2.2 Where should the complaint be investigated?

As discussed in section 3.4, assessing odour at the site boundary to establish the level of compliance with the requirement not to cause objectionable or offensive odour effects would be inappropriate in cases where the affected community is located further away[13]. Land-use sensitivity is a primary factor for considering whether an odour discharge is likely to cause adverse effects (objectionable or offensive effects). Section 17(3)(a) of the Act is ultimately concerned with adverse effects on 'sensitive receptors' in the community, which may be some distance from the site boundary, and there will be many situations where property beyond the site boundary could act as a buffer zone. Residential zones are typically the most sensitive areas to industrial or trade premises odours, and as such any assessment of objectionable or offensive odour effects within such areas should be conducted from within them.

On the other hand, there will be many situations – particularly in urban areas – where assessments at the site boundary will be appropriate. Even in some rural locations farmers may rightly object to industrial odours occurring within their property. As a general guide, undertake odour complaint investigations from the location of the complainant, and assess the odour from the perspective of that location.

5.2.3 Recommended investigation procedure

It is important that an investigating officer not go to the site of the alleged odour source until all off-property investigations are completed, because once the officer is exposed to the odour in strong concentrations he/she will lose the ability to detect the odour downwind at low concentrations due to nose desensitisation (see section 2.4). Observations of odour while near to or at the site are often unreliable because of these nose desensitisation effects.

When investigating the presence of odour close to the source, note that the discharge of emissions from stack or other elevated sources may not reach ground level until some distance from the base of the source.

[13] See section 3.4 for further discussion, including the wording of conditions for consents.

The general procedure recommended for the investigation of odour complaints by council enforcement staff is as follows.

1. Visit the location where the complainant claimed to be exposed to odour, but do not go to any potential source of the odour until the observations beyond the site boundary are completed. If required, obtain a signed witness statement from the complainant.

2. Assess odour at the location where the complainant claims the effect occurred. If the presence of odour is confirmed, record the *strength*, *character* and *persistence* of the odour, as well as *wind direction* at the location of the complainant.

3. Record whether or not the odour was considered to be offensive or objectionable given the location sensitivity (for example, residential or industrial area) and the results of the officer assessments made in step 2 above. Methods for evaluating whether the odour is offensive or objectionable are discussed in section 5.3.

4. If practical, assess the odour while moving perpendicular to the wind direction to establish the general width of the odour plume.

5. Having confirmed the likely source, conduct an assessment of any odour immediately upwind of this. Where there are a number of other potential sources of industrial or trade odour emission close by, and where the wind direction is substantially affected by nearby buildings or terrain features, then assessments from all sides of the apparent source are recommended (do a 360^{o} sweep of the source).

6. Visit the site considered to be the cause of the odour to explain the initial findings, the assessments beyond the site boundary, and to confirm the site's operating status. If an investigation is to be used for prosecution, a warranted enforcement officer needs to show their warrant to the offender. The officer should explain that they are investigating a possible breach of a consent condition or unconsented discharge, and warn that there is the possibility of enforcement action.

7. Request an explanation for the odour discharge, warning that this may be used as evidence.

8. Consider whether odour effects beyond the boundary were due to abnormal or temporary, or normal/day-to-day operating conditions at the site, and record evidence to support the conclusions made.

The procedure may have to be modified to incorporate the specific requirements of the resource consent. For example, the council may need to obtain declarations from the neighbours, and, if it is established that an odour incident has occurred, ask the consent holder to provide a report. The following is an example of how such a procedure could be incorporated as a consent conditions.[14]

> *In the event of an odour or nuisance incident occurring the grantee shall forward to the … Council within two weeks of the incident, a written report stating what mitigation measures have been employed to rectify the problem. An odour or nuisance incident will have occurred if:*
>
> *(i) The …Council determines it has, or*
>
> *(ii) No less than five individuals from at least two different properties, declare in writing that an objectionable odour or nuisance was detected, provided the Council is satisfied that this declaration is not vexatious. That declaration shall include individuals' names and addresses, the date and time the objectionable odour/nuisance was detected, and the bcation where it was detected. The individuals shall also state the circumstances that led to the declaration, for example, called upon by another individual, detected from a distance. The declaration shall be signed and dated.*[15]

There may be some situations where the investigating officer will want to deviate from the procedure, perhaps omitting some of the steps in the investigation. Two examples of when this may be appropriate would be where the aim of an investigation is merely to confirm the likely source of an odour on a specific occasion, or when it is apparent that subsequent complaints relate to the same incident for which a detailed investigation has already been undertaken.

5.2.4 Reporting and documenting investigations

The associated investigation report should include:

1. the date, time and location of complaint and the complainant's description of the alleged odour event, including the *strength*, *duration* and *character* of the odour

2. the observation of *strength*, *duration* and *character* of odour at the complainant's location as assessed by the council officer, including the *time of arrival and departure* from this location

3. the officer's opinion on the extent to which they considered the odour to be causing *objectionable or offensive effects* on the specific occasion being investigated, while accounting for the location of the odour and other factors listed above (was the odour incident of sufficient strength and character to be causing adverse effects?)

[14] This is provided as an example only and does not represent the type of monitoring that would be required in every consent.

[15] This condition was imposed by the Court in Pokeno *Farm Family Trust & Others* v *Franklin* DCA37/97 – fertiliser storage facility.

4. the *wind direction, strength* and *weather conditions* throughout the investigation, and how these were determined

5. the observation of any recognisable odour at other locations surrounding the alleged source (including upwind), and *times of observations* at each location

6. confirmation of the likely source, or sources, of odour, including the method used for excluding other potential odour sources

7. the date and time that staff at the alleged source were contacted, the name(s) of persons spoken to at the site, and their comments regarding the status of the site activities during the time the complainant(s) considered the odour to have occurred

8. any explanations given for the likely presence or absence of odour effects from the source and any measures taken, where appropriate

9. the officer's opinion and supporting evidence for the odour being caused by either abnormal/temporary or normal operating conditions at the site.

Provide a copy of the investigating officer's report to the site management staff regarding the odour incident and subsequent investigation findings.

All notebooks and officers' reports are discoverable, so care should be taken with any written comments, as these can be referred to in court. Notes must be made contemporaneously (within 24 hours). Council officers cannot use someone else's comments as evidence if they themselves are not giving evidence. This is hearsay. Therefore the officer should endeavour to get a witness statement from the complainant if they are alleging adverse effects. Witness statements need to be made in the first person and should be made within 24 hours of the complaint. Such witness statements can be used by witnesses to refresh their memory when giving evidence in court.

5.3 Using FIDOL factors and scales to rate odour observations

Some regional councils use the FIDOL factors (see section 3.2.1) during a site investigation to help determine if an observed odour is offensive or objectionable. However, the historical development of FIDOL factors and their application to odour nuisance assessment as described by Watts (1993) implies that long-term assessment is necessary. Consequently, the consideration of frequency, intensity and duration of odour during short periods of half an hour or less should be completed via a standardised manner to enable future consistent evaluation of odour events.

An example of the guidance provided to investigating officers by one regional council is given below. The investigating officers record their observations according to this guidance, and then take all the factors into account in making an overall decisions as to whether the odour was offensive or objectionable.

Frequency:
- During an investigation how many times is the odour detected (for example, wafts every few minutes)?

Intensity:
- Perceived strength or concentration of the odour.
- Does not relate to degree of pleasantness or unpleasantness
- Assessed subjectively using a 0–5 intensity scale (ambient):

  0. *Not detectable – no odour*
  1. *Very light – odour detected but may not be recognisable*
  2. *Light – odour recognisable (i.e. discernible)*
  3. *Moderate – odour very distinct and clearly distinguishable*
  4. *Strong – odour causes a person to try to avoid it*
  5. *Very strong – odour overpowering and intolerable*

Duration:
- The length of time people are exposed to odour.
- During an investigation how long does the odour persist (for example, 1–2 seconds or several minutes)?

Offensiveness:
- A rating of an odour's pleasantness or unpleasantness (hedonic tone).
- This does not necessarily have the same meaning as *offensiveness* in the Act or consent conditions.
- A subjective assessment which can vary between individuals.

Location:
- Where the odour is detected from.
- Note type of area (for example, agricultural, residential or industrial).

The above procedure does not define how the frequency duration should be recorded, and the intensity scale could be criticised for requiring the officer to record comments relating to their feelings when assessing a single parameter such as intensity. For example, the explanatory descriptions used for the '4' and '5' ratings include an adverse effect observation as well as an intensity observation, but it is possible for an odour to be rated as 'very strong' yet not be overpowering and intolerable, or for an odour to be 'strong' yet not make a person want to avoid it.

5.3.1 Ranking odour intensity in the field

Ranking the intensity of odour experienced over time during a field observation provides the most crucial information regarding intensity and its variation during the assessment. Odour intensity rating in the field has recently been used in Australia for assessing odour impacts from a tall industrial stack. The standard scale for describing odour intensity is that detailed in the German Standard VDI 3882 (I), which relates to odour measurement. The odour intensity scale is summarised in Table 5.

Table 5. German VDI 3882 Odour Intensity Scale

Odour intensity	*Intensity level (I)*
Extremely strong	6
Very strong	5
Strong	4
Distinct	3
Weak	2
Very weak	1
Not perceptible	0

There is also a standard procedure for recording the above odour intensity scales in the field, as detailed in the German VDI 3940 (*Determination of Odorants in Ambient Air by Field Inspection*). VDI 3940 describes a procedure for logging odour in the field, and involves noting the odour intensity every 10 seconds over a 30-minute period at a specific location.

The odour intensity observations are made every 10 seconds (within a margin of error estimated to be typically ±10%), but the actual sampling of odour occurs only during inhalation, which typically has a duration of 2–3 seconds. Thus, the odour data represent 2- to 3-second average samples once every 10 seconds.

5.3.2 Rating offensiveness/character

Objective recording of FIDOL factors needs to include the *intrinsic nature* of the odour. This is because the offensiveness factor would ideally be independent of the other FIDOL factors and is therefore recommended as being reduced to the intrinsic odour character (such as fishy, sewage, bakery, etc). The odour character description list from the Ministry for the Environment (1995), reproduced in Table 6, or a simplified list derived from this, can be used.

Table 6. Odour character descriptors

001	Fragrant	050	Vanilla-like	099	Alcohol-like
002	Sweaty	051	Faecal (like manure)	100	Dill-like
003	Almond-like	052	Floral	101	Chemical
004	Burnt, smoky	053	Yeasty	102	Creosote
005	Herbal, green, cut grass	054	Cheesy	103	Green pepper
006	Etherish, anaesthetic	055	Honey-like	104	Household gas
007	Sour, acid, vinegar	056	Anise (licorice)	105	Peanut butter
008	Like blood, raw meat	057	Turpentine (pine oil)	106	Violets
009	Dry, powdery	058	Fresh green vegetables	107	Tea leaves-like
010	Like ammonia	059	Medicinal	108	Strawberry-like
011	Disinfectant, carbolic	060	Orange (fruit)	109	Stale
012	Aromatic	061	Buttery (fresh)	110	Cork-like
013	Meaty (cooked, good)	062	Like burnt paper	111	Lavender
014	Sickening	063	Cologne	112	Cat urine-like
015	Musty, earthy, mouldy	064	Caraway	113	Pineapple (fruit)
016	Sharp, pungent, acid	065	Bark-like, birch bark	114	Fresh tobacco smoke
017	Camphor-like	066	Rose-like	115	Nutty (walnut, etc)
018	Light	067	Celery	116	Fried chicken
019	Heavy	068	Burnt candle	117	Wet paper-like
020	Cool, cooling	069	Mushroom-like	118	Coffee-like
021	Warm	070	Wet wool, wet dog	119	Peach (fruit)
022	Metallic	071	Chalky	120	Laurel leaves
023	Perfumy	072	Leather-like	121	Burnt milk
024	Malty	073	Pear (fruit)	122	Sewer odor
025	Cinnamon	074	Stale tobacco smoke	123	Sooty
026	Popcorn	075	Raw cucumber-like	124	Crushed weeds
027	Incense	076	Raw potato-like	125	Rubbery (new rubber)
028	Cantaloupe, honey dew melon	077	Mouse-like	126	Bakery (fresh bread)
029	Tar-like	078	Black pepper-like	127	Oak-wood, cognac-like
030	Eucalyptus	079	Bean-like	128	Grapefruit
031	Oily, fatty	080	Banana-like	129	Grape juice-like
032	Like mothballs	081	Burnt rubber-like	130	Eggy (fresh eggs)
033	Like gasoline, solvent	082	Geranium leaves	131	Bitter
034	Cooked vegetables	083	Urine-like	132	Cadaverous, like dead animal
035	Sweet	084	Beery (beer-like)	133	Maple (as in syrup)
036	Fishy	085	Cedarwood-like	134	Seasoning (for meat)
037	Spicy	086	Coconut-like	135	Apple (fruit)
038	Paint-like	087	Rope-like	136	Soupy
039	Rancid	088	Seminal, sperm-like	137	Grainy (as grain)
040	Minty, peppermint	089	Like cleaning fluid (Carbona)	138	Clove-like
041	Sulphidic	090	Cardboard-like	139	Raisins
042	Fruity (citrus)	091	Lemon (fruit)	140	Hay
043	Fruity (other)	092	Dirty linen-like	141	Kerosene
044	Putrid, foul, decayed	093	Kippery (smoked fish)	142	Nail polish remover
045	Woody, resinous	094	Caramel	143	Fermented (rotten) fruit
046	Musk-like	095	Sauerkraut-like	144	Cherry (berry)
047	Soapy	096	Crushed grass	145	Varnish
048	Garlic, onion	097	Chocolate	146	Sour milk
049	Animal	098	Molasses		

Source: Ministry for the Environment (1995).

5.3.3 Making the decision: is the effect offensive or objectionable?

Section 5.3.2 provided guidance on recording single odour events or field observations by highlighting the individual FIDOL factors in a consistent and standardised way. However, these procedures serve only to provide clear supporting evidence and transparency to the overall conclusion reached. For acute or short-term odour events, the opinion of an officer is still required for judging the extent to which a specific odour event is objectionable or offensive. This is because there are currently no clear guidelines for a maximum percentile odour intensity for short-term periods of, say, an hour or less that should not cause an objectionable or offensive odour. This situation may change if field observations of odour events are recorded throughout New Zealand following standardised procedures like those described in sections 5.3.2, and if this data is recorded against officer opinions and the nature of the complaints.

By comparison, we can utilise long-term FIDOL information that relates to repeated odour impacts to make a more mechanical, or objective, decision on the likelihood of chronic adverse odour effects. This is because acceptable odour impact frequency can be inferred from modelling guidelines as well as from general experience. In fact, when considering chronic odour effects, the officer's opinion should only be based on FIDOL data, as they are very unlikely to have first-hand experience of the effects of repeated odour impacts.

Given the need to rely on the relatively subjective response or feeling of an individual officer in deciding whether a specific odour event is objectionable or offensive, and therefore causing an acute adverse odour effect, one regional council has provided a scale of adverse effect rating, as shown in Table 7. We do not recommend that this be used *instead* of the FIDOL factor analysis discussed in sections 5.3.2, but it would be a useful additional step for helping an officer to make a decision.

The scale in Table 7 covers the potential for both chronic and acute adverse effects, and has a natural progression from no adverse effect potential for chronic effects, through to acute effects. Response categories 2 to 5 would indicate the need to establish the longer-term FIDOL factors more carefully to assess the actual potential for chronic adverse effects. Response categories 6 to 10 could indicate the presence of varying degrees of objectionable and offensive odour and should be supported by the analysis of short-term FIDOL factors.

Table 7. An example of a scale for rating adverse effects

1.	Odour can be detected but is not noticeable under normal conditions.
2.	The odour can be detected but is very moderate.
3.	The odour can be detected but is not objectionable or offensive, unless it is inside a house and is continuous, in which case it is objectionable/offensive.
4.	The odour is moderately strong and is offensive or objectionable if it is continuous or if its occurrence is very frequent, even outdoors.
5.	The odour is moderately strong and is offensive or objectionable if it occurs for periods of more than 5 to 10 minutes. Short, infrequent occurrences are not objectionable or offensive.

6. The odour is moderately strong and is offensive or objectionable even in periods of short duration.
7. The odour is strong and is offensive or objectionable even in periods of short duration. The odour can be nauseating if it is continuous.
8. The odour is very strong and is offensive or objectionable even in periods of short duration. The odour is nauseating if it is continuous or if intermittent and very frequent.
9. The odour is very strong and even exposure of less than one minute is offensive or objectionable. This odour is nauseating or makes breathing difficult at all times.
10. The odour is extremely offensive, the worst odour, nauseating.

5.4 Summarising and evaluating complaint data

5.4.1 Summarising complaint data

The chronological summary of odour complaints, as number per month or week, can indicate the increase in chronic odour exposure following the establishment of a new industrial or trade facility, or the changing level of odour effect from established sites. Presenting complaint frequencies per month on a bar chart is a useful method of collating registered complaint data. Such monthly reporting of complaints also helps to illustrate seasonal changes in complaint frequency, which may be due either to seasonal peaks in plant production or to seasonal changes in prevailing meteorology. An example of such a bar chart is shown in Figure 5.

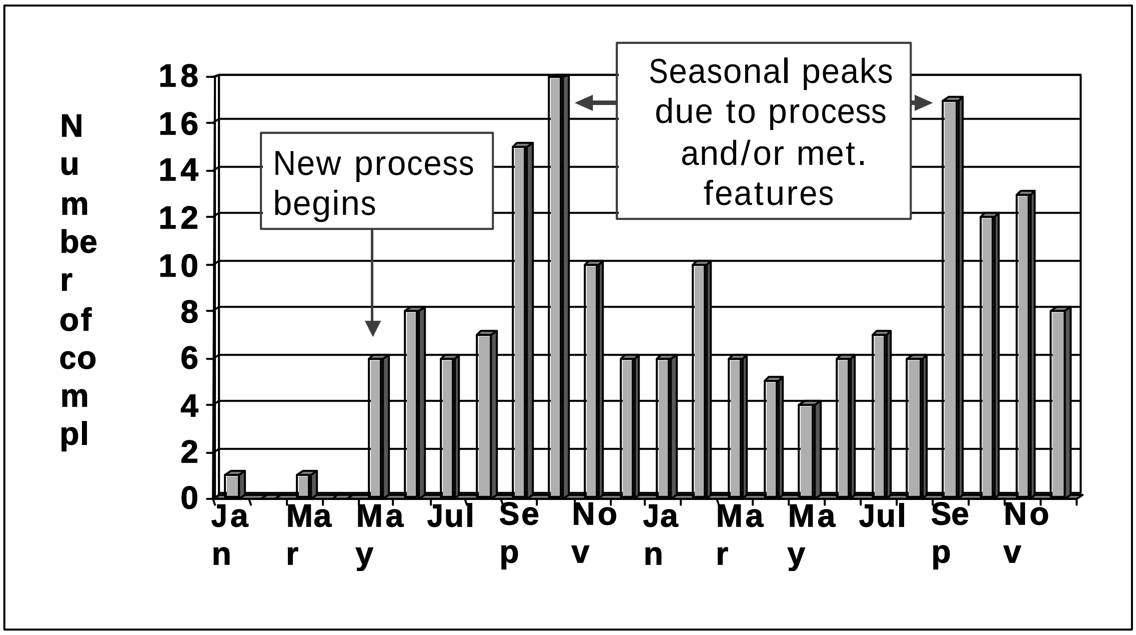


Figure 5. Example of complaint frequency graph

Varying degrees of more detailed analysis can also help to assess complaint frequency data. For example, in urban areas it can be useful to break the frequency chart information down to indicate results for different locations or zones within the general area. It can also be useful to plot wind-direction range and frequency data associated with complaints registered from particular locations. Analysing the weather conditions and other parameters (such as time of day and character of odour) associated with complaints can also be important. This is particularly so when odour complaints occur from rural areas/semi-urban areas, or for larger urban areas that may be affected by odour emissions from more than one industrial or trade site.

5.4.2 Assessing complaint records

Odour complaint records can be useful indicators of industrial odour emissions causing adverse effects where a dense urban or semi-urban population is affected, and complaint records can be validated against wind direction at the time of complaint. However, often the significance of effects is unclear because of low population density or the possibility of other sources of odour, or complaint records are not validated against wind conditions and site operations at the time. In such cases, complaint records are an unreliable indicator of the significance of adverse effects, and more detailed investigations are necessary.

A few odour complaints per month from a large urban population or rural–urban area may indicate the ongoing presence of odour from a site, but not necessarily to an extent that is causing significant adverse effects. If a facility has more than just a few odour complaints per month made against it, and these are verified for wind direction and lodged by different individuals within an urban population, this would indicate that closer monitoring by council staff or community surveys is justified.

The main problem with using complaints is where processing plants and various land-use activities are surrounded by isolated rural residences. Independent checking of wind directions and documented officer investigations that assess the odour and other potential sources may be necessary. Odour diaries programmes to establish the exposure patterns, as well as council officer investigations, are recommended before the likely extent of the adverse effects can be established.

Therefore, apart from scenarios where a relatively dense urban or semi-urban population is affected, odour complaint frequency should only be used as justification for a more rigorous assessment of the true extent of adverse effects. These more rigorous procedures could include annoyance surveys (see section 6.1), odour diaries (see section 6.2) and, in some instances, olfactometry and dispersion modelling (see chapters 7 and 8).

5.5 Calibrated noses

Dynamic dilution olfactometry (DDO, see section 7.3.2) uses a trained panel of people under controlled laboratory conditions to detect odour by sniffing from a series of ports. Because of the very high variation in nose sensitivity between people, and from day to day in a single person, people used as panellists in DDO laboratories are screened using the reference odorant n-butanol according to standard procedures (Australia/New Zealand standard AS/NZS 4323.3:2001). Panellists are required to have a certainty threshold for this compound between 20 and 80 parts per billion (ppb).

The standard panel-screening process for olfactometry measurements selects people whose ability to detect n-butanol is within a relatively narrow range compared to the range exhibited within the total population. It has become common practice to refer to such people as having ‘calibrated noses’.

Increasingly, air-quality investigating officers employed by regional councils are having their nose sensitivity assessed via the same n-butanol screening procedure. The results are generally summarised as shown in Table 8.

Table 8. N-butanol screening procedure results

Description of sensitivity	Response to n-butanol screening
Slightly to moderately sensitive	< 20 ppb
Average	20–80 ppb
Slightly to moderately insensitive	80–160 ppb
Moderately to highly insensitive	>160 ppb

This testing indicates the nose sensitivity of the officer to n-butanol for the day the test was performed. However, these tests are often not undertaken with sufficient frequency to ensure that the officer’s odour detection sensitivity is ‘calibrated’, as specified by the standard. Nonetheless, the procedure is useful for ensuring that enforcement officers are neither nose-dead nor highly sensitive.

Applying the term 'calibrated nose' to an enforcement officer may well be misinterpreted by laypersons – including lawyers and judges – as describing a person with greater credibility in assessing the environmental significance of odours in the real environment. However, individuals who can detect n-butanol within specific concentration limits are not necessarily more capable of assessing the strength or character of an environmental odour than individuals whose n-butanol detection thresholds do not fit within some arbitrary range. This is because calibration does not include an evaluation of such factors as strength or character, which are critical to determining the potential for objectionable or offensive effects.

Therefore the term 'calibrated nose' when used in relation to an enforcement officer should only be considered as some evidence that the officer has the ability to detect industrial or trade premise odours that is neither very poor, nor very good. This balance is important given the differing perspectives of the owners of an odour-emitting activity and the potentially impacted community.

Despite these limitations, regional council officers have indicated to us that nose calibration is useful for developing officer confidence in their ability to assess odours, and as a screening tool to provide reassurance to the public and odour dischargers that the officers are neither overly sensitive nor insensitive to odour.

Chapter 5: Recommendations

1. Odour complaints regarding environmental odours should be chronologically graphed on a bar chart, as number per month or week, to indicate any increase in odour effects following the establishment of a new industrial or trade facility, or to monitor the changing level of odour effect from established sites.

2. For urban areas, complaint frequency results should be plotted for different locations or zones within the general area. Weather conditions and other parameters (such as time of day and character of odour) should also be assessed. This is particularly important when odour complaints occur from rural/semi-urban areas, or urban areas that are affected by odour emissions from more than one industrial or trade premise.

3. Odour complaints should only be used as clear evidence of significant adverse effects when generated from relatively dense urban or semi-urban populations, and then only when these have been validated against wind direction at the time of the complaints.

4. For areas of low population density, or where there are other substantial sources of odour, or complaint records are not validated against wind conditions and site operations at the time, then complaint records alone should not be relied on to assess the significance of adverse effects. In these circumstances the records

should be used as a justification for implementing a more detailed investigation using other assessment tools.

5. If a facility has only a few odour complaints made against it per month, and these are lodged by different individuals within an urban population and independently verified for wind direction, this should be used as a justification for implementing a more detailed investigation using other assessment tools.

6. When investigating odour complaints, the general protocol to follow is that recommended in section 5.2.

7. When assessing the observed odour during a complaint investigation, a systematic recording of odour intensity versus time as per the procedures detailed in Table 7 should be used: VDI guideline 3882 for intensity rating and VDI 3940 for intensity recording frequency. The recording of odour intensity versus time should span a minimum period of 30 minutes. This provides short-term information on the first three FIDOL factors.

8. For the fourth FIDOL factor, the site investigation of odour offensiveness should be limited to recording the inherent odour character, using descriptors such as those given in Table 6.

9. When evaluating the combination of the recorded FIDOL factors, and accounting for the location as well as the personal response to the observed odour, use Table 7 or a similar scale for guidance in deciding what type of odour effect is likely to be occurring. Use this table also to provide guidance on the appropriate regulatory response.

10. A full report of field FIDOL factor recordings should be recorded to allow for an independent review of the final evaluation with reference to Table 7, especially where these indicate significant chronic or acute odour effects were/are occurring.

11. If the summary of complaint frequency over time and/or site observations indicate a chronic odour effect, consider the use of other assessment tools to confirm the significance of these odour effects as well as the ongoing recording of complaint frequency.

12. Any staff involved in odour assessments should have their detection sensitivity to n-butanol assessed as a means of indicating their general ability to smell environmental odours. However, it is not recommended that this be a mandatory requirement for enforcement staff. The term 'calibrated nose' with regard to an enforcement officer should only be considered as some evidence that the officer has the ability to detect industrial or trade premise odours that is neither very poor, nor very good.

6. Community Surveys and Diaries

6.1 Odour surveys

Odour annoyance surveys quantify the extent to which a community is adversely affected by industrial odour emissions. We recommend this tool because it allows the extent of psychological stress caused by industrial odours (whether acute or chronic exposures) to be established in a way that is more robust and defensible than that provided by other assessment tools.

Note that the term 'annoyance' (like 'offensiveness') can have different meanings depending on its context. When used in relation to an odour's character or pleasantness, annoyance is akin to the hedonic rating of an odour – an immediate response to a specific occasion. When 'annoyance' is used in relation to annoyance surveys, it is a function of the feelings of the community towards a source of recurring odour impacts. The greater the combined effect of an odour's FIDOL factors (see section 3.2.1) within a community, the greater the proportion of the community who are likely to be annoyed (or worse) by the ongoing odour impacts. Therefore odour annoyance surveys can provide a simple and cost-effective approach for assessing the relative extent of odour effects being caused within a community.

A survey can also help to rank different industrial facilities in terms of their contribution to the overall cumulative stress or annoyance within a specific community. Therefore, where information is needed about the odour effects on a substantial-sized community in an urban or semi-urban area, we recommend using an odour annoyance survey in preference to other tools.

The size and density of the community is important in order to achieve meaningful and statistically significant results. In rural areas or industrial areas where residential development is scarce, odour surveys cannot be used to measure the degree of adverse effect. Here, odour diaries, odour-modelling assessments and complaint records are often the best alternatives.

In an odour survey the respondents are asked about the level of annoyance they experience from odour. Responses are classified according to the descriptions in Table 9. If the response indicates that the person is 'annoyed', 'quite annoyed', 'very annoyed' or 'extremely annoyed', then the response is counted in a 'percent at-least annoyed' category.

Table 9. Degrees of annoyance used in typical odour survey

• Definitely not annoying	
• Very little annoyance	
• Little annoyance	
• Some annoyance	
• Annoying	*Percent at-least annoyed*
• Quite annoying	
• Very annoying	
• Extremely annoying	

The odour annoyance survey methods used in New Zealand have been discussed by Aurora Environmental (2000) and are a simplified version of those reported by Miedema (1992). The resultant percentages of the community that report to the annoyed category or worse (the ‘percent at-least annoyed’) are difficult to evaluate unless there is a database of survey results from other control communities. It is therefore important that survey procedures and survey questions follow a very similar protocol (as detailed in Appendix 3) so that survey results can be evaluated effectively.

6.1.1 How to conduct an odour survey

Here is a brief summary of the process.

1. Identify the sub-groups of the community from which information on the extent of odour effects is required.

2. Conduct a telephone survey of randomly selected listings among these sub-groups during a 2-hour period in the evening, so that information is obtained quickly. Note that sometimes it may be necessary to conduct face-to-face interviews, such as in industrial or commercial zones.

3. Ask the respondents a set of standard and often unrelated questions regarding the state of the environment before asking questions that determine (a) how often they detect odours, (b) how annoyed they are about the odours, and (c) which industries they attribute the odours to.

4. Calculate for each community the percentage of people who detected odours and were either annoyed or worse about these. Break this percentage down in relation to the main source(s) that were considered responsible.

5. Compare the results to those for a nearby control population, or other control studies, and calculate survey margins of error.

A more detailed discussion of this methodology is outlined in section 6.1.3.

6.1.2 Surveys in New Zealand

Odour annoyance surveys following the standard procedure above have been undertaken in New Zealand since 1996. Over 14 have been undertaken on various rural communities and urban suburbs. In most cases the results were required as a condition of an air permit to discharge contaminants to the air, and they were often used to help make decisions regarding the level of compliance with the standard 'no objectionable or offensive odour effects' on the community due to the industries involved, and whether or not there was a need for further improvement in the control of odour emissions.

The use of odour surveys in this manner has been made possible by a recent change in emphasis from the regulation of specific odour events to the regulation of accumulated adverse effects of odour discharges. This translates to a greater use of community-based assessments, including odour annoyance surveys or odour diary programmes.

The findings from the surveys on control populations have consistently yielded a result of 5% to 15% responding to the 'percent at-least annoyed'. Control surveys in New Zealand have included the Wanganui City CBD, the rural township of Te Puki, Bay of Plenty, and the urban area of Kaiapoi, Christchurch.

6.1.3 Implementing odour surveys

A number of factors must be considered before an odour annoyance survey is undertaken, including:

- the existence of appropriate survey population sizes
- the most practical approach for conducting interviews
- the appropriate selection of target sub-groups within the general survey area.
- the prevalent wind directions within the area.

Completing a survey over an extensive area of a community, without sufficient pre-analysis of appropriate sub-groups, will almost certainly result in averaged survey data that is of little use.

Case study: Dunedin Woolscour

A woolscour that operates in Dunedin was issued an air permit by the Otago Regional Council in 1997. Condition 2 of this permit required the following:

> *There shall be no emission of odour from the consent holder's activities that is offensive or objectionable to such an extent that it has an adverse effect on the environment downwind of the consent holder's premises.*

The air permit also required the woolscour owners to:

> *… measure the emission of odour, undertake olfactometry, use computer modelling to determine the downwind concentrations of odour and prepare a report..*

In addition:

> *The methodology to be used required the measurement of the emission of odour from the vents above the wool-scour bowls and the vent from the wool drier at least once every 2 years in accordance with European Standard CEN TC264/WG2 'Odours', Odour Concentration Measurements by Dynamic Olfactometry 1995, or another method approved by the Otago Regional Council.*

Before the first modelling assessment was due to be completed, the woolscour management successfully applied for variation to their air permit to replace the requirement to conduct this with an odour survey via the following replacement condition:

> *The consent holder shall carry out a community odour assessment survey at least once every two years. The survey shall consult a random selection of people who live or work within a 500 metres radius of the consent holder's activities. The design and extent of the survey shall comply with recognised good practice and be to the satisfaction of the consent authority.*
>
> *The report on the community odour survey required by [this condition] shall include:*
>
> - *the design of the survey including sampling procedures and survey questionnaires.*
> - *an assessment of the proportion of community that are 'at-least annoyed' (i.e. report to being either annoyed, very annoyed or extremely annoyed) by the odour impacts from the consent holder's activity.*
> - *an assessment of the need for mitigation of adverse effects identified.*
> - *recommendations on future surveys.*

It was expected that to complete a reliable modelling study, including odour emission measurements and meteorological data generation, would cost well in the order of $10,000 to $15,000, whereas the design and completion of an odour annoyance survey would be less than half this. The other advantage of the odour survey in comparison to odour dispersion modelling was the ability to more reliably indicate the extent of compliance with the requirement of Condition 2 of the air permit to avoid offensive or objectionable odours. Disadvantages with the modelling approach also included the use of odour emissions, which were from only a snapshot in time, and the evaluation of percentile concentration data that related to woolscouring process emissions.

Selecting survey sub-groups

The careful selection of appropriate survey areas is crucial for obtaining useful survey data. The general rule is to ensure that 'percent at least-annoyed' survey results are only quoted in relation to a population sub-group that does not include sub-sections that have vastly different levels of odour impact. In some instances, experience in meteorology and local wind patterns is required to specify different sub-groups within an overall community, such that people living or working in these areas have a similar level of exposure to odours.

