Guidelines
for
Community Odour Assessment

by
Carolyn Blackford, Glen Greer and Jim Young

Department of Resource Management/Lincoln Environmental
Lincoln University

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1 Introduction

This project has been partially funded under the Ministry for the Environment's Sustainable Management Fund and contributes towards maintaining air quality in New Zealand. The management of effects of odour-producing activities has been limited to some degree by the fact that firm guidelines for gathering complaints had not been developed and that the international air quality regulatory community appeared to have been slow to develop standardised procedures for carrying out odour surveys and for determining overall community response to actual or perceived odour problems. In other words, there has been a need for procedures with which to collect subjective information using recognised objective approaches.

The purpose of this document is to provide guidance on a range of standardised techniques that can be used to establish when community odour problems exist and the magnitude of the problem. The guidelines focus on sociological and associated methods of community odour assessment and provide means by which local authority officers or the operators of odour-producing facilities can investigate whether facilities are causing adverse effects (in terms of the Resource Management Act 1991 (RMA)) or nuisance or offensiveness (in terms of the Health Act 1956).

The odour assessment techniques proposed were identified through consultation with the tangata whenua and the National Air Quality Working Group, a review of the relevant international literature, a survey of local authority staff and interviews with people in communities where odour is a problem.

Guidelines are provided for:

- community surveys (questioning on one occasion);
- odour diaries;
- community odour panels (questioning on several occasions);
- public meetings;
- working parties;
- consultation with the tangata whenua; and
- community consultation.

We have assumed two broad situations in which the techniques might be used. One is for internal monitoring purposes where the organisation does not intend to use the data collected in legal proceedings. In this instance the guidelines can serve as a guide to good practice. The second situation where information could be or is expected to be presented as evidence in legal proceedings. In this latter instance it is important that a recognised expert in question and sample design and data analysis be engaged to ensure that the evidence meets the requirements for admissibility.

2 Procedures for Gathering Odour Complaints

One question facing odour regulators is whether or not odour complaints provide a good indication of annoyance in the community. Complaints may be considered as good indicators of sudden instances of odour pollution such as industrial accidents, but they are poor indicators of the general level of satisfaction of the population. In other words they represent one of a number of means of providing an indication if there is a community problem with odour. Suggestions are given on information to be gathered that could also be used to complement data derived using any of the other techniques discussed below.

The guidelines on gathering odour complaints have been drawn in large part from the complaints procedures developed by the State of New Jersey's Department of Environmental Protection to investigate whether their regulation prohibiting air pollution has been or is being violated. These procedures are similar in many ways to those used by local authorities in New Zealand and the regulation is not dissimilar to requirements controlling discharges to air under the RMA and the Health Act.

3 Community Odour Assessment Techniques

For each technique we have suggested instances in which they could be used as well as examples of possible costs of using each technique.

We have included a brief section on Council staff and the range of roles they may have in odour management. The following techniques can assist them in carrying out those roles.

The word 'survey' can have different meanings for different people in different situations. In these guidelines we use the expression 'community survey' to mean the systematic gathering of quantitative data by way of 'questioning on one occasion'. A representative sample of people is chosen, they are all questioned on one occasion over a period of say one week or more, depending on the size of the survey, and their responses are collated and analysed at the end of that period. This kind of survey could be repeated on a subsequent occasion, say in a year or two, to see whether people's perceptions of odour have changed, for example.

The results of a community survey can give a gradation of annoyance/offensiveness measurement, provide information on the cumulative experience of the community over a period of time, as well as collecting data on the effects of annoyance/offence if that is required.

The method does not enable coverage of individual odour events in the way that the use of odour panels (or odour diaries) do and is therefore not suitable for describing real variations in annoyance/offence over time. On the other hand it is suitable for measuring the cumulated sensation or experience of offensiveness over time.

Guidelines for personal interviews, telephone surveys and postal questionnaires appear in the same section because basically they are different methods of systematically collecting data.

Issues relating to survey management, questionnaire development, sample design, and data analysis are provided.

The RMA permits the Environment Court to receive or call for anything in evidence to assist it in its deliberations. Market surveys have been admissible as evidence for some time and existing case law provides guidance as to whether (a) a survey may be admissible and (b) if it is, what weight could or should be put on that evidence. The guidelines provide a discussion of this case law.

'Odour diaries' (sometimes referred to as 'odour surveys'), and 'panel surveys' or 'odour panels' differ from what we refer to as 'community surveys' in that data is gathered from the same sample or group of people through 'questioning on several occasions'. They may be instructed to record information every day, every time they detect an odour, or every time they experience an 'offensive or objectionable' odour over a specified period although their responses are likely to be submitted to the person organising the exercise on a frequent basis.

This technique broadly involves people living in the vicinity of a suspected, known, or potential odour source keeping a record of odour occurrences (and sometimes non-occurrences). In addition to the FIDO factors (frequency, intensity, duration and offensiveness), diarists may be asked to record the time, date, prevailing weather conditions and suspected source.

We found no written information formally or scientifically describing diaries as odour assessment techniques during the course of developing these guidelines. The odour diary technique as it is used in New Zealand appears to embody components of other odour assessment techniques such as community odour panels, trained independent observers/field inspections, and odour community surveys. The guidelines are based on the authors' interpretation of similarities and differences of odour diaries with these other techniques, and with information gathered during interviews with selected local authority staff who had used odour diaries.

There are several different types of odour panel with each type being used to achieve particular objectives. These include:

- small panels of volunteers who are invited to have their noses calibrated and to assess odour concentrations through the use of an olfactometer;

- field inspection panels where carefully selected observers are trained to assess odours in ambient air 'in the field' at regular intervals to determine whether odours are discernible (and if so, the type and intensity);

- a sample of neighbours (and possibly out-of district panellists) on the down-wind side of an activity assess whether the size of a proposed buffer zone is sufficient to accommodate adverse effects of odour;

- relatively large panels of randomly-selected volunteers who indicate at regular intervals (generally once weekly) from their own homes whether they detect and are annoyed or offended by odour.

These guidelines focus on the last type mentioned. This approach involves the panellists standing outside their home at a specified time and on a specified day and checking for odour. They then complete a specially designed postcard which they return immediately to the organisation carrying out the exercise.

The term 'public meeting' is self-explanatory and implies meetings that are called for a particular purpose that are open to any interested person.

A Working Party is a group that is set up generally as a problem-solving entity with a specific task or tasks in mind. It may act as the driving force behind various techniques that are used to investigate issues.

The observations on consultation with the tangata whenua came from representatives of groups that have been involved in odour issues.

A range of approaches can be used when consulting the community. One approach (Meek, 1993) termed the **'LUCAT'** approach emphasises *'listening', 'understanding', 'credibility' and 'trust'*. It is based on seven principles of good consultation. These principles are also relevant to the other techniques that are presented in this document.

TECHNICAL TERMS

Assessment area — An area defined for measuring and assessing odorant emissions. The area is defined according to the objectives of the investigation. For measurement purposes, the area is covered by a grid of equidistant measurement points.

Assessment square — The grid measurement points are taken as assessment squares to show how the measurement results vary from place to place within the assessment area.

Bias — The difference, averaged over many samples, between the sample estimate and the true population value.

Cluster sampling — Items in the sampling frame are put into groups, so that the groups are as similar as possible. Groups often correspond to geographic areas. Some of the groups are then sampled. Typically this is not a very efficient method of sampling, but because all those in the sample live in just a few geographic areas, the costs of interviewing are lower than other methods.

Confidence interval — The range of values within which the true population value lies for a certain (high) percentage of all possible samples.

Control zone — A zone that is selected outside the environmental load area having comparable type and density of buildings but without any air quality load due to other odour emitters.

Correlation — A statistic that measures the association between two variable. A correlation has the following properties: (1) a positive correlation implies that as one variable increases, the other variable also increases; (2) a negative correlation implies that as one variable increases, the other decreases; (3) a correlation can take values from -1 to 1, and a value close to zero implies that there is little association between the two variables.

Definitive survey — A council or odour producer seeks information for legal purposes - as part of the resource consent process, or when enforcement orders or abatement notices are called into question.

Detection threshold — The concentration of odour substance in which 50% of cases exposed to the stimulus can smell something.

Efficiency — An unbiased estimate is more efficient than another if, for a given sample size, it has the smaller variance.

Estimation	Calculating the properties of the population from the properties of a sample.
Grid point (measurement point)	The grid points are the corners of the assessment squares and are the points at which emission measurements are performed.
Immission or environmental load area	The reach of impact from a source of emissions being considered.
Indicative survey	A council or odour producer seeks information for its own internal use - do a few complaints represent a wider problem; how to better manage odour? There is no intention to use this information for legal purposes (see 'Definitive survey').
Inference	The process of drawing conclusions about a population of interest from a sample taken from that population.
Investigation area	The area (within the immission area) covered by the investigation.
Investigation zone	That part of the investigation area in which a sufficiently homogeneous emission load from one or more sources can be assumed.
Measure of association	A statistic that measures in some way the tendency of particular values of two variables to occur together in sample data. A correlation is an example of a measure of association.
Population of interest	The group of people whose opinions you want to record. A formal definition will most likely include statements about the area in which these people live or work, and a time period during which these people may have found odour offensive.
Precision	Precision is the variability of an estimate about an average value if you were to repeatedly sampled the population - if the estimate isn't biased, then this average value will be the true value for the population.
Recognition threshold	The concentration of odour substance in which 50% of cases exposed to the stimulus results in identification ('I can smell *x*').
Sample design	The statistical aspects of running a survey - developing a sampling frame, selecting the sample, estimation, adjusting estimates to compensate for non-response.
Sampling frame	A list of all those items in the population that are, for practical reasons, available for selection.

Simple random sampling	A method of selecting a sample. Each item in the sampling frame has the same probability of ending up in the sample. Often abbreviated to SRS.
Stratified sampling	Items in the sampling frame are put in groups, so that items in each group are as similar as possible, and the groups differ as much as possible. A simple random sample is then taken from each group. This has the potential to be a very efficient method of sampling.
Variance	The variance of an estimate is a measure of how precise the estimate is.
With replacement sampling	An item is selected for the sample from the sampling frame, and then returned to the sampling frame before the next item is selected.

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1 INTRODUCTION

1.1 Scope and Purpose of the Guidelines

This project has been partially funded under the Ministry for the Environment's Sustainable Management Fund and contributes towards maintaining air quality in New Zealand. The management of effects of odour-producing activities has been limited to some degree by the fact that firm guidelines for gathering complaints had not been developed and that the international air quality regulatory community appeared to have been slow to develop standardised procedures for carrying out odour surveys and for determining overall community response to actual or perceived odour problems. In other words, there has been a need for procedures with which to collect subjective information using recognised objective approaches.

The overall purpose of this study (Lincoln Environmental, 1997) has been:

- to develop guidelines for gathering odour complaints;
- to assess various techniques that can be used to establish whether a community odour problem exists; and
- to provide detailed guidelines on how to use a range of appropriate techniques (including odour surveys).

The purpose of this document is to provide guidance on a range of standardised techniques that can be used to establish when community odour problems exist and the magnitude of the problem. These guidelines focus on sociological and associated methods of community odour assessment. They provide means by which local authority officers or companies can investigate whether facilities are causing adverse effects (in terms of section 17 of the Resource Management Act) and .... nuisance or offensiveness ..... (in terms of section 23 of the Health Act). Use of the techniques described in this report provides the opportunity for 'ordinary people' to express a view. They provide ways by which the perception of the 'ordinary person' can be captured through systematic and rigorous approaches.

The odour assessment techniques proposed were identified through consultation with the tangata whenua and the National Air Quality Working Group, a review of the international literature, a survey of local authority staff and interviews with people in communities where odour is a problem. Guidelines are provided for:

- community surveys (questioning on one occasion);
- odour diaries;
- working parties;
- community odour panels (questioning on a number of occasions);
- public meetings;
- consultation with the tangata whenua; and
- community consultation advice that can be utilised in a range of situations.

The techniques described can be for internal use such as monitoring by an odour-producing facility operator or for gathering information that could eventually be presented in legal proceedings. The guidelines are intended to provide a framework for good practice when investigating the community's perceptions and experiences of odour.

1.2 Legislative Context

The Ministry for the Environment's paper (1995) *Odour Management under the Resource Management Act* (1995, pp15-20) provides a broad overview of legislation that relates to the control of air pollution. Prior to the Resource Management Act (RMA) the Clean Air Act of 1972 was the core air pollution control statue. Transitional provisions for scheduled activities under the Clean Air Act 1972 (repealed by the RMA in 1991) were carried over until October 1996. The RMA 1991 and the Health Act 1956 are now the major statues of air pollution control in New Zealand.

The RMA 1991 has as a major focus the controlling of the 'effects' of activities rather than activities per se. Section 5(2) of the RMA states that "...'sustainable management' means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well being and for their health and safety while ..... Avoiding, remedying, or mitigating any **adverse effects** of activities on the environment".

The 'environment' is defined (in Section 2) as including:

> *"(a) Ecosystems and their constituent parts, including people and communities; and*
> *(b) All natural and physical resources; and*
> *(c) Amenity values; and*
> *(d) The social, economic, aesthetic, and cultural conditions which affect the matters stated in paragraphs (c) to (c) of this definition or which are affected by those matters:"*

'Amenity values' are defined (Section 2) as:

> *"those natural or physical qualities and characteristics of an area that contribute to people's appreciation of its pleasantness, aesthetic coherence, and cultural and recreational attributes".*

The meaning of 'effect' has been specifically set out in section 3 of the RMA. It can be argued that this section does not prescribe or define what the word effect actually means, but it does provide an indication of the broad range of effects that the term includes. These are:

> *"(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."*

Sections 7(c), (d), (f) and 8 of the RMA are also of particular relevance to odour management.

> *"7 **Other matters ....***
> *(c) The maintenance and enhancement of amenity values:*
> *(d) Intrinsic values of ecosystems: ....*
> *(f) Maintenance and enhancement of the quality of the environment: ....*
>
> ***8 Treaty of Waitangi ....***
> *....shall take into account the principles of the Treaty of Waitangi (Te Tiriti o Waitangi)."*

The management of odour under the RMA is facilitated through the development of national policy statements, regional policy statements and air quality plans, and in the resource consent process (where a company or local authority is proposing to establish a plant or plans to expand or modify an existing plant and conditions need to be placed on a consent, when a consent is to be renewed, or conditions reviewed).

The Health Act 1956 (section 23) also empowers local authorities to investigate conditions likely to be injurious to health of offensive. Section 29 of this Act contains 'nuisance' and 'offensive trade' provisions which, although making no specific references to odour, are "wide enough to cover odour where it is offensive or likely to be injurious to health" (Ministry for the Environment, 1995, p15). The Health Nuisance notice requires immediate abatement and has provision for an authority to take action and to recover costs from the discharger.

It should be noted that an offence under the Health Act is independent of a Regional or District Plan or Proposed Plan. Even though an activity might be permitted under a Plan, it may still be an offence under the Health Act (McLaren, 1996, pers. comm.[1]).

Section 276(1) of the RMA permits the Environment Court to:

> *"(a) Receive anything in evidence that it considers appropriate to receive; and*
> *(b) Call for anything to be provided in evidence which it considers will assist it to make a decision or recommendation; and*
> *(c) Call before it a person to give evidence who, in its opinion, will assist it in making a decision or recommendation".*

> *"Pursuant to the RMA guidelines have no legal status in that they are not part of the framework allowed by the Act ..... Guidelines are merely indicators as to a way of conducting procedures and the Court will consider guidelines as just one factor in addressing whether evidence should be admitted and whether weight should be placed upon that evidence"* (Somerville, 1997, pp5-6).

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1 McLaren, S, Ministry of Health.

Although the Environment Court (RMA, section 276(2)) *"is not bound by the rules of law about evidence that apply to judicial proceedings"* experience has shown that:

> *"... the Environment Court does generally test evidence by considering the principles of evidentiary law to determine whether or not reliance can be placed on any material."* (Somerville, 1997, p6).