Historical complaint records and prevalent wind pattern information need to be reviewed before selecting the physical boundaries of different survey areas. Where possible, these would be separated by a buffer distance. Sub-groups are normally defined by their location relative to the odour source, such that people living or working within a sub-group receive a similar level of odour impact during the same types of wind condition, while people living or working within different sub-groups receive different levels of odour impact. A useful approach for selecting a survey sub-group is to map out as large an area as possible that will receive a similar level of odour impact for some general wind condition. It may then be necessary to have three or four sub-groups within an overall survey area.

Because survey sub-groups are selected for their differing levels of odour exposure, and/or differing directions from the source, the results from such groups should generally stand alone (and not be averaged together to provide an overall result) when assessing adverse effects.

Control survey data

Surveys often involve a control area that is some distance away from industrial odour sources. Although there is now a significant survey database for control populations within New Zealand, it is still preferable to have a control population that is relevant to the survey population included within the survey design. Control populations in New Zealand and overseas typically return percent at-least annoyed results of 5% to 15% (Aurora Environmental, 2000). Because control populations have biased results, a minimum of 50 survey responses is generally adequate. Data from these control populations studies will be published in the *Clean Air Journal* some time during 2001 (Cudmore, 2000)

Method of contact

It is normal practice to survey residential areas by telephone interview between 7.00 pm and 9.00 pm on a single evening. This allows the survey to be completed quickly and with minimal opportunity for respondents to communicate with each other about the survey. However, sometimes the survey area may include commercial, industrial or educational activities. In these instances, face-to-face interviewing may be the only practical method to complete the odour annoyance survey questionnaires within a day or less.

It is sometimes necessary to engage a company that offers independent surveying services, so that the telephone interviews are completed within the 2-hour period, or all face-to-face interviews are completed within the same day.

Interpretation of survey results is discussed in section 9.2.2.

6.2 Odour diaries

Odour diaries provide a method for obtaining information from the community about odour impacts. The information is usually sought from a sub-group of the community rather than being passively received by a regulatory agency or industry. Odour diaries quantify the zone of influence from a specific odour source and the associated characteristics of the odour exposure pattern. This is different from an odour annoyance survey, which measures the extent of adverse effect caused by the odour exposure pattern.

An odour diary programme may be conducted for two reasons:

- to collate exposure pattern information, such as frequency of strong, moderate or weak odour impacts at various locations, over a defined period of time (*comprehensive diary programme*) – the resulting data can be used to calculate the percentage of time (hours per year) that people are exposed to industrial odours from a specific source, as well as the typical strength and character of the impacts

- to confirm whether a particular industrial or trade site is causing occasional odour impacts (*basic diary programme*).

The comprehensive programme requires considerably more detailed information and analysis than the basic programme, and is appropriate when it is necessary to establish the likelihood that adverse odour effects are occurring. The basic diary programme is used more as a diagnostic tool, which can be implemented with minimum effort to confirm whether or not odour emissions from a specific source can be detected by a neighbouring community. This information is not sufficient to establish the extent of adverse effects being caused, so we will focus on describing the comprehensive odour diary method.

6.2.1 Description of method

Odour diary information is recorded on a standard sheet (see Appendix 4). Participants are required to enter diary records into the sheet when they recognise industrial or trade odours at a particular location (which is their normal place of residence or work).

The information to record for a comprehensive diary programme is as follows:

- date and time of day
- duration of the event
- continuity of the odour during the event
- character and strength of odour
- likely source of odour
- wind direction and strength.

6.2.2 Implementing odour diaries

A common criticism of odour diaries is that the information received back is often not filled in correctly, and that volunteer diarists can quickly lose enthusiasm for the programme. Admittedly odour diary programmes are difficult to conduct in a way that provides useful data, and considerable diligence and effort is required from all parties. There are usually two main reasons for this: diarists are not provided with adequate instructions on the correct procedure for recording information in a consistent way that allows for objective analysis, particularly as the design of diary record sheets has not been standardised; and enthusiasm drops when there is a lack of feedback on previous diary results.

Using a standard diary sheet (as shown in Appendix 4) and providing diarists with hands-on instructions before commencing the programme helps to ensure that records are useful. Simply posting out diary sheets with a letter of explanation is *not* recommended. It is often necessary to check the returned diary sheets at the end of each month, so that procedural corrections can be discussed and rectified with diarists as necessary. In any case, it is important to maintain some informal contact with diarists on a monthly basis to confirm the usefulness of their previous information and maintain their enthusiasm for recording information.

The decision to use odour diaries

Before deciding to instigate an odour diary programme it is important to consider the desired outcome. For example, if the aim is to confirm that a potential source of odour is still creating some impacts in a community, then only the basic diary programme may be required. If the aim is to establish the likelihood of significant adverse odour effects, and the community is too sparse to allow for an odour annoyance survey, then a comprehensive diary programme is recommended.

Selecting participants

For a programme to be successful it is important to select participants to cover the main potential areas of odour impact. This may include either work or residential locations. It is also important to select participants democratically. This is generally done by holding an initial meeting between the organisation that instigates the programme, council air-quality staff, and community association / community liaison members to discuss the aims of the diary programme and decide on participants.

Instructions for participants

The following notes are recommended as instructions to provide participants before commencing a diary programme.

- *Same-day events:* odour impacts that occur on the same day should (ideally) be entered as separate events when (a) the time between the odours occurring is much greater than their duration, or (b) there has been a significant wind change between the different observations of odour. If, for example, the odour was noticed first in the morning and it persisted for most of the day, this can be recorded as a single event.

- *Location:* the idea is to quantify the extent of odour impacts at a residential location or some other premises, so recorded events must be restricted to those experienced at one fixed location where the diarist will routinely be present for a significant part of the day or evening.

- *Date and time of odour event:* the date and time of day the odour was first noticed and when it ceased should be recorded. This allows for future analysis of recorded wind conditions so that potential sources upwind of the receptor location can be checked.

- *Duration of odour event:* it is necessary to provide clear details about the overall duration of the odour event. This information allows for an estimation of the percentage of time that odour impacts occur, which is central to the assessment of comprehensive diary programme results. The duration needs to be recorded in hours, or as a time range (for example, 8.30 am to 2.30 pm.)

- *Continuity of each odour event:* it is useful to record whether or not the odour during an event is continuous or intermittent. A number of options are available on the sheet for each odour event to indicate this.

- *Character/description of odour:* diarists are required to describe the character or type of odour they experience. Examples include 'strong mouldy smell', 'blocked-drain smell', 'cooking meat smell', 'sulphurous, mothball smell', 'wet wool smell' or 'burning grease smell'. Note that descriptions such as 'horrible', 'sickening', 'awful' or 'not bad' are not useful in determining character.

Inconsistent and confusing descriptions of odour character for the same industrial or trade source can be expected, because individual diarists are typically untrained in odour sensory analysis. Because of this, it is often incorrectly assumed that people are not good at discerning different sources of environmental odours. However, although the odour description information in diary programmes is often inconsistent with the source and other diarists descriptions of that source, it should not be assumed that information from community members about the perceived source of a specific odour is not reliable. This is particularly so when a diarist's location has been confirmed to be downwind of the alleged source, and no other obvious sources of odour can be implicated.

- *Source of odour:* diarists are asked to record what they consider to be the likely source of the odour, or state if they do not know.
- *Strength of odour event:* this record relates only to the intensity of the odour and should use the same rating scale as recommended for field investigations (VDI 3882, see Table 5).
- *Wind conditions:* the general wind direction (for example, 'blowing from the north-west and hot summer's day' or 'cold overcast day with southerly winds') should be recorded as a compass direction (N, NE, etc) followed by the approximate wind strength (still/calm, light breeze, medium breeze, moderate wind, or strong wind).

Case study: AFFCO NZ Ltd

A useful example of a basic diary programme is provided by that operated by AFFCO NZ Ltd within the community that borders their meat-processing plant at Imlay, Wanganui. The large rendering plant had a history of odour problems, which resulted in the company undertaking a substantial upgrade of its process air extraction and treatment system. Following commissioning in January 1998 the company wanted to establish the effectiveness of the new system in eliminating rendering plant odours.

An odour annoyance survey had previously been undertaken by AFFCO during 1997, aimed at establishing the extent of adverse effects being caused on the neighbouring community. However, a basic style of odour diary programme was considered the more appropriate option for the second study, for two main reasons: the reduced level of odour annoyance within the community was expected to lag the actual reduction in odour impacts, due to the historical nuisance caused by the factory; and the object of the exercise was to establish if rendering-type odours were still occurring as a result of AFFCO's plant, while other sources of industrial or commercial odour were still present.

The five diarists used for the programme had residential dwellings downwind of the rendering plant during a prevalent wind condition at the site, at various distances from the AFFCO site. Importantly, the panel members were selected in consultation with the community liaison group. This group had been established by AFFCO over the previous years to allow the community and AFFCO to openly discuss views on odour impacts and measures being instigated to reduce these. Therefore it was important to work through the community group to ensure their support for the number of diarists, their location and the individual people involved.

The results from 6 months of diary records, corresponding plant-operating status and wind records confirmed that the predominant rendering odours had been eliminated from the community. The results also helped to identify other sources of odour within the community and their relative significance.

6.3 Repeat questioning method

An alternative to odour diaries is the German standard VDI 3883 (Part 2) for assessing annoyance by repeat questioning. This method involves the use of selected individuals within a community to routinely record their annoyance rating of any environmental odour that may be occurring at some pre-specified time of day and location. This annoyance rating scale is similar to, but a narrower version of, that used in New Zealand and the Netherlands when conducting odour annoyance surveys.

Repeat questioning surveys respond to the significance of environmental odours at a set time of day (and, in some cases, for one particular day of the week) as indicated by selected members of a community. In contrast, odour annoyance surveys respond to the accumulated effect of repeated odour impacts over time, as indicated by a randomly selected sample of a community.

6.3.1 Using a repeat-questioning survey

The annoyance index (I) calculated from the repeat questioning survey method can be used to monitor the relative change in the extent of odour impacts, if conducted over an extended period of time. This is because an odour annoyance index value is calculated from the responses obtained from participants during a specific week or day, and is then repeated the following day or week. A formula is then used to calculate the annoyance index, whereby the number of individuals responding to each annoyance category is multiplied by a weighting factor (see Table 10). Different weighting factors are used for different annoyance categories, and are increased for higher annoyance categories. The resultant value of I increases or decreases depending on the proportion of participants that select either low or high annoyance ratings.

The annoyance index is calculated as follows:

$$\mathbf{I_k = 1/N_k \;.\; SUM \sum_i (W_i . N_{ik})}$$

where:

$I_k =$ annoyance index in the kth observation week

$N_k =$ total of observations in the kth week

I **=** annoyance category (1 to 5)

W_I = number weighting factor for annoyance category I (see below)

N_{ik} = total number of observations in the annoyance category i in the kth week.

Table 10. Annoyance category versus weighting factor for repeated questioning method

Annoyance category	Weighting factor value
(0) no odour	0
(1) not annoying	0
(2) slightly annoying	25
(3) annoying	50
(4) very annoying	75
(5) extremely annoying	100

6.3.2 Discussion

The annoyance index (I_k) measured by VDI 3883 Part 2 is a function of previous odour impacts that occurred at a specific time of day, and as experienced by selected members of a community.

Note that the percent-at-least annoyed parameter calculated by odour annoyance surveys is very different to the annoyance index parameter for the VDI standard, so it would be difficult to infer a direct relationship between the two. For odour annoyance surveys we have sufficient experience to be able to use the results to indicate the significance of the odour effects being caused. It is also clear that the percent-at-least annoyed parameter is a strong function of FIDOL factors. However, there is little knowledge in New Zealand of the context for this particular VDI standard, or how to appropriately evaluate the index values calculated, so it is not clear if this parameter (and general method) would be as useful for indicating when odours are causing significant adverse effects.

The potential use of the VDI standard 3883 Part 2 as an alternative to odour diaries needs careful consideration. Both approaches rely on selecting individuals within a community to record a response to an environmental odour at a specific time and place. The main differences is that the odour diary approach requires individuals to record odour events whenever they occur, and provide basic FIDOL factor information regarding these events, while the VDI method requires an annoyance rating – but only for odour present at a pre-specified time of the day, and possibly only for a specified day of the week. This restriction would require the VDI approach to involve significantly more participants than an odour diary to provide reliable information over the same time period. Often in New Zealand there are only 5 to 10 participants available for this type of odour monitoring.

There is another potential problem with the VDI method. In New Zealand the monitoring of odour effects using diary programmes is increasingly undertaken by industry, and industries that run these programmes would be aware of the precise time of day that individuals would assess any odour their site is discharging. Activities such as asphalt manufacturing could readily adjust operations to account for such an odour-monitoring regime. Also, for activities that tend to create short-term and acute odour effects, the VDI monitoring approach may require an extremely long period to demonstrate a statistically significant trend in relative odour effects.

Finally, the VDI annoyance index is not as strongly linked to the FIDOL factors as the ‘percent-at-least annoyed’ parameter established via annoyance surveys, so the significance or meaning of ‘annoyance’ as measured by the VDI annoyance index is very different from that established by existing odour annoyance surveys.

Taking the above difficulties into consideration, the use of the VDI standard for repeat questioning is not recommended as an assessment tool for New Zealand. This does not preclude its use of at some stage in the future, but its introduction now would be premature. Before allowing the VDI standard 3883 Part 2 to be considered for general use in New Zealand, the procedure should be trialled and evaluated (as odour annoyance surveys have been since the mid 1990s).

6.4 Community consultation

Consultation with the community can be a very useful management and assessment tool for obtaining community feedback on odour effects, or the community feeling towards a proposed new development. There are two main forms:

- the organisation creating the odours holds a general public meeting
- a group of community members is formed, with whom regular meetings are held.

The latter is often referred to as a community liaison group (CLG).

The use of a CLG is a common method, which companies increasingly employ to maintain consultation with the local community over ongoing environmental effects and their management. The main environmental issue in a specific instance may be odour impacts from the site. However, the discussion of other environmental issues – such as water discharges, dust, noise and landscaping matters – are often also discussed at CLG meetings.

Members of the CLG normally include company management staff, chief engineers and members of the local community. It is also common practice – although not essential – for the group meetings to be chaired by an independent mediator/chairperson. Normal meetings rules and standard procedures should be followed to ensure that order can be maintained, which also requires minutes and matters arising from the minutes to be recorded and discussed.

To ensure that the general community has confidence in members of a CLG, it is important that the membership of the group is selected in a democratic and transparent way. This can be achieved by forming the group via an initial invitation to a public meeting, which allows the aims and use of the group to be discussed. Involvement of the local community association can also be an effective way to identify respected members of a community who could be available to serve on the CLG.

It is important to note that although CLGs are formed to allow for efficient consultation with the community, the views of the CLG's community members may not always indicate the views of the wider community.

Chapter 6: Recommendations

1. Odour annoyance surveys should only be implemented to assess areas with moderate to high population densities, which allows for statistically significant results to be obtained.

2. Odour annoyance surveys for New Zealand communities should be completed using the questionnaire contained in Appendix 3.

3. The key parameter to calculate from an odour annoyance survey is the percentage of the population who report to being 'at-least annoyed'. This can then be broken down into the source contributions that make-up the overall result.

4. When implementing odour surveys it is recommended that, where possible, a control population of similar demographics and culture is also surveyed. The target control population should be defined in consultation with the local regional and/or district council air-quality staff.

5. For evaluating an acceptable level of cumulative adverse odour effect due to all sources, the criteria of ≤ 20 % at-least annoyed is recommended for all zones.

6. Odour diaries should be used in preference to odour annoyance surveys where there are low population densities, using the standard diary sheet contained in Appendix 4.

7. The use of the VDI standard for repeat questioning is not recommended as an assessment tool for New Zealand. This does not preclude the use of the method at some stage in the future, but its introduction at this time would be premature.

7. Measuring odour emission

We began this document by looking at what odours are, and the effects they can cause. We then moved on to look at various ways that the human nose can be utilised to detect an odour and assess whether it is having an adverse effect. The human noses in question belonged to enforcement officers, participants in odour diary programmes, and participants in several forms of community survey.

Early in our discussion we defined odour as ‘a sensory response to the inhalation of air containing chemicals’. There are also many objective ways to measure the concentration of chemicals in air, and it would seem likely that these measurements would be related in some way to what the human nose registers, even if, as we have seen, there are confounding factors such as sensitisation and adaptation.

We turn in this chapter to looking at ways of measuring the chemicals that constitute odours, and how the result can be used to assess odour effects. We begin by focusing on how to get a representative sample of odorous air from the various sources, and then look at the best way to analyse it, primarily by using human ‘sniffers’.

7.1 Sampling odour sources

Five types of odour sources are referred to in this report:

- *point source* **–** discharges from a small opening such as a stack or vent
- *area source* – a source with a large surface area such as a landfill surface, a pile of solid material, or a liquid surface
- *volume source* – a bulky, diffuse source such as from within a building
- *line source* – a long, narrow source such as a roadway or roofline vent along a long, narrow building
- *fugitive source* – any type of odour emission that cannot be readily quantified or defined. This covers leaks in pipes, flanges, pump seals or structures; openings in buildings; floor spills; or occasional sources such as uncovered truck loads or releases from pressure relief valves, and leaks in seals on covered tanks.

7.1.1 Overview

To measure the concentration of an odour, a sample of the odorous air is collected from the source and then taken to a laboratory for analysis to quantify the odour concentration. In this report, although alternative methods of odour quantification are briefly addressed, the primary means of odour analysis is assumed to be olfactometry.

Olfactometry is the science of odour measurement using sensory methods. This method uses panels of trained individuals and controlled laboratory conditions to assess odour concentrations. It measures odour strength in terms of the degree of dilution with clean air required to reduce a given odour sample to the level where it is barely detectable. We will return to a more detailed description of how olfactometry works after covering the sampling procedures.

The procedures of collection and analysis of the sample are quite separate activities, each with its own issues and problems.

The *odour emission rate* (OER) is measured in units of odour per time (OU/s or OU/hr), and is used to quantify the rate of odour discharge from odour sources. Two methods can be used to determine the OER, depending on the type of source:

1. point sources: OER = odour concentration of the discharge multiplied by the normalised gas flow rate (normalisation to 20°C is required, since that is the temperature of the laboratory where the olfactometry is carried out (see section 7.3.2)

2. area sources: measurement determines the specific odour emission rate (SOER) = the odour discharge per unit area of surface. The SOER has units of odour per unit area per time (for example, OU/m^2s or OU/m^2h). The OER for an area is then determined by multiplying the SOER by the total exposed area.

Unless appropriate techniques are followed, errors incurred in the process of measuring an OER or SOER may accumulate so that the final calculated emission rate carries a large uncertainty. The most likely sources of error include:

- contamination of air samples by the sampling equipment used
- instability of odour concentration in the air sample
- erroneous measurement of air flow rates in stacks and sampling hoods
- additional problems with area source sampling relating to whether the type of sample hood used reflects actual ambient emission conditions
- uncertainties in odour concentration determined by the olfactometry procedure.

The potential for these errors should be considered in any odour assessment study involving odour measurement.

7.1.2 Point source sampling

General method

Point sources are discharges from a small opening such as a stack (a factory chimney). When collecting samples from stacks, the method recommended in the *Guide to Compliance Monitoring and Emissions Testing* (Ministry for the Environment, 1998) should be followed for:

- selecting a suitable sampling point in the stack or duct, or confirmation that existing sampling points conform to requirements
- measuring the velocity, temperature, static pressure and bulk gas properties of the stack gas.

These stack gas measurements are necessary to calculate the OER.

Isokinetic sampling

Using isokinetic sampling means that the velocity of the gases entering the sample nozzle is the same as that in the duct. This is required when gas streams containing particles and droplets are being sampled. It is not possible to measure odours from particles and droplets (see below), so isokinetic sampling will generally not be an issue when sampling odours. As noted in CASANZ (1998), "Although some odorous emissions are known to be associated with particulate matter, isokinetic sampling is not considered either practical or viable."

Particulates and droplets

Odours are sometimes associated with particulate matter in an air stream (for example, when they are emitted from wood-burning equipment, or fume discharges in the smelting industry). However, the DDO method used for olfactometry means that odour concentration determinations cannot include contributions from suspended particulate matter.

The same constraint applies for discharges containing droplets and large amounts of steam. When discharged to the atmosphere, these can vaporise so that any entrained odours contribute to the ambient odour levels. However, unless very large amounts of dilution are provided as the samples are collected (if possible), the droplets and steam condense in the sample collection equipment and any odours contained in the liquid will not be measured by olfactometry. Conversely, in different ambient conditions the droplets and steam can condense when discharged and fall out as precipitation close to the source, removing condensable odours. In this case, measurement of odours in the stack would over-estimate the odours available to cause adverse effects in the ambient air.

High temperatures and instability

High-temperature discharges will usually need to be diluted before being collected into sample bags to prevent damage to the bag materials and condensation. Errors in the OER may occur if the rapid change in sample temperature or dilution when sampling means that any processes of chemical conversion occurring naturally in the discharge at high temperature or concentration are halted.

You should also be aware of potential problems with unstable samples, where considerable delays between sampling and passing the sample through the olfactometry laboratory may result in changes to the intensity and character of the sample. A maximum of 30 hours' sample storage time is recommended (AS/NZS 4323.3:2001). For example, discharges that include combustion gases from the burning of fossil fuels, in particular nitrogen oxide emissions, are often not fully oxidised during combustion and form complexes with other chemicals or continue to oxidise to nitrogen dioxide once they are discharged. The rate of complex formation and oxidation depends on the chemical concentration, the amount of oxygen, and the other oxidising agents available. This is a major problem which may undermine the feasibility of sampling combustion sources.

A further example comes from the Netherlands, where waste gas samples from blood processing in the rendering industry showed an increase in odour concentration of about five times when analysed 24 hours after sampling relative to analysis done 4 hours after sampling (van Doorn and van Harreveld, 1994).

Correcting samples for temperature and other factors

The OER from a point source (for example, units of OU/s) is calculated by multiplying the volumetric flow rate from the source (for example, units of m^3/s) by the odour concentration measured in the sample bag (for example, units of OU/m^3), corrected for the dilution ratio, if necessary. Odour determinations by olfactometry are measured at room temperature (for example, 20°C), and the volumetric flow rate (usually quoted as "operating temperature" or "standard conditions (0°C)") must be corrected to the same temperature basis as the odour concentration before this multiplication is carried out. This is called normalising the flow rate. An example of this correction is given below:

- Volumetric flow rate = 5 m^3/s at stack temperature of 300°C (573 K).
- Temperature of odour sample at olfactometry laboratory = 20°C.
- Odour concentration determined in laboratory, after correction for dilution during sampling = 1000 OU/m^3.
- Before calculating OER, volumetric discharge from stack must be normalised to 20°C by a simple temperature ratio (assuming Ideal Gas Law applies):

$$V_2 = V_1 \times (T_2/T_1)$$

where V_1 = volumetric flow at temperature 1 (m^3/s)

V_2 = volumetric flow at temperature 2 (m^3/s)

T_1 = temperature 1 (K)

T_2 = temperature 2 (K)

- In this example, using this formula the volumetric flow rate normalised to 20^o C = 5 x (293/573) = 2.6 m^3/s, and the OER = 1000 x 2.6 = 2600 OU/s.

Sometimes the volumetric flow rate is also corrected for other factors, such as for a dry gas basis (0% moisture), or for combustion sources, to 12% carbon dioxide. These factors must be eliminated (not included in the calculation) when multiplying the volumetric flow rate by the odour concentration, to give the actual OER at operating conditions.

Corrosive/reactive materials

Some types of industrial discharges may contain chemicals that are corrosive or react with the materials used in olfactometry sampling and analysis equipment. You should consider this potential before sampling from such sources, because such chemicals could cause the odour concentrations in the collected samples to be quite different in intensity and character to the original air stream, and could also cause expensive damage to the equipment itself.

7.1.3 Area source sampling

Sampling hoods

SOER measurement from an area source involves isolating a portion of the surface with a sampling hood, blowing odour-free air across the surface at a set 'sweep' rate to pick up any odours emitted from the surface, and then collecting that air into a bag made of special odour-free materials. The odour concentration of the air sample is measured in an olfactometry laboratory away from the site using a panel of human sniffers, and the SOER is then calculated by multiplying by the air sweep rate and dividing by the exposed liquid surface area within the sampling hood. Therefore, the accuracy of the SOER depends on the accuracy of the measurement of the odour concentration.

The design of hoods for SOER measurement is the subject of substantial debate in New Zealand and Australia. Most of the debate centres around two types of hood – the *static flux hood* and the *wind tunnel*. These are shown in Figure 6 and Figure 7. The main differences between the two hoods are the ventilation flow rate and the airflow dynamics that are established over the liquid surface. SOER measurements collected with a wind tunnel are not equivalent to static flux hood results, nor is there a consistent ratio between the two types of measurement.

Overall, wind tunnels are currently the favoured type of sampling hood in Australasia. However, the science used to develop the wind tunnel is currently being challenged by scientists from the US, and debate is expected in 2002 on this matter.

Wind-tunnel hoods are best suited to sampling from area sources that have a medium to high SOER, where the collected sample odour concentration will be more than 100–200 OU/m^3, thereby reducing errors that can occur when operating at the lower limit of performance of olfactometers. For example, the SOER$_{0.05}$ corresponding to a ‘bagged’ sample concentration of 30 OU/m^3 at a hood sweep rate of 0.3 m/s is 1.14 OU/m^{2}s. This value is the *lowest* practical SOER measurement that can be collected using modern olfactometry and wind tunnels. Extreme caution is required when using wind-tunnel SOER data to determine OERs for large areas with very low observed odour emission rates (such as oxidation ponds). In many cases the calculated OER for that type of source will dominate other OERs from obviously more odorous point sources. For this reason there is an emerging view in Australia that, for large area sources, ‘If it doesn’t smell, don’t sample it’ using any type of flux hood technique.

Two types of wind-tunnel design are currently used in New Zealand. The Auckland olfactometry laboratory uses a design similar to that in Figure 6. Lincoln Environmental uses a slightly different design, with a smaller vertical cross-section that uses nitrogen as sweep gas rather than carbon-filtered air. Each design is likely to produce different odour emission rate measurements for the same source (not verified by experiment) by virtue of the different designs. Care should be taken not to intermix the results from the two wind tunnels, unless these are appropriately adjusted to account for hood design differences.

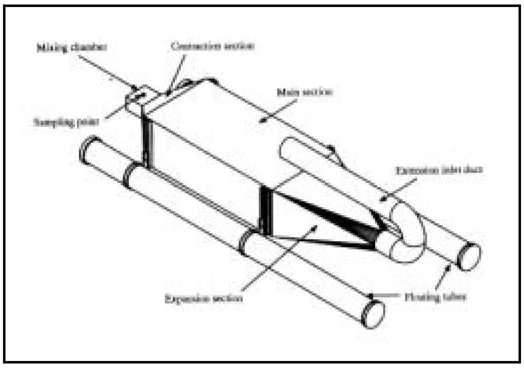


Figure 6. Wind tunnel

Figure 7. Static flux hood

Adjustments to wind-tunnel measurements

SOER data is obtained from wind tunnels at an internal sweep rate of 1.0–3.0 m/s. However, in water the odour emission rate will vary with wind speed across the surface. This is because the frictional force of wind depends on the surface renewal – the mixing of fresh liquid to the surface where diffusion of gases across the water:air interface can occur. This means that at any practical wind speeds, the surface renewal resulting from frictional forces is much faster than the rate of diffusion of the gas in water, from the bulk water to the surface layer. Therefore, for liquid surfaces, the SOER data measured by the wind tunnel at a sweep rate of 1–3 m/s needs to be corrected to a surface wind velocity compatible with the surface wind velocities that prevail under the meteorological conditions that tend to give rise to odour complaints.

For the correction, a standardised surface wind velocity of 0.05 m/s is often used. This value corresponds approximately to the wind velocity at a height of 100 mm above the surface (one half of a sampling hood height) for a recorded wind velocity of 0.5 m/s.

This correction is made using the following formula:

$$SOER_2 = SOER_1 \times \sqrt{(V_2/V_1)}$$

where:

$SOER_1$ = specific odour emission rate measured using the wind tunnel

$SOER_2$ = specific odour emission rate corresponding to actual ground-level wind speed

V_1 = air velocity inside wind tunnel for sample collection

V_2 = actual ground level wind speed.

This relationship between emission rates and air velocities is derived from boundary layer theory, and has been verified experimentally (Schulz et al., 1996). This formula can be used to calculate SOER values at other wind speeds, which can then be used in a dispersion model to simulate changes in SOER with changing wind speed. This same formula can also be used to vary the SOER with wind speed, to take the increase in SOER into account in a dispersion model.

Obviously, for solid or semi-solid media the mixing involved in surface renewal cannot occur, because any fluid present is trapped in an immobile, effectively solid matrix. The emission rate from solid or semi-solid media is therefore determined solely by the diffusion rate to the surface from within the medium. This means that the emission rate from a solid or semi-solid medium is essentially independent of wind speed.

Critical evaluation of sampling hood options

Each of the sampling hoods discussed above is recognised as having limitations. Until clear guidance is available on area source sampling methods, as may eventually arise from the Working Group set up by CASANZ Odour Special Interest Group, the choice of appropriate sampling hoods should consider the following.

1. *What practically can be used?*

- What air sweep rate is required, and what flow rate of odour-free air is required to support this?
- Can such air volumes be produced conveniently at the sampling site (for example, in the middle of a pond on a boat)?
- How manoeuvrable are the hoods on the surface in question?

2. *What will produce useable results?*

- Will the concentrations determined be valid, or close to the lower detection limit (LDL)?
- What type of hood will minimise the potential sampling errors?

3. *What will produce results that reflect real emissions from the source?*

- Do you want the results to reflect worst-case emissions for use in a worst-case dispersion model, or to reflect a more real-time situation to estimate normal, average emissions?

7.1.4 Back-calculation as an alternative to sampling for area sources

'Back-calculation' is the estimation of the SOER from an area source by measuring ambient odour concentrations at a known distance downwind from the source, under known meteorological conditions, and the source OER is then determined utilising a dispersion model. Back-calculation can be useful in situations where the overall odour emission from the site is the sum of a large number of small sources (such as cattle feedlots or large composting facilities), provided that the ambient odours are high enough for olfactometry measurement, and the odour source can be isolated from other sources.

However, some sources of error in the back-calculation approach mean that this is not often a preferred method (although some consultants do favour it). Sources of error include:

- multiple odour sources and background odours can contribute to total odour measurement
- if ambient odour concentrations are low, the limit for olfactometry can fall below its lower detection limit
- inaccuracies in dispersion modelling if sampling is done too close to the source relative to the size of the source (particularly for area sources); however, some techniques have been developed in Australia to overcome this problem and allow for sampling close to the source.

- dispersion model errors (particularly for stack sources, where accuracy maybe close to a factor of 2, and could be a factor of 10 or more if predicting concentrations at a specified downwind location)

- errors in estimating meteorological conditions and determining the exact wind direction and plume centreline.

Back-calculation is recommended as a technique for estimating odour emission rates when other methods such as emission monitoring are not practicable. In such circumstances, good-quality meteorological data needs to be available, and the emission rates determined should be related to the averaging time (typically 0.5 hours or more) needed to complete the measurements. With these averaging times, the emission rates are an average of both the total odour emission from the site and the variability of the wind direction.

One of the big advantages of the back-calculation method is that, irrespective of any modelling uncertainties, it effectively calibrates the modelling for the particular assessment. The key issue therefore becomes one of sample numbers covering varying meteorological conditions and the statistical variation within the resultant data. This latter factor is often a significant problem when directly sampling many area sources.

7.1.5 Sampling from fugitive sources

Determining OERs for fugitive sources is often difficult – or even impossible – and the reasons for needing to quantify the emission rate should be questioned. Fugitive sources can often be removed or reduced by inexpensive maintenance or changes in operating procedures. It may be sufficient to make a subjective judgement as to the significance of the fugitive source, and implement appropriate mitigation procedures without going through the process of dispersion modelling assessment. In brief, just ‘fix the leak’.

7.2 Design of sampling programmes

7.2.1 Variable emission rates

If a single sample is collected, analysed and an OER determined, there can be considerable uncertainty in the result due to typical olfactometry errors (see section 7.3.2), and a lack of confidence in whether this single sample is representative of either the whole source or the worst-case emission conditions.

Odour sources will rarely discharge at a constant rate, instead varying with time and across the surface of large area sources, such as oxidation ponds, tanks, compost windrows and landfills. The greater the number of samples collected, the better the confidence in the emission rates. This applies both to repeat measurements on different occasions at the same position on the source, and to sampling at different locations on the source over a short time.

7.2.2 Is sampling always warranted?

In some circumstances the necessity for any odour measurement at all must be questioned. If, for example, the main odour problem is known to be from occasional or 'upset' emission rates, is there any need to spend large sums of money quantifying the other odour emissions at the site, particularly if interpretation of odour diaries or complaints indicates that there is no adverse effect from odours under normal operations? Also, for sites with multiple odour sources, can the various sources be prioritised by subjective assessment, odour complaint records, or even by initial dispersion modelling with guessed or borrowed emission rates before designing odour-sampling programmes that target only the major sources?

7.2.3 Replicate samples

To be useful for practical odour management, olfactometry needs to have a defined accuracy, repeatability and reproducibility of the odour measurement data.

- *Accuracy* is the closeness of agreement between a test result and the accepted reference value of 40 ppb n-butanol.

- *Repeatability (r')* (or precision) is the difference between two single measurements performed on the same testing material by the same laboratory under repeatable conditions.

- *Reproducibility (R')* is the difference between two measurements undertaken by different laboratories on the same material using the same method.

Replicate samples are useful to improve the accuracy of the olfactometry results. Van Doorn and van Harreveld (1994) discuss sampling strategies and statistical aspects for measuring odour emission rates, and report that the best compromise between accuracy and expense was achieved when three to four replicate samples were collected. A figure from the paper is reproduced in Figure 8. The confidence interval widens markedly if fewer than three samples are collected, so taking three samples was current practice in the Netherlands when that paper was published (1994). Similarly, as the number of samples increases above about four, the improvement in confidence interval again reduces, yielding relatively little extra accuracy for the additional costs involved.

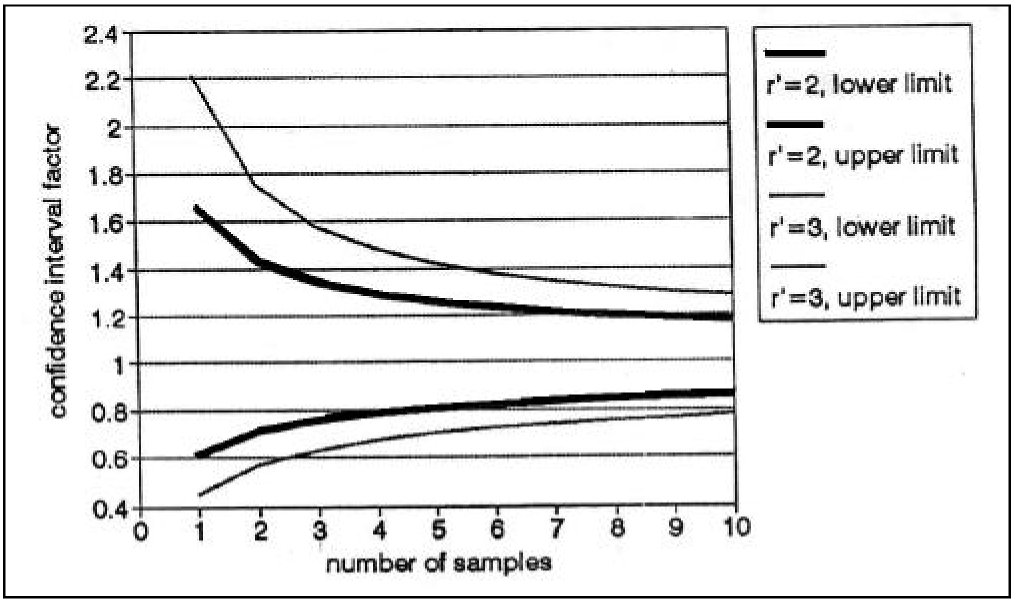


Figure 8. 95% confidence interval factor around a mean odour concentration of 1 in relation to the number of samples

Source: Van Doorn and van Harreveld (1994)

The repeatabilities quoted by the Dutch authors refer to measurements carried out using the reference gas n-butanol. It is widely reported (and accepted) that the human nose responds better to mixtures of odorant compounds than to pure compounds. For this reason, the repeatability values obtained for results of testing of actual samples tend to be far lower than the values reported for n-butanol. Experience over several years in a large Australian olfactometry laboratory indicates that repeatability equivalent to ±25% can be expected.

AS/NZS 4323.3:2001 contains guidance on how to calculate the number of samples to be taken within a required precision of the odour concentration.

Odour samples cost approximately \$500–\$600 per sample in New Zealand, when the cost of collecting the samples is factored in. The costs per sample decrease as the total number of samples increases, so a compromise between number of samples and cost is always required. For this reason, we do not make any specific recommendations on the number of replicate samples. However, you will need to give some consideration to the likely error in the sampling determinations when using the results in dispersion modelling, and when using the sampling measurements for compliance testing of source odour emission rates.

7.3 Measuring odour samples

Having looked at how we should go about collecting samples from various types of odour sources, we now turn to examine the best way of analysing them.

7.3.1 Chemical versus sensory analysis

The measurement of odour is based on one of two approaches: chemical analysis using a variety of instruments, and sensory analysis using a human nose. In chemical analysis, the concentration of an odorous compound is measured, and then multiplied by a known odour 'detection threshold' for that compound. Roughly, this amounts to converting an objective number into a subjective smell. There are several difficulties with this method (NZWWA, 2000).

- An odorous gas can comprise a cocktail of many odorous compounds. This is a major challenge to the accurate measurement of odour due to the difficulty of identifying all the compounds, and the synergistic relationship that may exist between the various compounds.
- The nuisance impact of an odorous compound is often perceived at extremely low concentrations (in the parts per billion range), making instrumental analysis difficult.
- Published odour thresholds may differ depending on the source of the information. This is due to differences in sensory techniques used by laboratories in the past (although this is becoming more standardised in the late 1990s), and also to different definitions of the odour threshold, such as detection, certainty and recognition levels.

Because of the complex nature of odours, the human nose cannot be matched by any presently known instrument. Nor can any instrument measure the degree of unpleasantness of an odour. Sensory methods of odour measurement, on the other hand, avoid this problem by using the human nose as the sensor in the measurement process. The sensory method of odour measurement, called olfactometry, is discussed in section 7.3.2.

Electronic noses

Electronic instruments known as 'electronic noses' are able to conduct complex chemical analyses and determine an odour measurement from the chemical concentrations. These electronic odour monitors are based on conducting metal oxide, polymer and other sensors able to detect odour-causing chemical molecules in trace concentrations. Like the human perception of odours, the electronic instrument can directly characterise an odour without reference to its chemical composition.

Electronic nose technology may be more appropriately termed electronic detection technology. These instruments operate in a way that is a simple analogy to how our sense of odour works. The spectral patterns these devices produce when exposed to a mixture of chemical compounds are similar to those produced using gas-chromatic graphs, which are also related to the mass concentration of the compounds.

Recent research in the UK and Australia has highlighted the potential for using electronic noses as a substitute for olfactometry (Stuetz and Fenner, 1998; Young et al., 2000). The work by Stuetz and Fenner compared olfactometry results with electronic nose readings for odour samples collected from 10 waste-water treatment plants, with an odour concentration range of 100–800,000 OU/m^3 (measured by forced-choice dynamic dilution olfactometry). No universal correlation was found between the electronic nose and olfactometry responses for odours from different sources. However, a good correlation between the two responses was found when only samples from a single treatment plant were analysed. This confirmed that a relationship existed between sewage odour and the electronic nose response for odours that are source-/site-specific, suggesting a role for electronic noses in site-specific studies. However, the instrument still needed to be calibrated initially using olfactometry.

If an electronic nose is proposed as an odour measurement device, it should be remembered that:

- the instrument's responses need to be calibrated against olfactometry, and definite correlations between the electronic and olfactometric responses determined before the electronic nose is used
- the calibration will be specific to one type of odour source, and may give misleading responses if there is interference from independent background odours
- a measurement from an electronic nose is not a substitute for a true sensory response by an adversely affected human being.

Odour sensing by electronic noses is an emerging technology, which is likely to gain increasing popularity in the future.

Chemical odour thresholds

Due to the time, costs and other difficulties associated with dynamic dilution olfactometry, chemical analyses are sometimes used instead as *indicators* of odour. This method assumes that by measuring for the presence of a certain chemical compound, such as hydrogen sulphide (H_2S), one can estimate the amount of odour present. The assumption is valid for odour discharges where the odour is predominantly caused by one component, such as sulphide discharged from a fellmongery. The main limitation is the variability in representativeness of one chemical component to represent the overall odour effect of a mixture of compounds.

In some circumstances the chemical odour of a gas sample can be determined by using a gas chromatograph/mass spectrometer (GC-MS) to identify as many of the odorous constituents as possible, and the total odour can then be estimated by summing the individual odour thresholds of each chemical compound. Research reported by Stone (1997) indicates that this can be a reliable method of odour measurement for any source where sufficient chemical compounds to representatively describe the odour can be analysed reproducibly. The paper concludes that a correlation between olfactometric and chemical measures of odour does exist in samples where a small number of relatively strong odorants are responsible for the majority of the odour.

This suggests that GC-MS may be used to predict odour intensity in certain circumstances. This is illustrated by a case (cited in Stone, 1997) where a starch factory odour source was found to readily provide a clear odour fingerprint dominated by sulphurous and aldehydic compounds, and a good correlation between olfactometry and analytical chemistry was obtained by linear regression analysis. However, the paper also noted that in several cases of very complicated odours with data obtained over an extended period, no correlation could be found. In reality, most cases of odour discharge will fall into this category, particularly when one considers the effects of mixtures of different odours combining in ambient air downwind of a site containing multiple odour sources.

If the use of chemical odour thresholds is appropriate as an odour indicator, this technique can be useful to determine the efficiency/effectiveness of control equipment, and to monitor the activity's compliance with resource consent conditions.

7.3.2 Dynamic dilution olfactometry

Description of method

Olfactometry is the science of odour measurement using sensory methods. In dynamic dilution olfactometry (DDO), a sample of odorous gas is collected and taken to a controlled environment, where odour-free air and the odorous gas are continuously mixed to produce a diluted stream for presentation. This dilute air stream is presented to a panel of trained individuals through sniffing ports. The concentration of the sample in the air stream is then increased until all panel members can detect the odour. This method gives a measure of odour strength in terms of the degree of dilution with odour-free air required to reduce a given sample to the level where its odour is barely perceptible.

This 'dilution to threshold' approach to odour measurement provides a measure of odour strength that is far easier to interpret than chemical methods. This is because it indicates the degree of dilution required by natural dispersion, or the amount of source strength reduction required, to reduce the original emission strength to threshold level where its impact will be zero.

There are two ways to conduct DDO: the yes/no response and the forced-choice response.

Yes/no response

In this method each panellist has one sniffing port. When a test is run they must sniff the port and indicate if they can smell an odour. This would normally be done by the panellist pressing a button when they can smell an odour. This technique is the simplest to implement, as only one sniffing port and one response button are needed per panellist.

The yes/no method was common in the early 1990s, but is now being replaced by the more sensitive forced-choice response. The yes/no method is no longer used commercially in New Zealand, but is still used by some Australian laboratories, and is still the regulatory accepted standard in Victoria and South Australia.

Forced-choice response

The forced-choice technique differs from the simple yes/no technique in that each panellist has two or three sniffing ports. At any one time one port will contain the diluted odour sample while the other(s) have clean air. The port containing the odour is randomly changed after each presentation. Panellists have no prior knowledge of which port contains the odour, and are forced to guess if they cannot detect an odour from either (any) port.

When indicating their choice of port, the panellists also indicate if they were 'guessing', 'uncertain' or 'certain' about their choice. From these responses it is possible to arrive at two endpoints. The first is where the panellist is constantly correct in their choice of port, but not certain about it. This is often referred to as the 'detection threshold', and is given the units OU_d/m^3. The other is where the panellist is constantly correct in their choice of port, but is also *certain* about the choice. This is often reported as the 'certainty threshold', and can be given in units of OU_c/m^3. However, since the use of the certainty threshold is becoming standard practice, the subscript can be dropped so the units are OU/m^3. This convention will be used throughout the report (unless otherwise specified).

In theory, odour concentrations calculated using certainty thresholds are one-half to one-third of those calculated using detection thresholds, although in practice this ratio can be much greater (see below). AS/NZS 4323.3:2001 has standardised the use of certainty thresholds, although many laboratories still report odour concentrations for both detection and certainty thresholds, because both concentrations can be calculated from the same sample.

The 'recognition threshold' of a substance or odour is also often used in the literature. This is the concentration at which the odour exhibits a recognisable character (for example, 'compost') to 50% of the test panel. Recognition thresholds are largely only of academic interest.

Studies have shown that in order to achieve improved repeatability and reproducibility (see section 7.2), careful panel selection is crucial. Prospective panellists are screened by testing their response to a reference gas, n-butanol. Panellist screening eliminates candidates with either a very sensitive or an insensitive sense of smell. Panellists are also screened in the same way every day before olfactometry testing begins. Those with unacceptable sensitivity on that particular day (for example, they may have had a cold, which can affect nasal sensor response) are not allowed to take part on that day, or their responses are excluded from the calculations of odour concentration. In using a panel selection method based on a reference gas you need to abandon the notion that the panel reflects the sensory characteristic of the entire population (van Harrevald, 1994).

Instead the panel is designed to be a reliable 'composite sensor' representing an 'average nose'.

Yes/no versus forced-choice response

Forced choice has the advantage of being more sensitive, because the tendency of people to develop a conservative bias seen with yes/no olfactometry is eliminated. In the yes/no case, panellists, through a fear of giving a false result, are reluctant to indicate yes when they are unsure about the presence of an odour in the port. They tend to wait until they are sure before responding positively. When a panellist is forced to give a response, they must make their best estimate of which port contains the odour.

In addition, the human nose is more sensitive when able to compare an odorous environment with a non-odorous environment, so forced-choice olfactometry methods will produce lower odour thresholds.

For these reasons, the forced-choice technique should give a lower threshold than the yes/no technique (Köster, 1985). However, results obtained using the yes/no technique are thought to be comparable to results using the forced-choice certainty threshold technique provided that quality control and panel screening procedures are undertaken. The overall change from yes/no to forced-choice response, followed by using certainty thresholds for the forced-choice response method, has been driven by the desire to standardise the technique and produce results with a higher degree of accuracy and repeatability.

When utilising odour concentration data published in the literature, or comparing old data (pre-1995) with that collected in recent years, it is essential to take into account the response method and data calculation procedures used. The key variables are:

- whether or not panellist screening to the standard odorant n-butanol was undertaken
- whether the yes/no or forced-choice response was used
- whether the forced-choice response was used with or without certainty criteria for panel selection and results reporting.

If data has been obtained using a method not utilising any form of panellist screening, the results are unlikely to be comparable to more recent measurements. If panel screening data is available, it may be possible to further refine the conversion factor required to convert the data from yes/no response methods, so that it is comparable with that measured using forced-choice response and certainty criteria.

Prior to the publishing of the Draft European CEN Standard in March 1995, most forced-choice response olfactometry was conducted without the use of certainty thresholds for panel selection and in reporting the results. After the standard was published most laboratories moved to using certainty thresholds, and it is now the most common technique used worldwide. The two commercial laboratories in New Zealand (the Watercare laboratory in Auckland and the Lincoln Environmental laboratory in Canterbury) both use this method.

The methodology of forced-choice DDO has been the subject of much research over the past 10 to 15 years, particularly in Europe and Australasia, and is now standardised and subject to strict quality control requirements to ensure consistency between laboratories. The standardisation of the methodology has only developed in the last five years or so.

Australia/New Zealand olfactometry methodology standard

Standards Australia has published an Australia/New Zealand standard: 'Stationary source emissions – Determination of odour concentration by dynamic olfactometry', code AS/NZS 4323.3:2001. The standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EV/7, 'Methods for Examination of Air'. The standard is based on a CEN (Comité Européen de Normalisation) pre-draft of the same title (CEN, 1995).

The objective of AS/NZS 4323.3:2001 is to provide a method for determining the odour concentration of a gaseous sample using DDO with a panel of human assessors as the sensor. The standard can be downloaded from the Standards Australia website: http://www.standards.com.au. AS/NZS 4323.3:2001 applies to both yes/no and forced-choice response methods.

Relationship between detection and certainty thresholds

Van Harreveld and Heeres (1995) present experimental data and analyses on the effect of using either certainty or detection thresholds on the repeatability of olfactometry results. The evidence presented in the paper strongly supports the conclusion that the use of the certainty threshold considerably reduces the variability in measuring results, both for the quality control reference chemical n-butanol and with ambient odour samples. This is supported by the data in Appendix 5. The paper goes on to demonstrate that quality parameters assessed with n-butanol as a reference can be transferred to environmental odorants when using the certainty threshold (if panellists meet the sensitivity range for n-butanol they are likely to respond in a similar controlled manner to environmental odours – this is critical for quality control in olfactometry), but that there is reason to doubt whether this conclusion is also valid for the detection threshold.

There are differing reports on the appropriate scale factor to convert between detection and certainty thresholds, although the most commonly used value is 2. Figure 9 shows detection:certainty (D:C) ratios from 684 samples analysed by the two New Zealand olfactometry laboratories between 1997 and 1999. The samples represent a range of sources from waste-water treatment plants and landfills. Of this sizeable number of data records, only about 10% of the samples had a D:C ratio of 2. The median ratio was 4, and the maximum was about 25.

Figure 9 also shows the D:C ratio of 195 odour samples from a single industrial odour source in New Zealand collected during 1995–97. The D:C ratio spread for this single source is much narrower, with 50% of the samples having a ratio of 2 or less, and 55% of the samples having a ratio of between 1.5 and 2.5. Similar results to this latter data set have also been noted for some other industrial sources in New Zealand. The extreme difference between these two sets of data may reflect the types of chemicals in the odours, with the chemical make-up of the industrial odour source being more consistent, or differing psychophysical relationships between odour intensity and concentration. However, more research would be required to confirm such a hypothesis.

Figure 10 shows D:C ratios for two individual types of odour measured in Australia. These results also indicate a consistent ratio between detection and certainty, but the average ratio is closer to 3–4 than 2.

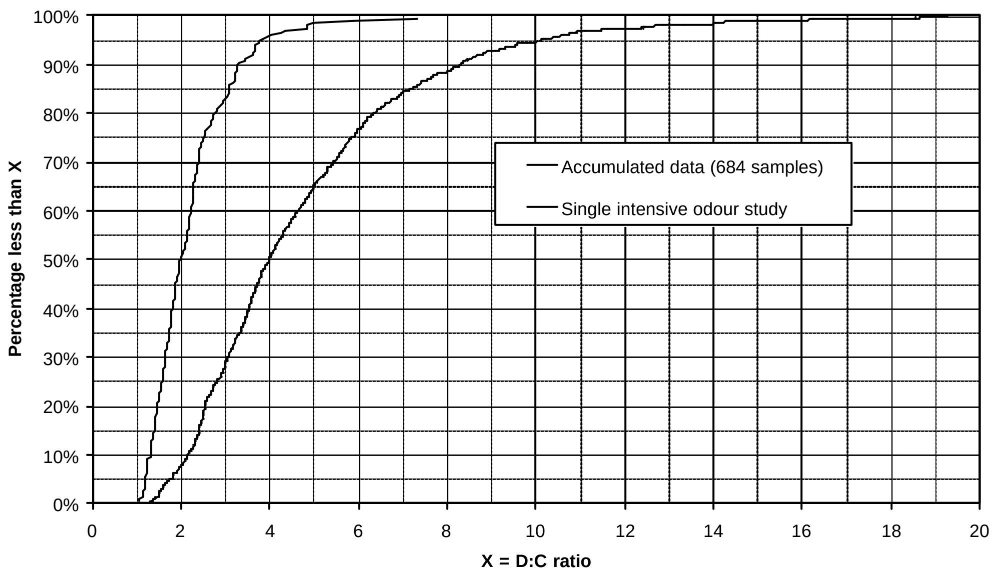
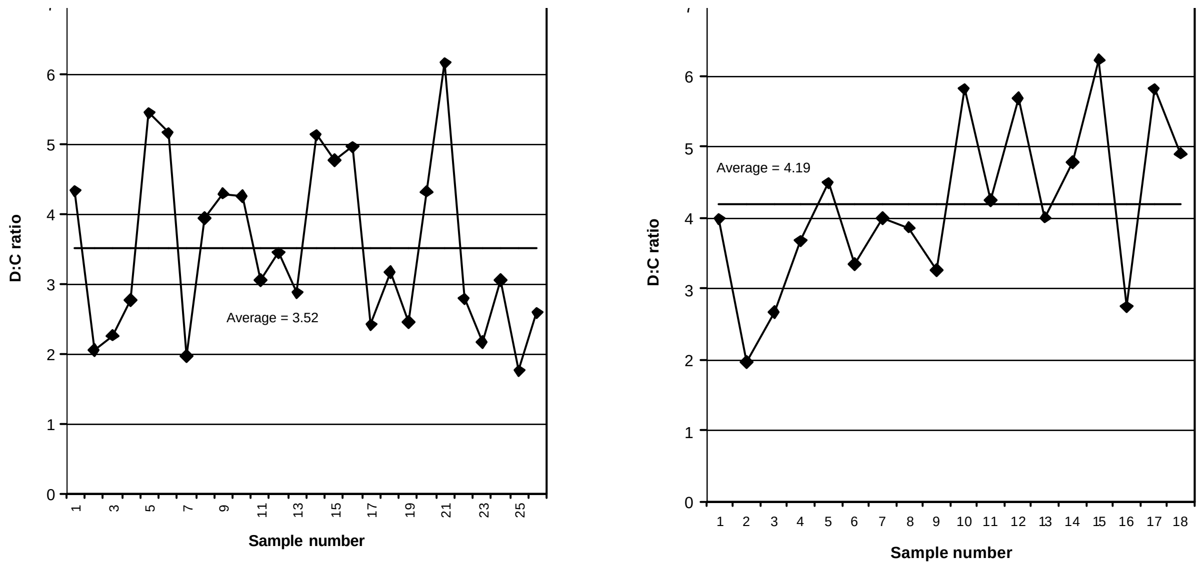


Figure 9. Detection:certainty ratios for samples measured by New Zealand olfactometry laboratories



(a) Coke Works **(b) Mushroom Composting**

Figure 10. Detection:certainty ratios for two different types of odour measured by an Australian laboratory

Independent confirmation of the occurrence of higher D:C ratios comes from two other sources. Jiang (1997) has calculated data using detection and certainty criteria, and states that:

> *... for a given sample, the values of the two thresholds may differ by a factor typically from 1.5 to 10 depending on the instrument, the number of sniffing ports and the number of panellists. There is no reliable correlation between these thresholds.*

Watts (1999) prepared a report for the Pig Research and Development Corporation of Australia, in which the primary objective was to develop a database of useful odour emission-rate information for Australian piggeries through a comprehensive literature search. Watts refers to the paper by Jiang (1997), and then states on page 27: “Consultants have found it necessary to use [detection] data in odour assessments based on the [certainty measurement] standard. It is generally agreed that the conversion factor should lie in the range of 2 to 5 with 4 commonly used.” The author then emphasises that “this conversion is not scientifically validated and should be used with caution”.

For the moment, for the reasons of quality control presented by Van Harreveld and Heeres (1995) discussed above, and the fact that the methodology for DDO has standardised on the measurement of certainty thresholds, we recommend the use of certainty thresholds over detection thresholds.

However, the time may come when more is understood about the relationship between certainty and detection thresholds, and the use of detection thresholds increases. Therefore, we also recommend that laboratories continue to report both certainty and detection threshold data when reporting on olfactometry tests, so that the detection threshold data is not lost for future reference. Monitoring detection:certainty ratios is also a good quality control procedure for laboratories.

Limit of detection

The lower detection limit (LDL) of the odour measurement is the lowest detectable odour concentration that can be determined by the olfactometry laboratory with 95% statistical confidence. It can be determined by filling an odour-sampling bag with neutral gas, leaving the sample for the normal storage time, then analysing the sample using the normal procedure. AS/NZS 4323.3:2001 outlines a procedure by which the LDL may be assessed. In practical terms, the LDL is often in the range of 10–25 OU/m^3, depending on the bag material and sampling apparatus used.

This has important implications, in that weak ambient odours that may be capable of causing annoyance are not readily measurable by olfactometry. It also has implications for the accurate measurement of low-level odour emissions, such as may be discharged from a large area source. This is discussed in section 7.1.3.

As an example of the effect of the LDL, Table 11 lists the results of blank sample testing carried out as part of an oxidation pond monitoring programme in New Zealand. The values presented are the raw data concentrations of the gas samples collected, in OU/m^3, rather than the SOERs, which are derived from the concentrations. The blank samples were taken using the same method as the samples from the oxidation ponds, with the wind-tunnel-type sampling hood floating in a pool of fresh water. The values obtained from these samples provided a practical detection limit for the subsequent oxidation pond measurements. Concentrations of up to 116 OU/m^3 were measured. Any concentrations from actual samples in this same range, for that particular monitoring programme, were rejected as being too low to be accurate.

Table 11. Concentrations measured with blank samples

Number of samples	Concentrations of sample collected (OU/m^3)
5	8, 9, 9, 77, 116

Similar problems have been encountered in monitoring low odour concentrations emitted from some landfill surfaces.

Repeatability and reproducibility

Van Harreveld and Heeres (1995) also present results on the quality control and optimisation of DDO, including procedures for ensuring that sample analyses are repeatable (r’) and reproducible (R’) (these are defined in section 7.2). A repeatability of r’ < 2 implies that the result of one single odour measurement is no more than a factor of 2 different from one other single measurement in 95% of cases. Reproducibility is a similar concept, applied to differences between single measurements done in different laboratories.

Appendix 5 shows the repeatability of panel thresholds for n-butanol, the reference odorant, varying the number of rounds or passes (the number of times each panellist sniffs the same odour sample) and the number of panel members. Repeatability for both certainty and detection thresholds is also shown in the Appendix, as this supports the discussion in section 7.3.2 on the reduction in variability between samples offered by the certainty criterion.

The Australia and New Zealand standard on olfactometry (AS/NZS 4323.3:2001) is consistent with the CEN standard in recommending a repeatability of less than 2.0. The standard also recommends that samples be analysed by certainty thresholds, using six panellists and three passes, with the first pass being ignored in the calculation of the odour concentration (the 2+3 row in Appendix 5). However, the standard also allows any other combination of panellists and passes that achieves the same or better (lower) repeatability. These combinations are shown in the table in Appendix 5 in **bold** text.

Practitioners in Australia have reported better repeatability with actual environmental odour samples made up of a mixture of compounds than with the reference odorant n-butanol. This means that repeatability with actual field samples may be better than that shown in Appendix 5.

7.3.3 Offensiveness testing

The *offensiveness* of an odour is a subjective rating of its unpleasantness (often called the hedonic tone) at a standardised concentration above the threshold that is readily detectable to most people (see discussion in chapter 2). For example, people typically rate odours from a wet feedlot as more offensive than those from a dry feedlot pad, when at the standardised concentration of 10 OU_d/m^3. So, although both odours can be considered unpleasant, the wet feedlot odour has greater nuisance potential. Put another way, the dry feedlot odours would need to be present at greater concentration to elicit the same offensiveness response as the wet feedlot.

Considerable research has been carried out in Europe over the last 10 years to quantify the quality of an odour and to compare different odorants according to their hedonic tone. In contrast to the similarity of perception of intensity between a variety of people, in the evaluation of odour offensiveness there are clear differences between test subjects, related to differing odour experiences, upbringing, and socioeconomic status (Paduch et al., 1995). Therefore, the test population required for offensiveness testing is correspondingly large.

Another example of the use of offensiveness testing is the testing of gases entering and exiting a biofilter. The exit gas from a biofilter can have a measurable odour, typically due to soil and bark-type odour picked up by the air as it passes through the biofilter media. Therefore, consideration of the hedonic tone is important when interpreting dispersion modelling results, particularly when assessing the effectiveness of odour abatement processes such as biofilters and scrubbers. The quality of an odour is changed by most odour abatement procedures, and the resulting odour can be much more pleasant than the original crude gas. Therefore the annoyance potential may be lower than predicted from odour concentration measurements and modelling.

While offensiveness tests give a comparative indication of the relative unpleasantness of various odours, such values cannot at this stage be readily extrapolated to predict population annoyance to odours. This is because the applicability of laboratory-based offensiveness tests to the real environment is yet to be confirmed. In addition, a person in the olfactometer is likely to be more sensitive to odours than in the real environment, because they are concentrating on detecting the odours and are isolated from normal, background odours. Social surveys are a good method of measuring the level of annoyance in a community due to odour exposure.

Chapter 7: Recommendations

1. Odour emission measurements should be undertaken in accordance with the joint Australian and New Zealand standard AS/NZS 4323.3:2001.

2. The methods used for odour sampling and pre-dilution should be those described in the joint Australian and New Zealand standard AS/NZS 4323.3:200, except in circumstances where alternative approaches are justified to ensure sample integrity.

3. Isokinetic sampling is generally not required when sampling air for odour analysis.

4. Back-calculation is recommended as a technique for estimating odour emission rates when other methods, such as emission monitoring, are not practicable.

5. Replicate samples are useful to improve the accuracy of the olfactometry results. AS/NZS 4323.3:2001 contains guidance on how to calculate the number of samples to be taken within a required precision of the odour concentration.

6. The budget available at an industry for odour measurement needs to be balanced between replicate measurements at one time, and repeated measurements at a number of different times and process conditions.

7. The use of certainty thresholds over detection thresholds is recommended.

8. Olfactometry laboratories should continue to report both certainty and detection threshold data when reporting on olfactometry tests, so that the detection threshold data is not lost for future reference.

8. Odour Dispersion Modelling

So far we have been looking at situations where an odour is already being emitted and we want to assess its effects. But suppose an industry group wishes to set up a site that is likely to produce odours. Is there any way to predict whether these odours will cause adverse effects on the surrounding community? This can be a crucial question when applying for a resource consent under the RMA, or when looking at ways to comply with consent conditions for a pre-existing activity.

Odour dispersion modelling attempts to do this by creating a sophisticated computer program to predict the concentration of contaminants – including odours – once they are discharged to the atmosphere. The models use the characteristics of the discharge, local ground contours (topography) and local meteorological conditions to predict where the air emissions will be transported to, and the concentration in which they will arrive at any particular location (called a receptor) relative to the assumed concentration at the source. The model's predicted concentrations of odour are then compared with a numerical guideline, called an *odour-modelling guideline* (see chapter 9), to determine whether there is a potential for adverse effects.

Natural dispersion is more rapid in turbulent, windy conditions than in calm conditions. By modelling the downwind concentrations under different atmospheric conditions, it is possible to predict the effect of worst-possible conditions, or even to simulate a full year of atmospheric conditions.

However, this is not a textbook on dispersion modelling practices. It simply introduces dispersion modelling and refers to modelling features relevant to predicting the dispersion of odour. Readers who want detailed guidance should refer to the Ministry's good practice guide on dispersion modelling, which will be published in 2002/03.

8.1 The role of dispersion modelling in regulating odours

Atmospheric dispersion modelling is used worldwide. The accuracy of computer models in predicting dispersion (particularly those based on the gaussian equations) and the assumptions in them have been well researched and verified by field measurements under carefully controlled conditions over the last 30 years. The use of these models is an essential requirement of the assessment of environment effects of air discharges by the Environmental Protection Agency in the USA (US EPA) and Australian state environmental authorities.

In New Zealand the use of gaussian models (see below) is widespread, and is recognised by regional councils. However, the validation of these models during cold-air drainage flow conditions has rarely been considered, and it is known that contaminant dispersion rates/pathways during such conditions cannot be accurately established using these steady-strate models. In such circumstances it is necessary to use non-steady-state models that can account for contaminant diffusion and terrain effects during stable conditions. These types of models are relatively new to New Zealand, but their use in complex modelling situations is becoming more common.

Dispersion models can allow individual sources of odour to be ‘switched off’ to investigate the contribution of the remaining sources to the overall odour concentration impact. For example, individual odour sources contributing to the overall odour emission from an industrial site can be ranked in terms of their odour effects on the surrounding environment. In doing so, the user always needs to account for differences in the power law relationships of intensity versus odour concentration (see section 2.3.1), as it has been confirmed that the largest contributor to the cumulative odour impact is not necessarily the dominant source (Ormerod and Cudmore, 1996). Therefore, with some care, the best practical means of odour control can be identified without extensive site trials, and before capital works begin.

Dispersion models can also be used to predict the likely potential adverse effects of odour discharges, particularly for proposed activities or proposed changes to existing activities. The model’s predicted concentrations of odour are compared with a numerical guideline, called an odour-modelling guideline, to determine whether there is a potential for adverse effects.

8.2 Limitations of dispersion modelling

For existing activities, dispersion modelling predictions of odour impact are less relevant than the community’s feedback, if this can be obtained in a non-biased manner. For example, if the public still complain of odour nuisance even though the modelling results may predict compliance with the guidelines, then the complaint should not necessarily be disregarded. The more common reasons for this situation occurring include the following.

- The odour concentration guideline is not low enough to avoid adverse effects for the specific odour involved, or is adequate for protection against chronic adverse effects but not for short-term peak emissions that cause acute adverse effects (for example, the infrequent peak emissions that occur during the mixing of sludge-composting heaps).

- Some sources of odour have not been identified and modelled (such as occasional sources or leaks through covers, or the release of significant fugitive emissions that cannot be readily quantified).

- The true variability of the odour emission rates from the source are not adequately characterised by the typically limited number of emission measurements, to the extent that peak emission scenarios are not accounted for.

- Poor measurement techniques have been used, resulting in under-estimation of emission rates.

- A gaussian dispersion model is being used in a complex situations, such that the meteorological conditions and surrounding terrain influence the odour plume direction and dispersion rate in a way that can only be established using more complex wind field models.

A common error when interpreting model results is to assume that an activity will be considered to 'pass' or 'fail' the test for adverse effects depending on whether the results are higher or lower than the odour guideline. However, because of the possible sources of error described above, it is essential that the likely extent of conservatism and reliability of the predicted odour exposure levels is also considered.. Therefore, when evaluating the environmental significance of odour-modelling data, an assessment of reliability of both the modelling process and the modelling guideline should be performed. Difficulties associated with modelling odour discharges will be discussed in section 8.2.1

Once an industrial process has been established, the continued use of dispersion models and comparisons against guidelines may be of limited value, although still useful in order to:

- indicate the direction of plume paths, and where the highest impacts are likely to occur within the surrounding community, when unexpected complaints are received

- establish the likely frequency of occurrence of odour impacts at a specific location (if data for a period of real meteorology is available).

- compare the relative effects of various sources

- test the sensitivity to upsets of individual sources

- compare the noticeable effects of mitigation options

- compare existing versus future odour effects at a site.

8.2.1 Difficulties in modelling odours

There are several characteristics peculiar to odours that directly affect the modelling process.