If there is any likelihood that information obtained through the use of these techniques might be used in legal proceedings, then you should employ the services of an expert to design your survey, community odour panel, or odour diary and to carry out the necessary statistical analyses. The guidelines will help you to understand what your expert is doing. If you plan to use the material for internal purposes within your organisation, the design and analysis could be done 'in house', although you may wish to pay for some professional peer review.

1.3 Odour Nuisance

Odour nuisance is a significant environmental issue in New Zealand, one that results in numerous complaints to regulatory authorities.

Those involved in odour management face the multiple challenges of determining the source of an odour, the potential and actual adverse effects of that odour on the community, the extent of those effects, and trying to develop emission standards that aim to avoid, remedy or mitigate the adverse effects of odour emissions. They have the option of issuing enforcement orders or abatement notices if an activity 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"* (RMA 1991, s.17(3)(a)). Provisions such as no '*discernible*' or '*objectionable*' odour beyond the boundary, for example, are now appearing in air plans and resource consent conditions.

> *"The evaluation of odour pollution problems can be based on chemical-analytical, psychophysical [including olfactometry] or sociological methods. However, results from each of these methods give information only on some part of the problem."* (van Langenhove *et al.*, 1988, p2509).

An underlying premise of these guidelines is that the people affected by offensive or objectionable odours are the best source of information on the offensiveness and objectionable character of those odours. The use of sociological and associated methods are therefore the most appropriate to use in evaluating this aspect of the odour 'problem'.

> *"Whether an odour is judged to be annoying, depends mainly on its character and on the expectation of the human perceiver about its occurrence in a certain context. Only when unacceptable smells are concerned, odour concentration starts playing a role in the amount of annoyance experienced, but even there the relationship is not always simple. A smell which at low concentrations is judged acceptable and even slightly pleasant in a given context (e.g. manure in the countryside), can all of a sudden become annoying at higher concentrations."* (Punter *et al.*, source unknown, p151).

The perception of odour effects is subjective in nature *"..... but are effects to be taken as effects perceived by the general community and people or one or two particularly sensitive people?"* (Hearn, 1994, p6). The Planning Tribunal (now Environment Court) has proposed that:

> *"The correct test, I am satisfied, is whether or not the ordinary person, neither hypersensitive nor insensitive, would find the extraneous thing to be ...."* (*Zdrahal v Wellington City Council* referred to in Ministry for the Environment, 1995, p18)

These guidelines provide means by which the perceptions and experiences of "the ordinary person" can be assessed.

2 GUIDELINES FOR GATHERING ODOUR COMPLAINTS

2.1 Limitations of Odour Complaints Records

"Approximately half of all air pollution complaints in Western society involve odor" (Porteus cited in Tapper and Sudbury, 1991, p433) despite the fact that very few people register formal complaints with regard to odour problems. Generally the number of different complainants is less than 15% of the number of documented residences (USEPA cited in Jones, 1994, p2).

One of the questions facing odour regulators is whether odour complaints provide a good indication of annoyance in the community. Köster *et al.* (1984, pp3-4) present a number of reservations:

> *"1. Complaints are ungraded, all-or-nothing, responses. They are unfit to measure small amounts of annoyance in a sensitive way. They only occur when a certain threshold of dissatisfaction has been surpassed.*
>
> *2. Complaints are human responses with a refractory period. After making a complaint it will take some time before the same person will make a complaint again.*
>
> *3. People differ very strongly in the heights of their thresholds for making complaints and in the length of their refractory period. A large part of the population will never make a complaint. Others will be habitual complainers. Complaining behaviour therefore is not representative for the annoyance experienced by the total population.*
>
> *4. The frequency of complaining behaviour is influenced by factors other than the annoyance itself. Thus, the accessibility of the authorities and the costs, both financial and in terms of human effort, of making complaints will influence it.*
>
> ***Also, people may lose faith in the effectiveness of making complaints. This especially is true in cases of odour pollution, where no immediate remedy is available and where it may take months or years to cure a problem.*** (Authors' highlighting)
>
> **[Members of the public may well be reluctant to state publicly their objections to an odour if, for example, they are employed at the facility or are related to someone who works there.]**
>
> **[Perceptions of the quality of the person/company generating the odour can also influence complaining behaviour.]**

5. *The frequency of complaining behaviour is subject to the influence of factors that, although they change the feeling of annoyance, are extraneous to the odour pollution itself. Press publications may influence the tolerance for annoyance or they may lower the threshold for making complaints temporarily. Pressure groups also can exert a strong influence on the number of complaints registered in a certain period. Even if such a group represents only a small part of the population, it may influence the number of complaints dramatically when all members decide to double the frequency of their complaints.*

   In general, complaints may be considered as good indicators of sudden instances of odour pollution such as industrial accidents, but they are poor indicators of the general level of satisfaction of the population".

2.2 Potential Uses for Complaints Data

The following guidelines for gathering odour complaints are intended to assist in investigating, reporting on, and monitoring of complaints. They are intended for use by both regional and territorial authority staff who generally take the lead responsibility in responding to odour complaints. They have obligations under section 35 of the RMA as well as to intervene on behalf of reticent affected parties, to counteract vexatious complaints, etc.

The information gathered can be used for meeting the legal requirements of the RMA above and for pursuing complaints under the nuisance provisions of the Health Act (section 29). (They are designed to seek information that could provide the basis for supplementary techniques for community odour assessment techniques that are presented in subsequent sections of these guidelines.) Implementing such guidelines may be beyond the resources of some organisations and the guidelines could then be interpreted as a 'guide to best practice'.

The provision of guidelines is not intended to imply that local authorities should carry the whole burden of responsibility when it comes to odour complaints. Encouraging complainants to contact the source when they experience problems has several advantages. The complainant takes responsibility for his or her complaint so the complaint must be genuine, and the company/facility operator also has to take more responsibility because they have to deal with people directly. Problems are also more likely to be identified and dealt with promptly. Councils then provide a back up for the public if they believe they are not getting some kind of response. However, where the odour producers also collects the complaints, there is the potential for that data to be presented in a favourable manner to themselves.

Examples of circumstances when complaint information might be used include:

- State of the environment reporting (SER)
- Developing rules for regional and district plans
- Monitoring consent conditions, preparation for renewal of a consent, breaches of consent conditions or deemed a nuisance under the Health Act
- Enforcement proceedings where an 'odour incident' contravenes a consent or breaches the conditions
- A complying or permitted activity that is having an adverse effect

- Where an activity requiring a resource consent does not have one
- Determining whether an abatement notice should be served under both the RMA and the Health Act
- Where there is uncertainty about the source of an odour.

2.3 Procedures for Gathering Complaints

These following guidelines have been drawn in large part from the procedures developed by the State of New Jersey's Department of Environmental Protection to investigate whether their regulation prohibiting air pollution has been or is being violated. The Department must be able to verity and prove that there is the presence of:

> *"... air contaminants in such quantities and duration as are, or tend to be, injurious to human health or welfare, animal or plant life or property, or would unreasonably interfere with the enjoyment of life or property."* (Beck and Day, 1991, p27)

These procedures are similar in many ways to those used by local authorities in New Zealand and the regulation is not dissimilar to requirements controlling discharges to air under the RMA and the Health Act 1956.

Timeliness is a significant factor in investigating odour complaints although it assumes the availability of resources particularly in terms of available staff or access to meteorological data and computer programmes with which to assist in identifying the source immediately or as soon as possible.

Nonetheless, if certain data is recorded when complaints are lodged it may save valuable time and will go a long way to making the investigation proceed more efficiently and effectively. The suggestions below incorporate a wide range of data that could or should be collected and council officers need to consider the different end-needs they or others in their organisation may have for that information.

(i) In the first instance there are several basic details that should be recorded when a complaint is lodged (including when an investigator is not available or the call is 'after hours'). Confirming the source of an odour can at times be a difficult and time-consuming activity. Any information that can be gathered at that time is invaluable, especially when investigating transient sources or when changeable wind or weather conditions mean that impacts at a particular site are intermittent.

Recording details of the address of the complainant provides information on the location of where the odour was perceived (i.e. the zone of effect); recording the name of the complainant can act as a deterrent to so-called vexatious or frivolous complaints and is also critical if action is to be taken against the producer of the odour. Some councils may not act on a complaint if a name is not given, but guarantee anonymity to those who give their name (complaint information may be passed on to the odour producer). A phone number enables a council officer to get more information if required or if an investigator is not available.

- **Name**
- **Address**
- **Phone**

Information such as the date and time could be required for seasonal monitoring or to be used in evidence for enforcement proceedings or abatement notices. Date and time information is also vital for tracking odour back to a particular activity at source (starting/stopping of a particular manufacturing process, spreading/pumping of effluent, transfer of a product, breakdown of process, etc.).

- **Date**
- **Time**

It is important that the person receiving a complaint also records themselves clearly as the receiver of the data. Data received by an anonymous person, even though it may be from a named source, is not useful data.

(ii) When complaints are received, determine whether they should be forwarded immediately to a Consents Investigating Officer or an Enforcement Officer for investigation. (N.B. In some cases complainants simply want to register a complaint on an ongoing issue. Follow-up within 24 hours is usually satisfactory in these cases.)

Suggest to the caller that they also contact the site directly (if the source is known). If the person is reluctant to do so, then a council staff member may agree to do so so that site action can be taken straight away.

When complaints are made you may also want to use the opportunity to recruit the complainant into related monitoring programmes such as keeping odour diaries.

(iii) The investigator should ascertain the current situation and try to obtain the following relevant information:

- Is the problem currently occurring?
- Are other neighbours concerned?
- Has the complainant contacted or tried to contact the source (if known)?
- Weather conditions
- The suspected source
- A description of the odour, including the nature, frequency, intensity, duration, offensiveness, location and circumstances (FIDOL [C])
- Any adverse effects incurred by the complainant (including nuisance)

Complainants may be able to provide limited meteorological data and a description of the prevailing weather conditions. This may be particularly important regarding activities that have consent conditions restricting the activity to certain wind directions. Air temperature may be of less importance to councils in the enforcement and abatement processes but of use to industry in analysing when they have odour problems and plan when to adopt a 'precautionary approach' or implement more mitigation procedures.

- **Windspeed**
- **Wind direction**
- **Prevailing weather conditions (e.g. overcast, misty, hot and still, humid)**
- **Air temperature**
- **Turbulence) unlikely to be available from complainant**
- **Humidity)**

Indicators of wind speed (Beaufort wind scale) used in a number of New Zealand surveys are:

0	Calm	Calm; smoke rises vertically
1	Light air	Smoke drifts but wind not felt on face
2	Slight breeze	Wind felt on face, grass moves
3	Gentle breeze	Leaves and small twigs in constant motion, dry clothing on clothesline begins to move
4	Moderate breeze	Loose paper blows around, small branches sway
5	Fresh breeze	Small trees sway
6	Strong breeze	Large branches move, telephone lines whistle, umbrellas inconvenient to use

A description of the type of odour can sometimes assist in determining the source although people vary widely in their perceptions of odour from the same source. Figure 2.1 provides a list of odour character descriptors provided in the Ministry for the Environment's 1995 odour management guide, and Table 2.1 outlines common odour sources and their characteristics.

- **Odour description**
- **Suspected source/offender**

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$_3$ 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, peppennint	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		

Figure 2.1: Odour character descriptors
(Source: Ministry for the Environment, 1995, p46)

Table 2.1: Odour sources and characteristics (Source: Ministry for the Environment, 1995, p13)

Source	Activity	Odour Characteristics
Agricultural activities	Silage Intensive farming Piggeries Poultry farming	Pungent, amines, sulphidic – hydrogen sulphide, mercaptans
Agricultural chemicals	Manufacture Use (particularly organophosphates)	Pungent, garlic-like – organophosphates
Animal & fish processes	By-product rendering Tanneries Fellmongeries Fish meal	Fishy, pungent, sulphidic, rotten, putrid - amines, reduced sulphur compounds
Asphalt/bitumen	Hot-mix asphalt manufacture Blowing bitumen	Hot tar, oily
Biogas manufacture		Rotten eggs – hydrogen sulphide
Chemical manufacture	Acrylic co-polymer resin Varnish manufacture Soaps & detergents Perfume & cosmetic manufacture	Chemical smells ranging from sweet and musty to solvent and hot plastic – esters, acrylates, solvents, aliphatic hydrocarbons
Food processing	Margarine Coffee & nut roasting Brewing of beer Bakeries & hot bread shops Take-away restaurants	Various food odours, most considered non-offensive, but some cane be quite sickening
Drying	Grain, lucerne	Hot grass
Fertiliser manufacture		Sulphidic – sulphur dioxide
Geothermal steam		Sulphidic – sulphur dioxide
Incineration	Medical waste Rubber Crematoria	Sooty, smoke
Metal processes	Smelting Galvanising Core moulding	Phenolic, oily, smoke
Oil refining	Refining crude oil Re-refining lubricating oil	Rotten eggs, sulphidic – hydrogen Sulphide, reduced sulphur compounds
Paint baking	Car painting Can coating	Sweet, solvent smells – xylene, toluene, ketones, etc
Plastics, fibreglass	Manufacture Laying up	Sweet, solvent smells – xylene and styrene, etc.
Solvent evaporation	Adhesive tape manufacture Magazine printing	Sweet, solvent smells – xylene and solvents, ketones, etc.
Waste/refuse	Landfills Composting Sewage treatment Water treatment ponds Lnad treatment	Landfill gas Rotten sulphidic – hydrogen sulphide, reduced sulphur compounds
Wood processing	Wood drying Patricle board, plywood Pulp & Paper Charcoal manufacture	Wood volatiles – pinenes, turpenes Sweet, aldehyde smell – vanillin Rotten, sulphidic smell – reduced sulphur Compounds

(iv) The decision whether to carry out a field investigation is generally taken by the officer. That decision will need to be made on a case-by-case basis. Aspects of this decision are whether the odour is still present and whether there is a need to verify that it is offensive. If a field investigation is to be undertaken it should be conducted as soon as practicable. Regulatory authorities vary with regard to the time-frame within which they respond; this will depend on the resources and staff available.

At this point there are two major tasks to be undertaken; one is to identity the odour source and the other is to enquire about the effects of the odour on the complainant. The order in which these tasks are undertaken may depend on whether the source is easily identifiable because of a history of complaints, etc. and the investigator may be able to direct his/her attention to the effects. However, if there are a number of potential odour sources located close together, identifying the source may be very difficult, especially if two facilities are carrying out the same or a similar activity, e.g. two rendering plants side by side. The following steps assume that identifying the source is the initial concern.

a) If a suspected source is suggested by the complainant, the investigator may choose to check the files (if they already exist) of the facility to assess the likelihood of it being the actual source. He/she is likely to be familiar with potentially problematic facilities in his/her assigned geographical area.

At least two approaches are possible for identifying the source:

- The few councils that have direct access to meteorological data may already use or wish to adopt the approach used by the Victorian Environmental Protection Authority (VEPA, 1996) in Melbourne. Staff have developed an on-line computerised tool comprising a trajectory programme that has access to meteorological information on local wind patterns. The location of the complainant is entered on to a map and a path is plotted to the source by tracing back the movement of a wind parcel over the previous few hours. An inspector is sent to the point identified and checks up and down wind to identify the actual source.

- For those councils that do not have a computerised facility, the approach used by the New Jersey Department of Environmental Protection is possibly a familiar one. If the problem is currently occurring, the investigator should proceed to the complainant's location and record his/her arrival time. The investigator then conducts a 360 degree odour survey of the suspected source. An odour investigation map could be drawn that clearly indicates the points at which odour is detected. When an odour is detected the investigator records the characteristics of the odour as well as weather conditions (including wind direction and speed).

It is recommended that the investigation start from outside the suspected area. This can avoid the situation where an investigator is subject to high levels of odour/gases and may become insensitive to low odour levels.