- Odours are complex and subjective by nature and are difficult to quantify, so it is difficult (and often expensive) to gain an accurate odour emission rate profile for some sources.

- Odorous sources are often characterised by a varied and often complicated network of structures, such as roof vents, stacks, large area sources and door leaks, which can make their quantification very difficult.

- Odour interactions are rarely cumulative. Odours from one source may totally mask those from another source. They can also change in their intensity with distance and exposure to air and light. Odours are not essentially additive, and it can be incorrect to model assuming they are so. This is discussed further below (see 8.2.2).

8.2.2 Implications of Steven's Law

Dispersion models generally assume that the mass of contaminants is conserved (not affected by chemical reaction in the atmosphere) as dilution takes place. Some models allow simple exceptions to this rule to account for chemical reactions of some compounds if the reaction can be specified by a simple exponential equation.

In a dispersion model, odour is treated as a pure substance rather than a combination of different chemicals. It is assumed that the odour intensity of a mixture of two (or more) odorous gases is equal to the sum of the odour intensity of the individual gases. Consider the case of a person smelling an odour from sludge lagoons at a waste-water treatment plant. An additional odour source from primary sedimentation tanks (odour comprising different chemicals) is then introduced. The model assumes that the odour intensity noticed by the sniffer would increase by the same amount as if the primary sedimentation tanks were being sniffed on their own: if source A causes a concentration of X_A OU/m^3 at a certain downwind receptor, and source B (made up of a different balance of chemical constituents) causes a concentration of X_B OU/m^3 at the same receptor in the same wind conditions, then the model assumes that the combined downwind concentration at that receptor from these two sources will be $X_A + X_B$ OU/m^3.

However, as described in section 2.3.1, in reality odours are not additive, nor does the intensity vary linearly with concentration. This cannot be accounted for in the dispersion model because the mathematical functions that describe the relationship between concentration and intensity, and masking and synergistic effects, are complex and vary for each mixture of odorants.

8.2.3 Dealing with multiple sources of odour

Dispersion models with multiple sources of odour and mixtures of chemical compounds are likely to over-predict downwind concentrations, because the diluted odour mixture will be dominated by the more offensive components in the mixture, which mask the less offensive components. There are two options to moderate the effect of this over-prediction.

(1) Where the odour discharges on a site can be classified according to their offensiveness, say, 'very offensive' and 'slightly annoying' categories, the 'very offensive' sources are likely to dominate the 'slightly annoying' sources unless the latter group has a very high predicted downwind concentration relative to the other group. Therefore, the groups of sources can be modelled separately.

(2) Where a small number of sources on a site are of much lower offensiveness than the others, such as a biofilter on a rendering plant, then the odour emission rate determined for that source (or those sources) could be corrected downwards by dividing the source's emission rate by suitable factors.

Alternatively, depending on the complexity of the situation, it may be just as appropriate to model all the sources together, and to bear in mind that the model is likely to have over-predicted the actual situation when interpreting the model results.

8.3 Types of models

There are a range of dispersion models available. These can be broadly grouped into four classes:

- screening gaussian models
- full meteorology gaussian models
- puff models
- Langrangian/prognostic weather models.

These types are described briefly below. More information on all these models will be included in the Ministry's good practice guide for modelling.

8.3.1 Screening gaussian models

The most commonly and easily used dispersion models are the gaussian models, so-called because the equations used to estimate the rate of dispersion assume that the spread of contaminants across wind and downwind can be described by the normal or 'gaussian' distribution, which is well known in statistics and can easily be described mathematically.

Where real-time meteorological data is not available, it may be satisfactory to run a model with a set of hypothetical meteorological conditions. A screening set of data should contain the full range of possible meteorological conditions, including the worst case. In models such as ISC-PRIME and AUSPLUME, a screening input data file is already provided. Averaging periods of greater than 1 hour cannot be predicted with screening input data. Screening can be used to determine an order of magnitude indication of dispersion, and, provided the highest ground-level concentrations are well below regulatory guidelines, no further modelling may be required.

Screening meteorological data should be used with caution where terrain or complicated coastal effects are likely to affect the dispersion conditions. The screening files are also not suitable for complicated source geometry, because they contain only one wind direction. If you can determine which source geometry represents the worst case, it is possible to adjust the wind direction so that the odour sources are aligned parallel with the wind. This is shown in Figure 11.

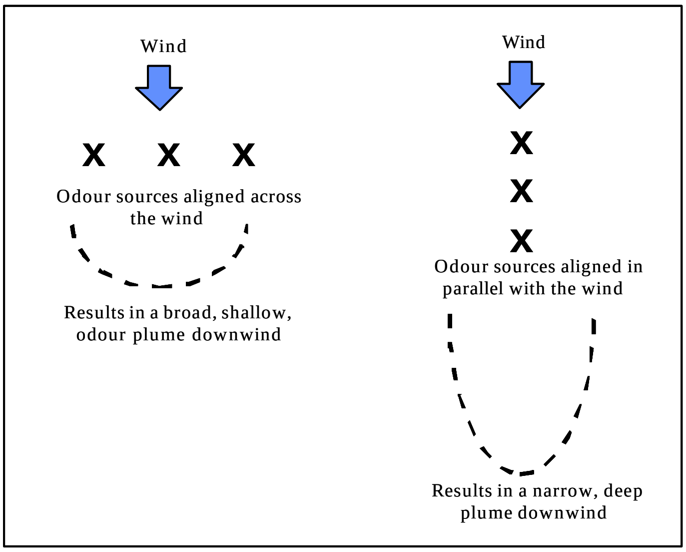


Figure 11. Effect of source alignment in dispersion modelling

8.3.2 Full meteorology gaussian models

If a screening model does not show satisfactory compliance with guidelines, or if the odour guideline needs to consider a percentage compliance component (for example, exclude the highest 0.5% of predictions with a year of meteorological data), then a full meteorology gaussian model will be required. The gaussian model is run using a large data set of hourly meteorological records specific to the site being investigated. Gaussian models are by far the most commonly used types of models because of their simplicity and broad application. However, for ground-level sources you need to be wary when applying them because they can grossly understate impacts during conditions that are classified as calm. In such circumstances, deficiencies in the raw meteorological data (specifically, wind-vane information) are often the main problem.

8.3.3 Puff models

These models (CALPUFF/CALMET, AUSPUFF) are a significant advance on gaussian models. However, they require significantly more computing resources and detailed input data, and are more complex to use. The models have a number of advanced features that make them more widely applicable, including:

- space and time variations in the meteorological input fields
- better turbulence representation
- better handling of coastal effects
- ability to handle low wind speed and calm conditions

- better handling of complex terrain
- upgraded treatment of building downwash.

Due to the complexity in using them and the detailed input data required, these models need to be operated by individuals with advanced expertise in meteorological and atmospheric dispersion physics. Despite this, their use for modelling complex odour dispersion processes is considered to be essential to ensure that potential adverse effects are neither grossly overstated nor understated through the use of steady-state gaussian models.

8.3.4 Langrangian/prognostic models

TAPM (Hurley, 1999) is a three-dimensional meteorological and air pollution model produced by the CSIRO Division of Atmospheric Research (Hurley, 1999). TAPM includes a prognostic meteorological modelling component, and is designed to evaluate local atmospheric conditions without the requirement of input data from a meteorological station. It also has the ability to provide its meteorological results in a form that can be used as input to other air dispersion models, such as AUSPLUME, ISC-PRIME and CALPUFF.

TAPM solves the fundamental fluid dynamics and scalar transport equations to predict meteorology and pollutant concentrations. It consists of coupled prognostic meteorological and air pollution concentration components. The model predicts airflow important to regional and local-scale air pollution, such as sea breezes and terrain-induced flows, against a background of larger-scale meteorology provided by synoptic analyses.

8.4 Micro-meteorology

For proposed new activities, as well as existing activities, the assessment of the local micro-meteorology in both qualitative and quantitative terms is an important assessment tool that is often under-utilised. The occurrence of unexpected adverse odour effects from newly established activities often results from the local micro-meteorology being too simplistically characterised. This simplicity is often driven by the relatively low requirements of steady-state gaussian dispersion models.

In practice, a robust odour impact assessment generally requires an in-depth analysis of potential odour plume behaviour, which modelling tools such as AUSPLUME and ISC-PRIME cannot account for. A high level of expertise in micro-meteorology is therefore necessary to at least produce a qualitative assessment of the significance of cold-air drainage flows, high terrain and/or sea breeze patterns at a particular site.

For example, it has been standard practice for odour impact assessments to be based on establishing wind data from a nearby 10-metre high wind-monitoring station. These stations generate the usual wind-rose data, including the hours of calms, and wind-speed frequencies as a function of various direction categories. Even industry-standard wind direction and speed instrumentation can struggle to provide a realistic picture of the actual movement of cold air during stable atmospheric conditions. Consequently, models such as AUSPLUME or ISC-PRIME can assume no impact of odour downwind of a site during calm conditions (< 0.5m/s for AUSPLUME, and < 1.0m/s for ISC-PRIME), when in practice the worst case impacts would be occurring.

It is possible to make an allowance for the limitations of the meteorological data by manipulating directions and speeds within the data set. However, this requires specialist expertise and knowledge of meteorological principles, which is often lacking from odour impact assessments. For example, this type of expertise can allow relatively deficient meteorological data sets to be augmented so that they can more realistically account for both regional and localised drainage flow patterns in an area. (Stable air conditions do not only happen on cold winter nights.)

The analysis of site micro-meteorology is also desirable when importing experiences from other sites. This allows for the use of buffer distances from other similar activities to be assessed for the new site. For example, an adequate buffer distance cannot necessarily be confirmed from the experiences of other sites when potential odour effects at these sites occurred during different types of atmospheric conditions. This is also an argument against the use of fixed buffer distances as a robust odour assessment tool.

Running wind-field models such as TAPM and CALMET can allow complex dispersion characteristics to be accounted for, and can allow for the limitations of AUSPLUME and ISC-PRIME to be overcome. However, specialist meteorological and modelling skills are mandatory for their correct use.

8.5 Averaging times and peak-to-mean ratios

The shortest-term predictions produced by gaussian dispersion models are 1-hour averages, because this is how the meteorological data is provided. This means that the predicted concentration is the average concentration that would occur at a downwind location over the period of an hour. Within that interval, the actual odour concentration will fluctuate above and below the average concentration. Human response to odours is very quick, usually of the order of milliseconds or a maximum of a few seconds (the duration of one breath). The concentration of a pollutant in the air smelled by the nose over a few seconds can be significantly higher than the average over one hour. Therefore a factor needs to be incorporated in the model results to take into account what is called the peak-to-mean ratio: the ratio of the odour peak smelled by the nose over a very short period, and the average result of a dispersion model over 1 hour.

A comparison between the odour model's predicted result for any particular hour, and what would typically happen during that hour in reality, is shown in Figure 12. The graph shows that although the model predicts a concentration of 2 OU/m^3 for the entire hour, this is not actually the case because of small changes in wind speed and direction from minute to minute. The actual ambient odour concentration could vary between, say, 0 and 5 OU/m^3 (depending on the peak-to-mean ratio for that source). The fluctuation could be even greater if the emission rate was varying as well. Therefore, the amount of time that people would be able to detect the odour is much less than the model results suggest.

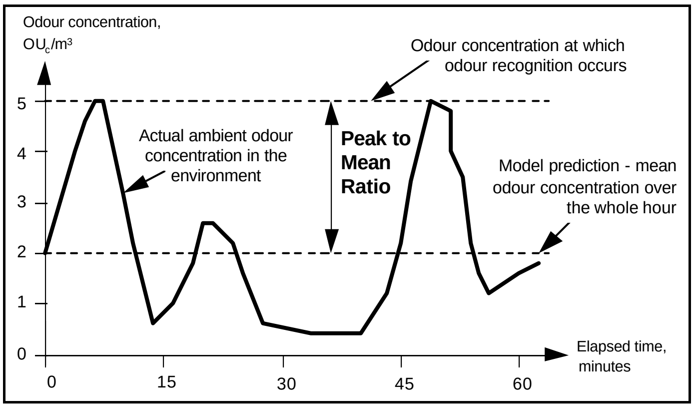


Figure 12. Odour dispersion model predictions compared with reality

The value of the peak-to-mean ratio depends on the type of source, atmospheric stability and downwind distance. In Australia, guidelines are being established to define a set of peak-to-mean ratios for a variety of sources, a range of stability conditions and several regimes of downwind distance (Katestone Scientific, 1998). (A summary of this work is presented in Appendix 6.) The report by Katestone Scientific comments that although common practice in Australia and New Zealand is to use AUSPLUME to predict 3-minute odour concentration averages, the selection of 1-hour averages for all dispersion modelling is recommended because the 3-minute average calculation is based on erroneous assumptions. This recommendation is supported by the authors of this report.

8.6 Selection of emission rates

The measurement of odour emission rates and subsequent prediction of ambient odour levels using dispersion models is more complicated than for many other air contaminants. Monitoring odour sources commonly produces emission rates that are quite variable. For example, an odorous pond may have emission rates that vary significantly across the surface, from season to season, and at different times of the day. Emission rates can be several orders of magnitude higher during upset events than under normal operation.

For simple dispersion model scenarios with only one or two sources, the maximum measured emission rate from the source is typically used for dispersion calculations. However, because of the intermittent nature of odours, use of worst-case emission rates assumed to occur continuously may result in overly conservative and unrealistic results. Infrequent bursts of strong odour may actually be considered to be less of a nuisance than long exposures to lower-intensity odours.

Alternatively, the following statistically based guidelines for emission rate selection are suggested.

A source with multiple measurements over a period of time (e.g. a vent monitored on a number of occasions)

If only a few data points are available, use the maximum measurement. If a number of data points are available, a curve can be drawn and a certain percentile (such as 50th or 70th) emission rate selected (the percentile to be selected and justified at the discretion of the modeller). Otherwise the mean could be used, but this should be considered on a case-by-case basis, because one or two very high or very low data points can significantly skew the mean.

A source with a large area

Measurements should be taken at a number of locations over the surface in a short space of time, and a mean calculated which represents the average emission over the surface at that point in time.

A source that contains separate zones of different emission rates

Each zone should be modelled as a separate source.

Dispersion models using these 'average' emission rates will provide an indication of normal operating conditions. However, modelling with individual sources subject to extreme emission rates may also be needed to demonstrate the sensitivity of the activity to variations in the magnitude of odour emissions.

Chapter 8: Recommendations

1. Once an industrial process has been established, the continued use of dispersion models may be useful to:

- indicate where the highest impacts occur within the surrounding community
- establish the likely frequency of occurrence of odour impacts at a specific location
- compare the relative effects of various sources
- test the sensitivity to upsets of individual sources
- compare the noticeable effects of mitigation options
- compare existing versus future odour effects at a site.

2. Readers who want detailed guidance on dispersion modelling should refer to the Ministry's good practice guide on dispersion modelling.

3. Odour emission measurements and subsequent modelling are appropriate for processes with quantifiable emission sources that discharge odour continuously, or semi-continuously, and therefore where potential chronic odour effects are more predominant than potential acute odour effects.

4. Processes where significant odour emissions occur from sporadic, infrequent discharges or abnormal processing conditions should only be assessed by odour-modelling methods that consider the impact of specific odour events and when the short-term emissions can be reliably quantified.

5. When assessing proposed new activities where complex drainage flows are an issue, or where there are terrain effects that have the potential to increase odour impacts, it is important to consider whether or not simple gaussian models such as AUSPLUME or ISC-Prime are adequate, or whether the use of a complex non-steady-state model such as TAPM or CALPUFF is justified.

6. Although common practice in Australia and New Zealand is to use AUSPLUME to predict 3-minute odour concentration averages, the selection of 1-hour averages for all dispersion modelling is recommended because the 3-minute average calculation is based on erroneous assumptions.

7. A 99.5 percentile concentration provides a useful indication of the potential for chronic adverse odour effects, whereas a 99.9 percentile concentration would also provide an indication of the potential for acute (stronger short-term odour) impacts.

9. Odour-modelling guidelines

9.1 Typical form of guideline values

In the last chapter we looked at the use of odour dispersion modelling to come up with predictions for the concentrations of odour at various receptor sites. However, merely coming up with a predicted concentration is meaningless unless we can relate this value to the occurrence of adverse effects. This is the *odour-modelling guideline* value, against which the dispersion model results are compared to determine whether the model results predict that significant adverse effects could occur.

Odour-modelling guideline values usually contain two components:

- a *concentration*
- 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 'no offensive or objectionable odour'.

Odour-modelling guidelines are sometimes worded so that the odour concentration shall be less than X OU/m^3 for more than (1–Z)% of the meteorological conditions (for example, Z may be 0.5%, and (1–Z) would be 99.5%). These two forms are effectively the same. In this report, for consistency all odour-modelling guidelines are worded in the general form 'for more than Z% of the meteorological conditions'. (If a dispersion model is being used in screening mode, using screening meteorological data, the selection of Z is not relevant because the percentage compliance component cannot be used.)

Figure 13 shows an example of the percentage of time (the percentage of hours in a year of meteorological data) that odours are predicted by a dispersion model to occur at a single receptor. For this site, 5 OU at 99.5% compliance is equivalent to 2 OU at 99.9% compliance, and represents the same degree of adverse effect.

A series of case studies was investigated in the Netherlands and reported by Miedema (1992). This work indicated that higher percentile concentrations are best correlated to odour annoyance when the emission source is active for less than 50% of the time. Therefore, for highly variable and intermittent sources, the 99.9 percentile concentration may be a stronger determinant of odour annoyance than the 99.5 percentile. A 99.5 percentile concentration provides a useful indication of the potential for chronic adverse odour effects, whereas a 99.9 percentile concentration prediction would also provide some indication of the potential for acute (stronger short-term odour) impacts.

It is useful to consider the typical relationship between odour concentration and perceived intensity. For many (but not all) industrial odours, a 5 OU/m^3 would very approximately equate to a weak odour, but sufficient for the underlying character to be recognised. For industrial or agricultural odours to appear strong to people, concentrations of 30 OU/m^3 or higher would most likely be necessary, and probably much higher in some cases. Within the range of 10–30 OU/m^3 we can expect the perceived odour intensity to change from faint or weak to moderate, and possibly strong.

It follows that there is very little difference between the perception of an odour concentration at 5 OU/m^3 versus one at 8 OU/m^3. However, when these concentrations are described as percentile concentrations, the difference is more significant. This can be appreciated when considering what a 99.5 or 99.9 percentile concentration means.

When specifying guideline concentrations as either 99.5 or 99.9 percentiles, the relevance of 5 OU/m^3 or 8 OU/m^3 is not the perceived strength, but the frequency with which stronger odour impacts are likely to occur over the set time implied by these percentile concentrations. For example, a 99.5 percentile concentration of 5 OU_c/m^3 indicates that this concentration is reached or exceeded for 0.5% of the time. This is about 44 hours a year, and suggests that odours that are more than faint or mild in intensity may occur for an hour, and almost weekly, over a long period. Alternatively, the 99.9 percentile concentration of 10 OU_c/m^3 indicates that this concentration is reached or exceeded for only 0.1% of the time. This is about 9 hours a year, and indicates that odours that could be moderate to strong intensity may occur for an hour and almost once a month over a long-term period.

9.2 Approaches to setting guidelines

Practitioners in New Zealand have used either one of two types of approach to set a guideline to use in any particular assessment:

- an annoyance threshold approach, using theoretical odour annoyance thresholds and adjustments for site-specific factors
- a community response empirical approach, using modelling of existing plant emissions and relating this to actual community survey data to set a guideline value that can be adjusted for site-specific factors.

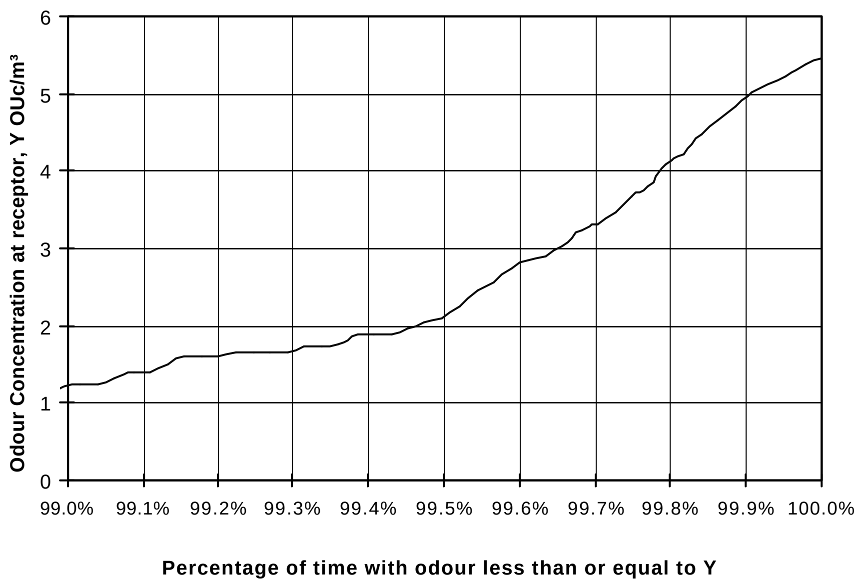


Figure 13. Example of percentage occurrence of odours at a single receptor

The use of these two approaches has been the subject of considerable debate in New Zealand in recent years. The first approach was used in the mid-1990s to develop a design odour-modelling criterion for the upgrade of the Mangere Wastewater Treatment Plant in Auckland. This was then adopted by the Auckland Regional Council as an interim standard for both new and existing odour assessments within that region. Very similar criteria have also been used in other regions of New Zealand, in particular the Waikato. This approach is also currently widely used in Australia.

The alternative empirical approach, which utilises community survey data, is a more difficult and expensive process to implement, but is more robust if it can be implemented appropriately. This approach has tended to indicate higher modelling guideline values than those derived by the annoyance threshold approach, particularly for odour sources that are not related to sewage treatment (Aurora Environmental, 2000).

Sections 9.2.1 and 9.2.2 discuss the two methods with the aim of providing the basis for the interim criteria that are recommended as New Zealand's first national odour concentration guideline values for all types of odour sources. The resulting interim guidelines are summarised in section 9.5.

9.2.1 Using the annoyance threshold approach to develop guidelines

The annoyance threshold approach to deriving values of X and Z in the odour-modelling guideline (see section 9.1 for definitions of X and Z) is discussed by

CH2M-Beca (1999) and is also discussed by Aurora Environmental (2000). The following general procedure is summarised from the former report.

Step 1: Define an ambient odour concentration (typically 5.0 OU/m^3) that represents an *annoyance threshold* that should only be exceeded on rare occasions. This is the minimum concentration at which the odour will cause annoyance.

Step 2: Scale this concentration down by a peak-to-mean ratio that accounts for the fact that the concentration predicted via a dispersion model relates to a 1-hour average rather than the short-term concentration peaks that will occur in practice. This gives the concentration component X in the odour-modelling guideline.

Step 3: Define a percentile component that allows for a small level of exceedance (such as 0.5% or 0.1% of the time) of predicted concentrations above the annoyance threshold criteria.

We will now look at these steps in detail.

Step 1: Define an annoyance threshold

Many guideline values in use today in New Zealand are based on an assumed odour annoyance threshold of 5 OU/m^3. This means that it is assumed that people do not find odours annoying at concentrations less than 5 OU/m^3.

This odour annoyance threshold resulted from an essentially theory-based analysis of odour definitions from first principles. Examples of published odour detection and recognition data are shown in Table 12. These show the relationship between the *detection threshold* (the concentration at which the odorant is detected with certainty by an olfactometry panel) and the *recognition threshold* (the concentration at which the character and hedonic tone of the odorant is recognisable). For the range of odorants in the table, the ratio between the two thresholds varies considerably, between 1 (no difference between the thresholds) and 50 (large difference). The typical ratio is in the range of 2–10.

Table 12 shows data for single, pure compounds. The detection and recognition thresholds can change markedly from these levels if several odorants are present in a mixture and act synergistically to produce either a greater or lesser-perceived odour strength than their individual components.

Table 12. Detection and recognition thresholds for some odorous compounds

Compound name	Detection threshold, ppm (v/v)	Recognition threshold, ppm (v/v)	Odour description	Recognition : detection ratio
Acetaldehyde	0.067	0.21	Pungent, fruity	3.1
Allyl mercaptan	0.0001	0.0015	Disagreeable, garlic	15
Ammonia	17	37	Pungent, irritating	2.2
Benzyl mercaptan	0.0002	0.0026	Unpleasant, strong	13
n-Butyl amine	0.080	1.8	Sour, ammonia	22.5
Chlorine	0.080	0.31	Pungent, suffocating	3.9
Di-isopropyl amine	0.13	0.38	Fishy	2.9
Dimethyl sulfide	0.001	0.001	Decayed cabbage	1
Diphenyl sulfide	0.0001	0.0021	Unpleasant	21
Ethyl amine	0.27	1.7	Ammonia-like	6.3
Ethyl mercaptan	0.0003	0.001	Decayed cabbage	3.3
Hydrogen sulfide	0.0005	0.0047	Rotten eggs	9.4
Methyl mercaptan	0.0005	0.0010	Rotten cabbage	2
Phenyl mercaptan	0.0003	0.0015	Putrid, garlic	5
Propyl mercaptan	0.0005	0.020	Unpleasant	40
Pyridine	0.66	0.74	Pungent, irritating	1.1
Skatole	0.001	0.050	Faecal, nauseating	50
Sulphur dioxide	2.7	4.4	Pungent, irritating	1.6

Source: WEF, 1995

In theory, a single odorant detected in ambient air will not cause nuisance until it is present at a concentration that is at the recognition threshold or higher. However, as many odours occurring in ambient air are mixtures of odorants, and to allow for those members of the community with greater sensitivity to odours, this approach assumes that the recognition threshold would equate to the annoyance threshold concentration. Based on this assumption, then considering the data in Table 12, defining the annoyance threshold as 2–10 times the detection threshold is appropriate. To be conservative and to ensure that most circumstances are covered, a value towards the lower end of this range should be used, hence the application of 5 OU/m^3 as the annoyance threshold. However, it has been argued that this assumption is not valid because this level was established under laboratory conditions (Aurora Environmental, 2000), often using non-standardised procedures.

When using the annoyance threshold approach to develop concentration guideline values it is recommended that the annoyance threshold be set at 5 OU/m^3 when the sensitivity of the receiving environment is high. Circumstances where taking the annoyance threshold to be 5 OU/m^3 may be too conservative include:

- odours with a low offensiveness rating, such as those discharged from biofilters
- where the sensitivity of the receiving environment is low – the value of 5 OU/m^3 may be appropriate in a sensitive receiving environment such as a residential zone boundary, but not in areas of lower sensitivity such as a rural zone
- areas where significant background odours are present and therefore cumulative adverse effects may already be occurring.

Some possible methods for adjusting the annoyance threshold to account for offensiveness and background odours are discussed in section 9.4.3. Adjusting the annoyance threshold to account for the sensitivity of the receiving environment is discussed in the section below.

Step 2: Incorporate the peak-to-mean ratio to determine the concentration component

The annoyance threshold is divided by a peak-to-mean ratio to determine the concentration component. Our intention is to recommend generic odour concentration guideline values that do not require the user to incorporate any peak-to-mean ratios to account for differing types of source characteristics. This simplifies the selection of guideline values, and will also facilitate comparison of the odour guideline values with results from community-response studies, where the peak-to-mean ratio is inherently included in the concentration component as a 1-hour average.

Peak-to-mean ratios were introduced in section 8.5 and are tabulated in Appendix 6. Two examples of published documents that use this annoyance threshold approach to recommend odour-modelling guideline values are Woodward-Clyde (1997) and NSW EPA (2001).

Table 13 shows how the peak-to-mean ratios can be used to determine the concentration component, assuming an annoyance threshold of 5 OU/m^3. For an area source, wake-affected stack or volume source, the 1-hour average concentration is 2 OU/m^3 in both the near-field and far-field (a distance of more than 10 times the stack height) when rounded to one significant figure. Tall stacks, surface point sources and line sources would require a different, much lower concentration component, and different treatment in the near-field and far-field. This is reflected in the policies recommended in Woodward-Clyde (1997) and NSW EPA (2001).

Table 13. Examples for single sources in flat terrain of simplified odour-modelling guideline values for 1-hour averages to avoid annoyance at the instantaneous 5 OU/m³ level

Source type	Odour concentration component (1-hour average)	
	Near-field peak-to-mean ratios*	Far-field peak-to-mean ratios*
Area	2.0–2.2	2.2–2.6
Tall wake-free stack	0.14–0.3	0.8–1.6
Wake-affected stack	2.2	2.2
Volume source	2.2	2.2
Line	0.8	0.8
Surface point	0.2–0.4	0.7–1.7

* Range indicates variety of peak-to-mean ratios recommended dependent on atmospheric stability.

Surface point sources are rarely encountered in odour assessments, and it is difficult to define the near-field and far-field dimensions for such sources using the guidelines in Appendix 6. Sources that could be defined as a surface point could also be defined as an area or volume source, so in the interests of simplifying we do not consider that this type of source needs special peak-to-mean ratio attention. Similar comments apply to ground-level line sources.

Tall stacks

How tall is a tall stack? One definition is provided in Appendix 6, taken from NSW EPA (2001). For the purposes of this report, a stack is tall when it is high enough to allow its discharged contaminants to disperse into the atmosphere as an elevated plume that is not substantially affected by the wake effects of surrounding building structures. This typically means that peak ground-level impacts occur during semi- to unstable atmospheric conditions and at locations well beyond the stack and site building structures.

The much higher peak-to-mean ratios exhibited by tall stacks compared with area, volume and wake-affected stack sources has previously been used to infer the need for substantially lower hourly average odour concentration guideline values for tall stacks compared to other sources. However, it has been argued that there are other important factors to consider apart from peak-to-mean ratios that apply to each source type, and that there is limited case study experience to support the need for significantly different odour guideline values for different source types (Aurora Environmental, 2000). Much of this limited experience indicates that the difference in hourly average guideline values is much less than that inferred by a theoretical analysis of peak-to-mean ratios for tall stacks versus other source types.

In some cases this may be because the community was subjected to odours from tall stacks while in the far-field zone of influence, and the odours will occur during convective conditions when peak ground-level concentrations from tall stacks occur. In such cases, the appropriate peak-to-mean ratio is 3, similar to the ratio of about 2.2–2.5 recommended for area, volume and wake-affected stack sources. This is supported by the Tasman Pulp and Paper study reported in section 9.2.3.

As discussed above, the same peak-to-mean ratio can be applied to area, volume and wake-affected stack sources in both the near-field and far-field zones of influence, and to tall stacks in the far-field zone. However, a different guideline value may be necessary for tall stacks in the near-field zone.

Case studies currently under way in New Zealand and Australia using community annoyance surveys are indicating that the near-field peak-to-mean ratios for tall stacks may be too high. This is also supported by the New Zealand Starch study reported in section 9.2.3. As a result, we recommend that any decisions on concentration components incorporating the peak-to-mean ratio for tall stacks in the near-field be postponed, pending further investigation and research using community annoyance studies. In any case, examples where there are receptors in the near-field zone of influence from tall stacks will not be common in New Zealand.

Another reason why the proposed theoretical peak-to-mean ratio difference between tall stacks and area, volume and wake-affected stack sources has not been observed in practice is the issue of emission rate stability and reliability. Stack odour emission profiles can be accurately characterised and are generally the result of controlled chemical/physical reaction chemistry that produces a relatively consistent emission rate over time. By comparison, area source odour emissions often relate to processes that can exhibit enormous variations in emission rates over time which can not be reliably characterised. When one considers the much wider nuisance issues that exist beyond the discipline of atmospheric dispersion physics, it is not surprising that actual case studies have not indicated the need for stack odour-modelling guideline values that are lower than area source guideline values.

To conclude, the recommended approach to using a peak-to-mean ratio to determine the concentration component is as follows:

1. Odour annoyance threshold = 5 OU/m^{3}.
2. Peak-to-mean ratio = 2.5 (all source types except tall stacks in near-field).
3. Therefore concentration component = 5/2.5 = 2 OU/m^{3}.

Different ratios may apply to tall stacks in the near-field, pending further research and investigation.

Make adjustments for the sensitivity of the receiving environment

The concentration component should be higher for receiving environments of lower sensitivity. Using the three sensitivity categories defined in section 3.2.4 of high, moderate or low sensitivity, there are several options for changes to the concentration component.

The guideline value recommended by Aurora Environmental (2000) of 10 OU/m^3 (1-hour average) for 0.5% of the time (with adjustment for peak-to-mean ratio built in) was recommended for assessing existing industrial activities in areas of relatively low sensitivity. Applying a tolerance factor of 2 to this guideline value (see section 9.2.4 for the use of tolerance factors with guidelines derived from the community response approach) is the minimum required to allow for the development of a new activity in a moderate or low sensitivity area. This results in a recommended guideline value of 5 OU/m^3 (1-hour average, peak-to-mean ratio already built in) for new proposed activities in areas that are not highly sensitive.

When the sensitivity of the receiving environment is low (as opposed to moderate), this tends to be because of the presence of significant background odours and/or because the opportunities for people to be affected by the odours are reduced since the occupation density is low or infrequent. In this situation it is better to allow for the background odours (as discussed below) or to interpret the model results by considering when, and for how long, the highest predicted odour concentration will occur, rather than raising the annoyance threshold.

Another factor influencing the sensitivity of the receiving environment is the offensiveness of the odour relative to the location in question, particularly if that odour is new to the area (see section 3.2.4). If this factor is significant, modifying the concentration component to take account of the sensitivity of the receiving environment may not be appropriate.

Therefore, we recommend that in areas of low sensitivity, the corrected annoyance threshold be kept at the same level as for the moderately sensitive receiving environment (5 OU/m^3, 1-hour average, peak-to-mean ratio already built in).

Step 3: Define a percentile compliance component

In an odour-modelling guideline, the percentile compliance component indicates the allowable fraction of time above the concentration component, in terms of 1-hour averages.

Recommendations for percentile components in current use in New Zealand and Australia range from 0.1% to 1.0%, with the most common being 0.1% and 0.5%. The use of 1.0% arose from the CASANZ Odour Special Interest Group's position paper from the Second National Odour Workshop in March 1998, but this has not been adopted in any odour-modelling guidelines.

There is little convincing evidence to support the use of any particular percentile component. Other authors who cover this issue appear to have selected a certain percentile component and then varied the concentration component to match the odour-modelling guideline with their particular model to their case study data. In this report we recommend that the baseline percentile for all guidelines be 0.5%, although 0.1% should also be used to assist in the evaluation of model results for highly and moderately sensitive receiving environments.

The percentage exceedance calculated by the model does not necessarily mean that odour nuisance would occur for all of those hours, for the following reasons.

- Model results give an hourly average, and the peak odour concentration will only occur for short times within that hour. When the model predicts that the odour annoyance threshold will occur, this means that for a few minutes during that hour a noticeable odour may occur. For the rest of the hour the actual odour concentration will be less than the peak concentration, and will not be noticeable.

- The model assumes that for each 1-hour period the wind direction is constant, with a small amount of deviation around the average direction. It therefore predicts that the same downwind receptor location will be affected for the whole hour. However, the wind direction can fluctuate widely within an hour, so the odour plume will not always be carried towards the same location.

- The dispersion model assumes that the estimated rate of odour emission from each source is constant from hour to hour. In reality this is not the case, as the emission rate can vary over time and, in the case of area sources, from one place to another over the surface of the odour source. The best way to be confident that the emission rate data for the model is typical for the source is to make a number of emission rate measurements over a period of time. The usual approach to modelling is then to use the mean of all the measurements as the typical emission rate in the model. However, because the rate of odour emission will sometimes be lower than the average, the model prediction tends to over-estimate the number of exceedances of the guideline.

9.2.2 Using the community response approach to set guidelines

Community response-based odour guidelines have an identical form to those developed using an annoyance-threshold-based approach: both contain a concentration and percentile component based on 1-hour modelling results. Community response data arises from sampled members of the population during a population annoyance survey, as discussed in section 6.1. The correlation of community response to the modelled odour exposure level is often referred to as 'dose-response' research.

The dose-response approach requires an existing community that represents a suitable case study, and requires considerable resources to implement effectively. The advantage is that the resulting odour concentration guidelines can account for the real effects and interactions of multiple physical and social factors. To this end it is recommended as the default method for any future revision of the interim odour concentration guidelines recommended in this report.

Odour dose-response studies

Odour dose-response studies indicate the varying extent of annoyance or stress experienced by a community as a result of varying odour exposure levels. This is quantified by the modelled percentile odour concentration that occurs at a specific location. Typically the $C_{99.5}$ concentration (1-hour average) is used, which is the odour concentration (OU/m^3) that is only exceeded for 0.5% of the time or less. All research of odour exposure versus annoyance relationships to date has involved the use of 1-hour average odour concentrations. Modelling at smaller time periods provides no clear advantage, as the significance of actual short-term fluctuations in odour are accounted for by the dose-response relationship.

An example of an odour annoyance dose-response curve is shown in Figure 14. The Y-axis is the percentage of the population exposed to the odours from nearby industrial source(s) who reported being 'at least annoyed'. This feedback is obtained by carrying out a social survey using the standard design discussed in section 6.1. The corresponding level of time-accumulated exposure to odours (percentile odour concentration) is established by odour measurement at the industrial site and the use of a standard dispersion model with a full year of local meteorological data. Note that there is nothing special about the 99.5 percentile. When other percentile concentrations are used, the response curves adjust in a way that reflects the exposure time the specific percentile defines. Therefore the percentile value (%) and concentration value (OU/m^3) are intrinsically linked when developing an odour concentration guideline.

Studies have consistently found a good correlation between population annoyance level (%) and percentile odour concentration values (OU/m^3). Therefore, an odour concentration guideline can be developed by establishing the odour exposure level at which the population annoyance remains close to that measured for unexposed populations. These communities typically return annoyance values within the range of 5% to 15% at-least annoyed. The 99.5 percentile concentration where this occurs equates to the level of odour exposure that causes no measurable effect on the community annoyance level. This is a useful means for objectively defining when 'objectionable or offensive' odour effects have occurred.

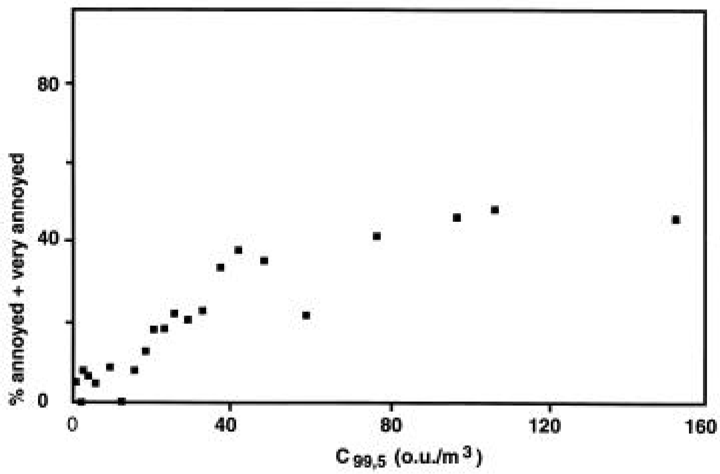


Figure 14. Odour dose-response curve

Source: Miedema 1988

Odour dose-response relationships are derived for existing communities, so factors such as peak-to-mean ratios, hedonic tone, day-to-day exposure profiles and all complex social/cultural factors are accounted for. In comparison, the annoyance-threshold method of developing a guideline value relies on an annoyance threshold derived from responses from individuals on an olfactometer laboratory panel. The laboratory environment is controlled to produce repeatable and reproducible odour threshold measurement values. This environment can result in a substantially over-stated potential for adverse odour effects, when used as a basis for developing annoyance-threshold odour concentration guideline values.

Investigation procedure

The process for completing an annoyance dose-response investigation is as follows.

1. Site selection

Select appropriate study sites with care to ensure that you obtain reliable information. The features of a good study site include:

- existence of some odour effects in the community
- local topography not too complex to model
- quantifiable odour sources at the site
- suitable population density and demographic variation.

2. Odour emission measurements

Quantify the odour emission rates using dynamic dilution olfactometry (DDO). A rigorous sampling programme is required to ensure that any temporal variations in the odour emission rates are well defined.

Sampling procedures need to follow an agreed method, particularly for area sources, where wind-tunnel designs can have a large effect on the outcome. Ultimately the dose-response relationship and resulting odour concentration guideline will be related to the method of emissions sampling and odour measurement.

3. Atmospheric dispersion modelling/meteorological data

Use either a simple gaussian plume dispersion model or a non-steady-state model to predict percentile odour concentration contours within the community surrounding the site. On-site meteorological data for a minimum period of 1 year is also required to allow for an accurate prediction of percentile odour concentration values.

4. Community annoyance surveys

Conduct the odour annoyance survey by a standard telephone interview protocol, which is then replicated for all investigations. The protocol includes sub-sections of the population that range from close to far away from the industrial site, and is specifically designed to minimise the effects of biased responses and obtain a response that is directly comparable to other studies, including those involving control populations. (The survey methodology is discussed in section 6.1.)

The community response parameter is percent at-least annoyed, and represents the percentage of individuals within various sub-sections of the survey site that reported to the categories 'annoyed', 'very annoyed or 'extremely annoyed' when asked to rate their level of annoyance from industrial odour impacts. The term 'population annoyance' refers to the numerical value of 'percent at-least annoyed'. This parameter is a measure of the accumulated impacts of ambient odour on the population. Population annoyance is a function of the pattern of past and present experiences of industrial odours that have occurred within a specific sub-area of the affected community over a given time.

The meaning of 'annoyance' as used in developing annoyance threshold-based odour guidelines (see section above) is therefore fundamentally different to its meaning when used in conjunction with guidelines based on community annoyance surveys. The former relate to the immediate response of an individual to an unpleasant odour, whereas the latter is a sustained condition (state of mind or level of stress) that some individuals are experiencing because of the situation.

5. Non-zero response

It may seem reasonable for population annoyance within a community to fall to zero when industrial odours are not present, but this does not happen in practice. When annoyance surveys are conducted in relatively unexposed areas, 5% to 15% of the community typically report to being 'at least annoyed' by industrial odours. Therefore the significance of population annoyance data needs to be compared to the baseline level of annoyance. The existence of a non-zero response needs to be accounted for when assessing the environmental significance of population annoyance survey data.

The failure to correctly interpret population annoyance survey data often results in erroneous conclusions being drawn about the level of environmental protection that community response-based guidelines impose. For example, percentile odour guidelines that allow for 10% population annoyance will generally equate to no significant adverse environmental effects and would allow for odour exposure levels that could be expected to be well below the threshold of complaint. However, such guidelines are often viewed as only protecting 90% of the population, and it is then incorrectly inferred that 10% will be adversely affected and may well complain.

6. Odour versus community annoyance curves

Correlate the population annoyance results to percentile odour concentrations using multi-regression techniques.

7. Interim assessment criteria

The guideline criteria recommended by Aurora Environmental (2000) for assessing survey results was 20% at-least annoyed. The rationale for using this as a starting point was the no-effects level appearing to be as high as 15% based on the results from control populations. The 20% at-least annoyed criterion is chosen to allow for some degree of effect that would still be considered minor by reasonable people. As for any air-quality guideline, the value of 20% at-least annoyed should be open to future review. At this stage it does appear to be a useful indicator of when odour effects (either chronic or acute) are starting to become significant.

In some instances industries have returned survey results for their surrounding communities that have complied with the 20% criterion, while others have not. In the former cases the anecdotal evidence from the communities appears to have confirmed that the 20% criterion is not too high. It may in some cases be too low, although several industries that have returned values of 30% at-least annoyed have undertaken to reduce odour emission based on these results.

9.2.3 Case studies

The key consideration when deriving odour concentration guidelines from community-response data is the level of population annoyance that equates to minimal adverse odour effects (either chronic effects, acute effects, or a combination of both). There appear to have been no formal odour-dose versus community annoyance investigations completed in New Zealand or Australia.

However, there have been some useful case studies, and these are discussed below. Two types of case study are presented. The first is based on population annoyance data from an odour survey. Virtually all other similar investigations in Australasia have compared modelling results to areas of varying levels of complaint, so the latter three case studies are based on population annoyance data from complaint analyses. Community complaint-based studies are conducted as described above for odour survey studies; both are empirical relationships of a community response compared to modelled concentration data. The difference between the two is the response parameter used, and therefore the collection method and interpretation of data is different.

Case study 4: Stuart Oil Shale, Gladstone, Australia

The Stuart Oil Shale process in Gladstone has undergone a detailed odour emission-testing and modelling programme in conjunction with field and community investigations (Ormerod et. al., 2002). During the initial stages of the plant's commissioning the emissions were less controlled and the local community (several kilometres away) made numerous complaints about odour. This community became adversely conditioned to the hydrocarbon odours and are now highly sensitised and intolerant of any odour being recognised from the plant. The main process discharge stack is approximately 50 metres high and worst-case impacts of odour occur during semi-unstable to unstable atmospheric conditions. This is therefore a very good case study for assisting in the development and understanding of odour concentration guidelines.

Observations of odour intensity in the field for the Stuart Oil Shale project were as per the VDI scale in Table 5 and recorded as per the approach detailed in the German VDI 3940 (*Determination of Odorants in Ambient Air by Field Inspection*). Observations were made at various locations downwind of the plant. The observed odour intensity measurements were used as a basis for estimating mean and peak odour concentrations and peak-to-mean ratios, and for relating the field observations to odour complaints and other reports. The observations also provide a basis for ground-truthing model simulations of odour concentration.

The determination of the odour intensity–concentration relationship for the main stack emissions was completed by asking trained odour panel members to rate the odour intensity on the same scale listed in Table 5, at levels of odour concentration that were known to the assessor but not to the panellists. This was done as an adjunct to the normal dynamic olfactometry procedure, which determines the odour concentration of a sample. The standard method of testing is followed, but the presentations are allowed to continue beyond the point where the odours are detectable (the 'suprathreshold' area). The panel's intensity rating for each odour concentration step was determined as the geometric mean of the individual responses and plotted against the odour concentration on a log-linear scale.

The general conclusions of this project supported the need for a 99.5 percentile concentration guideline (1-hour average) of approximately 1 OU/m^3 where worst-case impacts occur during semi-unstable to stable atmospheric conditions, and where the community is highly sensitive to these odours. It is possible that due to atmospheric conditions the peak-to-mean ratios at this site would be larger than those experienced in New Zealand, which could make the inferred guideline slightly conservative but still applicable to highly sensitive communities in this country. In this instance the local community appeared to be sensitised due to historical adverse conditioning from higher odour exposures and fractious relationships with the plant managers during the initial period of the new plant being operated.

It was also concluded that the type of emission source (volume, area, wake-affected stack, or tall stack with no wake effects) does not have a strong bearing on the appropriate 1-hour average concentration guideline. Instead the key consideration appears to be whether or not worst-case impacts occur during semi-unstable to unstable conditions or neutral to stable conditions. This provides further evidence of the limitation inherent in the use of theoretical peak-to-mean ratios as a function of source type for developing odour guidelines (see Katestone Scientific, 1998).

Dominion Oil Refinery Company, Auckland, New Zealand

We have reviewed an assessment of odour impacts prepared for the Dominion Oil Refining Company Ltd, Te Papapa, Auckland (Woodward-Clyde, 1998). The refinery had caused odour complaints in the past, but these reduced following the installation of a fume collection and incineration system in 1993. Fugitive odours that managed to evade the fume extraction and incineration system still caused localised odour impacts, so the extraction and containment of these odours was subsequently improved in 1997.

The assessment report contained modelling predictions of maximum hourly average odour concentrations that could result from the combination of stack and fugitive emissions to air if the fume incineration unit failed. It was noted that historical odour complaints attributed to the refinery site were within the 2 OU/m^3 contour (3-minute average) predicted for this failure scenario. This result could be used to support the need for 1-hour average concentration guidelines that are $\leq$ 1 OU/m^3 for this type of industry. However, the odour emission data derived for this assessment was not sufficiently reliable for such a conclusion to have been made with reasonable certainty, largely because the methods used to quantify fugitive odour emissions at the site are not considered to be reliable for validating an appropriate concentration guideline. The methods for quantifying fugitive odour emissions may well have been adequate for indicating a relative reduction in fugitive odour emissions due to new mitigation measures at the site. However, true historical odour emission rate data from the refinery site in terms equivalent to the Australian/New Zealand olfactometry standard could easily have been much higher than assumed. This would translate into a higher guideline value concentration.

This case study provides a good example of where odour measurements may be used to indicate the benefit of mitigation, and how implementation of practical mitigation measures can effectively minimise fugitive odours. However, it is also an example of where odour modelling would not be recommended as an assessment tool because of the difficulty of accurately defining the odour emission rates.

Tasman Pulp and Paper Co Ltd, Kawerau, New Zealand

The odour assessment work conducted in the Bay of Plenty, New Zealand, by Tasman Pulp and Paper Company Ltd (now Carter Holt Harvey Tasman Ltd) is possibly the only example in Australasia where robust odour-modelling results can be compared to annoyance survey results. Two odour annoyance surveys (1996 and 2000) were conducted in Edgecumbe following the general procedure described in section 6.1, and one survey in Kawerau. Edgecumbe is 14 km away from the odour source, whereas the Kawerau township is approximately 1 km away. The modelling was undertaken using AUSPLUME and site meteorological data collected near the mill, and is described by Fisher (1998). Edgecumbe had approximately 2000 residents, and modelling predicted a 99.5 percentile odour concentration of 33 OU_d/m^3 (detection-based). The level of annoyance measured by the survey was consistent with that predicted using odour dose-community-response curves reported by Miedema (1992). The results indicated that the dose-response curves, although developed for other industries and using a Dutch community response, appeared to be valid for pulp mill odours in the Bay of Plenty.

The primary use of the odour dose-community-response curves in this case was to help to assist in the assessment of the cost/benefit of various odour control options. However, as later discussed by Aurora Environmental (2000), the validated curves could also indicate an odour-modelling guideline. This was a percentile 1-hour odour concentration of 15–20 OU_d/m^3 for 0.5% of a year. The certainty-to-detection concentration ratio for the pulp mill odours was 2.0, so this guideline equated to a certainty concentration of 10 OU/m^3. Interestingly, the percentile odour concentration impacts predicted for parts of the nearby Kawerau Township were substantially higher than those predicted for Edgecumbe, although the Kawerau area had historically produced very few odour complaints. This aside, Kawerau did indicate a higher level of odour annoyance, as indicated by the 2000 survey.

In the final analysis, the Tasman Pulp and Paper Co Ltd study indicated that for a moderately offensive industrial odour impact within a relatively low-sensitivity rural area, an odour exposure in the order of 10 OU/m^3 appeared to represent acceptable odour effects, or close to this for an existing community. Allowing for a tolerance factor of 2 to 5 to convert this to a guideline for assessing the potential effects of a proposed activity, then a modelling guideline of 2 OU/m^3 to 5 OU/m^3 (1-hour average) is derived. This is essentially the same odour guideline as that recommended in section 9.5 based on the annoyance-threshold approach, if the peak-to-mean ratio is accepted as about 2.5.

Meadow Mushrooms Ltd, Prebbleton, New Zealand

The old Meadow Mushrooms site at Prebbleton (now relocated) was one of New Zealand's longest-running odour nuisance disputes. The original odour emission data was modelled using AUSPLUME and compared to complaint records from the previous 15-year period. The results of this assessment indicated that the 1-hour average 99.5 percentile concentration below which odour complaints should not occur was 30 OU_d/m^3 (detection), as reported by Brown and Cudmore (1996). Furthermore, an acceptable exposure level appeared to be 20 OU_d/m^3. Again, when applying a tolerance factor of 2 to 5 to convert this to a guideline for assessing the potential effects of a proposed activity, the same modelling guideline as described in the first case study above of 2 OU/m^3 to 5 OU/m^3 (1-hour average) is derived for new activities.

Penrith Sewage Treatment Station, Sydney, Australia

The study of a sewage treatment facility in Sydney was reported by Kaye (1997). As for the Meadow Mushrooms case study, it established the link between observed levels of complaint and percentile odour concentrations. The odour concentrations of the plant emissions were also measured using European methods, and ambient concentrations were modelled using AUSPLUME. The measurement of areal odour emissions was achieved using a wind tunnel, and the resulting data was adjusted for actual wind speed.

The community was alerted to the study by means of regular advertising, and so the community response may have been enhanced. Nevertheless, the study found that for sewage plant emissions, 99.5 percentile concentrations below 46 OU_d/m^3 are unlikely to lead to complaint. The equivalent certainty threshold concentration for this study was 5 OU/m^3. The application of the 2 to 5 tolerance factor to convert this to a guideline for assessing a proposed new activity indicates a modelling guideline for new sewage plants near sensitive areas in the range of 1 to 3 OU/m^3 (1-hour average, 99.5%, certainty) odour-modelling guideline.

NZ Starch Products Ltd, Auckland:

NZ Starch is situated in the suburb of Onehunga, Auckland, and had odour emission rates quantified in 1997 from its main air emission sources using European olfactometry methods. There had been three odour complaints since 1994, but it was not clear if these were actually attributable to the plant. Therefore, at face value the site did not have a significant odour problem. Despite this, the preliminary odour-modelling results indicated that the odour guideline of 5 OU/m^3, divided by the tall-stack peak-to-mean ratio value would extend beyond 2 km. The differences between experience and the predictions using the above odour-modelling guideline provided some evidence of the potential problem that such guidelines could pose for stack discharges to air. However, note that in their written response to this draft document, the Auckland Regional Council claimed that they have previously observed NZ Starch processing odours for at least 2 km downwind and that perhaps people had been unaware of the source, but may have been adversely affected.

9.2.4 Comparison of annoyance threshold and community response approaches

The annoyance threshold approach offers a procedure that is relatively fast and inexpensive for deriving odour-modelling guideline values. It has not always been practical to conduct empirical case-study-style research to develop these guidelines, so a practical and conservative approach has been necessary. Community dose-response studies do require considerable resources to undertake successfully and generally require industry sector and/or government support. This aside, various limitations with the annoyance threshold approach for setting guidelines have been raised and discussed (Aurora Environmental, 2000), two of which are as follows.

- The annoyance threshold approach represents a highly simplified mechanism for how nuisance occurs in many cases and assumes that any momentary exposure to some threshold concentration or higher has the potential to cause adverse effects.

- The derivation of an annoyance threshold using a modern-day olfactometer panel may not relate to the real environment and may generally overstate the actual annoyance threshold.

The above two factors have the potential to derive very conservative guidelines. However, despite these concerns, the approach has indicated modelling guidelines for area sources that are at least consistent with the findings of various case studies using the community response survey approaches. Section 9.5 summarises the recommended interim odour-modelling guidelines derived using the theoretical annoyance threshold approach.

Given the selection of a definable odour source and sufficient population density, the use of a real case study of modelling versus community responses is the only robust method for either validating or revising the proposed interim odour-modelling guidelines in the future.

In the community response-based studies, an odour-modelling guideline is determined for a particular site based on population annoyance data, and therefore is based on the tolerance of an existing community to an existing industrial or trade activity. The tolerance of an *existing* community to a *new* industrial or trade activity, or increased odour emissions from an existing activity, would be expected to be lower.

Therefore, it is appropriate to apply a tolerance factor to reduce the odour-modelling guideline determined by community response-based studies before comparing to odour-modelling guidelines determined by the annoyance threshold approach. This tolerance factor represents the lower tolerance of existing communities to new sources of odour. In the case studies in section 9.2.3 above, the tolerance factor has been estimated at approximately 2–5, based on comparison of odour-modelling guidelines determined by the two approaches in this report. Such a tolerance factor appears to be about right.

If the use of such a tolerance factor is accepted, there is little difference between the interim odour-modelling guidelines proposed in section 9.5 and those derived from the case studies in section 9.2.3. The exception remains the question about the interpretation of peak-to-mean ratios for tall stacks, for which further investigation and research is required.

9.3 Evaluating modelling results against guideline values

We are now in a position to look at how to compare the results from odour dispersion models to an appropriate odour modelling guideline value to determine whether the model results predict that significant adverse effects would occur.

9.3.1 Not a pass/fail interpretation

Having prepared the dispersion model input data, run the model, and compared the results with the appropriate odour modelling guideline, the next (and most important) question is: Do these results indicate that adverse effects are likely or unlikely to occur?.

It is important to see this as not just a simple pass/fail test for adverse effects depending on whether the results are higher or lower than the odour modelling guideline. If two variations on a proposed activity produce model results of 4.5 and 5.5 OU/m^3, and these are compared to a concentration component in the odour modelling guideline of 5.0 OU/m^3, this does not mean that the former will cause no significant adverse effects while the latter will.

An evaluation of the potential for adverse effects must always be in terms of probability, so it is best to be conservative when interpreting modelling predictions. Irrespective of the model results, remember that they are just one of the indicators of the potential for adverse effects and that other tools should also be used.

9.3.2 Assessing sensitivity and conservatism in model results

When interpreting dispersion model results, bear in mind the sensitivity of the model results to changes in the input data assumptions, and the amount of conservatism in that input data. Aspects of the input data where sensitivity and conservatism should be checked could include the following, although not all aspects may be applicable to a particular modelling application.

1. *Odour emission rate data used*

- Where did this data come from (actual site measurements, imported from another site, calculated estimates based on chemical discharge rates, ‘guesstimates’, etc)?

- If variable emission rates are likely, how have these been accounted for in the model?

- If the data was measured, how was it measured, are the results statistically significant, and have the measurements captured likely worst-case situations?

- If the data was measured, were appropriate sampling and olfactometry procedures used?

- What is the nature/hedonic tone of the odour, and has the offensiveness (or lack of) of the odour been accounted for in the odour emission rates or odour-modelling guideline?

2. *Land use and occupation where adverse effects are predicted to occur*

- What is the population density where the offensive/objectionable odours are predicted?

- Has the odour-modelling guideline used taken the sensitivity of the receiving environment into account?

- What time of day will the adverse effects occur, and does this correspond with the time of day when people would be in the area that would be adversely affected?

3. *Model algorithm assumptions*

- What dispersion coefficients (for example, rural, urban) have been used, and is this appropriate for the area where the adverse effects are predicted? How would the model results change if the other type of coefficient was used?

- Has a surface roughness factor been used, and is it appropriate? How would a change in the surface roughness factor affect the results?

- Have the other model settings been used appropriately (for example, plume rise, partial penetration of inversions, distance from source at which results are predicted)?

4. *Meteorological file used*

- How are the model results affected by prevailing winds? If this is significant, has an appropriate site-specific file been used?

- If the standard meteorological data file for the Auckland region has been used, is this appropriate for the site in question?

- How significant would calm conditions be at the site?

- If a non-standard meteorological data file is used, have the critical meteorological parameters been calculated in an approved way?

- What is the likelihood of adverse meteorological conditions occurring at the same time that the odour emission rates are high enough to cause offensive/objectionable odours?

- How would a change to the percentile compliance component of the odour modelling guideline affect the interpretation of results?

9.3.3 Interpretation of frequency and duration factors

The odour-modelling guideline does not satisfactorily take into account the duration or frequency of the predicted odour events. These are an important part of the assessment of whether offensive or objectionable odours would occur in a manner likely to cause adverse effects.

Aside from looking at either the maximum model prediction or the maximum from a percentage of the meteorological data, dispersion model results can be used in other ways to consider the frequency and duration factors, such as:

- running the model with subsets of the full meteorological file to look at effects occurring in particular hours, months, or seasons that relate to the times when people are more likely to experience the adverse effects

- for particular receptors of interest, looking at the time of day when the high odour concentrations are predicted to occur

- for particular receptors of interest, looking at the number of consecutive hours where high odour concentrations occur, and the number of days when this is predicted to occur.

A subjective assessment of whether these analyses indicate that an adverse effect could occur would then be required.

9.3.4 Flow chart for decision making

Figure 15 shows a flow chart providing guidance for selecting an odour-modelling guideline and carrying out subjective interpretation of model results.

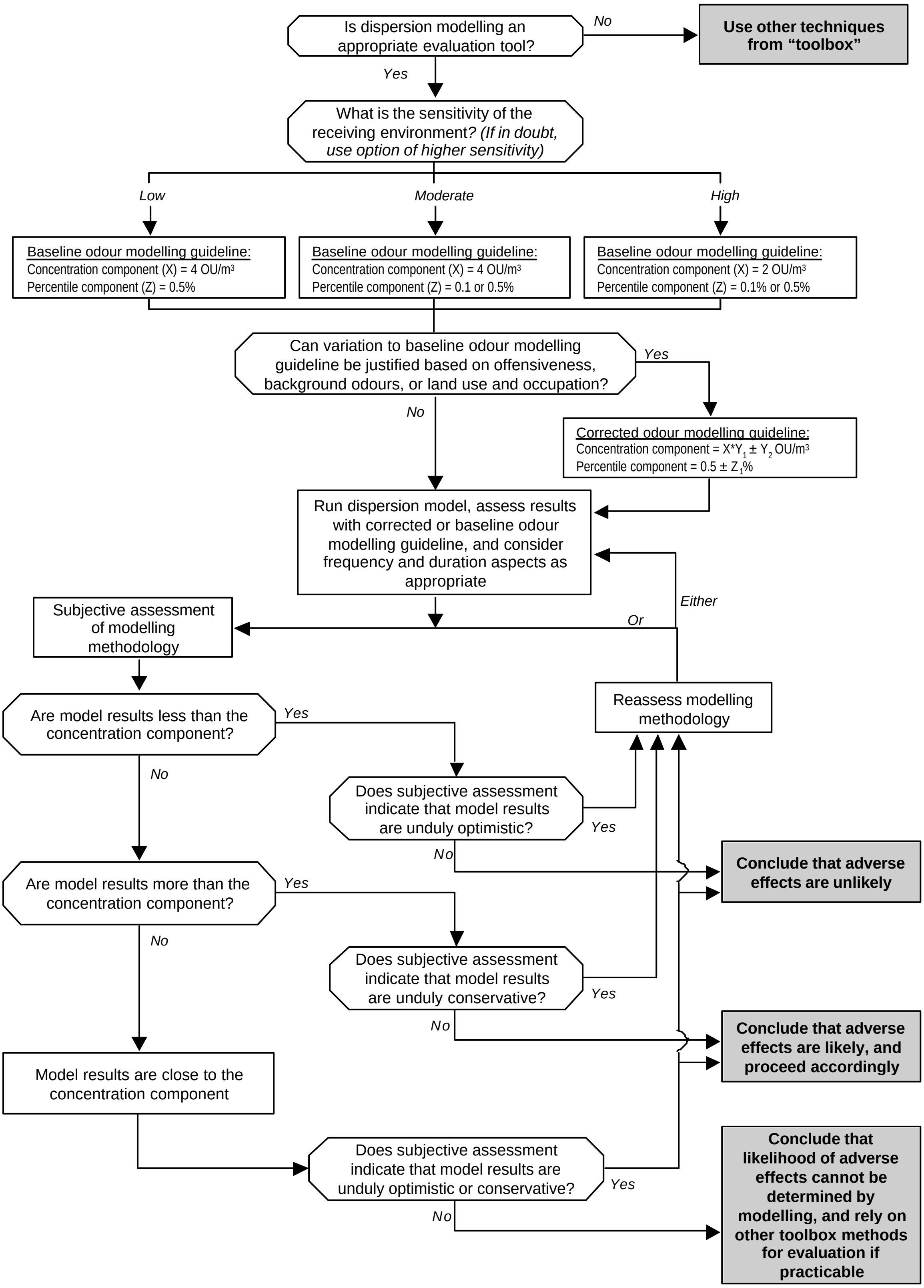


Figure 15. Decision-making flow chart for evaluation using dispersion modelling

9.4 Adjusting the recommended guidelines

This section summarises the options for varying the guidelines recommended in this report to adjust for various site-specific factors. The approaches are summarised from CH2M-Beca (1999). In our opinion, these methods require further research and validation before being adopted as part of a national guideline.

To reiterate: this report recommends the use of real case studies, where possible, for adjusting the recommended concentration guidelines. This aside, the following discussion provides some useful background to what to consider when evaluating modelling results for a specific odour source and location.

9.4.1 Approach to modifying the concentration component

Factors that affect whether an odour is offensive or objectionable (see section 3.2) which could be accommodated via variations to the concentration component, are offensiveness, location and background odour. Initial suggestions for variation due to location are discussed in section 9.2.1. he duration and frequency factors are directly related to the meteorology and do not need to be accounted for in the concentration value.

Increases in the concentration component could be expressed mathematically in one of the following ways:

- *Odour concentration shall not exceed* $(X+Y)$ *OU/m*^{3} *...*
- *Odour concentration shall not exceed* $(X \times Y)$ *OU/m*^{3} *...*
- *Odour concentration shall not exceed* $(X \times Y_1 + Y_2)$ *OU/m*^{3} *...*

where X is the baseline odour annoyance threshold, and Y, Y_1 and Y_2 are additional odour allowances for other factors.

In other words, the baseline annoyance threshold can be corrected either by adding to, or multiplying by, a correction factor. The appropriate correction depends on the reason for the correction. This is discussed below.

9.4.2 Approach to modifying the percentile component

Factors that affect whether an odour is offensive or objectionable, which could be accommodated via variations to the percentile component, are the offensiveness, location, and background odour factors, as well as the frequency factor to some extent. As with the concentration component, the duration factor would not be accounted for by changing the percentile component.

There is little evidence available to support the use of any particular percentile component. However, Miedema (1992), after summarising the results of five odour dose-response research programmes in the Netherlands, indicates that the use of the 0.1% percentile would be better than the 0.5% percentile when the source operates intermittently and less than 50% of the time, because the infrequent peak impacts of odour in such cases were the main driver of nuisance. Also, the 0.1% percentile value will detect the change in peak impacts due to multiple sources as a function of their spatial arrangement, despite there being no significant change in the 0.5% percentile concentration.

9.4.3 Options for varying the concentration component

Corrections for offensiveness and nature of odour

Odour discharges from industrial and trade premises can comprise one or many individual sources. Two extreme examples would be a single-stack discharge from a small, fully enclosed factory, and a multitude of discharges from a wastewater treatment plant, large industry site or landfill. The single-stack source would be easy to quantify, and would be of consistent hedonic tone (the offensiveness rating). The detection and recognition thresholds of the odour or its components could be readily measured, and an odour-modelling guideline customised for that particular discharge.

In the second example, odours would be discharged from a number of different activities carried out on the site, such as those listed in Table 14. Each of the individual sources is a mixture of chemical constituents, and the mixture may be different for each source. Therefore, each source can contribute different offensiveness weightings, and may even have a totally different character. In a wastewater treatment plant, for example, discharges from earth filters are described as "earthy/musty/organic", discharges from primary effluent as "sulphur/sewage/rotten eggs", and discharges from biogas combustion engines as "chemical/gas/smoke".

In reality, most odour discharges from industrial and trade premises will fall somewhere between the above two examples in terms of complexity.

The introduction of odour-control technologies may modify the offensiveness of a discharge; for example, biofilters generate an earthy/musty odour which may be of lower offensiveness than the untreated air stream, and chemical scrubbers can produce a chlorine/chemical odour.