Photographic evidence may be collected if there is any physical evidence that could be linked to an odour.

b) The next step is to consult with the complainant on a number of factors and for the investigator to record his/her assessment of those factors too. The information gained can help in the decision as to 'do nothing/a verbal caution/ abatement'. The nature or character of the odour has been referred to above and descriptors appear in Figure 2.1 and Table 2.1 above. The FIDOL(C) factors (Ministry for the Environment, 1995, pp 14, 36) can influence the significance of adverse effects. Data on the FIDO factors can be used for comparative purposes in any future analyses that incorporate information from assessment methods such as surveys, diaries, etc. Table 2.2 illustrates an odour strength/intensity scale.

- **Frequency of odour incidents**
- **Odour strength/intensity**
- **Duration of odour incident**
- **Degree of offensiveness**
- **Adverse effects experienced**

Frequency of the odour occurrence; in other words, how often an individual is exposed to odour in the ambient environment. Frequency is influenced by the odour emission source and characteristics, prevailing wind conditions, the location of the source in relation to the individual, and the topography of the area.

Intensity is the perceived strength of the odour at the complainant's location. However, if the complaint is not able to be investigated immediately, changes in emission and/or meteorological parameters can give rise to differences in perception between the complainant and investigating officers.

A scale for describing intensity is outlined in Table 2.2. The descriptions alongside each point on the scale have come from a number of sources. The range of descriptions may be helpful in determining an appropriate point, or alternatively a scale could be constructed using just one or two descriptors for each point.

Duration of exposure to the odour. The length of time of exposure is related to the odour source, meteorological data, and the location of the odour source.

Offensiveness is a subjective rating of the pleasantness or unpleasantness of an odour and relates closely to hedonic tone. The degree of offensiveness to an individual can be influenced by experience, frequency and duration of exposure to the odour, odour character and intensity, and the sensitivity of a person's sense of smell.

People's past experience of exposure to offensive odours may have an impact on their current perceptions of offensiveness/annoyance. When they have experienced a high degree of odour annoyance in the past, they may become annoyed more easily at lesser exposures.

Little research has been carried out on this last factor although quite significant research has been devoted to 'annoyance', particularly in Europe. 'Offensiveness' was identified as one of the key questions put forward by the Odour Special Interest Group (OSPIG) of the Clean Air Society of Australia and New Zealand (CASANZ).

Table 2.2: Odour intensity scale
(Source: Modified from Beck and Day, 1991, and incorporates (in brackets) a strength of odour scale used by four of the local authorities surveyed)

SCALE	ODOUR INTENSITY DESCRIPTION
0	..... - odour not detectable
	..... (no noticeable/distinguishable odours)
	.....(undetectable)
	..... (none)
1 – Very light:	Odorant present in the air
	.....-activates the sense of smell
	.....- characteristics may not be distinguishable
	.....(slight occasional wafts)
	.....(faint, intermittent: recognisable to those who know its source)
	.....(trace, hint of)
	..... (caught momentarily, disappears when attention focused on it)
	..... (detection threshold[2])
2 – Light:	Odorant present in the air
	..... activates the sense of smell
	.....distinguishable and definite
	..... - not necessarily objectionable in short durations
	.....(recognition threshold[3])
	..... (slight but constant odour)
	..... (aware occasionally during day)
	..... (noticeable)
	.....(distinct – one can deliberately sniff and detect at will)
3 – Moderate:	Odorant present in the air
	.....- easily activates the sense of smell
	.....- very distinct and clearly distinguishable
	..... - may tend to be objectionable and/or irritating
	..... (moderate but frequent odour)
	..... (frequently noticeable)
	..... (very noticeable)
4 – Strong:	Odorant present in the air
	.....- objectionable
	..... - cause a person to attempt to avoid it completely
	.....- could indicate a tendency to possibly produce physiological effects during prolonged exposure
	..... (unpleasant odours)
	.....(a – frequently strong; b – continuously noticeable)
	..... (objectionable)
	.....(strong – forces itself on one's attention)
5 – Very Strong:	Odorant present
	.....- so strong it is overpowering and intolerable for any length of time
	.....- could tend to easily produce some physiological effects
	..... (putrid)
	..... (offensive, overwhelming)
	.....(overpowering – intolerable so that one is physically sickened or forced to seek relief)

---

2 "The **detection threshold** is defined as the lowest concentration that will elicit a response without reference to odour quality" (Dean and Freeman, 1994, p403).

3 "The **recognition threshold** is defined as the minimum concentration that is recognised as having a characteristic odour quality" (Dean and Freeman, 1994, p403).

Location of the odour source may affect the production and dispersion of odour depending on local topography and meteorological conditions.

The acceptability of or tolerance to certain odours may vary according to location - e.g. the expectation of rural smells in the rural environment and industrial smells in an industrial area - whereas objectionable smells from either may not be acceptable in residential areas. "Unpleasant farm odours may be acceptable in reasonable strengths and duration in country areas. Conversely a coffee odour may be acceptable, even attractive in association with eating, but unacceptable as a continuous night time smell interfering with sleep" (Dean and Freeman, 1994, p404). Consideration of 'sensitivity of the receiving environment' as required under s.104(3) of the RMA could usefully take place in the context of 'circumstances'.

Circumstances (Court, 1996). Information is not yet available to the authors as to the characteristics of 'circumstances' but it may relate important aspect of location as it is viewed in the New Zealand context.

This factor could take into account whether the complainant was indoors or outdoors as well as a description of the activity of the complainant at the time. This is quite important because if a person is in a state of relative inactivity and conscious or sub-conscious preparedness to perceive an odour, it may influence their perception of and concern about an odour.

It has been suggested that the FIDOL factors could be more comprehensive if they include the complainant's resulting changes in behaviour/activity attributable to the odour (MidCentral Health, pers. comm.). An additional yet critical factor that has possibly not been comprehensively addressed is that of the effect an odour is having on a complainant. To date, 'effects' have been largely considered in terms of 'nuisance' (Health Act 1956). The Resource Management Act is described as 'effects-based' rather than activity based, and those managing physical and natural resources are charged with avoiding, remedying or mitigating adverse effects of activities. Community odour assessment requires an assessment of 'effects' as well as the other factors referred to above. Consideration of this factor may also go some way towards addressing the issue of whether localised, small-scale odour sources are community odour problems in the same way that large-scale, odour-producing facilities are seen to be. The crux of this issue is the effects of the activity, and not the activity itself.

If we are to determine whether people and communities and their social, economic, and cultural well-being, amenity values, and health and safety are being adversely affected, then a catalogue of effects relating to social, economic, and cultural well-being (derived within the framework of the definition of effects in section 3 of the RMA) and a scale of levels of adversity could be developed.

Table 2.2 (Odour Intensity Scale) potentially provides a starting point from which to consider adverse effects. When the odour can be described in terms of the scale, we can examine the kinds of effects that different points on the scale may give rise to.

(v) Figure 2.2 provides an example of a standard form that could be used for registering odour complaints, although it should be noted that this example has no legal status. One council reported that an electronic register is being developed and this would enable easy retrieval of all or some of the details recorded.

XYZ Regional/District/City Council

ODOUR COMPLMNT REGISTRATION

Details from complainant

- Name
- Address
- Phone
- Date
- Time
- Odour description
- Suspected source
- Frequency of odour incidents
- Odour intensity
- Duration of odour incident
- Degree of offensiveness/pleasantness of odour
- Adverse effects/nuisance

Meteorological information

- Weather indicators (MfE, 1995, p50)
  - wind direction
  - wind speed and turbulence
  - air temperature
  - humidity level

Other comments/observations

.....

Administrative requirements

- Method of notification - letter, telephone, meeting, other
- Referred for action (name of staff member to investigate)
- Company/facility contacted (date and name of employee)
- Other-authority notified (e.g. Department of Health)
- Authorised/unauthorised emission
- Inspection record (including name of staff who referred and dealt with complaint)
- Action taken (including date and description of action)
- Result of investigation (remedy or mitigation)
- Completed action filed
- Follow up
- Whether complainant notified and date of notification
- Complainant confidentiality required - Yes/No
- File reference (e.g. if requiring consent number)

Figure 2.2: Example of an Odour Complaint Registration Form

(vi) The procedures above assume that a large-scale facility is producing odour. Feedback from the local authority clearly indicated that for some councils a moderate or even substantial proportion of their odour complaints relate to small-scale sources, i.e. domestic fifes, outdoor burning, small-scale piggery, cattery, etc. The investigator may need to consult the proposed/operational regional/district plan to determine whether the activity is a permitted one in the area concerned or whether a resource consent might be required. (If there is no relevant regional plan the regional policy statement may provide some guidance.) Even if an activity is permitted under a plan it may constitute an offence under the Health Act.

One approach to small-scale ubiquitous odour sources is that on receipt of a complaint Council could phone the 'offender' and suggest that they advise neighbours when they plan to spread manure, rubbish fire, etc. However, this does not imply permission to offend, nor is it the affected party's duty to either go out or put up with a situation they should not have to tolerate.

(vii) Finally, particular attention should be paid to the response given to complainants, particularly when a complaint is lodged by phone. Give them a clear message as to whether any investigation might occur and whether they can expect to be provided with any follow-up within a given period of time.

2.4 Enforcement

After an assessment of a complaint(s) has been carried out, an officer may decide to implement enforcement proceedings. The information set out in the section above is intended to provide guidance for gathering details for enforcement purposes.

Figure 2.3 illustrates an example of a Statement of Complaint form (filled in by the complainant) that could provide a standardised approach across councils but could add more work to the complaint procedure. (It would need to become part of the Resource Management Forms Regulations in order to provide a standardised approach.) It could be used if it seems likely that the enforcement is going to be appealed and if the complainant does not mind the possibility of losing anonymity. However, if the complainant is employed by or related to an employee of the offending facility he or she is unlikely to want to be identified.

The investigator would need to independently concur with the complainant that he or she has been adversely affected. An investigator would encourage the complainant to complete the form in their own words and not provide leading or suggestive information (State of New Jersey Department of Environmental Protection, 1995, p6). The complainant would also need to be made aware from the outset that they were able to, or might be requested to testify at an Environment Court or District Court hearing if they filed a Statement of Complaint.

Complainants can also be advised that they are able to take their own enforcement actions before the Environment Court (under section 316 of the RMA).

XYZ Regional/District/City Council

STATEMENT OF COMPLAINT

Name .....

Address .....

Phone ..... Age .....

Address Where Employed (if applicable) .....

Lived/Worked at Above Address for ..... (months/years)

Source of Complaint .....

Noticed on (date) ..... at about (time) .....

Distance from Facility to Home/Work/Recreation ..... (approx. no. of metres)

Nature of complaint

.....
.....
.....
.....
.....

Frequency of odour incidents .....

Odour intensity (see Table 2.2) ..... (minutes, hours)

Degree of pleasantness/offensiveness of odour .....

This Condition has been continuing for about ..... (days, months, years)

Describe activity and where problem was noticed (circumstances)

.....
.....
.....

Figure 2.3: Example of a Statement of Complaint Form (Source: Modified from Beck and Day, 1991, p33)

Adverse effects

.....
.....
.....
.....
.....

I confirm that the above statement is a true and accurate account of my complaint Further, I am aware that I may be requested to present testimony at an Environmental Court or District Court hearing pertaining to this statement of complaint

.....
Signature

.....
Date

Witnessed by:

.....
Signature

.....
Date

(cont'd) Figure 2.3: Example of a Statement of Complaint Form (Source: Modified from Beck and Day, 1991, p33)

3 GUIDELINES FOR IMPLEMENTING THE TECHNIQUES

A range of community odour assessment techniques are already being used in New Zealand in the resource consent process in particular and requirements to use these techniques can be specifically included in resource consent conditions, for example.

One of the conditions of *Fortex v Ashburton District Council and Canterbury Regional Council* (I993 C41/93) was the establishment of an advisory liaison committee to empower local residents by providing a point of access to the company for complaints. Representation included company staff, community members and regional and district council staff. A sequel to this case was that of *Carlow Farm Ltd v Canterbury Regional Council and Selwyn District Council* RMA 249/94 where the granting of a discharge to Huttons Kiwi at Te Pirita (Canterbury) was appealed by local residents. A condition was established requiring that an advisory liaison committee be set up and that the managing director (who was based in Auckland) attend at least two meetings a year (Hearn, 1996, pers. comm.[4]).

Negotiated agreements between parties is another common means of resolving odour conflicts. For example, in 1989/1990 (prior to the RMA) Fortex Ltd applied for a discharge permit for its Silverstream Plant, inter alia, to pass contaminated air through a soil purification/filtration plant. The closest neighbour to the plant, Fisher & Paykel Ltd, intended to appeal the granting of a resource consent by the Dunedin City Council but the appeal was forestalled by way of a memorandum of agreement on a contractual basis between the parties. "An odour panel was set up involving the neighbours of the plant with the ability to refer to an independent expert and finally an arbitrator. The Planning Tribunal accepted this agreement as a condition to the land use consent on the basis that it was contractually binding to the parties." (Sommerville, 1997, p3).

Further, consents may be granted that contain a certification procedure involving the monitoring of conditions by an independent panel. The legal term used here is condition subsequent where an operation can start but cannot continue if the conditions are breached. Protocols can be developed for the panel, and people in the neighbourhood of a potential odour source keep diaries of events and report to the local authority which can then act on the information contained in the diaries. If the consent applicant agrees to such a condition, e.g. diaries as an acceptable way of proving violation, the applicant/consent holder cannot attempt estoppel, that is, he/she cannot retrospectively object to the condition although he/she can attempt to demonstrate that evidence was taken outside the protocol (Sommerville, 1996, pers. comm.[5]).

Community consultation is generally required where a company's current discharge permit may be up for renewal. One example is of a company that was aware of potential community opposition and employed consultants to design a programme. Direct consultation was carried out with those adjacent to the site (around 20 people) and they were also given odour diaries to complete. These people were also offered the opportunity to be shown round the plant so that company representatives could explain the technical work being undertaken to solve the problem. Two public meetings were also held. Prior to the public meetings the company meet with both staff and elected representatives of the regional council and with the local

4 Hearn, A, Queen's Counsel.

5 Sommerville, R, Barrister, Dunedin.

business association. A meeting was also held with the company, lawyers, and the regional council. Press releases were made to explain what work was being undertaken and what the resource consent renewal involved. The situation was found to be improving by the time the application was notified (Small, 1996, pers comm.[6]).

Recently AFFCO Wanganui applied to renew its discharge permit. Consent conditions included requirements that the consent holder maintain a complaints register, that an odour assessment survey be carried out no less than once per year by consulting those in the area potentially affected odours from the consent holder's operation, and that a community liaison group be maintained (with membership and minimum frequency of meetings also being specified) (Manawatu-Wanganui Regional Council, 1996, p27).

Odour diaries have been used in Great Britain as part of a 'whole package of techniques' to prove cases for prosecution. In one instance, a lot of complaints had been received and an overview was wanted of the nature of the odour and the sensitivity of the receiving environment. A large group of about 100 households were affected at any one time and there was a core group of spokespeople for the community. A range of observations was wanted in relation to the plume, so everyone in the area was asked to keep records. Only 10 households filled in diaries on a regular basis, but they were prepared to give evidence with their diaries. Others were prepared to give anecdotal evidence relating to the admissibility of hearsay (i.e. non-direct) evidence.

The local council also monitored the situation - in times of problematic emissions an officer would visit a particularly bad spot and spend several hours over a period of three weeks to try and get sufficient evidence for a prosecution. A computer log of complaints was kept as to where and when odour was experienced, but the use of the log as evidence failed because of legal tests. (Atkins, 1996, pers. comm.[7])

Another company employs an independent observer (with no scientific qualifications) to walk around the boundaries of the plant and to record in a log book if he/she can smell any emissions from the plant. There are a number of odour emitting industries in the area and the company wants to determine whether it is their facility that is emitting. This practice could become a condition of a discharge permit (Small, pers. comm.[6]).

These examples demonstrate something of the range of uses of community odour assessment techniques. However, the use of the odour observation/community response/community surveys approach, for example, has been limited to some degree by the fact that firm guidelines for gathering complaints have not been developed and it was believed that *"the international air quality regulatory community has been slow to develop standardised procedures for carrying out odour surveys and determining overall community response to actual or perceived odour problems"* (Ministry for the Environment, 1995, p40). These guidelines present standardised procedures for a number of community odour assessment techniques and 'good practice' advice for others.

This absence of recognised or standardised procedures goes some way towards explaining why many councils are not 'up to speed' in New Zealand when it comes to enforcement particularly because information available is insufficient. The quality of information should

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6 Small, J, Chapman Tripp Sheffield Young.

7 Atkins H, Russell McVeagh McKenzie Bartleet & Co.

be high in cases which may be taken to prosecution, and a range of techniques and approaches ensure that this occurs. In Great Britain, for example, council officers are trained to take evidence (they receive training similar to that of the police), and advice needs to be made available to the community on how to put information together. It is also important to explain, for example, why odour diaries are being kept and how difficult it is to take cases to prosecution. In instances where odour problems cannot be resolved rapidly, the investigation is likely to involve the use of several of the identified techniques either concurrently or during different stages of the investigation. What is important to remember is that each of the techniques outlined below is but a tool in a 'workbox of tools'; each is appropriate to carry out a specific task but all have their limitations, and it is only through using a mix of techniques that we can better understand the effects of odour on people and communities.

The only case-law found during the course of this study that related to community odour assessment techniques was on what are referred to as 'market surveys'. Case law has been established with regard to the admissibility as evidence of the results of surveys. Surveys are being used to investigate social, economic and environmental effects of activities in Resource Management Act decision making. Examples include: recreational uses of resources; the psychological effects of establishing an LPG facility in a particular area and local residents' perceptions of fear. Surveys are sometimes used in advance of establishing a facility and for exploring perceptions of existing facilities (Somerville, 1996, pers. comm.[5]). However, to use surveys that have the potential to be admissible as evidence in the area of community odour assessment would be breaking new ground (Hearn, 1996, pers. comm.[4])

It should be noted that the costs and benefits associated with the techniques discussed below will vary markedly with the magnitude of the odour problem, whether it is rapidly resolved, the complexity of the issues involved and the approach taken to implementing the technique. Discussions with representatives from a number of local authorities who have implemented the techniques in the past show that implementation methods vary markedly. Thus it is possible only to discuss the diversity of implementation techniques, costs and likely response rates to each approach, using the experiences of the local authority staff interviewed (Lincoln Environmental, 1997), as well as previous professional experience, as a guide. The issue of who should pay the costs is beyond the scope of this project.

To use these guidelines, you will need to know some basic statistics - a good pass in sixth form statistics or mathematics should be enough. You will also need to consult suggested texts and/or professionals - **these are guidelines only.**

3.1 Council Staff - Site Inspection, Monitoring and Decision

Specific guidelines have not been developed for the use of council staff as each local authority has its own unique organisation and approaches to odour management. However we have reported on the circumstances in which council staff get involved, and have also listed some of the costs of the role of council officers in odour management[8]. These comments can be borne in mind when considering the use of the complementary techniques that are discussed in this guideline.

In the local authority survey (Lincoln Environmental, 1997), it was reported that council staff roles can be: to determine source conditions, follow up, to determine if an odour problem

8 This information was derived from the survey of local authorities (Lincoln Environmental, 1997).

exists/reason for odour/interaction with source owner, response to/verification of complaint, to determine if valid/legitimate complaint, to ascertain extent of problem from complainants/ investigate source at point of origin, to assess complaint and source, to collect data on complaint or compliance with resource consent, to determine nuisance/offensiveness factor or to establish if nuisance conditions exist, enforcement, to determine if offence under RMA/Health Act/bylaw, objectivity, establish nature of complaint, to determine conditions and abate odour, to identity sources on site, to determine cause of odour/consider remedies/determine resource consent conditions, to determine effects, to decide appropriate action, to scope problem.

A majority of district councils and regional councils deal with relatively small problems by sending one or more trained members of staff out to inspect the site, discuss the problem with the complainant and the consent holder, make a decision and revisit the site to ensure that the decision is complied with. A typical example of the time and costs involved is:

Staff member visits site twice to assess the situation (2 hours @ $50 per hour)	$100
Handling telephone complaint (0.5 hour @ $50 per hour)	$25
Administration, letters, setting time-frame (2 hours @ $50 per hour)	$100
Staff member visits site again to ensure compliance (1 hour @ $50 per hour)	$50
Mileage (120 km @ $0.40/km)	$48
TOTAL COST	$323

Although each Council apportioned time amongst tasks differently it was generally conceded that such cases involved approximately 5 to 6 hours of staff time and a total cost of approximately $300.

Where an odour is deemed to be a nuisance, Section 32 of the Health Act permits territorial authorities (city and district councils) to contract out the work required to eliminate the odour and charge all costs back to the owner. None of those interviewed for the purpose of this cost-benefit analysis (Lincoln Environmental, 1997) had had experience with this process. Section 330 **Emergency works and power to take preventative or remedial action** and section 331 **Reimbursement or compensation for emergency works** are similar provisions under the RMA.

Where a more protracted issue is dealt with in this manner, the *costs* can be very much higher.

The advantage of using this technique is that it can be implemented rapidly and the presence of council staff at the site gives the complainant assurance that the issue is being taken seriously by the local authority. However, it is undoubtedly a completely subjective approach and both complainant and consent holder are vulnerable to this subjectivity. The approach may be regarded as less subjective if council staff involved in this type of assessment have their noses "calibrated" in the same manner as participants in odour panels. In addition, the involvement of more than one staff member in the odour assessment adds validity.

3.2 Community Surveys

3.2.1 What do we mean by 'community surveys'?

We need to clarify what we mean by 'community surveys' because the word 'survey' can have different meanings for different people in different situations. In this section *(Community Surveys)* we are focusing on the systematic gathering of quantitative data by way of 'questioning on one occasion'. A representative sample of people is chosen, they are all questioned on one occasion over a period of say one week or two, depending on the size of the survey, and their responses are collated and analysed at the end of that period. This kind of survey could be repeated on a subsequent occasion, say in a year or two, to see whether people's perceptions of odour have changed.

The results of a community survey can give a gradation of annoyance/offensiveness measurement, as well as providing information on the cumulative experience of residents over a period of time (Verein Deutscher Ingenieure, 1993, p4) as well as collecting data on the effects of annoyance/offence if that is required.

The method does not enable coverage of individual odour events in the way that the use of odour panels or odour diaries do (see sections 3.3 and 3.4 below), and is therefore not suitable for describing real variations in annoyance/offence over short timeframes. On the other hand it is suitable for measuring the cumulated sensation or experience of annoyance (offensiveness) over time (ibid.).

'Odour diaries' (sometimes referred to as 'odour surveys'), and 'panel surveys' or 'odour panels' differ from what we are calling 'community surveys' in that data is gathered from the same sample or group of people through 'questioning on several occasions'. They may be instructed to record information every day, every time they detect an odour, or every time they experience an 'offensive or objectionable' odour over a period of say, three months, although their responses are likely to be submitted to the person organising the exercise on a frequent basis.

Guidelines for personal interviews, telephone surveys and postal questionnaires all appear in this section because basically they are different methods of systematically collecting data on one occasion.

3.2.2 When to use a survey

In the local authority survey council staff (Lincoln Environmental, 1997) reported that they had used surveys in the following ways:

> (nuisance) complaint investigation; to determine how affected residents were; to establish data on multi and on-going complaints; to gain public opinion on variety of odour issues; to determine frequency and effects; to provide complainant with record to fill in details and visit neighbours to discuss problem; to investigate odours from plant with consent specifying no odour beyond the boundary; to scope problem and gather information on duration, offensiveness, time; to identify affected parties of odour discharge; response to complaint to take action under general provisions; to gauge public opinion (on variety of odour issues); to gauge if there is/extent of problem (in area adjacent to odour source); to quantity and qualify odour problem; to determine effect on community and to decide whether effects lessened or worsened.

Other instances could be:

- to obtain baseline data on existing odour sources, for example, before a new plant or operation is established. The information obtained can be very valuable in fixture monitoring in the event that complaints are received about the new operation. However, any fixture surveys may only measure the cumulative effect of all sources, ie the new source may be exceeding its consent conditions but this could be masked by decreases in odour from other sources.

- to verify the validity of odour complaints as part of monitoring resource consent conditions or to determine whether an enforcement order or abatement notice needs to be served.

- to identify the social effects of odour annoyance and the impacts of odour on social well--being.

- to investigate what is acceptable to the community, especially with regard to the FIDO factors.

- to measure, over time, trends in attitudes towards a particular industry, or on specific aspects of the plant where a survey may be used as a *"benchmark against which future surveys can be compared"* (Bolton, 1993, pp102-103).

3.2.3 What are we trying to achieve when carrying out a survey?

Some of the perceived weaknesses of surveys mentioned in the local authority survey were that: they are unscientific and subjective, that it is difficult to develop a data survey that is not 'biased' or 'leading', they exhibit the 'usual weaknesses of opinion surveys', and it is questionable if they are legally sound.

Submissions to the Ministry for the Environment's 1994 discussion document also raised a number of related issues. In order to address these issues support was expressed for:

- a **common flexible procedure**
- avoidance of *'interest group capture'* and the potential for bias
- the use of **scientific procedures** to avoid bias

Scientific procedures for carrying out community surveys that meet the requirements of reliability and validity are well developed and subjective information can be gathered in a rigorous, objective manner.

3.2.4 Admissibility of survey evidence in legal proceedings

This section sets out the requirements for the admissibility of survey evidence in legal proceedings. These requirements also reflect aspects of rigorous scientific procedures. For this reason, they provide a framework for good practice for surveys for internal use by the operators of odour producing facilities, while highlighting the wisdom of hiring recognised experts to undertake surveys if there is any likelihood that they may be submitted in legal proceedings.

Case law has been established for some time as to the admissibility as evidence of what are referred to as market surveys. In *Customglass Boats Ltd v Salthouse Brothers Ltd* [1976] 1 NZLR36:

> *".... Mahon J said that even though such evidence was hearsay (and thus normally inadmissible), it was an exception to the hearsay rule because it exhibited a state of mind held in common by a designated class of persons)."* (Somerville, 1997, p8).

In *Klissers Farmhouse Bakeries Ltd v Harvest Bakeries Ltd* [1985] 2 NZLR 129 Davidson CJ:

> *".... preferred not to treat market research evidence as being hearsay at all but rather the factual foundation upon which the expert market researcher bases his (or her) opinions. The evidence is tendered not to establish the truth of statements of interviewees but rather to establish that those statements were made. It was upon the basis of these statements that the opinions of the expert market researchers were formed (see Subramaniam v Public Prosecutor [1956] 1 WLR 965 at p969)."* (ibid.).

While Holland J in *Noel Leeming Television Ltd v Noel's Appliance Centre Ltd* [1985] 5 IPR 249 held a similar view with regard to the admissibility of market surveys he observed that defects in the research procedures could well affect the weight given to that evidence. More recent case law has focused on what are seen to be proper procedures for carrying out surveys while these procedures relate to the admissibility of surveys in legal proceedings, they also provide a framework for good practice for surveys that are intended for internal use of the local authority or odour producing facility operator.

In *Auckland Regional Authority V Mutual Rental Cars* [1987] 2 NZLR 647 at *658* Barker J referred to *Imperial Group plc V Philip Morris Ltd* [1984] RPC 293,294 in which Whitford J offered a measuring stick for market survey evidence; the requirements are summarised as follows:

> *"(a) The interviewees must be selected so as to represent a relevant cross-section of the public;*
> *(b) The size of the survey must be statistically significant;*
> *(c) The survey must be conducted fairly;*
> *(d) All the surveys carried out must be disclosed including the number carried out, how they were conducted, and the totality of the persons involved;*
> *(e) The totality of the answers given must be disclosed and made available to the defendant;*
> *(f) The questions must not be leading nor should they lead the person answering into a field of speculation he would never have embarked upon had the question not been put;*
> *(g) The exact answers and not some abbreviated form must be recorded;*
> *(h) The instructions to the interviewers as to how to carry out the survey must be disclosed; and*
> *(i) Where the answers are coded for computer input, the coding instructions must be disclosed".*

Justice Barker (ibid.) also referred to an unreported Australian case *Greynell Investments Pty Ltd v Hunter Douglas Ltd,* Lockhart J in the Federal Court of Australia which contained a number of additional conditions including:

> *"(a) The respondent establishes that the survey was designed and conducted in accordance with accepted principles of survey research producing a result which is trustworthy, including (without limiting the generality of the foregoing):*
> *(i) That the proper universe was examined;*
> *(ii) That a representative sample was drawn from that universe;*
> *(iii) That the persons conducting the survey were recognised experts;*
> *(iv) That the data gathered was accurately recorded;*
> *(v) That the questionnaire, sample design and interviewing were in accordance with generally accepted standards of objective procedure and statistics in the filed of such survey.*
> *(b) A complete record of –*
> *(i) The methods by which the universe and sample were selected, and of the techniques employed for selecting and instructing the interviewers, and the experience of those interviewers;*
> *(ii) Any data underlying the survey, methods of interpretation and conclusions reached;*
> *(iii) The responses to the survey with names and addresses of those interviewed deleted;*
> *(iv) Any tests applied and the results of any tests applied to determine the extent to which the survey or results of the survey can be trusted;*
> *(v) The nature of and results of any audit applied in connection with the survey;*
> *(vi) The method employed in assigning the answers to open-ended questions to categories:-*
> *be supplied to the applicant in reasonable time in advance of the hearing;*
> *(c) Such persons as were involved in the conduct of the survey are, if required by the applicant, called by the respondent as witnesses in the proceedings."*

However, Davidson CJ in the High Court in *Klissers Farmhouse Bakeries Ltd v Harvest Bakeries Ltd* (supra) at 132 said that he was not prepared to say that evidence that did not meet the criteria (as above) is necessarily inadmissible in New Zealand (without stating why) but that the requirements for the validity of survey evidence needed to be treated with caution (Somerville, 1997, p7).

According to Williams J in the High Court in *Levi Strauss & Co v Kimbyr Investments* [199] 1 NZLR 332, 364 held that there were two essential requirements for a survey to be admissible. These were:

- that the interviewees were selected so as to represent a cross-section of the relevant public, and

- that the precise instructions given to the interviewers as to how to carry out the survey were disclosed.

In the event that a survey was admissible,

> *"... the value of the answers and the integrity and fairness of the survey questionnaire and the individual questions incorporated in it"* (Somerville, 1997, p7).

A number of technical challenges have been levied at surveys presented as evidence in New Zealand courts. The focus on the role of experts, leading questions, and instructions to interviewees.

While New Zealand case law does not appear to specifically address the issue of experts as in the unreported Australian case *(Greynell Investments Pty Ltd v Hunter Douglas Ltd* (supra)) technical challenges with regard to survey expertise in the New Zealand courts have included:

> *"(a) That the person involved in formulating the questions has insufficient experience in statistics.*
> *(b) The survey must be statistically reliable to be accepted in evidence.*
> *.....have had cases where the designer of the survey has been called and cross examined as to his or her expertise in statistics.* " (Somerville, 1997, p10)

If a questionnaire has been designed in consultation with other groups, evidence needs to be provided as to their input, their expertise or credibility and the process or methodology that was used (ibid.). For example, a video could be used to demonstrate to the court the process followed (Somerville, 1997, pers. comm.[5]).

In Levi Strauss & Co v Kimbyr Investments (supra) Williams J also discussed (at 364 and 365) what constitutes a leading question. Leading questions can include instances where problems and the degree of the problem are identified and these can have less weight than an unbiased response. An example of a survey that was vulnerable to attack suggested perceived odours in the questioning and offered a ranking of 'bad' to 'unacceptable' (Somerville, 1997, pp10-11). Respondents should have also had the opportunity of indicating that an odour was neither bad nor unacceptable. The issue of leading questions can give rise to a 'Catch 22' situation where an attempt to avoid asking leading questions can result in getting data back that is not particularly useful (Somerville, 1997, pers. comm.[5]).

Another frequent defect in survey procedures is when evidence is not provided as to the explanatory instructions given to respondents. The objectiveness of those initial instructions cannot then be established (Somerville, 1997, p10).