Table 14. Examples of multiple odour sources

Possible sources of odour at a wastewater treatment plant	Possible sources of odour at a landfill	Possible sources of odour at a large industrial site
• inlet works • screening facilities • pre-aeration and grit removal tanks • primary sedimentation tanks • secondary aeration and sedimentation tanks • flow-splitting structures • final discharge structures • screenings and grit dewatering and reception bins • sludge treatment and dewatering • biogas combustion engines/generators • odour treatment (e.g. biofilters/scrubbers)	• waste reception facilities and trucks • landfill gas diffusing through capped refuse, or evolved when covered refuse is opened • open work faces • landfill gas flares • leachate treatment and disposal	• raw material reception • stack discharges from process equipment • discharges of building ventilation air (could be from open doors, roofline ridge vents, or stacks) • fugitive releases from leaks in process equipment, doorways left open, truck loading, etc. • boiler stacks • odour treatment equipment

Objective measurement of odour offensiveness is difficult and costly, and there are no accepted standardised methods for doing this. The benefits of determining an offensiveness rating, and the sensitivity of the conclusions from the odour evaluation process to the offensiveness rating, need to be determined before embarking on such a task. Even if the offensiveness measurement is comprehensive, the result reflects only the laboratory hedonic tone of the odour, not the offensiveness as may be rated in the environment in the context of the RMA, where other factors such as frequency and activity of the affected person come into play.

Handling background odours and multiple sources

Background odours may result from other industrial sources within an area, or from a widely dispersed natural source such as geothermal activity, pine forests or sea weed. Natural sources of background odour are more likely to reduce the sensitivity of the receiving environment to an industrial source, whereas the existence of other industrial sources of background odour can do the reverse, as they may already be causing some degree of adverse nuisance effect. Additional odour impacts (especially during different wind conditions) are most likely to effectively increase the overall odour burden (increase the extent of cumulative adverse effects).

Therefore, when considering the background odour source, a decision must first be made as to whether this background odour will provide significant masking of the other odorants in question, or whether they are more likely to impact during different times and conditions. If two odour sources have impacts that overlap at some locations, it is most likely that only one source will dominate and that the effects will not be additive, unless they are of a very similar nature and character (for example, two piggeries). If, however, the two different sources impact at a specific location during different wind conditions, then their cumulative effects on the percent odour concentration will most likely be additive.

Background odours can act by masking the presence of other odorants, so that a person does not recognise the presence of that other odorant until it is present in higher concentrations than would be necessary if the background odour was not there. The degree to which this masking occurs depends on the type and strength of background odour, whether the other odorant is a similar type of chemical species, the intensity of the other odorant, and how the individual chemical species in the background and other odours react together. If the other odorant contains the same key chemical species as the background odour, then the degree of masking could be quite significant. On the other hand, if the other odorant is of quite different character, then the background odour could have little effect as a masking agent.

The effect of background odours needs to be considered on a case-by-case basis. If the other odorant is quite different to, or much stronger than, the background odour, then background odours should probably be ignored in the assessment of effects. Obvious examples would be an odour from a chemical manufacturing plant occurring in a rural area, or septic effluent from an intensive pig farm being spread on farmland on the outskirts of a rural/residential area.

Where the assessment is based on an existing activity or a proposed change to an existing activity, then if possible some field information on the masking effects of the background odour with the particular odour in question should be gained. A justification for incorporating the background odour effect into the annoyance threshold could then be developed.

However, if the assessment is for a new activity, or field data cannot be gathered, and the circumstances of the case indicate that interactions between the background odour and the odour source in question are likely, this needs to be allowed for in the assessment of effects and interpretation of dispersion model results. Including the background source in the model itself is not recommended unless the nature and source of the background odour are well defined (such as from a stack source). Most background odours are discharged at low emission rates from large areas or from diffuse or fluctuating sources, and are too difficult to define accurately. In addition, results from cumulative modelling runs will be difficult to interpret unless the interactions between the background odour and the other odour sources are well defined.

Rather than including the background source in the model itself, the background source should be allowed for by subjective assessment after the model has been run. Considerations would include:

- Is the background source present all the time? (For example, odours from mudflats may only be present at low tides).

- If the background source is present all the time, what type of atmospheric conditions would make ambient odours from the background source worse, and do those conditions occur at the same time as the highest concentrations from the other odorant would occur?

Depending on the answers to these questions, an appropriate course of action could be determined on a case-by-case basis. If the answer to either of these questions is no, then the background odour will not act cumulatively with the other odorant and can be eliminated from the assessment.

The discussion above considers the case where only one source is being assessed. In many cases, however, the task is to predict the cumulative effect of a number of odour sources, often of quite different composition and offensiveness. As discussed in section 8.2.1, a major drawback of dispersion modelling with multiple sources of odour is that the model assumes that the odours are additive.

As a result of this assumption, dispersion models of multiple sources of odour and mixtures of chemical compounds are likely to over-predict downwind concentrations, because the diluted odour mixture will be dominated by the more offensive components in the mixture, which mask the less offensive components. Alternatively, depending on the complexity of the situation, it may be just as useful to model all the sources together, while keeping in mind that the model is likely to have over-predicted the actual situation when interpreting the model results.

9.5 Summary of recommended guidelines

The recommended application of concentration and percentile components in the odour-modelling guideline is as follows.

(i) The baseline percentile is 0.5%, although 0.1% will also be used to assist in the evaluation of model results.

(ii) The concentration components below already include the peak-to-mean ratio adjustment for all source types, and should be treated as design ground-level concentrations for 1-hour modelling averages.

Table 15. Odour-modelling guidelines

Sensitivity of the receiving environment	Concentration component	Percentile component
High (worst-case impacts during unstable to semi-unstable conditions)	1 OU/m^3	0.5%
High (worst-case impacts during neutral to stable conditions)	2 OU/m^3	0.1% and 0.5%
Moderate (all conditions)	5OU/m^3	0.1% and 0.5%
Low (all conditions)	5OU/m^3	0.5%

This approach may be unsuitable if highly conservative or, conversely, unreliable emission rate data is available and/or the development of a robust meteorological data file has not been undertaken

The numbers tabulated above are the *interim odour-modelling guidelines* recommended by this report. These interim guidelines can be revised in future as case study evidence becomes available to justify any changes to the guidelines. Any changes will most likely be published through the Ministry's website: www.mfe.govt.nz.

The method for developing alternative modelling guidelines for a specific industry will be by the use of robust odour modelling versus odour annoyance survey results (dose-response research), which includes an impacted population and a control population. The full details of the methods used to generate the raw data, sample numbers, etc. should be documented and must have undergone a peer review by recognised and independent air-quality professionals.

Chapter 9: Recommendations

1. The recommended application of concentration and percentile components in the odour modelling guideline is given in Table 15.

2. The concentration components in this table already include the peak-to-mean ratio adjustment for all source types, and should be treated as design ground-level concentrations for 1-hour modelling averages when linked to the joint Australian and New Zealand standard AS/NZS 4323.3:2001.

3. The values given in Table 15 are the interim odour-modelling guidelines recommended by this report. These interim guidelines can be revised in future as case study evidence becomes available. Any changes will most likely be published through the Ministry's website, www.mfe.govt.nz. The main method

for revision to the interim guidelines is likely to be via the community response approach to developing guidelines, rather than the annoyance threshold approach.

4. The interim modelling concentration guidelines should be used by default unless alternative industry-specific guidelines are available. The method for developing alternative modelling guidelines for a specific industry should be by the use of robust odour-modelling versus odour annoyance survey results (dose-response research), which includes an impacted population and a control population. The full details of the methods used to generate the raw data, sample numbers, etc. should be documented and must have undergone a peer review by recognised and independent air-quality professionals.

10. Mitigation Tools

In this final chapter we look at what can be done to avoid or mitigate adverse effects from odours. Much of this discussion centres around the concept of the 'best practical option' for minimising harm to the environment and how it applies under the RMA.

10.1 Best practicable option

10.1.1 Definition

The 'best practical option' (BPO) is defined by the RMA as the best method for minimising the discharge of contaminants when taking the following into account (Section 2):

- *the nature of the discharge or emission and the sensitivity of the receiving environment to adverse effects; and*
- *the financial implications, and the effects on the environment, of that option when compared with other options; and*
- *the current state of technical knowledge and likelihood that the option can be successfully applied.*

This definition can often require an air pollution control expert and/or an individual with industry-specific expertise to assess whether or not proposed odour emission control measures represent the use of a BPO in any particular instance. Because the Act's definition of a BPO allows for a substantial degree of discretion, experts will not always agree on what represents the BPO in a specific circumstance. Furthermore what may be deemed to be the BPO for any one activity often changes with time, as technical developments are made.

The circumstances in which a regulatory body staff can use this tool require careful consideration of the requirements of the Act (see Appendix 2 for case law).

10.1.2 The BPO for new activities

For new activities, the requirement for a discharger to adopt the BPO could only be mandatory if that approach was supported by the operative regional plan. For example, if the plan required that the environmental effects of air discharges be minimised irrespective of the likelihood of adverse effects, this result might be achieved by adopting the BPO to minimise potential adverse effects to a practical level.

If a plan does not have policies that can require new activities to adopt a BPO, then an application for a consent to discharge odour from such an activity may only be declined on the basis that adverse environmental effects are considered likely to occur. The application could not be declined because the level of emission control does not represent what is considered to be the BPO in that circumstance.

In practice, the ability of a consent authority to impose a BPO-type condition on a new consent, or one that is being renewed, is substantially restricted by the Act. Section 108(8) of the Act specifies various considerations and requirements that restrict a consent authority's ability to impose a BPO as a condition of consent. Specifically, the consent authority is required by the Act to be satisfied that the inclusion of a particular BPO condition is the most efficient and effective means of preventing or minimising any actual or likely adverse effects on the environment. This assessment must be made while having regard to the nature of the discharge and receiving environment, and the use of alternative conditions.

For examples of BPO conditions that have been approved by the Court, see Appendix 2. As one example, in Te Aroha Air Quality Protection Appeal Group *v* Waikato RC, the Tribunal held that:

> *Occupiers, business people and their patrons should be free of rendering plant odour at all times without condition or qualification. It would not be sufficient for the proprietor of a rendering plant to demonstrate that emission of rendering plant odour which reached adjacent properties was the result of an unforeseen or random accident or malfunction. Nor would it be sufficient for the proprietor of a rendering plant to demonstrate that the best practicable option had been taken to avoid emission of odour which might reach adjacent properties.*

10.1.3 The BPO for existing activities

The mandatory requirement to adopt the BPO for minimising odour emissions may be applied to existing activities where either their resource consent has a condition that requires this, or the consent is under review by a regulatory body, or the activity is undergoing a resource consent renewal process. Therefore it is important to consider the circumstances in which the Act allows for resource consents to have a BPO condition applied.

For resource consents issued with either a BPO-type condition under Section 108(1)(e) of the Act, or with a review condition under Section 128(a)(ii), the use of a process review and assessment of the BPO could be an assessment tool when actual adverse effects are occurring, or are likely. However, in Australasian Peat Ltd *v* Southland RC,[16] the Planning Tribunal held that it is not adequate in setting conditions for a discharge permit simply to require the consent holder to use the best practicable option without specifying the option to be adopted (or the date by

[16] (PT) C44/96

which the consent holder would be permitted to apply to amend the conditions under section 127(1)).

For resource consents that do not contain such BPO conditions (as discussed above), the consideration of a BPO may still be applied if a consent review process is instigated in accordance with the requirements of the Act. For example, when a new Plan becomes operative an activity may be required to adopt the BPO, as part of a review of the resource consent and subject to Section 128(b) of the Act. Alternatively, an activity may be required to adopt the BPO as part of a consent review under Section 128(c) when it can be established that inaccuracies within the original assessment of effects information supplied to the hearing committee had materially influenced the decisions made in granting the consent.

Section 131(2) specifies the considerations required before a new BPO condition should be included into an existing resource consent as a result of the consent review process. These are:

a) the nature of the discharge and the receiving environment

b) the financial implications for the applicant of including that condition

c) other alternatives, including a condition requiring the observance of minimum standards of quality of the receiving environment.

10.2 Performance standards

The use of performance standards implies the following types of restrictions on an activity, which are put into resource consents as conditions:

- odour emission limits (for example, measured from a stack)
- requirements for mitigation equipment performance (for example, 95% reduction in odour concentration through a biofilter or scrubber)
- requirements for mitigation equipment design (for example, specifying biofilter depth, or retention time).

Performance standards are common in consents for some types of air discharges, especially the discharge of particulate matter and/or fuel combustion gases. Some examples where performance standards have been used as conditions in odour consents in New Zealand are listed in Appendix 7.

Performance standards are easy to monitor as consent conditions. Such conditions tend to be placed on resource consents to support the generic condition ‘no offensive or objectionable odour beyond the boundary’ rather than to replace it. The ultimate test under the RMA is still whether adverse odour effects occur. Reasons for putting performance standards in the consent tend to be to ensure that the grantee undertakes any mitigation offered or agreed to during the consent application process, and that the mitigation equipment design meets a minimum acceptable design standard. Conditions like odour emission limits may also be used to give the regulator reason to review the consent if emissions are a lot higher than was predicted in the evaluation process.

There can be confusion if the consent holder meets all the performance standards in the conditions, yet still cannot comply with a 'no offensive or objectionable odour beyond the boundary' condition. The consent holder must *not* see performance standards as giving certainty that the residual odours will be acceptable provided the performance standards are met. All parties must be clear that the no offensive odour condition is the overriding one, and that the performance standards reflect a minimum acceptable design condition, rather than a 'You'll be all right as long as you meet these performance standards' condition.

During the evaluation process, dispute may arise if there is disagreement between the applicant and the regulator about the type of performance standard required to meet the no offensive odour condition. The RMA requires only that activities "avoid, remedy or mitigate" adverse effects, and plant owners may wish only to add sufficient mitigation equipment to avoid a problem, rather than implement a system that is over-designed and more expensive than necessary. Any such disputes must be resolved by communication between the applicant and regulator during the consent evaluation process. Further problems may arise if the plant owner later wants to change the design basis for any mitigation equipment after the consent is granted, even though the alternative equipment may perform just as well as – or even better than – that contained in the original proposal.

10.3 Importing solutions, and codes of practice

Sometimes solutions that have worked for odour problems at similar sites may be imported for the activity under evaluation. However, care should be taken when importing solutions because there are many variables that may make a solution for one site unsuitable for another, and you will need to consider the following questions:

- Is the meteorology (particularly the occurrence of calm conditions and Katabatic air flows) the same?
- Is the surrounding land population density the same, particularly for the area downwind under the prevailing wind conditions?
- Is the terrain sufficiently similar in terms of effects on rate of dispersion?
- Is the method of processing similar enough? Does the odour have the same chemical constituents? Is the quality of raw materials the same (particularly trace elements that could cause odours)?

For example, every rendering plant can be different depending on the quality of the raw materials, conveyance methods, type of rendering process, age of the equipment, condition of the building, operational aspects (such as open doorways and opportunities for fugitive releases), and isolation of individual processes for ventilation and odour treatment. Similarly, for a piggery the strength and character of odours discharged from sheds housing the pigs will depend on building temperature, building design and means of ventilation (passive or active), pig population density, type of feed, method of food and water supply, effluent collection and removal system, shed-flushing arrangements, and age of buildings.

Industry codes of practice can also be used as a guide, but you must be aware what the objective of the code of practice is (for example, to protect neighbours from odour, noise or health effects), the type of land use anticipated at the boundary of the site or separation distance, the types of processes envisaged in the code of practice (these could affect the character and offensiveness of the odour – have recent changes in processes made the code of practice out of date?), the degree of operator skill, and management practices required/anticipated by the code of practice.

Industry codes of practice for minimising odour effects should not be relied on as proof of acceptable odour effects for new proposals. However, good operating practice and design criteria specified in an industry code can be considered to represent the BPO for that industry.

10.4 Management and contingency plans

10.4.1 General

Effective management and contingency plans can sometimes appear to represent the BPO for minimising odour effects, especially where the extent of odour emissions is strongly related to standard site procedures and how these are managed. In this case, the review of a particular site's proposed odour management plan is possibly the most important tool for assessing the potential for adverse odour effects.

There are two possible procedures for management plans[17]:

- the management plan is approved by the local authority (or the Court, in the case of an appeal) and written into the conditions of the resource consent; or
- the resource consent requires the consent holder to prepare and lodge a management plan from time to time with the local authority.

The first procedure has some difficulties in that the management plan cannot be altered without a change to the consent, which will require formal processes under the Act. The second procedure has the advantage of avoiding this, but requires the consent holder to go through the discipline of setting out in detail how it proposes to manage its activity through the various stages of development to

[17] See Appendix 2 for a discussion of case law.

completion.[18] The second procedure recognises that management procedures need to be continually reviewed and updated with the benefit of experience. Requiring a variation to a consent to update such changes would be inefficient and possibly hinder the ability of consent holders to improve their management approaches over time.

In some cases the Court has insisted that a management plan be written into the conditions of the resource consent (see Appendix 2). Wood *v* West Coast RC[19] concerned a series of applications for resource consents made by Solid Energy to construct and operate a West Coast coal terminal in Westport. The Court accepted that it was appropriate for the consent holder to lodge a management plan from time to time with the council, and commented that:

> *…a management plan can be required to be prepared pursuant to section 108(3) of the Act, but its purpose should be to provide the consent authority and anyone else who might be interested, with information about the way in which the consent holder intends to comply with the more specific controls or parameters laid down by the other conditions of a consent. … However, because technology might change over time the consent holder should have the ability to change the management plan without having to go through the process of seeking a change to the conditions of consent.*

Odour management plans should not be considered as the BPO, but may well specify the use of operating practices and engineering systems for controlling odour emissions that represent the BPO. The focus of odour management plans should be to demonstrate, in a transparent manner, the management system that will ensure the reliable operation of odour-control systems and performance monitoring, and the reporting of these.

10.4.2 Content of management plans

An odour management plan may include a number of components that collectively achieve the efficient and proactive minimisation of odour effects from a particular activity. The extensiveness of information recording and verification will vary greatly for different activities and production scales. Increasingly some industries are implementing ISO 14000-type environmental management systems that would include odour effects, where appropriate. However, for many industries the development of effective relationships and reporting mechanisms with the local council and community can provide sufficient transparency and performance review.

The key components of an odour management plan are listed below, approximately in decreasing order of importance (the appropriate level of detail

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[18] *Walker v Manukau CC* EnvC C213/99

[19] EnvC C127/99

for each will vary greatly from one industry to another, depending on the main sources of odour that need to be controlled):

- the technology, hardware and/or operating procedures used to mitigate adverse effects
- the procedures and personnel for ensuring these controls are successfully implemented
- the system for monitoring and reporting the performance of the overall system
- the system for ensuring transparency in the implementation of the overall system
- the process for reviewing the site's environmental performance with regard to odour.

An example of a table of contents for an odour management plan is provided in Appendix 8. This is not an exhaustive list, but should provide a general guide to what content headings need to be considered.

Chapter 10: Recommendations

1. The requirement to adopt the best practical option (BPO) for ensuring only minor odour effects should be used with caution, as the definition of what constitutes a BPO for controlling odour emissions is usually a matter of expert opinion, is open to debate, and is specific to a particular industry.

2. The definition of a BPO should be related to the specifics of engineering systems and processing technologies that minimise odour emissions.

3. Performance standards for odour-control systems can include treatment efficiency as well as appropriate design specifications for ensuring that engineering systems are appropriately sized and designed to treat odorous emissions.

4. Industry codes of practice for minimising odour effects should not be relied on as proof of acceptable odour effects for new proposals. However, good operating practice and design criteria that are specified in an industry code can be considered to represent the BPO for that industry.

5. Odour management plans should not be considered as the BPO, but may well specify the use of operating practices and engineering systems for controlling odour emissions that represent the BPO. The focus of odour management plans should be to demonstrate, in a transparent manner, the management system that will ensure the reliable operation of odour-control systems and performance monitoring, and the reporting of these.

6. Odour management plans should contain information, as described in section 10.4.2 and be structured in a similar way to the example provided in Appendix 8.

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APPENDIX 1: Feedback on 1995 Odour Guide

We received a total of 24 responses to the odour survey that we sent out in December to over 100 members of the Odour Guide's target audience. We also received another 4 responses that are of no use because the respondents have not used the Guide.

An analysis of the 24 responses is outlined below.

Type of occupation/employer:

Consultant	6
Reg council	10
City council	3
Lawyer	2
Health officer	1
Industry	2

Responses to General Questions:

1.	Aware of the existence of the 1995 guide	23	Yes
		1	No
2.	Has access to a copy of the guide	22	Yes
		2	No
3.	Has used the guide to assist with odour management	16	Yes
		2	No
		6	Used to, but not any more because guide is out of date

Purposes for which guide has been used:

- Enforcement action (prosecution or defence)
- Odour assessment
- Resource consent applications
- Writing reports on consent applications (regional council)
- Air plan preparation (both Regional and District plans)
- Compliance monitoring
- Background information

- Training staff in FIDOL
- Information source for community consultation
- Preparation of evidence for hearings

Some reasons why guide hasn't been used:

- Not helpful in assessing discharges
- Not aware of this guide until the survey arrived
- No need to refer to guide
- Out of data and limited specific information

Responses to rating of guide in specific topic areas:

Topic area	No. of responses in category				
	1 (poor)	2 (fair)	3 (good)	4 (very good)	Nil or n/a
a) Assessment of odour effects for existing activities	1	12	9	0	2
b) Assessment of odour effects for proposed activities	2	14	4	0	4
c) Assistance in preparing AEE reports or auditing consent applications	3	12	4	1	4
d) Assistance in monitoring odour effects (compliance monitoring)	2	9	11	0	2
e) Use as a diagnostic tool where odour impacts are of concern	2	12	5	0	5
f) Assistance in developing regional or district plans	3	6	4	0	11
g) Selection and use of appropriate odour assessment tools	7	8	5	0	4

Most respondents found most topic areas to be covered 'fairly', with (a) and (e) covered slightly better and (g) covered poorly.

Most respondents wanted more information to be provided on most topics.

Comments provided by respondents:

A large range of comments was provided. These are summarized below. The scope of our report does not cover odour control technologies (i.e. biofilters, scrubber technology etc), which several people have mentioned.

Respondent's employer type	Comments
Regional council	o Preferable if new Guide was generally consistent with existing Regional Air Plans and work recently completed by ARC. This would avoid having to look at Plan changes in order to give effect to the MfE Guide. o One issue that has arisen through our Plan development process is the difficulty with use of the term 'objectionable odour' in permitted activity rules. Even with guidelines and procedures identified in the Plan as to how we will determine whether an activity complies with the Plan there is still real doubt as to whether such conditions are truly vires. In order to be vires conditions on a permitted activity rule must be sufficiently certain that the person using the Plan can be clear as to whether they comply with the rule or not. The term 'objectionable' even with procedures in guidelines is in no way as certain as this test implies, and permitted activity rules in Plans across the country are therefore probably on shaky ground. o Whilst I acknowledge that odour is by its very nature subjective, and that objectionable odour is the right test, what is required is some very black and white procedures for determining compliance with objectionable odour conditions on a permitted activity rule. The majority of the work done so far in our guidelines and I understand in ARC's guidelines too relates to resource consents and AEEs and is less than useful for monitoring of permitted activities. The end result is that a range of uses permitted in Regional Plans will generate odours, and due to the uncertainty of the term will not be effectively managed until a long, expensive and convoluted process is followed through. Something simpler for Permitted Activity Rules is required that does not leave both complainants and resource users dangling in anticipation for years while Council follows through its process to determine whether an activity complies with the rules in the Plan. Perhaps the Guide could include a detailed section on permitted activity rules in Plans and identify how to make the test of 'objectionable odour' on permitted activity rules more certain and efficient to apply.
Regional council	o The guideline has not been able to keep up with changes in technology, so has become less useful. Also changes being proposed (accepted) to the ambient air quality guidelines indicate a change in the threshold levels for some contaminants. This information needs to be referenced accordingly.
Regional council	o Assessment tools options not complete or comprehensive in 1995 Guide.
Regional council	o Main concern on a day-to-day basis is how to reduce odours, rather than arguments over which definition or odour measurement technique to use.
Regional council	o Since 1995 the knowledge base on odour management has increased hugely and this needs to be reflected in the guide, even if it references more prescriptive documents or includes these as appendices. The present guide has very scant information on assessing existing sources, new sources or plan development. It seems to be overly obsessed with pigs! It really needs an update of what is there and expansion of the most

	important bits like assessment techniques and management options.
Regional council	o Out of date particularly with respect to dispersion modelling. More emphasis and updating of odour abatement technologies.
Regional council	o The guide needs more depth. The current guide is trying to be all things to all people and it doesn't work well. There have been a lot of developments in the odour field over the past 5 years, and these need to be brought out and people told about how they have worked (or haven't worked). o There needs to be more information along the lines of the report that Tracy did for ARC and the report Roger did for the Aurora submission to Environment Waikato. Have a look at the EW air plan and improve it. o I would love to see objectionable odour defined in a way that was easy to enforce for regional councils.
Regional council	o The notes you have already put together regarding odour diaries should be included as these are practical methods for on-the-ground studies of problems. The FIDOL stuff is good for explaining the concepts to new people. Olfactometry discussion is okay but is only useful in a limited amount of areas so should actually be a lesser emphasis in the document. If you are going to have a technical part to the document you might as well discuss modelling and the Netherlands curves as well, as these techniques have been used since the first document was put together. You would need to watch how much detail you went into though as these topics can get a bit overboard. o For people starting the field some comment on the likely discharges from certain activities and some possible methods for reducing the odour would be helpful. More detail on odour reduction options would be helpful for the use as handout material for problem places that we have to deal with as then they can make an informed choice as to the best option for reducing their odour ie should they use an afterburner or a wet scrubber or a biofilter. The afterburner requires fuel and heat-resistant material, scrubbers make a liquid effluent and you have to buy chemicals, and biofilters can take up a bit of area.
City council	o Generally more comprehensive. o Up-to-date list of technical back-up (private and public) resources to be included (could be updated regularly) to serve as resource for territorial local authorities. o *.PDF file version of Guide should be available on Internet.
City council	o Some more practical applications for enforcement/monitoring situations. o Include some more suggestions/assessment techniques for common residential area odour problems. o Section on EIAs and their application as an enforcement tool. o Comparison/references to successful plans in NZ and relevant case studies.

	o Include regional meetings for both policy and enforcement officers to get feedback on plan [guide?] (i.e. not just surveys).
Lawyer	Some material that should be included: o example of an odour diary o information on requirement to do a 360-degree check to exclude other odour sources o update on case law.
Medical officer of health	o Difficult area to evaluate quantitatively and qualitatively. More detailed/updated guidelines always useful.
Industry	o Under the control technologies section it would be good to have some references to control technologies that have been put in place and their performances and some real-life industry results. o I.e. perhaps a contact for each industry that has used some of the technology unbiased by interested parties. By interested parties I mean manufacturers of the pollution control technology or consultants who have been used in the process of developing the equipment. o An end user and public response?
Consultant	o The current document is really too general. In fact I believe the original consultant's draft was significantly better than the final guide. o It's time we formalised odour-modelling guideline criteria and proposed a general methodology. o We need to be careful with too much emphasis on modelling, however. In particular, we do not want to become as obsessed with this tool as appears to be the case in Australia. Suggest the new guide discuss areas where modelling is not any use by extending the approach in the Auckland RC document and discussing issues like large area sources, etc. o We need much better guidance on survey and diary methodologies: when these can be done, what they can achieve, etc. o A good discussion on complaints may be helpful. What do we do when our modelling and surveys meet the criteria but we still get people ringing the council?
Consultant	o 'Selection and use of appropriate odour assessment tools' is probably the most important area, as you need good information to be able to deal with a problem, or even identify if a problem exists. This whole section needs to be more comprehensive, perhaps an amalgam of the ARC document (which is heavy on modelling), and the Lincoln document (which looked more into surveys).
Consultant	o The old document is out of date, especially in relation to monitoring methods and interpretation of results. It is also too general. An update is needed, containing more detail and more practical advice.

Consultant	o Reasonable guide at the time, but needs updating, much more content, like the *Manual on Wastewater Odour Management*, for various odour sources. Appendix should include other international sources and relevant guidelines.

APPENDIX 2: Legal Considerations and Consent Conditions

Meaning of Effect

Definition

Effect is defined in section 3 of the RMA.

The then Planning Tribunal in *Te Aroha Air Quality Protection Appeal Group v Waikato RC*[20] and *RC Vosper & Sons Ltd v New Plymouth DC*[21] considered the meaning of effect. A summary of the conclusions from these two cases is as follows:

Te Aroha Air Quality Protection Appeal Group v Waikato RC

These appeals were against a proposal for a new by-products rendering plant located adjacent to an export beef plant in Te Aroha. A joint committee of the Waikato Regional Council and the Matamata-Piako District Council had granted the applicant land use consent and permits to discharge contaminants to air, with conditions. On appeal the Tribunal refused consent, concluding that the potential high impact that might result from the low probability occurrence of an emission from the proposed rendering plant was not an acceptable risk under the RMA. There was a plausible risk, albeit of low probability, that objectionable odours would reach other properties as a result of management error, malfunction or mechanical failure. The Court found that objectionable odours would adversely affect people and the social, economic, aesthetic and cultural conditions, and the amenity values that contributed to people's appreciation of the pleasantness of the area. Any escape would have a potentially high impact on business at the nearby racecourse and the motor camp. The Court took into account the fact that the proposal would be located on land zoned Rural A1, where it would be a non-complying activity.

RC Vosper & Sons Ltd v New Plymouth DC

This was an appeal against Council refusal to grant consent to install a cremator unit and modify part of an existing building as a crematory in New Plymouth. Though the Tribunal found in favour of the applicant in relation to the odour issue, the Tribunal refused consent for other reasons. It was contended that, if an unexpected event were to occur resulting in off-site perception of a gaseous odour, the impact upon the recipient would be high and that even though the smell may not be offensive as such, it would nevertheless become so when linked in the

[20] (No 2) (1993) 2 NZRMA 574 (PT)

[21] [1994] NZRMA 324 (PT)

mind with the cremator's function of consuming human remains. The Tribunal considered the meaning of "effect" under section 3(f), but did not consider the phrase "high potential impact" to be appropriate in this case. The Tribunal found that "the potential impact could not be compared with the breadth of impact apprehended in the *Te Aroha Air Quality Protection Appeal Group* case"

Under section 105(2)(b)(i) the Tribunal was concerned with "adverse effects on the environment". It considered the meaning of "environment" in section 2. While the Tribunal accepted that there would be an impact if odour was unexpectedly detected off-site, such an impact in its view would, at most, be temporary and not liable to affect a wide area. It was not persuaded that its conclusion as to the minor nature of any likely adverse effects on the environment was misconceived. The feelings of some people over the presence of funeral establishments in locations in or near residential areas were insufficient to warrant rejection of proposals otherwise found to be unlikely to detract from neighbourhood amenities.

Offensive or objectionable

Section 17 of the Act imposes an overriding duty on persons carrying on activities to avoid, remedy, or mitigate any adverse effect on the environment. The duty can be enforced by enforcement orders and abatement notices to (section 17(3)(a) and (b)):

“(a) Require a person to cease, or prohibit a person from commencing, anything that, in the opinion of the Environment Court or an enforcement officer, is or is likely to be noxious, dangerous, offensive, or objectionable to such an extent that it has or is likely to have an adverse effect on the environment; or

(b) Require a person to do something that, in the opinion of the Environment Court or an enforcement officer, is necessary in order to avoid, remedy, or mitigate any actual or likely adverse effect on the environment caused by, or on behalf of, that person.”

The reference to "noxious, dangerous, offensive, or objectionable to such an extent that has or is likely have adverse effect on the environment" is repeated in section 314(1)(a)(ii) as grounds for an application for an enforcement order and in section 322(1)(a)(ii) as grounds for an abatement notice.

In relation to odour, the terms "noxious", "offensive " and "objectionable" are all appropriate. In some cases the chemicals that make up the odour may be toxic and the meaning of "dangerous" will have to be considered.