An issue that arises out of the criteria referred to above is that of privacy. In instances where public preferences may not be contentious (e.g. in the case of preferences for rental car firms) it might be preferable to check those responses with the person who gave them. When being questioned on a sensitive topic or an environmental issue over which the community is sharply divided survey respondents could be warned of the possibility of a check-up enquiry in the event of litigation and given the option of forbidding his or her name being disclosed in such an event. It is conceivable that many interviewees would not want their names to be disclosed. In this instance:

> *"The Privacy Act 1993 would only apply to information collected from interviewees where the interviewee has been identified, since personal information ' as defined in*

s2 of the Privacy Act means information about an identifiable individual" (Somerville, 1997, pp8-9).

Whether or not the names of the survey respondents are disclosed is unlikely to be decisive to the admissibility of any survey evidence (Somerville, 1997, pers. comm.[5]).

However, it is evident from *Auckland Regional Authority v Mutual Rental Cars* (supra) that while it may not be necessary for the interviewees to be called *as* witnesses, it may be sufficient for the field survey organiser to be called to give evidence or to provide an affidavit as to how the interviewees were selected and exactly what instructions were given to the interviewers. If the only ground for objecting to the admissibility of survey evidence was the fact that some of the respondents could not be identified the survey evidence is unlikely to be inadmissible

"...but it would lessen the weight of that evidence substantially " (Somerville, 1997, p9).

There was no reference to response rates in the survey at issue in *Auckland Regional Authority V Mutual Rental Cars* (supra) at 657 (apart from the fact that less than a third of respondents did not answer all the questions) nor in the other cases Barker J referred to. It is possible that the significance of response rates in market surveys with regard to their admissibility and the weight put on admissible evidence has yet to be addressed.

3.2.5 Survey objectives

Councils and odour producers may survey a community's perceptions of odour for different reasons. While a council could also be an odour producer, in general there will be three parties: the council, whose job it is to monitor odour and complaints about odour and to consider resource consent applications for permission to discharge odour; the odour producer - that part of the community producing the odour; and the community - the rest of the community, those not responsible for the odour but actually or potentially affected by it.

Surveying a community's perceptions of odour is not the same as environmental monitoring. The latter is concerned with whether there is odour; the former *is* concerned with whether odour is perceived to be a problem. Environmental monitoring will most likely involve spatial sampling, rather than survey sampling.[9]

If there is more than one source of odour, a community survey may not tell you which source *is* causing a problem in the community. Collecting data from people (perhaps using odour diaries) on the meteorological conditions at the time they detect an odour will help. But to really separate the effect of each individual source will probably require environmental monitoring and chemical analysis (Ministry for the Environment, 1994, p14).

In surveying the community, the council or odour producer could be seeking information for its own internal use, or for legal purposes. We will call the first sort of survey an 'indicative' survey, and the second sort a 'definitive' survey. Indicative surveys need to be quick and

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9 Isaaks, EH; Srivastava, RM (1989): *An introduction to applied geostatistics*. Oxford: Oxford University Press. On p108: 'In a study of the concentration of some pollutant, for example, we are not really interested in the average concentration of the pollutant in the samples we have collected. What we actually want to know is the concentration of the pollutant over some larger region'.

cheap. Definitive surveys need to be able to withstand legal challenge. Criteria to be met before survey results will be admitted as evidence are discussed in section 3.2.4 above.

The council may wish to run an indicative survey to determine whether a complaint represents a wider problem (which will then need to be acted on), or whether the complaint is 'vexatious'. The odour producer may wish to run an indicative survey to gather information which will help it to better manage odour. Both council and odour producer may require definitive surveys as part of the resource consent process, or when enforcement orders are called into question.

3.2.6 Planning the survey

Throughout each stage you will be looking at ways of minimising sampling and non-sampling error (Statistics New Zealand, 1995, pp63-64). Sampling error manifests in the process of seeking information from a portion of the survey (or target) population rather than the full survey population. Non-sampling error can give rise to bias in the results, and can arise in any of the stages discussed below.

3.2.6.1 To survey or not to survey?

The first step is to clarify what sort of information you want to gather (Berdie and Anderson, 1974, p25) and then to consider whether a survey is the most appropriate means of gaining that information (Taylor *et al.*, 1995, p143). Would odour diaries or odour panels, for example, be better means of getting the data you require or could an odour survey complement other information already gathered (see section 3.2.1)? Are other sources available such as written records, earlier surveys, etc.

Once you are satisfied that a survey is the most appropriate technique, then you will need to start planning. The resources available both in terms of human (time, expertise) and financial will place limits on the extent and scope of the survey.

3.2.6.2 Defining objectives

The next task is to clarify the kind of information that you want to collect from a survey and how the results or findings are to be used (see section 3.2.14). At this stage you will look at developing broad objectives that will reflect those information needs. The objectives may need to be revised as the survey planning progresses.

The kind of survey that you might wish to undertake is likely to be descriptive in the main, where you may report on the community's perceptions of odour as well as the potential influence of say the FIDO factors. On the other hand someone involved in basic social or psychological research is more likely to carry out surveys that try to understand which personal attributes could influence those perceptions (e.g. age, gender, attitudes towards industry/the environment, perception of personal health, etc. (Winneke and Kastka, 1987).

Section 3.2.5 has covered the different objectives councils and odour producers may have when surveying a community. While a council could also be an odour producer, in general there will be three parties; a council, an odour producer, and the rest of the community. Both councils and odour producers need to select a sample of people to represent the community. A council often has a list of ratepayers from which it can draw its sample. An odour producer will typically not have this sort of information. So, councils and odour producers

will tend to use different sorts of surveys because their objectives differ, and because councils already know where people live and work in the community.

3.2.6.3 Scoping the issues

In the scoping phase you look to identify the key issues as perceived by a range of potentially affected groups so that these issues can be explored and measured quantitatively in the actual survey. An historical perspective can be brought together using existing sources of information that the council or company already has, (including a complaints register), newspaper items, etc.

Focus groups (Krueger, 1988) and/or interviews with people chosen from specified demographic groups and who live in the vicinity of the industry/facility under study can be used at the outset to explore issues and to define the points that will be addressed in the survey.

Objectives may now need to be modified or more tightly focused depending on what has been learned to this point. Imprecise definition of the objectives is one source of non-sampling error and may result in collecting information that does not meet the needs of the decision maker. *"An example might be confusion about whether information was required for families or households"* (Statistics New Zealand, 1995, p64).

3.2.6.4 Who is to be surveyed?

Careful delineation of the geographic area and definition of the population of interest living in that area helps minimise another potential source of non-sampling error (Statistics New Zealand 1995, p64). The population of interest is the group of people whose opinions you want to record. Obviously if you define your population as those living within a certain area and this area is very large, then the proportion of people who perceive odour to be a problem may be very small, even though perhaps a large number of people are actually affected. But you won't collect much information in your survey about those affected, because most of the people you talk to will not perceive odour to be a problem. On the other hand, if you define your population as those living within a small area, the proportion who perceive odour to be a problem may be very large, but you may be excluding from your survey others outside your population of interest who are also affected. So this definition of a population of interest is crucial to the conclusions you will be able to draw from your survey. Section A2 of Appendix A covers in more detail how to define your population of interest.

You may want to describe the demographic characteristics of your population of interest. Then later, you will be able to compare the demographic characteristics of your sample with those of your population. You can find information on your population from Statistic New Zealand's publications or from their 'Supermap' database of Census data. Most major libraries will have these sources of information in their reference collection.

3.2.6.5 *When will they be surveyed?*

Time of year may be a significant consideration when investigating odour effects. If a survey is carried out at a time when meteorological conditions are not representative of those generally prevailing or when a facility is working at a reduced capacity because of the seasonal nature of the operation, for example, then the results may not represent an accurate or reasonable portrayal of the situation. The credibility of the survey may then be undermined.

3.2.6.6 *How will they be surveyed - personal face-to-face interview, telephone interview, or self-administered postal questionnaire?*

There are a number of factors to consider when choosing your data collection method (Statistics NZ, 1995, p68):

- Nature of the questions
  - Complexity, sensitivity and depth of topics are very likely to influence the choice of method.
  - Complex issues and long questionnaires favour face-to-face interviews while people may be more willing to respond to sensitive issues by telephone.

- Resources available
  - The costs both in time and transportation for face-to-face interviewing mean that telephone interviews and postal questionnaires are usually significantly cheaper, particularly if the sample size is large.

- Response rate
  - Face-to-face interviews tend to achieve a higher response rate than the other two methods; response rates affect the quality and reliability of the data gathered.

- Survey population
  - If those to be surveyed are widely dispersed geographically it may be more practical to use telephone interviews or postal questionnaires if the budget is limited. On the other hand this approach would not be appropriate if there is low phone penetration in your area of interest (Weston, 1995, p14).

- Time
  - If there are time constraints on the survey then telephone interviews are preferable to both face-to-face interviews and postal questionnaires.

- Non-sampling errors
  - Collecting data by telephone excludes groups within the scope of the survey (those without telephones or those with unlisted or confidential numbers (these latter two groups can be reached if CATI [Computer Assisted Telephone interviewing] is used).

Note that the costings below do not include scoping (see section 3.2.6.3) and this is an important and potentially time-consuming aspect of your survey.

(a) Personal face-to-face interviews

The advantages of personal interview surveys arise primarily from the improved level of communication possible in face-to-face situations. Where council staff carry out the interviews they serve as an exercise in public relations, giving a face to the local authority, as well as simply a means of obtaining information about a specific problem. Response rates are generally high as the interviews are short and no on-going effort is required. They can be designed to ensure statistical validity in obtaining an accurate picture of community concerns.

Like telephone surveys there is considerable variation in the scale of the surveys undertaken by local authorities involved in odour assessment. For most, the problems addressed will affect only a small number of near neighbours and the costs will be little higher than those of telephone survey of the same number of respondents.

Questionnaire design etc. (1 hour @ $50 per hour)	$50
Personal interviews (3/4 people) (2 hours @ $50 per hour)	$100
Visit site (1 hour @ $50 per hour)	$50
Administration, letters (2 hours @ $50 per hour)	$100
Staff member visits site again to discuss results with consent holder (1 hour @ $50 per hour)	$50
Mileage (40 km @ $0.40/km)	$16
TOTAL COST	$366

A professionally conducted survey of 200 households within a defined radius commissioned by one local authority (Lincoln Environmental, 1997) cost $4,200, which is very similar to the cost of the telephone interview survey quoted below. However, the design and analysis and surveying costs of this survey are extremely low as the survey was a simple one, involving few questions and relatively little analysis.

Questionnaire design etc. (1 day @ $400 per day)	$400
Printing	$50
Conducting the survey	$3,000
Survey analysis	$750
TOTAL COST	$4,200

For a more complex survey involving longer interviewing times and more time spent on analysis and reporting, costs of $6,000 or more could easily be incurred.

As in the case of telephone surveys, professional assistance may be required with survey design and analysis unless the local authority has suitably trained staff.

(b) Telephone surveys

The advantages of a telephone survey over a personal interview survey include the fact that it is possible to achieve a high degree of statistical validity in the results at a lower cost than a personal interview survey. Telephone interviews do not involve the costs of travelling time or mileage and the temptation of interviewees to discuss the issue under consideration beyond the scope of the survey or to discuss other issues is less than in a face-to-face situation. Consequently the total time taken to complete telephone interviews may well be only a third of the time required for personal interviews and mileage costs etc. are not incurred. The response rate to such surveys appears to be high as council staff with whom the technique was discussed generally reported that few people declined to participate. It is possible that respondents feel a greater inclination to exaggerate the severity of the problem within the anonymous context of a telephone interview.

A number of local authorities (Lincoln Environmental, 1997) responded that they had carried out telephone interviews in response to odour problems. These may range in scale small number of calls made by members of council staff to statistically valid surveys out using students to carry out the interviews or by a professional interview team.

Where a small scale problem such as an offal pit is to be investigated telephoning households in the affected area typical costs include:

Questionnaire design etc. (1 day @ $50 per day)	$50
Telephone interviews (3/4 people) (1.5 hours @ $50 per hour)	$75
Visit site (1 hour @ $50 per hour)	$50
Administration, letters (2 hours @ $50 per hour)	$100
Staff member visits site again to discuss results with consent holder (1 hour @ $50 per hour)	$50
Mileage (40 km @ $0.40/km)	$16
TOTAL COST	$341

The costs associated with an example of a more extensive survey where 100 households in an area believed to be affected by odours from a sewage treatment plant included:

Survey design and analysis (Council staff 60 hours @ $56)	$3,360
Student labour (20 hours @ $10)	$200
Tolls	$90
Incidentals (e.g. printing, supper for interviewers etc.)	$40
Consultancy costs – advice on design and analysis	$530
TOTAL COST	$4,220

While the use of student labour reduced the interview costs to well below the level of a professional interview team, a professionally conducted survey may have cost less in terms of design and analysis. The time taken by the council staff member to complete the study was higher than might have been expected for a professional with experience in such work and professional advice on design and analysis was required in addition to that time. For any survey there is a considerable variation in the costs quoted by firms but at $10 per completed

interview plus six days of professional time (at $500 per day) in design, analysis and reporting plus tolls and incidentals the cost of $4,130 would be very similar to the level reported above. Unless there are members of council staff with tertiary training or experience in survey design, the services of a professional are desirable to ensure that the desired level of statistical validity is achieved and that questionnaires are unbiased and will collect the required information. It may even be less costly to use outside expertise if qualified personal can undertake the work in less time than local authority staff.

(c) Postal questionnaires

This method is used by very few councils and no specific feedback was received in the local authority survey. A few brief comments have been included here as it is a method that has been used in overseas odour surveys. Dilman's *The Total Design Method: Mail and Telephone Surveys* is a useful reference for those who choose this option.

It is the most reliable of the three approaches, particularly for open-ended questions, where the *'exact answers and not some abbreviated form must be recorded'* for a survey that is to be used in evidence. The cost can be relatively low compared to personal and telephone interviews.

On the other hand respondents can be a typical of the population of interest. (Weston, 1995, p14), postal questionnaires can seem impersonal, the response rate can be relatively low if the topic is not of immediate interest to respondents, and getting addresses can be time-consuming if the survey population covers a large geographical area and does not conform to an existing *database.*

The main costs are likely to include: questionnaire and sample design, printing of questionnaire forms and introductory letter, postage and envelopes (including at least one follow-up-see section 3.2.6.7 below), obtaining addresses, and the analysis.

3.2.6.7 Means enhancing/increasing response rates

During the planning stage means of enhancing the response rate should be identified according to the method of data collection that is to be used.

- Telephone interviews
  - Each unit in the sample should be called back at least twice if there is no reply at the first call.

- Postal questionnaires
  - Include a postage-paid, pre-addressed envelope for the questionnaire return.
  - A second questionnaire should be sent to those who have not responded by the due date.
  - A follow-up phone call to see if the household has received the forms.

A prize could be offered with any of the methods as an incentive for people to participate/respond. However, it is important that relevant regulations be checked to ensure that this approach is being undertaken legally.

3.2.6.8 Who will collect the data?

People with appropriate qualifications need to be recruited and trained and an interviewer supervisor needs to be appointed (Statistics NZ, 1995, p69). In the case of definitive surveys it would be wise to use a professional firm; they should also be able to provide appropriate input into the questionnaire design and will also know the importance of strict adherence to data collection instructions.

3.2.6.9 Pre-testing the questionnaire and sample design

Preparation for pre-testing of both the questionnaire and sample design should be planned for too. Although the questions may seem straightforward to you or to the person who designed them, that may not be so for the people who will eventually be questioned.

3.2.6.10 Data preparation

It is necessary to determine the form in which the data will be coded, identify who will be undertaking the coding of responses, and liaise with the person who will be entering the data into a computer file ready for subsequent analysis.

3.2.6.11 Analysing your data - choice of analyses

Appropriate statistical analyses need to be identified at the planning stage; your choice will depend on the objectives of your survey, the type of data you have collected (nominal, ordinal, or interval), your sampling method and whether it is an indicative or definitive type of survey (see section 3.2.5).

3.2.7 Sample design

Typically you will have neither the time nor the resources to contact everyone in your population of interest. You can only afford to contact a sample of those in your population. Sample design refers to the process of choosing respondents for your survey and then later, calculating your survey's results - what the sample has to say about your wider population of interest. The first two of Justice Whitford's criteria (see section 3.2.4) summarise what good sample design is all about:

> *"(a) The interviewees must be selected so as to represent a relevant cross-section of the public;*
> *(b) The size of the survey must be statistically significant;"*

The first of four steps in the sample design process is to define your population of interest - the people you wish to make statements about. You then need some sort of sampling frame - basically a list of all those in your population of interest.

Once you have a sampling frame, the second step is to randomly select respondents from it. And there are many ways to do this. In most cases, you will use either simple random sampling or stratified random sampling. Having decided on the method of random sampling, you then need to calculate how many respondents are necessary to get suitably precise results from your survey.

The third step is calculating the results, once the survey's questionnaires have been collected. You also need to calculate how precisely these results are known - so you know how confident you can be about the results of your survey. These results are what your sample has to say about the wider population of interest.

You may also need a fourth step. You may need to adjust your results to take account of non-response. Typically those who do not respond to a survey are different from those who do. Non-response introduces a bias: on average the results from the survey will differ from the true value. Many things can be done, as part of survey management, to reduce non-response and good questionnaire design helps too. But having done your best to minimise non-response, you may still need to use statistical methods to adjust your results so that they are less biased.

Done properly, the first two steps above will give you a relevant cross-section of the public. And the third and fourth steps will demonstrate the statistical significance of your survey's results.

We have put detailed instructions on appropriate sample designs in Appendix A. There are different designs for each combination of council or odour producer and indicative or definitive survey (see section 3.2.5). We believe that with these instructions you should be able to run an indicative survey in-house, although paying for professional peer review would be wise. But if there is any chance that your survey results will be used in legal proceedings (a definitive survey), we strongly recommend contracting the sample design and analysis of survey data out to a statistician and questionnaire design to an appropriate expert. One of Justice Lockhart's criteria (section 3.2.4), for a survey to be admissible as evidence, is that "the persons conducting the survey were recognised experts". The information in the appendix will help you understand what your expert is up to.

3.2.8 Questionnaire development

> *"(f) The questions must not be leading nor should they lead the person answering into a field of speculation he would never have embarked upon had the question not been put;" (Auckland Regional Authority v Mutual Rental Cars* (supra)).

This is a critical stage of the survey and is closely linked to other major stages (see Statistics New Zealand, 1995, p42). The questionnaire is the measuring instrument and it is critical that the questions are worded correctly. If the questionnaire is not developed properly you run the risk of, amongst other things, not getting the information you want, of not measuring what you want to measure, and of introducing non-sampling error.

3.2.8.1 Frame of reference

It is necessary to have a frame of reference within which you will interpret your results (de Vaus, 1986, p33) and within which you will develop your questionnaire. This frame is likely to be derived from overseas or local research or studies on odour, for example, as well as from the legislative framework within which odour management is carried out, i.e. the Resource Management Act, the Health Act and related case-law.

3.2.8.2 Survey concepts

However the major concept that is the focus of much overseas research is that of 'odour annoyance' and not 'offensive' or 'objectionable' odour. We need to be cautious when comparing the findings of studies carried out here because of course the meanings of these concepts differ. Terms such as 'offensiveness' need to be defined as precisely as possible at the outset (Fink and Kosecoff, 1985, p24) to avoid ambiguity when interpreting results.

3.2.8.3 Survey focus

When you have defined the problem that you plan to tackle with the survey you will narrow down the focus of the questions you will ask. The focus may reflect the FIDO factors, for example, and/or questions may be included to determine the effects of the odour on the community (including levels of adversity) and how it impacts on their everyday lives.

Your survey may also focus on the issue of 'Acceptability' of varying degrees of offensiveness and this could be related to 'Circumstances', ie whether the odour is being experienced in a rural or urban location and what people's expectations are of what is acceptable in a particular location.

During the course of questionnaire design you may wish to guard against responses that reflect a sensitisation to the issue of odour offensiveness. The survey can be introduced as an investigation into 'satisfaction with the 'living environment' generally (Miedema *et al.,* 1986, p248; Poustchi, 1991) or appreciation of the neighbourhood'. Questions on various forms of pollution (such as noise, visual, and air quality in general) can be included if there is a wish to de-emphasise the main interest of the survey in odour (Basarin and Cook, 1982, p28; van Langenhove *et al.,* 1988, p2510; Miedema and Ham, 1988, p2503; Poustchi *et al.,* 1991, p151). However, it is unethical to ask for information that you don't plan to use[10].

3.2.8.4 Question development

> *"A variable is a characteristic which has more than one category (or value). Thus sex is a variable with the categories male and female.... In cause and effect terms we can distinguish between dependent, independent and intervening variables. The effect is called a dependent variable (symbolised Y).... The assumed cause is called the independent variable (symbolised X).... An intervening variable (symbolised Z) is the means by which the independent variable affects the dependent variable"* (de Vaus, 1986, pp27-28).

When you come to analysing your data you may want to explore whether there are relationships between variables such as the location of the respondent and identifying the source of odour, for example. You will therefore need to specify variables that relate to the concept or concepts you want to investigate. These variables will then be reflected in your questions.

---

10 Saffron, K, 1996, Advisor Survey Design and Development, Statistics New Zealand, pers. comm.

3.2.8.4.1 Content

Question content may relate to factual information, opinion, motivation, and/or attitudes. Questions on demographic characteristics are examples of factual questions. Opinion questions are much more complex and give rise to a number of issues: (a) they require the respondent to 'think', (b) there is no one correct answer as opinions are many-sided, (c) the problem of intensity of feeling, and (d) they are more sensitive to changes in wording, emphasis, sequence, etc. than factual questions are.

When you want to gather data on opinions or attitudes you have a choice of two distinct approaches. The first simply estimates the proportion of your population of interest that agrees with a number of opinion statements, and the second asks a number of opinion questions and measures attitudes by assessing a respondent's answers to the set of questions (Moser and Kalton, 1985, pp3 10-318.). The latter approach involves the use of scales which need to be both reliable and valid (ibid., p353).

3.2.8.4.2 Wording

The wording is likely to be influenced by whether the questionnaire is to be self-administered (i.e. postal questionnaire) or whether it will be administered by an interviewer (face-to-face or telephone).

Questions need to be 'respondent friendly' so that people are willing and able to answer individual questions and to complete the whole questionnaire.

3.2.8.4.3 Type

Should you use open or closed (forced choice) questions? 'Open' questions give people the opportunity to use their own words in answering whereas 'closed' questions have several possible alternative responses to choose from. If you are conducting a definitive survey that is to be carried out by face-to-face or telephone interview it is possibly preferable to use closed questions throughout if that is possible because surveys that may be used in evidence need the respondent's "..... exact answers and not some abbreviated form....." *(Auckland Regional Authority v Mutual Rental Cars* (supra)) and this can be difficult to achieve in a face-to-face or telephone interview.

When you develop what will be closed or forced questions you will be faced with the decision as to the most appropriate response format. Refer to de Vaus (1986) for a range of response formats.

Figures 3.1 and 3.2 provide overlapping checklists for wording questions.

1. Is the language simple?
2. Can the question be shortened?
3. Is the question double-barrelled?
4. Is the question leading?
5. Is the question negative?
6. Is the respondent likely to have the necessary knowledge?
7. Will the words have the same meaning for everyone?
8. Is there a prestige bias in the question?
9. Is the question ambiguous?
10. Do you need a direct or indirect question?
11. Is the frame of reference for the question sufficiently clear?
12. Does the question artificially create opinions?
13. Is personal or impersonal wording preferable?
14. Is the question wording unnecessarily detailed or objectionable?

Figure 3.1: (Source: de Vaus, 1986, pp71-74)

1. Does the question ask for only one bit of information?
2. Does the question presuppose a certain state of affairs?
3. Does the question wording imply a desired answer?
4. Are any of the question's words emotionally loaded, vaguely defined or overly general?
5. Do any of the question's words have a double meaning that may cause misunderstanding?
6. Does the question use abbreviations which may be unfamiliar to respondents?
7. Are the response options mutually exclusive and sufficient to cover each conceivable answer?

Figure 3.2: (Source: Berdie and Anderson, 1974, p48)

3.2.8.5 Sample questions

We are now going to set out a few examples to demonstrate some of the points made above. The actual wording and response category will depend on the method of data collection you use. The number of questions you formulate will vary depending on the survey objectives.

In a definitive survey you need to get an expert to help design the questions, and expert peer review is recommended for indicative surveys.

Begin your survey with non-threatening or interesting questions (Berdie and Anderson, 1974, p35). Avoid questions that ask, for example, how often the respondent is at home during the day, because security-conscious people may become concerned (you could be someone who is interested in this information for reasons other than the survey.....) and refuse to participate further. If you want to gather this sort of information leave it until the end of the survey preferably.

Example 1

How long, to the nearest year, have you been living/working at this address/here? (Circle one only)

< 1 year 1-2 3-4 5-6 >6

(Could be used for a personal ace-to-face interview where the interviewer shows a card or for a postal questionnaire)

OR **How long have you been living/working at this address/here? Would it be** (Interviewer read and stop once they get a negative answer)

More than a year?
More than two years?
More than three years?
More than four years?
More than five years?

(Could be used for telephone interviewing)

- Ensure that each questionnaire refers to a home address (where the person will be surveyed, so that the work "here" can be used a lot) OR to a work address (Saffron, 1996, pers. comm.[10]).
- The maximum number of years that you indicate may depend on how many years the facility has been in operation. The breakdown of categories may reflect different periods of controversial/non-controversial operation.

You may want to explore whether odour has been a problem without predisposing the respondent to answer in a particular way. Avoid 'leading' or 'loaded' questions (people have a tendency to say 'yes' if asked if they have a problem) such as *"Can you smell offensive odour coming from the local sewage treatment plant?"*.

Example 2

During the past twelve months/since moving to that address have you noticed any smell or smells that came from beyond your home/address/workplace?

Yes (continue to question X)
No (thank and terminate interview)
Don't know (thank and terminate interview)

- The way this question *is* asked could take into account the answer given to a question like Example 1. Alternatively, it could be stated in the introduction that respondents are to consider the past twelve months (or 2 years - whatever time period is important/ relevant to the council/odour producer or the period of time they have been living there if it is less than twelve months).
- Data users may want to know whether the smell is detectable/offensive from inside the building or only when out-of-doors - if so, ensure something to that effect is included in the question. It might be useful to find out whether the building is air-conditioned, particularly in the work situation where this is more common (Saffron, 1996, pers. comm.[10]).

Example 3

Would you please describe the smell/s (list)

Odour 1: ❑

.....

.....

Odour 2: ❑

.....

.....

Odour 3: ❑

.....

.....

- Asking a person to describe a smell is likely to elicit a whole range of responses (Ministry for the Environment, 1995). However the main point of the question such as the one suggested here is to focus their attention on specific smells/odours.

- There may be several they notice. Your complaints records and/or pre-testing should give you a clear idea of how many odours are an actual or potential problem in the area. You could ask them which odour they are most bothered by although this approach may not provide the opportunity of gaining a full picture about the odour of interest. Alternatively, you could ask a series of questions (such as those in Examples 4 to 8 below) on each of the smells they mention. That way, you could be confident that if the respondent is noticing the smells that you are interested in, it will be covered in the questionnaire even if there is, say, a smell from neighbours that gives more offence. That would make the interview longer, but there are unlikely to be more than 2 or 3 smells (Saffron, 1996, pers. comm[10]).

Example 4

Where do you personally think that smell/the first smell/the second smell you mentioned comes from? (State source)

.....

.....

.....

- Pre-testing should indicate whether people state the facility, general geographical area/direction, or something non-specific such as 'animals' and whether the question needs to be reworded.

- Avoid asking for two pieces of information in the same question, for example, *"Could you describe the annoying odour or mention its source?"* (Miedema *et al.*, 1986, p249), as problems can be encountered when trying to code the responses after the data has been collected.

- Note that people can have different reasons for thinking that a smell comes from a particular source - it could be based on detection (e.g. the direction it comes from) or on publicity. That may or may not matter but if it does, an extra question would be needed (Saffron, 1996, pers. comm.).

Some or all of the FIDO[11] factors may be incorporated into the questionnaire design as they are believed to influence the significance of adverse odour effects. Information on individual factors may help determine what is causing the 'odour problem'. For example, is it a continuous dilute emission or an intermittent intense emission?

However, you should also be very clear on what you want information for on the FIDO factors of Frequency, Intensity and Duration if you ask respondents to provide one answer that relates to a long period of time such as a year or more. Some questions may be more appropriate in the context of an odour diary or an odour panel where these factors then relate to a very specific time period.

There are a number of issues to be considered when doing this and we will look at those relating to 'offensiveness' first.

Section 17(3)(a) of the RMA is concerned with the avoiding, remedying or mitigating adverse effects arising from activities that are likely to be noxious, dangerous, offensive or objectionable and the Health Act (s.23) is concerned with conditions that are, amongst other things, offensive. Associated case-law also reflects concerns about offensiveness. This focus on 'offensiveness' and 'objectionability' highlights the issue of the choice of words and the desirability of using plain, ordinary English and language that is appropriate to the people you will be surveying (Berdie and Anderson, 1974, pp39-40). The word 'offensive' tends to be an 'educated' word but it is difficult to replace it with a less educated word as the legislation focuses on this concept.

A second issue is that both Acts and related case-law do not appear to be explicitly concerned about degrees of offensiveness and for this reason we have included an example question that asks for a response that is either in the affirmative or is negative. However the practice has developed in New Zealand of asking people participating in surveys and odour diaries, etc. to use a scale when indicating their experience of an odour. This allows for gradations of experience as people may be unwilling or unable to give a definite positive or negative response.

The use of rating scales overseas for investigating odour 'annoyance' (VDI, 1993a; van Langenhove, *et al.*, 1988; Köster *et al.*, 1985) may have also influenced this practice. Criteria that have been used in developing these response scales are:

> *"- the notions in the scale are simple and easily comprehensible in all strata of the population,*
> *- the notions used in the scale are unambiguously interpretable by all members in the panel,*
> *- the scale is sensitive and reliable,*
> *- the scale is stable over time."* (Köster *et al.*, 1985, p301)

11 F = Frequency, I = Intensity, D = Duratiion and O = Offensiveness.

Building such scales can be a complex matter (see de Vaus, 1986, Chapter 7) and the one referred to above has been developed in a psychological laboratory. A number of questions or indicators make up a scale. In New Zealand there do not appear to have been attempts to build a valid and reliable scale to measure the concept of 'offensiveness' and the development of a single index of offensiveness is beyond the scope of this project. A number of question examples are given below on 'offensiveness'.

Example 5

Would you say that that smell is:

Offensive to you personally? ☐
Not offensive to you personally?
Don't know

OR **Would you say that that smell is:**

Not at all offensive to you personally? ☐
A little offensive to you personally? or
Very offensive to you personally?
Don't know

OR **Thinking about the smell, which of the following statements comes closest to what you personally think about** it?

Not at all offensive ☐
A little offensive
Very offensive
Don't know

(All 3 examples could be used for telephone interviewing)

OR **Thinking about the smell/odour, would you rate it on a scale of 5 to 1 where 5 = Extremely Offensive and 1 = Not Offensive.** (Circle one only)

Extremely offensive				Not offensive
5	4	3	2	1

(Could be used for a personal face-to-face interview where the interviewer shows the respondent a card or for a postal questionnaire.)

(Ten points could be used instead of five.)

There are a number of issues relating to the remaining FIDO factors. Respondents can have difficulty in answering questions where their individual experience has varied over time. For example, questions relating to 'frequency', 'intensity' and 'duration' may give rise to a response such as 'it depends' or 'it varies' (according to the time of year/day or to the wind direction. This situation is likely to manifest in the pre-test phase (see section 3.2.8 below) and the questions may need modifying to accommodate these responses.