Case law

Zdrahal v Wellington City Council

The High Court decision in *Zdrahal v Wellington City Council*[22] concerned an abatement notice requiring a person to remove two swastikas from his house on the grounds that they were offensive and objectionable and likely to have adverse effects on the environment. The High Court held that the correct test for what may be offensive or objectionable under the Act depends on the circumstances, the test must be an objective one but with subjective elements. The Court held that the swastikas were offensive or objectionable. Mr Justice Greig formulated the following test for what may be offensive or objectionable:

> *"What may be offensive or objectionable under this Act cannot, I think, be defined or prescribed except in the most general terms. Each case will perforce depend upon its own circumstances. What may be offensive or objectionable in a quiet suburban street may not be so in a busy commercial downtown area or in a zone where heavy industry is concentrated. It is necessary to have regard to the broad objects and purposes of the resource management legislation as set out in Part II. The promotion of sustainable management is inter alia, to enable people to provide for their cultural well-being, and to avoid adverse effects on the environment, maintenance and enhancement of amenity values and the quality of the environment are specifically referred to in s 7 as matters which are to be regarded in the protection of natural and physical resources. ….*

Justice Greig went on to say:

> *"There can be no doubt that the test must be an objective one. It is not enough that a neighbour or other person within the relevant environment considers the activity or matter to be offensive and objectionable. It is not enough that the Tribunal itself might think the matter was objectionable…."*
>
> ….
>
> *The conclusion of the Tribunal in this case was that the swastikas, as exhibited, were objectionable and offensive to neighbours but in doing so the Tribunal clearly found that those neighbours were not hypersensitive but that their views were, as it said, "reflective of the opinions of a significant proportion of the public." Moreover there was a finding that the swastikas were or would be objectionable to many other people who may be forced to view them. That clearly is not a subjective view in the sense that it is neither the opinion and feelings of the original complainants, the neighbours, nor of the opinions and views of the Tribunal, but is the view that that would be the perception of ordinary persons, members of the public. In a sense the decision in matters such as this is and must be subjective because it is what is perceived by the ears or the eyes and its effect on the individual and his personal well-being. Offensiveness or objectionability cannot be measured by a machine or by some standard with arithmetical gradations. It is a matter of perception and the interpretation of that perception in the mind. The Tribunal in a case*

[22] [1995] 1 NZLR 700; (1994) 2 HRNZ 196; [1995] NZRMA 289 (HC)

> *like this must transpose itself into the ordinary person, representative of the community at large, and so decide the matter.*
>
> *It is not merely the decision of offensive or objectionable in the particular circumstances, in this case the swastikas, but the extent of it such that it has or is likely to have an adverse effect on the environment. It is not just in isolation, then, or in relation to what the reasonable person as a neighbour might think or perceive. It is the whole phrase that has to the applied to the circumstances.*
>
> *Clearly there was an adverse effect on the neighbours and that was likely to be adverse on others. How is the environment to be defined and measured in this situation? The environment in this sense is more than the physical surroundings, the objects and substances which are in the vicinity. With its emphasis on people and communities, which must be the people in the communities, the resource management legislation intends that the environment includes the people, and must give them in this particular context predominant significance. Environment, in its definition in the Act, includes people and the social, economic, aesthetic and cultural conditions which affect people. Amenity values is also defined to take its standard from people's appreciation of the attributes including the pleasantness and aesthetic coherence of their surroundings. In any event, when it comes to offensive and objectionable that, as I have said, has to be measured by the effect it has on people and the reaction that people have to it. It is the people in their surroundings or environment, not the objects and substances in them, which are affected by swastikas or other things which can only be perceived by the eye and have an effect, depending upon the meaning and connotation and culture, the knowledge and experience of the perceivers, the people.*
>
> *Such things as noise and nuisance and other offensive or objectionable sights, sounds and smells which the human senses appreciate, may well be limited in their ambit but may still be such as to affect adversely the environment."*

Justice Greig noted that it was not a case of whether something was noxious, dangerous, offensive or objectionable but that it had to be *"to such an extent that it has or is likely to have an adverse effect on the environment"*. As noted in the above quoted sections of the judgment, "environment" is widely defined in the Act. It includes people. His Honour said:

> *"If it is objectively offensive or objectionable, that is if reasonable ordinary persons would be offended or find it objectionable, then it does affect the environment of those people and of any other such people living in the vicinity who are likely to be so affected. … As is clear, it is also the likelihood that is in issue which must widen the scope of the application of the section "*

De Coek v Central Otago District Council

The Environment Court in *De Coek v Central Otago District Council*[23] considered the words "offensive or objectionable" in the context of a building and held that the word "offensive" meant disgusting, nauseous or repulsive. The Court noted that both the Concise Oxford Dictionary and the Collins Dictionary tended to equate the word "objectionable" with "offensiveness", although the Concise Oxford Dictionary refers to "open to objection" in the sense of opposition or disapproval.

Watercare Services Ltd v Minhinnick

The Court of Appeal in *Watercare Services Ltd v Minhinnick*[24] confirmed and adopted the approach in *Zdrahal.* The Court of Appeal sets out four steps for establishing whether an enforcement order should be made under section 314(1)(a)(ii) - whether an activity is noxious, dangerous, offensive or objectionable. In summary these are:

5. That the Court must be satisfied that the applicant's assertion is honestly made;
6. That the subject matter of the application is or is likely to be noxious, dangerous, offensive or objectionable; and
7. If it is that it is of such an extent that it is likely to have an adverse effect on the environment;
8. If the first three steps are established, whether in all the circumstances the Court's discretion should be exercised in favour of making the enforcement order sought or otherwise.

The Court held that at the second and third steps the Court is acting as the representative of the community at large. It must weigh all the relevant competing considerations and ultimately make a value judgment on behalf of the community as a whole.

In the three cases referred to, *Zdrahal*, *De Coek* and *Minhinnick*, it was noted that whether something was noxious, dangerous, offensive or objectionable had to be linked to whether this was of such an extent that it has or is likely to have an adverse effect on the environment.

Internalisation

The principle of "internalisation" is that those who create adverse effects must internalise them rather than force the rest of society to bear the burden of dealing with them.

Hill v Matamata Piako DC & Waikato RC

[23] [1995] NZRMA 324

[24] [1998] 1 NZLR 294; (1997) 3 ELRNZ 511; [1998] NZRMA 113 (CA)

Hill v Matamata Piako DC & Waikato RC[25], an appeal against a decision of the Matamata-Piako District Council declining consent to erect two additional chicken broiler sheds on their property at Te Aroha, and against a decision of the Waikato Regional Council declining consent to discharge contaminants into air from the two proposed sheds and from two existing sheds for which extensions had been approved. The only matters that caused the Court concern was the effect of objectionable odour on the immediate neighbours. Were it not for the odour problem, the proposed expansion would have complied with sections 5 to 8 of the Act. The Court followed the approach in *Winstone Aggregates Ltd v Papakura DC*[26] and adopted the principle of "internalisation". The Court was not satisfied that objectionable odours could be contained on site:

> *"We reiterate again in this decision that we are of the view that adverse effects such as objectionable odour emissions should be confined on site. People living and working in rural neighbouring properties adjacent to sites where intensive farming such as broiler chicken rearing is carried out should not be subjected to objectionable and nauseating odours. It is incumbent upon the industry as a whole and upon individual farmers to so arrange their affairs in the way of siting, management, technology and feed formulations to ensure that objectionable odours are confined on site. This may well involve extra cost to the industry generally and to particular farmers. As a general principle we are of the view that such cost should be borne by the industry in the event that the siting of operations are such that there is potential to cause adverse effects."*

Reverse Sensitivity

The term "reverse sensitivity" is used to refer to the effects of the existence of sensitive activities on other activities in their vicinity, particularly by leading to restraints in the carrying on of those other activities[27].

McMillan v Waimakariri DC[28]

This was a reference concerning plan changes requested to allow 46 hectares of rural land to be rezoned to rural/residential. The zone change would allow up to 42 allotments on the land, which was adjacent to two pig farms. The submitters were concerned that if the plan change went ahead the future residents of the proposed rural/residential subdivision would complain about, or take steps to

[25] (EnvC) A65/99

[26] (EnvC) A96/98

[27] *Auckland RC v Auckland CC* [1997] NZRMA 205; (1997) 3 ELRNZ 54 (EnvC)

1. **[28] (EnvC) C87/98**

restrict or stop, the pig farming activities on their properties. The Court discussed the issue of reverse sensitivity, quoting relevant case law, and considered whether the proximity of the pig farms was a factor militating against the plan change.

The Court held under section 7 of the Act that the plan change would not be an efficient use of land in the area, while the pig farms would immediately challenge the amenity values of the subdivision. The Court considered reverse sensitivity issues in its section 32 analysis. Taking all matters into account in the balancing test, the Court concluded that the plan change should not proceed, as it did not meet the purpose of the Act. Two over riding factors taken into account were that the land was not unique (there was plenty of other similar land suitable for rural/residential development), and it had doubts whether the difficulties could be mitigated by nuisance easements. The appeal failed, the Council's decision was upheld, and the plan change was deleted.

Auckland RC v Auckland CC[29]

In this case the Court did not accept arguments that rules proposed by the Regional Council should be rejected on the basis that they provide for reverse sensitivity. Rules which would restrict the establishment of activities sensitive to low air quality were regarded by the Court as responding to the functions of territorial authorities under the Act.

Best Practicable Option

Definition of Best Practicable Option

The Environment Court considered the definition of BPO in *Auckland Kart Club Inc v Auckland CC*[30], the case concerned noise emissions, the Court's commentary on the definition is helpful:

> *"Turning to the question of what weight is to be given to each provision of section 2(1)(a), (b) and (c) including the "other things" mentioned in the preamble … we consider that each subsection requires careful consideration of the issues it contains. The phrase "other things" does not limit the regard given to just the three provisions. Nor does it mean that the provisions of one subsection should prevail over the other. …[T]he question of weight accorded each provision will depend on the particular case. The conjunctive use of the word "and" at the end of each subsection points to the fact that any evaluation of the best method to limit the noise emission should take into account all factors mentioned in the provision. However, one or two of the options may, at any one time, be exclusive of others. For example, although the technical knowledge might exist to reduce noise levels successfully under section 2(1)(c), the financial implications of doing so may be so prohibitively expensive that*

[29] (EnvC) C10/97

[30] (EnvC) A124/92

there is little likelihood that the option can be applied successfully. The effect of that occurring must be then assessed in relation to its impact on the environment under section 2(1)(b).”

Management and Contingency Plans

As explained in section 7.4.1, there are 2 different procedures for management plans[31]:

- The management plan is approved by the local authority (or the Court – in the case of an appeal) and written into the conditions of the resource consent.
- The resource consent requires the consent holder to prepare and lodge a management plan from time to time with the local authority.

Management plan incorporated as part of the consent

Hill v Matamata Piako DC[32] and Purnell v Waikato RC[33] are examples of cases in which the Court has required a management plan to be approved by the Court and incorporated as part of the consent.

In *Hill* the Court’s only concern with respect to a proposal for two additional chicken broiler sheds was the effect of objectionable odours on neighbours. The Court took the unusual step of issuing an interim decision to give the appellants an opportunity to present a suitable management plan for the Court’s approval. The Court ordered that the management plan was to be incorporated into a set of proposed conditions also for the Court's consideration. The Court held that it was incumbent upon the appellants to satisfy the Court that a proper management system can be put in place that will sufficiently mitigate the effects of odour to warrant the grant of a consent.

In *Purnell* the Court granted consent to discharges from a piggery only on the basis of appropriate management regime and comprehensive conditions. The Court stated:

“It is only on the basis of the intended management regime and with comprehensive conditions accompanying the grants of consent that we are prepared to uphold the Regional Council's decision. On occasion the assurances by or on behalf of an applicant as to the due implementation of appropriate management practices go to the core of whether or not consent should be granted.”

The resource consent included the following conditions:

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[31] See legal appendix for discussion of case law

[32] Supra note 6

[33] (EnvC) A85/96

“(j) The waste management plan for the disposal operation shall be the plan set forth in the second schedule to the decision of the Planning Tribunal (Environment Court). No changes shall be made to that plan without the written approval of the Council.

(k) The irrigation system shall be operated and maintained by the Grantee in accordance with the waste management plan referred to in condition (j) above.

(l) The Grantee shall ensure that all persons disposing of treated effluent are fully aware of the conditions of this permit and the details of the waste management plan referred to in condition (j) above.”

Resource consent requires consent holder to prepare and lodge a management plan from time to time with the local authority.

Wood v West Coast RC[34] and *Walker v Manukau CC*[35] are examples of cases in which the Court has taken the approach which is more advantageous to the consent holder and allowed the consent holder to lodge a management plan from time to time with the local authority.

Wood concerned a series of applications for resource consents made by Solid Energy, to construct and operate a West Coast Coal Terminal in Westport. The Court made the following comments on management plan conditions:

> *“In New Zealand Rail Ltd v Marlborough District Council (1993) 2 NZRMA 449 this Court took the view that if an applicant was relying on a management plan as a method of avoiding, remedying or mitigating adverse effects, that plan should be formulated so it could be scrutinised by the Court and if accepted, included as part of the conditions of consent. That may still be an appropriate way to proceed in some circumstances. However, in this case it was pointed out both by counsel and by Dr Philip Mitchell, a witness for Solid Energy New Zealand Limited, that practical difficulties can arise, particularly where a management plan might benefit from future amendments to keep pace with developments in technology.*
>
> *It was generally accepted that it is not appropriate to provide for a management plan on the basis that it is to be approved by a consent authority or some delegated official at a later time, except to the extent that they may be regarded as certifiers in terms of the leading case on this subject, Turner and Others v Allison and Others [1971] NZLR 833; 4 NZTPA 104 (CA). However, what is or is not a valid certifier condition can itself create considerable difficulties, particularly in regard to a management plan.*

[34] (EnvC) C127/99

[35] (EnvC) C213/99

In the end counsel were agreed on a submission by Ms Robinson that a management plan can be required to be prepared pursuant to section 108(3) of the Act, but its purpose should be to provide the consent authority and anyone else who might be interested, with information about the way in which the consent holder intends to comply with the more specific controls or parameters laid down by the other conditions of a consent. So, for example, in the case of noise, specific noise control limits can be laid down but the way in which these are to be complied with is for the consent holder who can be required to provide a management plan containing information about the method of compliance. However, because technology might change over time the consent holder should have the ability to change the management plan without having to go through the process of seeking a change to the conditions of consent.

We accept this as an appropriate alternative to requiring management plans to form part of the conditions of consent and in the consents to be granted in this case it will be seen we have followed this approach. For example, in the conditions relating to the consents for which the first respondent is the consent holder condition 16 requires the preparation of a contingency and response plan and a series of management plans but the terms of those management plans are not included as part of the relevant consents."

The Environment Court in *Walker* followed the approach in *Wood* and stated:

"On the matter of a quarry management plan it became common ground at the hearing that conditions 9 to 14 (inclusive) of the land use consent, at least to the extent that they require a management plan to be approved by an officer of the respondent, are invalid. Either there should be a management plan prepared now, approved by this Court, and written into the conditions of the land use consent, or there should be no more than a requirement that the consent holder prepares and lodges a management plan from time to time with the respondent.

The former procedure has some difficulties in that the management plan cannot be altered without a change to the consent which will require formal processes under the Act. The latter has the advantage of avoiding this but at the same time requiring the consent holder to go through the discipline of setting out in detail how it proposes to manage the quarry through the various stages of development to completion.

The plan produced by Mr Miller as attachment C has, as we understand it, been accepted as adequately depicting the completed or finished quarry area. All that is required now is that the consent holder should be required to prepare a management plan and lodge a copy with the respondent showing how it proposes to arrive at that end result. If there are changes in detail over time then the consent holder should also be required to prepare and lodge revised management plans.

...

For these reasons we think the view expressed by this Court in Wood v West Coast Regional Council Decision No: C127/99 is applicable and the appropriate alternative for a management plan in this case is the one discussed above."

Resource Consent Conditions

This part of the legal appendix provides examples of consent conditions that have been approved by the Environment Court and precedent conditions which are based on conditions that have been approved by the Court.

The Court reference and the subject matter of the resource consent are footnoted for consent conditions that have been approved by the Environment Court. The words which can be altered in the precedent condition are indicated by the […].

The conditions have been listed under the following headings:

- Compliance with site or management plan, or industry code of practice
- No odour beyond the boundary
- Operating conditions to prevent odour effects
- Odour emissions/complaints - requirement to maintain records, investigate, remedy, monitor, mitigate
- Review conditions
- Miscellaneous conditions

Conditions in a consent to discharge to air and conditions relating to odour in a land use consent, as with any other consent conditions, must be enforceable. To be valid at law, the Court has held that a condition must:

- Be for resource management purposes, not for an ulterior one;
- Fairly and reasonably relate to the development authorised by the consent to which the condition is attached;
- Not be so unreasonable that a reasonable local authority duly appreciating it's statutory duties, could not have approved it;
- Not be so unreasonable that Parliament clearly could not have intended that it should be imposed;
- Not be ultra vires the powers of the local authority;
- Not involve a delegation of the local authority's duties;

- Not lack finality;
- Be understandable to lay persons;
- Be clear and unambiguous.

The following precedents and examples of conditions meet the above tests.

For further information on drafting consent conditions refer to MfE publication "*Effective and Enforceable Consent Conditions*"[36].

The following precedents and examples of conditions may be used by local authorities to draft standard conditions. As noted in *Effective and Enforceable Consent Conditions*, standard conditions are a starting point only and conditions need to be drafted in direct consideration of the activity applied for, and be appropriate under section 108. The difficulty with standard conditions is the potential for the conditions to be applied to a consent without relevance to the particular environmental effects of the activity. Standard conditions should be checked to ensure that the conditions are effective, enforceable and fair, appropriate for the consent applied for and relevant to mitigating the effects of the proposal.

Compliance with Site or Management Plan, or Industry Code of Practice

Precedent condition

The consent holder shall [carry out/manage/proceed with] the [activity] in accordance with the [site plan/management plan/industry code of practice].

Examples:

The consent holder shall comply as far as practicable in the management of the piggery with the code of practice for pig farming published by the Pork Industry Board (November 1990) save for such modifications as indicated by these conditions.[37]

The operation shall be in accordance with the Composting Management Plan dated August 1994 attached to and forming part of this consent.[38]

No Odour beyond the Boundary

Precedent condition

[36] Available on the MfE website – http://www.mfe.govt.nz

[37] *Morgan v Banks Peninsula DC* (EnvC) C177/99 - new piggery

[38] *Meadow Mushrooms Ltd v Selwyn DC* (PT) C83/94 - composting operation

There shall be no odour able to be detected at the boundary of [specified location(s)] which is deemed to be noxious, offensive or objectionable by an enforcement officer [and/or X number of individuals who declare as such] to such an extent that it has, or is likely to have, an adverse effect on the environment.

The FIDOL factors (frequency, intensity, duration, offensiveness, and location - refer 3.2.1) provide guidance on the matters that could be included in the condition.

Examples:

As a result of the exercise of this permit there shall be no odour detected beyond the boundary of that land defined by Pt Allot 68, Parish of Maramarua, and Lot 1 DPS 63551,Block VI, Piako Survey District which is deemed to be objectionable or offensive by:

(i) An appropriately experienced officer of the Council after having considered the frequency, intensity, duration and offensiveness of an odour; or

(ii) No less than three individuals who declare in writing that an objectionable odour was detected, provided that the Council is satisfied that the declaration is not vexatious. That declaration shall include the individuals' names and addresses, the date and time that the objectionable odour was detected, the location where it was detected and, if known, the possible source/cause of the odour (for instance, the piggery building, or, downwind of spray irrigation). Where a declaration is made following a number of odour events, that declaration shall provide details of the frequency, intensity, duration and offensiveness of those events. The individuals shall also state the circumstances which led to the declaration (for example, called upon by another individual, or, detected from a distance). The declaration shall be signed and dated.[39]

No odour resulting from farming of pigs on the property which is the subject of this consent and relating to the storage of pig effluent and its conveyance and the conveyance and discharge of the pig effluent on to land shall occur at the boundary of the property with the properties owned by Mr and Mrs Morgan and Ms Wheeler respectively and as shown on Appendix 1 which is, in the opinion of an enforcement officer, noxious, offensive or objectionable to such an extent that it has, or is likely to have an adverse effect on the environment.[40]

Within 6 months of the date of the commencement of this consent, there shall be no odour:

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[39] ***Purnell*** **Supra note 14 – piggery, effluent ponds and disposal systems**

[40] Supra note 18

- At the boundary of any Township or Residential Zone or the area of land designated for the Fairton School as shown on the Proposed Ashburton District Maps as amended by Council decisions dated 23 July 1997; and/or

- Except as set out in the bullet point below, within 20 metres of any existing dwelling or existing factory building in a rural zone as shown in the Proposed Ashburton District Plan maps as amended by decision of Ashburton District Council dated 23 July 1997 as at the date of commencement of this consent; and

- Beyond a line 25 metres inside the boundary of the property currently owned by Talleys Fisheries Limited being comprised in Certificate of Title Volume 29A Folio 1094 (Canterbury Registry) and legally described as Lot 1 on Deposited Plan 49973 containing 69.5900 hectares and Certificate of Title Volume 29A Folio 1095 (Canterbury Registry) and legally described as Lot 5 and part Lot 2 on Deposited Plan 1018 and Lots 181, 182, 183, 184 and 185 Deposited Plan 1483, and Lot 2 on Deposited Plan 49973 containing 162.7471 hectares

caused by the conveyance and discharge of effluent on to land which is located on the land subject to this consent, and which in the opinion of an enforcement officer is noxious, offensive or objectionable to such an extent that it has, or is likely to have, an adverse effect on the environment; provided that this condition shall not apply to any land owned or occupied by the consent holder.[41]

Operating Conditions to Prevent Odour Effects

The conditions in this category range from a general requirement with respect to operating practices/BPO to specific and detailed operating system requirements. As the category is so broad, a precedent condition has not been provided and only examples of conditions approved by the Court have been included.

Examples:

The consent holder shall operate and maintain the plant so as to implement the best practicable option to minimise any odour emissions so that no odour is discernible beyond the boundary of the site.[42]

At all times the litter in the buildings in which the consent holder carries on business shall be maintained free of water spillage or leakage from the chicken drinking water system. [43]

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[41] *Talleys Fisheries Ltd v Ashburton DC & Canterbury RC* (EnvC) C112/00 - slaughtering facility

[42] *PH van den Brink (Karaka) Ltd v Franklin DC & Auckland RC* (EnvC) A79/99 - poultry expansion

Gases to be treated before air discharge

Within 12 months of the date of commencement of this consent the discharge of gases from the vents of all skin processing drums shall be treated in a biofilter before discharge to air designed, constructed and operated in accordance with the Woodward Clyde letter dated 8 January, product No. AC323002.0001, attached to and forming part of this consent.

Discharges through the roof vents above the paint tables and wool dryers shall be directed vertically into the air and shall not be impeded by an obstruction above the vent stacks.[44]

Ventilation air exchange system (poultry extension)

The buildings as extended in which the consent holder carries on business shall be ventilated with air exchange systems to be designed by a registered engineer to provide no fewer than 7 cubic feet of air per bird per minute when installed in the buildings. No bird shall be housed in any such building unless at all times such air exchange systems are properly maintained and capable of operation.

The output of each fan included in the air exchange systems shall be measured and recorded and each fan shall be fitted with an indicator light to operate when it is switched on.

The fans shall be of a type that will reduce in output not more than 5% when the vents are closed to an average of 80%.

The vents shall be "ganged" to enable their degree of opening to be readily ascertained by visual inspection.

The buildings in which the consent holder carries on business shall not be operated until a registered engineer has verified to the Selwyn District Council that the fans referred to in (b)(ii) and (b)(iii) above are capable of providing in excess of 7 cubic feet per minute per bird when the vents are fully open.

The fans shall be operated to provide air from outside the buildings in which the consent holder carries on business in volumes (cubic feet) calculated in accordance with the following table.

[43] *Wood v Selwyn DC* (PT) C35/94 – poultry extension

[44] *McFadden v Canterbury RC* (EnvC) C217/99 - fellmongery and tannery

NUMBER OF CUBIC FEET OF AIR PER MINUTE/BIRD TO BE SUPPLIED BY OPERATION OF FANS

	Period of Development (days)				
Outside temperature (to 10°C)	0-7	8-14	15-21	22-28	28+
To 10	0	0	0	0	0
10-15	0	0	1	3	3
15-20	0	1	3	3	4
20-25	1	3	4	4	6
25-30	2	3	4	5	7
30+	2	3	5	6	7[45]

Effluent system (piggery)

That the effluent storage system is operated in such a manner as to ensure that anaerobic conditions do not exist in that system. Prior to the consent holder commencing the activity authorised by this consent:

(a) The effluent treatment system shall be inspected by a qualified consultant (the identity of whom is acceptable to the District Council) engaged at the expense of the consent holder;

(b) The consultant shall provide a certificate that confirms that the system has been engineered and constructed so as to ensure efficiency of operation and that emission of offensive odour is minimised; and

(c) The consultant shall also confirm in his certificate that, on inspection, the effluent holding tank appears sound and not liable to leakage.[46]

Effluent is:

[45] *Wood* Supra note 24

[46] *Morgan* Supra note 18

(a) to be directed to areas of the property in such a way as to avoid or to mitigate adverse odour effects on neighbouring properties;

(b) to be spread in a way that does not:

(i) enter or contaminate stock water races

(ii) run off the consent holders land.[47]

Odour Emissions/Complaints – Requirements to Maintain Records, Investigate, Remedy, Monitor, Mitigate

The following precedent condition requires the consent holder to keep records of complaints.

Precedent Condition

A record shall be maintained of all odour complaints received by the consent holder and shall include:

(a) Location of complaint where odour was detected;

(b) Date, time and duration of odour detection;

(c) Estimated wind strength and direction when odour detected;

(d) General description of weather conditions (fine, dry, high/low cloud cover, temperature at the time of odour detected);

(e) Any possible cause of the odour complained of;

(f) Any corrective action taken.

The record shall be maintained by the consent holder and forwarded to [the council] upon request.

Examples:

"Odour incident" –requirements to investigate, remedy, monitor, and mitigate

An "odour incident" will be deemed to have occurred if:

(a) The GDC reasonably determines that an odour incident has taken place; or

(b) No less than three individuals declare in writing that an objectionable odour was detected, provided that GDC is satisfied that this declaration is not vexatious.

[47] *Morgan* Supra note 18

Each declaration shall include the individuals' names and addresses, the date and time the objectionable odour was detected and the prevailing weather conditions when it was detected each declaration shall be signed and date.

On receipt of any report of an odour incident as defined either direct to the consent holder, or to GDC, the consent holder shall consult with the reporter of the incident and GDC and conduct the following investigation: -

(a) Record the time, date and description where possible, of the odour;

(b) Investigate the point at which the odour was detected;

(c) Investigate all potential odour sources at the plant for any malfunction or possible site management problem;

(d) Identify and document the cause of the odour source as far as practical;

(e) Take all necessary action to prevent a recurrence of the odour;

(f) Monitor the effectiveness of the remedial actions taken;

(g) If requested by GDC provide a summary report of the events, including the above listed investigative and remedial work in items (a) to (f) leading to the production of the odour, within 72 hours of the event. The report shall include monitoring results from production process discharges, the wastewater treatment plant, and any other relevant monitoring information for the week preceding the event. The report shall include an explanation and interpretation of monitoring results. [48]

In the event of an odour or nuisance incident occurring the grantee shall forward to the Waikato Regional Council within two weeks of the incident, a written report stating what mitigation measures have been employed to rectify the problem. An odour or nuisance incident will have occurred if:

(i) The Waikato Regional Council determines it has, or

(ii) No less than five individuals from at least two different properties, declare in writing that an objectionable odour or nuisance was detected, provided the Council is satisfied that this declaration is not vexatious. That declaration shall include individuals' names and addresses, the date and time the objectionable odour/nuisance was detected, and the location where it was detected. The individuals shall also state the circumstances that led to the declaration, for example, called upon by another individual, detected from a distance. The declaration shall be signed and dated. [49]

[48] *Rayonier New Zealand Ltd v Gore DC* (PT) C37/96 - fibre board plant

[49] *Pokeno Farm Family Trust and Others v Franklin DC* (EnvC) A37/97 - fertiliser storage facility

Record of complaints to be kept

A record of complaints relating to odour emissions from the site shall be maintained, and shall include:

(i) Location of where odour was detected by complainant

(ii) Date and time when odour was detected

(iii) A description of wind speed and wind direction when odour was detected by complainant

(iv) The most likely cause of odour detected

(v) Any corrective action undertaken by' the consent holder to avoid, remedy or mitigate the odour detected by the complainant.

This record shall be provided to the Otago Regional Council on request. [50]

Complaints will be recorded by Council and evaluated by Council officers who have received odour evaluation training. Where the complaint is found to be justified this shall be recorded and the company advised. Attendance at the locality for an odour complaint which is found to be justified will incur a monitoring charge. [51]

The consent holder shall maintain a record of all odour complaints received. This record shall include:

(a) location of complaint when odour detected;

(b) date, time and duration of odour detection;

(c) wind speed and wind direction when odour detected by complainant;

(d) weather conditions on subject land when odour detected;

(e) any possible cause of odour complained of;

(f) any corrective action taken;

(g) whether the nature of the complaint was referred by a third party and if so, the name of that person.

[50] *Broomfield v Otago RC* (EnvC) W45/97 – landfill

[51] *Van den Brink* Supra note 23

The record kept pursuant to clause 11 above shall be made available to Banks Peninsula District Council on a yearly basis or on request from the Council.[52]

A record shall be maintained of all odour complaints received by the consent holder and shall include:

(a) location of complaint where odour was detected

(b) date, time and duration of odour detection

(c) estimated wind strength and direction when odour detected

(d) general description of weather conditions (fine, dry, high/low cloud cover, temperature at the time of odour detected)

(e) any possible cause of the odour complained of

(f) any corrective action taken

The record shall be maintained by the consent holder and forwarded to the Canterbury Regional Council upon request.[53]

Odour monitoring programmes

Should complaints of odour nuisance occur more than once a week over a period of a month from the same location as indicated by odour complaint records, then the Otago Regional Council may at the expense of the consent holder, instigate the following odour monitoring programmes:

(i) Conduct a standard odour annoyance survey in accordance with environmental survey protocols used by the Environment Bay of Plenty (April 1996) to assess odour 'impacts in the Kawarau/Whakatane Districts that result from odour emissions from Tasman Pulp and Paper Ltd Kawarau; or

(ii) Require the consent holder to set up a wind speed and direction (both with 0.5m/second SEC threshold speed) monitoring station near the landfill site and request that wind speed and direction corresponding to the time of each odour complaint received be recorded. Meteorological monitoring and automatic recordings of hourly averages will be conducted over a period of at least one year and in conjunction of the implementation of a community odour diary programme (ODP). The ODP will be conducted by the ORC and will involve the following stages:

a) correspondence with the local residents to invite the registration to participate in the ODP

[52] *Morgan* Supra note 18

[53] *McFadden* Supra note 25

b) preparation of standardised diary forms, instructions for their use and dissemination to registrants.

Odour diary forms will require registrants to record the following information, in response to an odour impact.

a date, time, duration of impacts

b rating of offensiveness

c Not annoying, little annoying, some annoyance, annoying quite annoying, very annoying, extremely annoying

Odour diary information will be correlated for a period of at least six months. Individual recordings will be checked against prevalent wind conditions, as recorded by the QLDC wind monitoring stations.

lf a source of persistent fugitive LFG odour through simple investigations carried out by landfill staff is detected, the consent holder will engage in an appropriate organisation to conduct a methane monitoring programme above the landfill surface. This will be performed in accordance with EPA new source performance standards for municipal solid waste landfills (volume 61, 1966).

A report summarising the results of above ground and soil methane levels will be provided to the ORC within 6 months of them instructing that investigation be undertaken.

Areas of landfill surface found to produce abnormally high levels of methane, CH4 will be covered in further top soil.[54]

Other complaint conditions

Provide an odour complaint hot line for recording complaints from the general public.[55]

The Grantee shall use reasonable endeavours to resolve any complaints by or concerns of neighbours about the activities authorised by this permit.[56]

Complaints will be recorded by Council and evaluated by Council officers who have received odour evaluation training. Where the complaint is found to be justified this shall be recorded and the company advised. Attendance at the

[54] *Broomfield* Supra note 31

[55] *Broomfield* Supra note 31

[56] *Purnell* Supra note 14

locality for an odour complaint which is found to be justified will incur a monitoring charge.[57]

Review Conditions

Precedent condition

The conditions of this consent may be reviewed [X months/years] after the granting of this permit and every [X months/years] thereafter, for the following purposes:

To avoid, remedy, or mitigate any adverse effects which may arise from the exercise of this consent and which it is appropriate to deal with later;

Requiring the adoption of the best practicable option to remove or reduce any adverse effects on the environment;

For any other purpose specified in this consent;

Complying with the requirements of a relevant rule in an operative plan.

Examples:

The conditions of this consent may be reviewed in terms of s128 RMA on the expiration of six calendar months from the completion of the buildings to which this consent relates, and thereafter at the end of every period of two years from that date during which the activity is continued for the purpose of dealing with any adverse effects on the environment which may arise from the exercise of this consent and which it may be appropriate to deal with at a later stage.[58]

The conditions of this permit may be reviewed two years after the granting of this permit and every two years thereafter and any such review may be for any or all of the following purposes:

(i) Evaluating the performance and management of the treatment system in avoiding spray drift and objectionable odour beyond the boundaries of the property.

(ii) To evaluate the appropriateness of the disposal area buffer distances.

(iii) To evaluate the current management practices and proposed future management practices as pertain to the exercise of this permit.

[57] *Van den Brink* Supra note 23

[58] *Wood* Supra note 24

(iv) To avoid, remedy or mitigate any adverse effects on the environment which may arise as a result of the exercise of this permit.

(v) Ensuring that the best practicable option is utilised to comply with the conditions of this permit to minimise the effect of the discharge on the receiving environments in terms of at least effect on air quality.

(vi) To investigate any unresolved complaints of odour nuisance.[59]

Pursuant to section 128 of the Resource Management Act 1991 the Banks Peninsula District Council may annually, on the anniversary of the effective date of this consent, serve notice of its intention to review the conditions of this consent for the purposes of:

(a) dealing with any adverse effect on the environment which may arise from the exercise of the consent and which it is appropriate to deal with at a later stage; or

(b) complying with the requirements of a relevant law in the operative Banks Peninsula District Plan.[60]

The Canterbury Regional Council may annually on the last working day of October, serve notice of its intention to review the conditions of this consent for the purposes of:

(a) dealing with any adverse effects which may arise from the exercise of this consent and which it is appropriate to deal with later,

(b) to avoid remedy or mitigate any adverse effects from the drum venting process, paint tables and wool dryer;

(c) requiring the adoption of the best practicable option to remove or reduce any adverse effects on the environment;

(d) complying with the requirements of a relevant rule in an operative plan.[61]

Miscellaneous Conditions

The conditions in this category are miscellaneous and a precedent condition has not been provided and only examples of conditions approved by the Court have been included.