Two sets of response categories are illustrated in Example 6 for a question on frequency. It is recommended that you avoid using the second set if possible because the expressions can be variable in interpretation (Saffron, 1996, pers. comm.[10]).

Example 6

Within the past twelve months how often have you smelt the smell?
(Read OR tick ONE only) (Instruction depends on how survey administered)

More once a month? ☐
More than once a fortnight?
More than once a week?
More than three times a week?
Everyday?
Other
Don't know

OR Almost never ☐
Seldom
Sometimes
Often
Almost always (Miedema *et al.*, 1985, p249)
Other
Don't know

- It might also be useful to know whether the smell is detectable on certain days, and especially whether it can be detected at the weekend (Saffron, 1996, pers. comm[10]).

Example 7

How long would you say the smell lasts?
(Interviewer read and stop once they get a negative answer)

More than five minutes ☐
More than ten minutes
More than fifteen minutes
More than half an hour
More than an hour
More than two hours
Other
Don't Know

- Again, pre-testing may show that respondents want to qualify their answers depending on season/wind direction/other - you may need to reword the question or include additional ones.

- You might also want to ask, as separate questions, how long the smell stays at the offensive level and how long it is noticeable, as they could well be different. This depends on which of these pieces of information you think will be needed (Saffron, 1996, pers. comm.[10]).

- People habituate to odours; after a while you may not smell an odour you have been smelling, though you can detect a new one. On the other hand, if you are getting whiffs of an odour rather than a steady dose, you may well keep on noticing it. So duration would be judged differently depending on how constant it is. And there may well be variability in the way people respond. If they are getting whiffs lasting a minute of two spread over a few hours, they could say that the smell lasted a few minutes or that it lasted a few hours (ibid.).

Example 8

I would like you to rate how strong the odour is when it is at its strongest using a scale where 5 = very strong, 4 = strong, 3 = moderate, 2 = light, 1 = very light.
(Read) (One response only)

Very strong ❑
Strong
Moderate
Light
Very light
Other
Don't know

- 'Strength of odour' may be a variable with limited use, in that it will be treated in analysis in the same way as 'frequency' which though perceptual is much less subjective than strength (Saffron, 1996, pers. comm.[10]).

The last question example (9) is best kept until last in your questionnaire if you want to collect this kind of information, as it might be sensitive from the point of view of home security. Note that responses may not necessarily be correct if people don't want to admit how frequently or when they might be out, etc. For this reason avoid using specific times or time periods unless absolutely necessary. You could use categories, as that seems less inquisitive, but interviewers would have to help most people work out their hours per week at home so that might result in being just as problematic (ibid.).

This is also a difficult question to answer as the times are likely to be very variable, especially between work-days and weekends. If the question is about a workplace, the number of hours spent there per week could be asked about, as that would be easier to answer than hours-per-day if that varies. The real problem is home.

One solution might be as follows:

Example 9

(a) **On most weekdays, that is Monday to Friday, how many hours per day are you home - would it be** (Interviewer read and stop once they get a positive answer)

Less than 10 hours? ❑
Less than 15 hours?
Less than 20 hours (or whatever seems likely)

(b) **At the weekend how many hours per day are you usually home - would it be**

Less than 10 hours? ❑
Less than 15 hours?
Less than 20 hours (or whatever seems likely)

- Even with this information it could be quite difficult to use this to give an estimate of their time per week at home so the data may have limited usefulness (ibid.).

How many hours do you spend at this address each work-day? (If business) (Read) (Tick one only)

Twenty four hours ❑
Between sixteen and twenty three hours
Between eight and fifteen hours
Less than eight hours

Thank you for participating in the survey, etc.

You may want to ask for the christian name of the respondent and record their phone number so that interviewers can be checked by their supervisor. This information could be removed for purposes of legal scrutiny but a code number would be attached for any future need.

3.2.8.6 Demographic characteristics

Demographic information can be asked for at the outset of the survey or at the end. Asking such questions at the end can be preferable as the interviewer will have developed a degree of rapport with the person who may then be more willing to provide what are perceived by some to be quite personal details.

Gather just the demographic information that will be used in some way in your study (e.g. to compare your sample with the population of interest, for post-stratification to take account of incomplete sampling frames (see section A8.4), or if you are intending to act on it by focusing on particular demographic groups for consultation, etc.). By doing so you save time during data collection and during your data analysis stage.

Use categories for sensitive issues such as age and income, for example (de Vaus, 1986, p74) as people are more likely to respond. Don't forget to provide *a* category for those who are unwilling to answer.

D1 Which of the following age groups do you fall into? ☐

0 to 19 years	1
20 to 29	2
30 to 39	3
40 to 49	4
50 to 59	5
60 to 69	6
70 years and over	7
Refused	9

D2 What is your occupation? ☐

.....

Don't know/Declined 99

D3 Record gender: ☐

Male	1
Female	2

Figure 3.3: Examples of questions on demographic characteristics

3.2.8.7 Questionnaire layout

Irrespective of whether your questionnaire is self-administered (e.g. postal questionnaire) or whether the respondent is interviewed, the Introduction needs to be carefully crafted so that it contains the relevant information and encourages the would-be respondent to participate. The following list suggests some of the items you would expect to be covered in the Introduction:

- Who is conducting the survey;
- Its purpose (if you want to avoid stating at the outset that it is about odour you might want to make a more general statement about the living environment or their neighbourhood, for example;
- Approximate time survey will take;
- Whether their responses will be treated as confidential or not (you might want to read the relevant sections in *Auckland Regional Authority v Mutual Rental Cars* (supra) and section 3.2.4 above to see how this issue might be treated in a legal situation).

At the end of the questionnaire thank them for their participation, advise them who they can contact if they have any questions about the survey, and let them know where and when they can find out the results.

A small introduction at the beginning of each section of the survey prepares the respondent for a change in focus potentially or explains why certain information may be required. Clear and precise instructions on how to answer each question make it easier for both the interviewer and/or interviewee as well as for the coding of that data at a later stage. If multiple choice answer options are given, for example, the respondent needs to know how to indicate his or her answer (e.g. tick in the box) and how many responses they can give to the one question. If your questionnaire contains contingency questions, ensure that you include 'go to' type instructions, e.g. 'if you answered No, to this question, please go to question 7' (de Vaus, 1986, p80).

Willingness to respond to self-administered questionnaires can be enhanced by a physical layout that has as much 'white space' as possible. There needs to be sufficient room to answer open-ended questions in particular (Berdie and Anderson, 1974, p62) and for a column on the right hand side of the page for computer coding (see section 3.2.11.2 below) (de Vaus, 1986, p80).

Print a box at the top of the questionnaire so that each form can be numbered before it is actually used.

3.2.9 Pre-test or pilot survey of the questionnaire and sampling procedures

As the questionnaire is being developed consult with interviewers/supervisor and with those who will code and enter the data into a computer file so that you don't find out about problems when the survey has started or when the data has all been collected.

You need to pre-test or pilot survey your questionnaire, your data collection process (section 3.2.10) as well as your data processing process (section 3.2.11) on a small sample of the population of interest.

To ensure that each question has the same meaning for each interviewee, that questions are not ambiguous, and that the kind of data that is required is actually collected, it is very important that the questionnaire be pre-tested on a small sample of the population of interest. You should pre-test it on at least 10 people for an indicative survey, and the expert advising on a definitive survey will recommend how many should be involved. It is not a good idea to test it solely on friends and colleagues as they may have a clearer understanding of the topic than the general public and their levels of reading and/or comprehension could also differ from the population of interest. However, you do need to ensure that the people involved in the pre-test are not surveyed again (Statistics NZ, 1995, p65) in the main survey itself.

> *"Pilot surveys should be able to provide preliminary information on the following:*
>
> - *feasibility of the sample selection plan*
> - *variability in the target population*
> - *fieldwork procedures*
> - *response rate*
> - *processing procedures*
> - *estimates of costs"*
>
> (Statistics NZ, 1995, pp65-66)

For indicative surveys pre-testing of the questionnaire may be sufficient, whereas for definitive surveys a pilot survey is likely to be more appropriate. Refer to Statistics NZ, 1995, pp49-52 on user studies and pp65-66 on pilot surveys to consider your options.

After pre-testing or pilot surveying, go back and modify your questions, sample selection plan, and fieldwork and processing procedures where necessary.

3.2.10 Data collection

> *"(h) The instructions to the interviewers as to how to carry out the survey must be disclosed;" (Auckland Regional Authority v Mutual Rental Cars* (supra))

The selection of the person who is to be interviewed will be carried out in accordance with the criteria selected during the sample design, e.g. person most often at home (see Appendix A3).

Training of interviewers will be necessary if personal face-to-face or telephone interviews are used to collect the survey information. They need to be given explicit written instructions as to when they are to carry out their interviews (often during the evening or at weekends), over what time period, how many times they are required to try and contact each person in the sample, and how much additional information, if any, they are allowed to give to interviewees.

Telephone call sheets provide a clear record of who was contacted, how many times, and whether they agreed to participate or not (refusals need to be recorded so that they can be compared to the number of successful interviews in order to calculate the response rate).

Face-to-face interviews are carried out 'face-to-face' with the interviewer asking questions and then recording them him or herself directly on to the questionnaire. Telephone interviews are conducted in a similar manner although the parties are obviously not speaking face-to-face. Self-completion questionnaires (postal surveys) are filled in by the respondent (Statistics New Zealand, 1995, pp67-68); they also need to be informed as to where and when they need to return their completed forms (de Vaus, 1986, p80).

Interviewer behaviour will need to be monitored to ensure that different interviewers are not collecting different information. This can be carried out by the supervisor who chooses a number of completed survey forms at random and contacts the respondent to confirm that the interview was actually carried out with the correct person and that it was according to the agreed upon procedures (Statistics NZ, 1995, p69).

3.2.11 Data preparation and processing

> *"(d) All the surveys carried out must be disclosed including the number carried out, how they were conducted, and the totality of the persons involved;.....*
> *(g) The exact answers and not some abbreviated form must be recorded;".....*
> *(i) Where the answers are coded for computer input, the coding instructions must be disclosed." (Auckland Regional Authority v Mutual Rental Cars* (supra)*).*

As with all other stages in the survey, data preparation and processing has to be carried out in a meticulous manner to minimise the risk of non-sampling error.

> *"Getting the data efficiently from paper format to a computer dataset means that questionnaire designers must follow established practices which allow a data capture operator to easily and quickly identify what is, and what is not to be captured."*

Refer to *A Guide to Good Survey Design* (Statistics NZ, 1995, pp72-73) on the issues associated with this process.

There are three major tasks before you begin your data analysis and they are: editing, coding, and tabulation (Moser and Kalton, 1985, pp410-411). Tabulation is discussed in section 3.2.12.

3.2.11.1 Editing

As soon as the data collection phase has ended, questionnaires should be checked for 'completeness', 'accuracy' and 'uniformity'. Have all questions been answered where appropriate (those who indicated that they had not noticed any odour coming from the boundary of their home/workplace obviously would not have answered the remainder of the questions and this issue will be dealt with in 3.2.11.2 below) and that the writing is legible in instances where an interviewer has had to record the response to an 'open-ended' question. Be vigilant in looking for inconsistencies. You also want to ensure that the questionnaires have been completed consistently by each interviewer according to the original instructions (Moser and Kalton, 1985, pp411-413.) - check immediately with the interviewers' supervisor for clarifications if required.

3.2.11.2 Coding

> *"The essence of coding is to give a number to each answer to a question. Each answer to a particular question must be given a distinctive code. This code is fed into the computer and the number thereafter represents a particular response to a given question."* (de Vaus, 1986, p187)

Forced-choice questions such as all of those except Example Questions 3 and 4 in section 3.2.8.5 can have codes allocated to them before the questionnaires are even filled in (those are the numbers to the right of each possible response). Open-ended questions can only be coded after the questionnaires have been returned, and there are two main approaches (ibid., p188) to this process:

(i) A pre-established scheme - for example, when coding 'occupation' (see demographic characteristics in section 3.2.8.6) a reliable pre-established scheme such as the *NZ Standard Classification of Occupations 1990* developed by the Department of Statistics (1990) can be used.

(ii) Develop categories after you have studied the answers given.

In the case of Example Questions 3 and 4 on descriptions and sources of odour, you may have a good idea before the survey as to the categories you will use although you may need to modify that decision if you find that you get answers that don't fit. Try to have no more than

say 5 categories at most otherwise you may have too few responses in each cell for cross tabulation analysis (especially if your sample size is small).

If someone doesn't answer one or several questions (such as in the instance referred to above where the respondent has had no experience of odour 'beyond his or her boundary') a 'missing data' code should be entered. This code must be kept exclusively for missing numbers - common missing data codes are 0, 9, 99 or -1 (de Vaus, 1986, pp189-190.).

It is always good practice to develop a coding schedule/book/frame, and essential if you are undertaking a definitive survey because the schedule is needed if your survey evidence is to be admissible. Preparing the schedule before collecting your data may alert you to any potential inconsistencies in your questionnaire.

The following points are normally included in a codebook:

> *"1 List the questions asked.*
> 2. *Most computer programs require that a variable has a short name by which it is referred to in the program. In the codebook list the name given to each variable.*
> 3. *List the record on which the variable is located.*
> 4. *List the columns in which the variable is located*
> 5. *List the valid codes for each question.*
> 6. *List the missing data codes for each question.*
> 7 *List any special coding instructions which were used for coding particular questions"* (ibid., p193).

(Note that point 3 may not be relevant now as this step depends on the mode of data entry – see Note 3 in Table 3.1 below.)

You will need to know whether you will have access to a computer package for your analysis, and if so, which package. Many packages also have specialist data entry modules which could be particularly useful. This aspect needs to be checked during the questionnaire design stage. A common package used in the social sciences is SPSS. You will also need to have decided on the form in which your coded data will be transferred from the questionnaires to a file. You may need to write a specific programme/s (Statistics NZ, 1995, p72) or be able to take advantage of programmes that are already written. University data entry operators may be willing to enter data for you if you have access to such resources, and you would need to consult with them on your needs for statistical analysis and their data entry processes. Councils/odour producers need to weigh up the pros and cons of investing in software, the hiring of specialist staff to enter the data, and the perceptions of the public with regard to impartiality or independence when monitoring their own performance (Weston, 1995, p15).

Table 3.1 provides an example of part of a coding schedule/book/frame based on the first three Example Questions in section 3.2.8.5.

Table 3.1: Example of a coding schedule/book/frame

Question No	Variable No	Variable Name[a]	Codes	No of Cols[b]	Column No
	1	Identif[c]	1-100	3	1-3
	2	Location[d]	1-3	1	4
1	3	Residence	1 = <1 year 2 = 1-2 years 3 = 3-4 years 4 = 5-6 years 5 = >6 years 9 = don't know -1 = missing values	1	5
2	4	Noticed	1 = yes 2 = no 3 = don't know -1 = missing values	1	6
3	5	Describe	1 = group one[e] 2 = group two 3 = group three 8 = not applicable[f] 9 = don't know -1 = missing values	1	7

Notes:

(a) Variable names are generally up to 8 letters long.

(b) No. cols. Is the number of columns that will be required for that variable if your data is to be analysed in a 'fixed' format within say SPSS. For example, if you have 100 respondents or more, you will require 3 columns, one for each digit – 001, 002, 003, etc. When you begin to analyse your data within say SPSS you will need to know which column to allocate each variable, thus the need for Col. No. (Column number) above. If you use 'free' format, the number of columns you use for each variable doesn't matter.

(c) Identif. is the unique number allocated to each questionnaire. The maximum number possible will be the size of your sample that responded.

(d) This variable would be used for definitive surveys where you may have several strata and want to compare and contrast responses within and between strata.

(e) 'Group one', 'group two' etc. can be given more appropriate names when the information from these open-ended questions have been categorised.

(f) 'Not applicable' in this instance will represent those who responded 'No" or 'Don't know' to Example Question No 2 and who would not have been asked any further questions.