Planting plan

[59] *Purnell* Supra note 14

[60] *Morgan* Supra note 18

[61] *McFadden* Supra note 25

A plan shall be prepared by an odour consultant (who is to be suitably qualified in the District Council's opinion) engaged at the expense of the consent holder to determine the appropriate scale, type and location of planting by the consent holder that will ensure that any risk of adverse odour effects on adjoining properties is minimised. Such a plan shall have regard to existing planting and particular regard to any catabatic or anabatic wind conditions that may arise. The consent holder shall plant vegetation in accordance with the plan. Plantings are to be maintained for the duration of the piggery activity with any dead trees being replaced in the first available growing season.[62]

Limits on physical operation, ie boundaries of site (landfill), number of stock (poultry, piggery)

The active working face will be restricted to a maximum size of 30m x 30m.[63]

That the proposed piggery be limited to a maximum of 45 pigs at any time and shall not include any breeding stock.[64]

Poultry: record of birds and log of outside temperatures

The consent holder is to maintain at all times a written record of the numbers and ages of the birds or chickens in the sheds and a log of the outside temperatures.[65]

Fly baiting programme

That a fly baiting programme be carried out by the consent holder during the spring, summer and autumn months of the year.[66]

Limit on odour emission rate and method of measurement

1. The total odour emission rate from the compost operation shall not exceed 120, 000 odour units per second.

2. The consent holder shall carry out odour emission tests to determine the total odour emission rate from the composting operation on a six monthly basis.

3. The sampling method to determine the total odour emission rate shall ensure that samples taken are representative of the entire composting process.

[62] *Morgan* Supra note 18

[63] *Broomfield* Supra note 31

[64] *Morgan* Supra note 18

[65] *Wood* Supra note 24

[66] *Morgan* Supra note 18

4. For the purposes of compliance with conditions 2 and 3 above the method of odour measurement shall be forced choice dynamic dilution olfactometry.

5. The oxygen concentration in the bottom 300 millimetres of the compost shall be maintained above 5%.[67]

Responsibility to survey site for fugitive odour sources

Landfill staff will survey the site for fugitive odour sources resulting from landfill gas leaks on a weekly basis. Any sources identified will have additional clay and/or topsoil applied such that fugitive landfill gas odours are removed.[68]

Responsibility for notifying relevant persons about conditions

The Grantee shall be solely responsible for ensuring that all persons disposing of treated effluent are fully aware of the conditions of this permit.[69]

Data to be supplied to council

Temperature and oxygen measurements recorded in accordance with section 3.3 of the Composting Management Plan and the volume of compost hem on site and measured at 5 p.m. each Friday shall be supplied to the Canterbury Regional Council on a monthly basis. All other monitoring data collected or recorded in accordance with the Composting Management Plan shall be supplied to the Canterbury Regional Council annually or on request.[70]

Enforcement

Part XII of the Act provides 9 enforcement mechanisms. Five of these enforcement mechanisms can be used in relation to odour. These enforcement mechanisms are infringement notices, abatement notices, application for interim enforcement orders, application for enforcement orders and prosecution. A brief explanation of these enforcement mechanisms is set out below[71]. The standard of proof for each of the mechanisms is identified. There are two different standards of proof: "beyond reasonable doubt"[72] and "on the balance of probabilities"[73].

[67] *Meadow Mushrooms* Supra note 19

[68] *Broomfield* Supra note 31

[69] *Purnell* Supra note 14

[70] *Meadow Mushrooms* Supra note 19

[71] For more detailed information on RMA enforcement refer to the Local Government New Zealand Resource Management Enforcement Manual which is available on the Local Government New Zealand website – http://www.lgnz.co.nz

[72] "Beyond reasonable doubt" - a reasonable doubt is a doubt that would prevent a reasonable and just Judge or jury from coming to a conclusion.

Infringement notices

The infringement notice procedure is the lowest level enforcement mechanism. The infringement fees range from $300 to $1000. The relevant sections of the Act are 343A to 343D. Infringement notices can only be issued by local authority enforcement officers. The procedure is straightforward and inexpensive, the recipient has to pay a fine and there is no conviction. If the recipient defends the notice, the local authority is required to prove the offence beyond reasonable doubt. Infringement notices may be useful where there are justified complaints of offensive/objectionable odour and the local authority wants to encourage the consent holder to comply with the conditions of the resource consent.

Abatement notices

An abatement notice is a warning to the recipient that he/she/it is contravening the provisions of the Act. The relevant sections of the Act are sections 322 to 325A. Abatement notices can only be issued by local authority enforcement officers. The procedure is relatively straightforward and inexpensive. If the recipient appeals the notice, the local authority is required to establish that it had grounds to issue the notice, the standard of proof is on the balance of probabilities. If the recipient fails to comply with the abatement notice, the local authority has the option of issuing an infringement notice or prosecuting. As with infringement notices, abatement notices may be useful where there are justified complaints of offensive/objectionable odour and the local authority wants to encourage the consent holder to comply with the conditions of the resource consent. Abatement notices can be used to enforce the section 17 duty, however if the recipient appeals the notice, the appeal acts as a stay of the notice until the appeal is heard.

Application for interim enforcement order

An application for interim enforcement order should only be made where there are serious adverse effects. The relevant sections of the Act are sections 314 to 319 and 320. The application is usually made on an ex parte basis (without notice to the respondent) which means that the person against whom the orders are sought does not have an opportunity to explain his/her/its position to the Court. A range of orders can be sought including requiring a person to take steps to comply with conditions of consent relating to odour. (Standard of proof - comment in relation to application for enforcement order applies).

Application for enforcement order

[73] "On the balance of probabilities" - means that once both sides have presented their evidence the Court will find for the party who on the whole has a stronger case, for example the party whose evidence tips the balance of probability, however slight the edge may be.

An application for enforcement order is made on notice to the person against whom the orders are sought. The relevant sections of the Act are sections 314 to 319 and 321. A range of orders can be sought including requiring a person to take steps to comply with conditions of consent relating to odour. The applicant for enforcement order has to prove on the balance of probabilities that an enforcement order is required. In applying this standard of proof, regard must be had to the seriousness of the consequences of making an enforcement order. If there is cause for doubt the benefit should be given to those against whom orders are sought[74].

Franklin DC v Van Den Bogaart[75]

The Council sought enforcement orders under section 316 of the Act against the respondents requiring that: they cease poultry farming within seven days; remove the manure and chickens from the land within 14 days; and that if they fail to do so the Council may comply with the order on their behalf. The Court found that, as a result of the persistent and flagrant failure to comply and poor farming practices generally, the poultry farming operation for four or five years had an adverse effect on the community, including the primary school across the road. The problem did not abate following the making of previous enforcement orders in 1995[76]. The odour emanating from the farming operation and the flies engendered by it were offensive and objectionable.

The Court considered evidence from a number of residents of the community whose lifestyles were severely restricted by the adverse effects of the odour and flies. With respect to the effects on the Buckland Primary School, situated across the road from the poultry farm, evidence from the school board stated that during the worst times it was difficult for the children to eat their lunch or use the playground, while classrooms were invaded by clouds of flies during the warmer months.

Noting the blatant and deliberate refusal to comply with the earlier enforcement orders, the Court saw no justifiable alternative but to make the orders sought by the Council. The respondents were ordered to cease the poultry farming operation and remove the manure and chickens within 14 days.

Prosecution

Prosecution is the highest level enforcement mechanism available under the Act. The maximum penalty is two years imprisonment and the maximum fine is $200,000. The principal purposes of prosecution are to punish the offender and deter. The standard of proof is beyond reasonable doubt. There have been a number of successful prosecutions for discharge of contaminants to air in

[74] *Hall v Port Otago Ltd* C48/96

[75] (PT) A21A/96

[76] [1994] NZRMA 324 (PT)

contravention of section 15(1)(c) of the Act. In the majority of these prosecutions the defendants have pleaded guilty and in a number, the defendant has provided data to the Council (as required by conditions of its resource consent), which has provided evidence for the prosecution.

In *Bay of Plenty RC v Tasman Pulp and Paper Co Ltd*[77], Tasman pleaded guilty for four charges of discharging reduced sulphur compounds in excess of the emission limits allowable under its resource consents for its Kawerau mill complex. Tasman was ordered to pay fines of $23,000 and agreed to pay Council costs of $17,200. It was contended that the emissions were not a health risk, only a smell and that there is some natural sulphur activity in the Kawerau area. Judge Bollard commented in sentencing Tasman that:

> *"I have reflected upon the "no health risk/only a smell contention", and am of the view that the repetitive nature of the offences, and consequent public nuisance factor, cannot be treated lightly. The public attitude to an artificially created ill-smelling effect by an industrial concern such as this is rather different from that towards one naturally occurring, say at Rotorua. Given the fact that, apart from the emissions earlier mentioned, two others were over eight times the permitted limit and another over six times, I cannot regard the offences as minor infringements only."*

In *Auckland RC v Nuplex Industries Ltd*[78], Nuplex Industries pleaded guilty to two charges for breach of section 15(1)(c), discharging contaminants into air from its factory at Penrose at which it manufactures synthetic resins and emulsions.

Nuplex had initially pleaded not guilty and the Court heard evidence from Mt Wellington residents that established that they suffered from odour problems as a result of the discharge from the Nuplex factory. One of the factors considered by the Court when sentencing Nuplex was the nature of the environment affected. The Court found that the nature of the environment affected could be divided into the immediate Penrose Industrial Area and the more distant Mt Wellington Residential Area. The Court accepted that the Nuplex factory is situated in the heart of the Penrose Industrial Area and industrial odours of various kinds are permanent feature of that area and that what constitutes unacceptable air quality standards in that area should be gauged by reference to that environment. The Court found that the more distant Mt Wellington Residential Area is however quite different and that those living in a residential area are entitled to be protected from unpleasant industrial odours.

[77] 26/2/1994, Judge Bollard, District Court Tauranga, CRN 3087008507-10

[78] 13/11/98, Judge Whiting, District Court Auckland, CRN 7004021704 & 7004021706

APPENDIX 3: Odour Survey Protocol

QUESTIONNAIRE FOR ENVIRONMENTAL SURVEY

PLEASE NOTE THAT FOR MOST OF THE QUESTIONS YOU ONLY ENTER THE CODES

Introduction

READ "Good evening, my name is <name> from <company>, an independent environmental research company. We are currently carrying out research looking at environmental issues in your bcal community. Could I please speak to a person in your household who is over 18 years old, and whose birthday it is next?"

ONCE CONTACT IS ESTABLISHED REINTRODUCE SELF IF NECESSARY AND READ…

"The survey only takes five minutes to complete and all your responses will remain totally confidential. Would now be a convenient time, or may I call back later?"

IF YES, CONTINUE.

IF NO, MAKE TIME TO CALL BACK, AND NOTE ON SUMMARY SHEET.

IF REFUSED, THANK AND CLOSE, AND NOTE ON SUMMARY SHEET.

IF ASKED WHO THE SURVEY IS FOR, READ …" We need to keep the research as objective as possible, so I can't tell you that straight away. However, I promise that I will tell you at the end of the questionnaire."

IF REFUSED, THANK AND CLOSE, AND NOTE ON SUMMARY SHEET

IF AGREE, CONTINUE (NOTE ON SUMMARY SHEET).

1. What do you consider to be the main environmental issues facing your local community at present, if any? By environmental issues I mean things that affect the physical environment like water quality and pollution, **DO NOT READ LIST, CODE ALL MENTIONS**

    1. Air pollution
    2. Noise
    3. Water pollution
    4. Drinking water quality
    5. Sprays / pesticides / herbicides etc.
    6. Motor vehicle emissions
    7. Other (specify)
    8. Don't know **GO TO Q2**
    9. None **GO TO Q2**

1b Of the issues you have mentioned, which do you feel is the most important to your community? **DO NOT READ LIST, CODE ONE ONLY**

    1. Air pollution (general)
    2. Air pollution from industry
    3. Noise (general)
    4. Noise from industry
    5. Water pollution (general)
    6. Water pollution from industry
    7. Drinking water quality
    8. Sprays / pesticides / herbicides etc.
    9. Motor vehicle emissions
    10. Other (specify)

2. During spring, do you suffer any effects from plant pollen such as hayfever or allergies?

    1. Yes **(CONTINUE)**

2. No **(GO TO Q3)**
3. Refused **(GO TO Q3)**

2b. How much of a problem is this for you? **READ AND ROTATE ORDER**

1. Not very serious
2. Somewhat serious
3. Very serious

2c. Does this problem require you to take any forms of medication?

1. Yes
2. No
3. Sometimes

3. How often do you notice noise from any local industries? **READ AND ROTATE ORDER**

1. All the time **(CONTINUE)**
2. Often
3. Sometimes
4. Seldom
5. Never **(GO TO Q4)**

3b. To what degree does this noise annoy you? You might want to write this scale down. Do you find this noise …. **READ SCALE AND ROTATE ORDER**

1. Definitely not annoying
2. Very little annoyance
3. Little annoyance
4. Some annoyance
5. Annoying
6. Quite annoying
7. Very annoying
8. Extremely annoying

3c. What is the most common source of this noise? **[DO NOT READ OUT]**

1. Industry
2. Parties
3. Traffic
4. Other (specify)

4. How often do you notice an odour or smell from industry in or around your home? **READ AND ROTATE ORDER**

1. All the time **(CONTINUE)**
2. Often
3. Sometimes
4. Seldom
5. Never **(GO TO Q5)**

4b. To what degree does this odour annoy you? Do you find this odour is … **READ SCALE AND ROTATE ORDER**

1. Definitely not annoying
2. Very little annoyance
3. Little annoyance
4. Some annoyance
5. Annoying
6. Quite annoying
7. Very annoying
8. Extremely annoying

4c. What do you think is the most common cause of this odour? **[DO NOT READ OUT]** Add appropriate causes, e.g.:

1. Fertiliser factory
2. Sewer line
3. Traffic

4. Asphalt
5. Woolscour
6. Fish processing
7. Other **(Please write it down**

______________________________**)**

4d. Can you **describe** this odour? **[DO NOT READ OUT] A**dd appropriate descriptors, e.g. >

1. Do not know
2. Chemical/acidic
3. Sulphur/rotten eggs
4. Fertiliser
5. Oily
6. Fishy
7. Coal fire
8. Sewer
9. Other **(Please write it down**

______________________________**)**

4e. Can you **specify the plant** that causes this odour? **[DO NOT READ OUT]** List relevant local industries:

1. Do not know
2.
3.
4.
5.
6. Other **(Please write it down**

______________________________**)**

5. Finally, just a few short questions to finish. What is your occupation?

1. Legislation, administration, management
2. Professional
3. Technical
4. Clerical
5. Sales/service
6. Agriculture/fishery
7. Trade
8. Plant/machine operators
9. Elementary (unskilled)
10. Home maker
11. Unemployed
12. Retired
13. Study

6. How old are you?

1. 18–19
2. 20–24
3. 25–29
4. 30–34
5. 35–39
6. 40–44
7. 45–49
8. 50–54
9. 55–59
10. 60–64
11. 65–69

12. 70–74

13. 75–79

14. 80–84

15. 85+

7. Do you live on the <east> side of <relevant road or local landmark> or on the <west> side of <relevant road or local landmark>. **(Please write response)**

IF RESPONDENT REFUSES ASSURE THEM THAT THEIR PERSONAL DETAILS WILL NOT BE DIVULGED

8. Code gender

1. Male
2. Female

Thank you for your time. This research has been conducted on behalf of the <client>. If you have any queries you can contact <contact>, collect on <phone>. My name is <name>.

APPENDIX 4: Odour Diary Sheet

Name:	Location of observations:
Month:	

Date	Time (am or pm)	Odour event duration (hrs)	Continuity of the odour for this event				Character of odour	Likely source of odour	Strength of odour	Description of effect odour has on you	Wind direction	Wind strength
			Continuous	Most of the time	< 50% of the time	Intermittent						
			(tick one)	(tick one)	(tick one)	(tick one)						

APPENDIX 5: Olfactometry Repeatability Data

Table A5: Repeatability of panel thresholds for n-butanol, by number of rounds and number of panel members, for both certainty and detection criteria

Rounds[1]	Number of panel members							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
***Certainty criterion*[2]**								
1+2+3+4	3.72	2.21	2.12	2.33	2.21	2.20	2.03	**1.91**
2+3+4	4.01	2.36	2.17	2.28	2.18	2.14	2.04	**1.89**
1+2+3	5.28	2.69	2.40	2.39	2.25	2.17	**1.99**	**1.85**
2+3	7.78	3.55	2.55	2.25	2.04	**1.93**	**1.87**	**1.70**
1+2	5.40	3.07	2.91	2.75	2.46	2.43	2.18	2.09
2	16.48	5.34	3.82	3.13	2.69	2.65	2.40	2.15
1	5.42	3.79	3.17	3.77	3.44	3.54	3.08	2.93
***Detection criterion*[2]**								
1+2+3+4	5.34	3.07	2.41	2.69	2.24	2.03	**1.88**	**1.81**
2+3+4	4.73	3.3	2.73	2.80	2.38	2.20	**1.99**	**1.84**
1+2+3	7.34	3.84	2.90	3.00	2.47	2.06	**1.91**	**1.89**
2+3	7.30	4.30	3.12	2.95	2.53	2.16	2.03	**1.96**
1+2	9.96	5.37	4.13	4.07	3.01	2.25	2.06	2.01
2	14.76	6.81	5.12	4.56	3.52	2.75	2.31	1.97
1	24.18	11.22	6.00	5.62	3.82	3.17	2.81	2.82

Source: van Harreveld and Heeres (1995).

Notes:

1. Rounds = number of times sample is presented to each panellist:

“1+2+3+4” = 4 rounds presented, and results of all 4 rounds used to determine concentration

“2+3+4” = 4 rounds presented, but first round results discarded before determining concentration

“1+2+3” = 3 rounds presented, and results of all 3 rounds used to determine concentration

“2+3” = 3 rounds presented, but first round results discarded before determining concentration

“1+2” = 2 rounds presented, and results of both rounds used to determine concentration

“2” = 2 rounds presented, but first round results discarded before determining concentration

“1” = 1 round only presented.

2. Repeatabilities in bold are below the r’ value of 2.0 recommended in DR99306

APPENDIX 6: Katestone Scientific Research into Peak-to-Mean Ratios

Katestone Scientific (1998) provides an introduction to a method for predicting peak (few-second) odour intensities from hourly average dispersion model predictions. The report uses theoretical considerations, numerical simulation, statistical analysis, available field measurements, and the results of wind-tunnel experiments to propose peak-to-mean (P/M) ratios for 1-hour dispersion model results, with the ratios dependent on source type, the influence of building wakes, atmospheric stability, and distance away from the source.

The report defines the *peak concentration* as the maximum concentration that is exceeded no more than a specified percentage of time, and a 10^{-3} probability level for exceedance with a nasal response time of 0.1–1 seconds is adopted. The report assumes that temporary annoyance is likely to be caused if there is a significant number of events above the recognition/annoyance threshold in a given hour. The German definition of an 'odour hour', for example, requires six positive identifications in a 10-minute period of 60 (10-second) observation periods. The Katestone Scientific research uses such a definition of 'peak' concentration and expects that complaints are likely if such events occur on a significant number of occasions, such as during 44–176 hours per year (0.5%–2.0% of all hours in year).

Table A6 shows the P/M ratios recommended by Katestone Scientific (1998). These ratios apply to the plume centreline (directly downwind of the source). Applying the process to the kinds of complex situations that may occur in practice is made more difficult by off-axis variation of the P/M ratio (away from the plume centreline), and this is most important for multiple source evaluations. For some situations (for example, elevated receptors), the vertical distribution of P/M ratios is also required. This distribution will depend on the source type, and can be considerable. For most sources there is, as yet, little suitable information.

The current state of knowledge on multiple source effects is extremely limited and no general conclusions can be made, except that the P/M values are likely to be reduced compared to a single source.

Source definitions

The following definitions of source types in Table A6 has been taken from NSW EPA (2001). In practice, overall source configuration may be simply one of the following types, or a combination of different source structures and/or different pollutants.

- *Point source* emissions emanate from a very small volume, so detailed source structure is unimportant. Elevated point sources will be referred to as stack sources (see below). A point source requires fairly equal lateral dimensions that are very small compared to the distance to the nearest receptor.

- An *area source* has a more realistic two-dimensional structure, but only a limited vertical extent.

- A *line source* is a special case of a long, thin area source. In practice these sources are taken to be at ground level and thin. A line source becomes an area source if the breadth exceeds 20% of the length.

- A *volume source* is essentially a three-dimensional structure. Usually there are a sufficient number of emission points to consider a uniform emission rate over the full source structure.

- An elevated source is usually a *stack*. Stacks have relatively small horizontal dimensions and usually emit hot gases forcefully into the atmosphere at a fixed height above ground level. The term *'tall' stack* usually refers to stacks that protrude out of the surface boundary layer (over 30–50 m tall).

- *Wake-free stacks* are sufficiently high (2.5 times the largest nearby building) so that the stack-top air flow is not influenced by surrounding buildings. If nearby buildings can interfere with the trajectory and growth of the stack plume, the source is called a *wake-affected stack*. For stack heights up to 2.5 times the surrounding building heights, wake effects may be significant, depending on source characteristics. Such intermediate cases should be dealt with on an individual basis.

Table A6 Peak-to-Mean (P/M) ratios proposed by Katestone Scientific (1998)

Source type	Stability[1]	P/M ratio (to apply to 60-minute average)[2]	
		Near-field[3]	Far-field[4]
Area	N	2.5	2.3
	S	2.3	1.9
	C	2.5	2.3
Line	N	6	6
	S	6	6
	C	6	6
Surface point	N	25	5-7
	S	25	5-7
	C	12	3-4
Tall wake-free point	N	35	6
	S	35	6
	C	17	3
Wake-affected point	N/C	2.3	2.3
Volume	N/S/C	2.3	2.3

Notes:

1. N, S and C denote neutral, stable and convective (or unstable) atmospheric stabilities.

2. Default values are given for area and line sources in convective conditions; tall, wake-free point sources in stable conditions; wake-affected sources in convective conditions; and volume sources in all stabilities. These may be updated by Katestone Scientific as more information becomes available.

3. Near-field = region where source structure directly affects plume dispersion and structure (typically 10 times the largest source dimension, either height or width).

4. Far-field = region where plume rise and meandering have fully occurred and the plume is well-mixed in the vertical plane (from ground level to the base of the first temperature inversion).

APPENDIX 7: Examples of Performance Standards in Odour Resource Consents

Some examples of performance standards used as conditions in odour consents in New Zealand are listed below.

- The odour emission from the stack shall not exceed 7000 OU/s [method and frequency of odour monitoring also specified].
- The consent holder shall ensure that the biofilter bed's moisture content is kept between 30% and 60% at all times.
- The biofilter moisture content shall be maintained between 40% and 60% based on weight, and the pH between 6.5 to 8.5.
- The emission rate of ammonia shall not exceed 0.9 g/s.
- Requirements for stack height and exit velocity.
- Offal age, quality and preservation requirements for rendering facilities.
- The total odour emission rate from the compost operation shall not exceed 120,000 OU/s.
- The deodorised gas discharge [from a chemical scrubber] shall contain no more than 0.01 ppm hydrogen sulphide and no more than 0.05 ppm total reduced sulphur compounds, including hydrogen sulphide [testing and reporting requirements also given].
- Without limiting the generality of condition [X] [no offensive or objectionable odour], the biofilter shall be maintained and operated according to the following criteria:
  - The air flow rate through the biofilter is to be maintained at design rates unless maintenance is being carried out on the biofilter or the pump station itself.
  - The moisture content of the filter media is to be maintained between 40 and 60% water by weight.
  - The pH of the top half of the filter bed is to be maintained between 6 and 8.
  - The temperature of the biofilter is to be maintained between 10 and 35°C.
  - The back-pressure of the filter system is to be maintained in the 1–2 kPa range.

- All biofilters shall be designed, operated and maintained to comply with the following criteria:
  - The biofilter shall be designed to achieve minimum theoretical residence time specified in the Operations Management Plan.
  - The distribution system shall be designed to ensure that gases are evenly dispersed throughout the filter bed.
  - The sides of the filter bed shall be designed and constructed to ensure that untreated process gases cannot bypass the filter media.
  - The moisture content and pH of the filter media shall be tested and maintained in accordance with the provisions in the Operations Management Plan.
  - The beds shall be designed so that at least one half of the bed can be isolated from the incoming gas flow for maintenance purposes.
- The air pollution control equipment selected for the sludge treatment complex shall be able to achieve a reduction in odour of greater than 95% as determined by dynamic dilution olfactometry, and shall be sufficient to ensure compliance with the provisions of Special Condition [X] ['no offensive or objectionable odour']. The design shall be subject to the approval of the [regional council] Group Manager prior to installation.
- All extracted landfill gas shall be combusted in a flare having the following minimum specifications:
  - flame arrester and backflow prevention devices, or similar equivalent system
  - continuous automatic ignition system
  - automatic isolation systems to ensure there is no discharge of unburnt landfill gas from the flare in the event of flame loss
  - minimum temperature of 750°C and retention time of 0.5 seconds …

APPENDIX 8: Example of Management Plan Table of Contents

1. **Title and purpose of plan**
   - define the adverse effect being controlled, company name and site location

2. **Key personnel and contact addresses/numbers**
   - company general manager
   - site manager
   - staff responsible for implementing the management system

3. **Process description and method of operation**
   - a general description of the activity
   - a description of the main potential sources of odour emission

4. **Methods of mitigation and operating procedures**
   - a full description of the odour mitigation system
   - relevant operating procedures and parameters that minimise emissions
   - an inventory of mitigation equipment and materials
   - equipment maintenance programmes
   - contingency procedures, abnormal operating alarms

5. **Monitoring**
   - environmental log maintenance and content
   - weather-monitoring system
   - odour complaint recording procedure
   - council investigation reports

6. **Staff training**
   - methods
   - frequency
   - training records.

7. System review and reporting procedures

- the process for reviewing the overall system performance
- the frequency of reports to council regarding complaint frequencies, site upgrades, etc.
- external audits and ISO certification (optional)

d level to the

Glossary

Acute odour effect	The effect due to short-term exposure to odours that are sufficiently intense to cause adverse effects.
Area source	A source of odour emission with a large surface area, such as a land-fill surface, a pile of solid material, or a waste-water treatment pond.
Annoyance	(1) When used in relation to an odour's character or pleasantness, annoyance is akin to the hedonic rating of an odour's pleasantness (e.g. it has been common practice for some olfactometers in Australasia to establish the concentration (OU/m^3) at which a specific odour is rated as annoying by a calibrated panel). (2) When used in conjunction with population annoyance surveys, it is a function of the attitude and feelings of the community towards a source (or sources) of ongoing odour impacts (see *Population annoyance*).
Annoyance threshold	The concentration (OU/m^3) at which a specific odour is considered to be annoying to calibrated panel members or to a community.
Back-calculation	Calculation of an equivalent odour emission rate from a defined source of odour by measuring an actual downwind concentration (OU/m^3) and then using a dispersion model to establish the necessary emission rate to achieve that result.
Best practical option (BPO)	Defined by the Resource Management Act 1991 as the best method for minimising the discharge of contaminants when taking into account: ▪ the nature of the discharge and receiving environment ▪ the financial implications ▪ current state of technical knowledge and likelihood that the option will be successful.

Calibrated panellist	A member of an olfactometer panel whose detection thresholds to n-butanol comply with the mean and variability requirements for conducting olfactometry experiments as per the draft of either the European or Australian/NZ standard for odour measurements.
Case study	The documentation of any specific investigation into the reported extent of odour effects compared to the predicted odour concentration exposures from an industrial odour source (or sources). This should include a full description of the emissions measurement and dispersion-modelling approach to an extent that provides sufficient transparency for an independent assessment of the case study conclusions.
Cavity region	Region on the lee-side (downwind side) of building structures where the wind direction reverses to form an eddy (also called a back rotor). It can include the locations downwind of structures or raised terrain where the air turbulence is significantly enhanced by the obstruction of the wind flow.
Certainty threshold	The concentration of a odorant at which it can be reliably detected by a calibrated olfactometer panel when at their group mean sensitivity, with the provision that the panellists are certain they can detect the odorant. Often (but not always) this equates to the concentration where only 50% of the calibrated panel can reliably detect the odorant while expressing certainty.
Calibrated noses	Individuals whose ability to detect n-butanol via their sense of smell lies within the limits necessary to allow then to be used as panellists for olfactometric measurements, as defined by the draft Australian–New Zealand standard DR99306. This means having a certainty threshold for n-butanol between 20 and 80 parts ppb, and whose variation with time lies within limits specified by the standard.
Chronic odour effects	The annoyance or psychological stresses caused by recurring odour impacts on neighbours of an industrial site or trade premise.
Detection threshold	The concentration of an odorant at which it can be reliably detected by a calibrated olfactometer panel when at their group mean sensitivity. Often (but not always) this equates to the concentration where 50% of the calibrated panel can reliably detect the odorant.
Dynamic dilution olfactometry (DDO)	The general procedure used to establish the relative odour concentration of a gas sample. The method establishes the extent of clean air dilution required to reduce the odour strength to a level that is at the threshold of detection for a calibrated

	panel. The sampling of the raw gas, dilution and presentation to the panel is undertaken in a continuous manner. The back-calculated concentration of the undiluted gas sample (OU/m^3) represents the number of dilutions with odour-free air required to reduce the odour of the gas down to the detection threshold. This concentration is also called the dilution to threshold concentration. There is currently a draft standard (Australian–New Zealand standard DR99306) for undertaking this procedure
Electronic nose	An electronic device that uses an array of solid-state sensors, or synthesised protein sensors, that respond to the presence of different chemical compounds. The resulting electronic signals are processed using neural network computing techniques to help produce a two-dimensional spectral pattern that is specific to a particular mix of chemical compounds. The aim is to create different spectral patterns that can identify/fingerprint specific types of odour character.
Fugitive source	Any type of odour emission that cannot be readily quantified or defined. This usually refers to such sources as leaks in pipes, flanges, pump seals or structures, openings in buildings, floor spills, occasional sources such as uncovered truck loads or releases from pressure relief valves, and leaks in seals on covered tanks.
Hedonic rating	The rating of odour pleasantness/unpleasantness, or the degree of annoyance it causes, on a simple numeric scale (typically 1 to 5) by individuals.
Neutral gas	Air or nitrogen treated in such a way that it is odourless, and which, according to panel members, does not interfere with the odour under investigation.
Odour annoyance survey	Standard survey method used to quantify the extent of population annoyance in different sectors of a community as a result of industrial odour impacts.
Odour concentration	The number of odour units in one cubic metre of gas at standard conditions. Note: odour concentration has a non-linear relationship with odour intensity.
Odour detection	To become aware of the sensation (smell) resulting from stimulation of the olfactometry system.
Odour diary	The systematic recording by individuals of odour events over a period of time at a defined location (normally a residential dwelling), including the date, time, duration, character, strength and weather conditions associated with each odour event.

Odour dose-response	The relationship derived between population annoyance and predicted odour impact concentrations, where the former is quantified via an odour annoyance survey and the latter is determined using odour emission measurement and modelling techniques.
Odour emission	The number of odour units per second discharged from a specific source.
Odour intensity	The perceived strength of an odour as rated by individuals against a numerical scale, such as that contained in the German Standard VDI 3882 Odour Intensity Scale.
Odour unit (OU)	The amount of odorant(s) that, when evaporated into one cubic metre (m^3) of neutral gas at standards conditions, elicits a physiological response from a calibrated panel (detection threshold) equivalent to that elicited by one reference odour mass (ROM), evaporated in 1 cubic metre of neutral gas at standards conditions.
Olfactometer	Apparatus in which a sample of odorous gas is diluted with a neutral gas in a defined ratio and then simultaneously presented to people for sniffing.
Percent at-least annoyed	The percentage of individuals within various sub-sections of the odour survey area that reported to the categories 'annoyed', 'very annoyed' or 'extremely annoyed' when asked to rate their level of annoyance from odour impacts.
Population annoyance	A measure of the percentage of people in a community who consider themselves to be 'annoyed' or even more adversely affected by the impacts of industrial odours in their community (percentage at-least annoyed). Note: the evaluation of survey responses can only be undertaken by comparing results to those obtained for control populations.
Recognition threshold	The concentration at which the character and hedonic tone of an odour are recognisable.
Reference odour mass	The ROM is equivalent to 123 µg of n-butanol evaporated in one cubic metre of neutral gas.
SOER	The surface odour emission rate per unit area of surface, which has units of odour per unit area per time (e.g. OU/m^2s or OU/m^2h).
Static flux hood	An odour-sampling hood that is placed over an area source and which has a low flow-rate of neutral gas injected to allow a mixed air stream to be expelled from the hood. These devices work on the same principle as wind-tunnel sampling hoods,

except that air within the static hood exhibits minimal turbulence.

Tall stack	For this report, a stack is tall when it is of an effective height to allow its discharged contaminants to disperse into the atmosphere as an elevated plume which is not substantially affected by the wake effects of surrounding building structures. This typically means that peak ground-level impacts occur during semi to unstable atmospheric conditions and at locations that are well beyond the stack and site building structures. Note: effective stack heights account for the site-specific effects of discharge momentum and thermal buoyancy.
Volume source	A source of odour emission such as a building structure from which odour diffuses from many different points.
Wind tunnel	Odour-sampling wind tunnels are generally elongated hoods that are placed on to an areal odour source and have a flow-rate of neutral gas passed through in a plug-flow manner (i.e. the gas enters one end of the hood and sweeps through to the outlet end, where it is expelled for sampling). These devices generate substantially more turbulence within the hood due to the greater airflows per unit area involved.