Finally, check for coding errors (de Vaus, 1986, p193-4). Three main checks include:

- Valid range checks
- Filter checks
- Logical checks

These checks can be carried out when analysis of frequencies (see section 3.2.12) are undertaken.

3.2.12 Presenting your data

Tabulation can be done using a calculator (for small samples) or by computer (for small or large samples). The first tables that you will generate will be frequency distributions to see the range of responses given to each.

The following tables illustrate hypothetical data that could have been derived through asking some of the sample questions set out in section 3.2.8.5. Some of the tables (e.g. Tables 3.2 to 3.5) illustrate analysis of single variables (univariate analysis) that could then be used in bivariate and multivariate analysis where interest is likely to focus on the responses of those who identified the source of odour under study

Tables 3.2 to 3.6 illustrate the kinds of findings that could have emerged from an **indicative survey** (either council or odour producer) where there was no attempt to divide the population of interest into strata.

Table 3.2: Noticed odour (Example question 2)

	No.	%	Cum %
Yes	20	50	50
No	20	50	100
Don't know	0	-	100
Total	40	100	100

Because this question asked for Yes/No/Don't know responses, it is a nominal variable, that is, one with non-rankable response categories (as outlined in section 3.2.13.1). It can be seen that half of the respondents noticed some form of odour in the time period under investigation.

Table 3.3: Source of odour (Example question 4)

	No.	%	Cum %
Group 1	5	25	25
Group 2	5	25	50
Group 3 (source of interest)	10	50	100
Don't know	0	0	-
Total	20	100	100

Of those in the sample who had noticed odour, 50% identified the source of interest whereas the other half had different ideas as to origin.

Table 3.4: Offensive odour (Example question 5, option 1)

	No.	%	Cum %
Yes	5	17	17
No	25	83	100
Don't know	0	-	-
Total	30	100	100

Table 3.5: Frequency of smell (Example question 6)

	No.	%	Cum %
More than once a month?	4	20	20
More than once a fortnight?	2	10	30
More than once a week?	8	40	70
More than three times a week?	5	25	95
Everyday	1	5	100
Other	0		-
Don't know	0	-	
Total	20	100	100

The following is an example of a cross tabulation (bivariate analysis) of two variables:

Table 3.6: Offensive odour by source (derived from Tables 3.3 and 3.4)

	Identified Source		Ident. Other Sources*		Total
	No.	%	No.	%	
Offensive					
Yes	5*		0		5
No	5		10		15
Don't know	0		0		0
Total	10		10		20

* Note that the values appearing in the column 'Ident. other sources' represent the combination of Groups 1 and 2 in Table 2.

In the section on developing a sampling frame (see Appendix A6.1) we suggest you might divide your survey population into three strata comprising inner, middle and outer rings for definitive surveys. Table 3.7 shows how the sample population would relate to the population of interest according to the strata.

Table 3.7: Geographical location (refer to the map used when originally drew sample to determine population of interest)

	No. in Population of Interest		No. in Sample	
	No.	%	No.	%
Inner ring	100	17	30 (50)	20
Middle ring	200	33	60 (100)	40
Outer ring	300	50	60 (100)	40
Total	600	100	150 (250*)	100

* Original sample size (250) allowing for 70% response rate. Note that the actual response rate for this hypothetical survey was 150/250 = 60%.

3.2.13 Data Analysis[12]

Data analysis involves firstly summarising sample data, and then secondly making inferences from sample data about the population of interest. For a survey to be admissible as evidence, Justice Whitford's requirements (see section 3.2.4) included that "The size of the survey must be statistically significant", and Justice Lockhart directed that a complete record was required of "any tests applied and the results of any tests applied to determine the extent to which the survey or results of the survey can be trusted". These criteria reflect good survey practice; survey data must be summarised and inferences made in a way that illustrates not only the survey's results, but how reliable these results are.

The guidelines in this section (and its subsections 3.2.13.1 to 3.2.13.3) are only for simple random samples from indicative surveys. If your respondents are a simple random sample of the population, you can use standard computer packages (such as Excel) to calculate summary and inferential statistics. Remember that an indicative survey will typically involve only a small sample. And as a result, typically you will not have enough data for sophisticated data analysis. The techniques discussed in sections 3.2.13.1 to 3.2.13.3 are simple and can usually be applied to small data sets.

A definitive survey poses special problems. Most definitive surveys will not use simple random sampling. Typically definitive surveys will use either stratified or cluster sampling - because cluster sampling is more practical for a large survey, and stratified sampling leads to a smaller sample size than simple random sampling (see Appendix A6.1, A6.2 and A8.1). Standard computer packages cannot be used to calculate statistics where data represent a stratified or cluster sample. We strongly recommend you consult a statistician for the design and the analysis of data from a definitive survey.

3.2.13.1 Summarising sample data

In your survey, you will have collected data for a number of variables. Rather than presenting all this data (in say a report), you should present just a summary of each variable. [This makes a report shorter and so your report is more likely to be read; and people will find

12 Includes contributions from Debbie Singh, Department of Sociology, University of Auckland.

it easier to interpret this summary than the raw data.] In summarising your sample data, you want to show the basic properties of each variable. The most important properties are central tendency (the middle of the variable's distribution) and dispersion (the spread of the variable about the middle of its distribution). Summary statistics indicate a variable's central tendency and dispersion, but the summary statistics to use depend on the type of data you have collected.

Data can be categorised into three main types, or levels of measurement:

Table 3.8: The three levels of measurement

Level of Measurement	Description	Example
Nominal	Data in categories – but these categories cannot be ranked or ordered meaningfully.	Gender
Ordinal	Data in categories – these categories can be ordered, but not with any exact numerical meaning.	Scales, such as 'Strongly agree, Agree, Disagree, Strongly Disagree'
Interval	Data can be ordered – in addition, the difference between two data points is a meaningful quantity.	Age (in years)

Only certain summary statistics can be used with each type of data. Appropriate summary statistics are:

Table 3.9: Summary statistics for each level of measurement

Level of Measurement	Central Tendency Statistic	Dispersion Statistic
Nominal	Mode	Variation ratio
Ordinal	Median	Inter-quartile range
Interval	Average	Standard deviation

The example questions in section 3.2.8.5 will collect either nominal (i.e. Example 2 - yes, no, don't know) or ordinal data (i.e. Example 9 - less than 10 hours, less than 15 hours, less than 20 hours). This means that modes and medians, variation ratios and inter-quartile ranges are the most appropriate statistics for indicating typical responses and the spread of responses.

Note that statistics appropriate for a low level of measurement (nominal is the lowest) can also be used with a higher level of measurement (interval is the highest level). But statistics appropriate for a high level of measurement cannot be used with a lower level. So you cannot summarise nominal or ordinal data using averages and standard deviations.

To illustrate, consider data collected in answer to a question based on Example 5 (section 2.3.8.5):

Table 3.10: Personal view of smell (Example question 5)

Personal View	Number Counted	Percent	Cumulative Percent
Not at all offensive	12	24	24
A little offensive	30	60	84
Very offensive	8	16	100
Don't know	0	0	100

If you never record a 'Don't know' response, you can think of the data as ordinal with three ordered categories. [The data are not interval because the difference between two categories is not a meaningful quantity]. The median and inter-quartile range are then appropriate as a summary of the responses to this question. The median, the middle value when responses are ordered (i.e. the 50^{th} cumulative percent), is within the category 'A little offensive'. The inter-quartile range, from the 25^{th} cumulative percent to the 75^{th} cumulative percent, is contained entirely within the category 'A little offensive'. Often this range will span several categories.

But if you record at least one 'Don't know' response (and it is likely that you will) then you will have to think of the data as nominal - because the 'Don't know' category doesn't fit into the 'natural order' of the other three categories. You would then summarise the variable by its mode and its variation ratio. The mode, the most frequent response, is the category 'A little offensive'. This category has 60 percent of the response - each of the other categories have a lower percentage of the response. The variation ratio, the proportion of the data not within the most frequently chosen category, is then 40 percent.

So far the summary statistics discussed here have been univariate statistics. That is, they summarise the properties of a single variable. Bivariate summary statistics can be useful too, to summarise the degree of association between two variables. The familiar (Pearson) correlation coefficient is a measure of association, appropriate where both variables are interval data. A correlation statistic will always lie within the range of -1 to 1. A negative correlation implies that as one variable increases, the other decreases. A positive correlation implies both variables increase together. A correlation close to zero implies there is little association between the two variables. As one variable increases, the other doesn't change much. The Pearson correlation coefficient is not appropriate for nominal nor ordinal data.

The correlation between two ordinal variables can be summarised by the gamma, Kendall's tau or Somers' D statistics (Agresti, 1990, p23). You will need to calculate these statistics by hand unless you have access to statistical software such as SAS or SPSS. For a brief explanation of how to calculate these three statistics, and the differences between them, see the SAS/STAT User's Guide (SAS, 1989, p864-871). Agresti (1990, p20-23) gives a worked example for the gamma statistic, and he refers to an earlier book in which he covers measures of association in more detail (Agresti, 1984, Chapters 9 and 10).

If at least one of the two variables is nominal, then notions of positive and negative correlation are no longer meaningful. Summary statistics of association include Goodman and Kruskal's concentration coefficient and Theil's uncertainty coefficient, but these

statistics are considered to be less useful than correlation statistics for ordinal or interval variables (Agresti, 1990, p23). Again you will need to calculate these statistics by hand unless you have access to statistical software. Agresti (1990, pp23-26) gives a worked example for these two statistics.

3.2.13.2 Inference

The whole point of a survey is to collect a sample which then tells you something about your of interest. This process of inference is concerned both with statements about the and with assessing how reliable these statements are:

Typically you will want to infer from the sample something about the central tendency of a single variable. A confidence interval for an average or a proportion is an appropriate way to do this. A confidence interval is a range of values within which the population average or proportion is likely to lie with a high degree of confidence. In Appendix A4.3, A5.3 and A7.3 cover how to calculate confidence intervals. Note that to be reliable, a confidence interval for an average or proportion needs to be based on a sample size of at least 30. For interval data, calculate a confidence interval for the average. For ordinal or nominal data, calculate a confidence interval for the proportion of data in the category containing the mode or median.

Bivariate inference (associations between two variables) and multivariate inference (associations between three or more variables) are more difficult. Appropriate techniques depend on what data types are involved (the variables could all be one data type, or a mixture of types) and how the data are distributed. For any sort of multivariate inference, or for bivariate inference with interval data, see a statistician. Possible techniques for the analysis of a single sample include the wide class of generalised linear models (log-linear and logit models; linear, logistic and Poisson regression) and non-parametric tests (Wilcoxon sign-ranked test, one sample Kolmogorov-Smirnov tests, Theil's C test for slope).

A simple method for bivariate inference where both variables are nominal is the chi-squared test. This test is also appropriate if either (or both) variables are ordinal, but there are more powerful tests available for ordinal data. However we recommend you use the chi-squared test with ordinal data, because many computer packages include this test and so you will be able to do the analysis yourself. This makes an indicative survey more affordable. But other tests with greater power to detect an association do exist, if you need them. With a chi-squared test you may find some evidence for an association you believe is likely, but the evidence may not be particularly strong (with say a p-value below 0.2 but above 0.05 - see section 3.2.13.3). A more powerful test may give stronger evidence for this association - see your statistician!

3.2.13.3 Chi-squared Test

The chi-squared test is a test of association between two categorical variables (i.e. nominal or ordinal). Many computer packages include this test. Usually the two variables are cross-classifying to form a table: the categories of one variable form the rows, and the categories of the other variable form the columns. In each cell of this table is an observed count - the number of people in the sample that gave this particular combination of row variable category and column variable category as their response.

The chi-squared test works by assuming that the two variables are independent. Under this assumption, expected counts are calculated - the count you would expect to see in each cell of the table if the row and column variables were independent. The chi-squared statistic is a measure comparing the observed counts to these expected counts. If the statistic is small, observed and expected counts are very similar, and this is evidence that the two variables are independent. But if the statistic is large, this is evidence that the two variables are associated in some way, because the observed counts are very different from what would be expected if the two variable were independent. If there is evidence that two variables are associated in some way, you can usually compare observed and expected counts to get some idea of the nature of this association.

Computer packages give a p-value for the chi-squared test. This value is the probability that two independent variables would give the chi-squared statistic calculated for your table. Where the p-value is very small (say below 0.05), it is very unlikely that the two variables are independent and this is evidence that the two variables are likely to be associated in some way.

There are some small sample restrictions with the chi-squared test. The test is valid provided that (1) none of the cells in the table has an expected count of less than one; and (2) fewer than 20% of the cells have expected counts less than five (Agresti, 1990, p246).

To illustrate, consider a cross-classification of answers from two questions, one based on Example 4 and the other based on Example 5 (section 3.2.8.5). The table below gives the observed counts for a sample, within parentheses the counts expected if the two variables were independent.

Table 3.11: Origin of odour and offensiveness (Example questions 4 and 5)

Origin of Odour	**Offensiveness**		
	'Not at all'	**'A little'**	**'Very'**
Source of interest	4 (8.1)	15 (16.7)	15 (9.2)
Other sources	3 (3.1)	8 (6.4)	2 (3.5)
Don't know	8 (3.8)	8 (7.9)	0 (4.3)

The chi-squared statistic for this table is 15.9, with p-value p=0.003. This statistic and its p-value are calculated by hand in Appendix B. Such a low p-value is strong evidence against the two variables being independent. Note that four cells (out of nine) have expected counts of less than five. This indicates that the sample size is too small for this table - the chi-squared test may not be reliable. But note that all the expected counts below five are not much less than five, and that the p-value is well below 0.05 - the evidence against independent is very strong. We can have reasonable confidence that there is some sort of association between these two variables.

To explore the nature of this association, look at cells where observed and expected counts are very different. It may help to identify these cells as 'high' if the observed count is much higher than expected, and as 'low' if the observed count is much lower than expected. For the table above:

Table 3.12: Observed counts compared to expected counts for Table 3.11

Origin of Odour	Offensiveness		
	'Not at all'	'A little'	'Very'
Source of interest	low		high
Other sources Don't know	high		low

This pattern suggests that as the odour is perceived as more offensive, more people perceive the origin of the odour to be the source of interest.

If the sample size is too small for the table, there are two options. The chi-squared test is based on an approximation: as the sample size increases for a fixed number of cells, the chi-squared statistic becomes distributed according to a chi-squared distribution (the distribution that *gives* the statistic its name). But there are exact methods which work regardless of the sample size - see your friendly statistician. Alternatively, you could combine categories to form a table with fewer cells. This has potential problems: by combining categories, you could mask associations that really exist, or create associations that really don't exist. So this needs to be done cautiously - for a start, it's best to only combine categories that are alike. To produce the above table, you would have already combined a number of alternative sources to form the category 'Other Sources'.

Perhaps you might now combine 'Other sources' with 'Don't know', to produce the following table:

Table 3.13: Observed counts compared to expected counts for Table 3.11 with 'Other sources' and 'Don't know' combined

Origin of Odour	Offensiveness		
	'Not at all'	'A little'	'Very'
Yes	4 (8.1)	15 (16.7)	15 (9.2)
No	11 (6.9)	16 (14.3)	2 (7.8)

The chi-squared statistic for this table is 12.9, with p=0.002. There are no cells with expected counts of less than five. By comparing observed and expected counts, you will see the nature of the association is as described before - as the odour is perceived as more offensive, more people perceive the origin of the odour to be the source of interest.

3.2.14 Final report

Keep a full and concise record of your research process; your report will outline that process including your findings and conclusions. Don't be tempted to take more out of the results than what is there; you should identify potential sources of error and how they may affect the results.

It is important to report on the response rate to add credibility to your findings. Include maps that define your population of interest as well as a community profile (showing information on selected demographic characteristics).

When you have analysed your survey results you will then present your conclusions in terms of the objective/s of the survey; clear, specific objectives make your task easier.

You may choose to carry out an analysis of odour complaints data to see how they compare with the findings of the survey. This is likely to demonstrate whether complaints have been spurious or whether others in the community have also found a particular odour offensive.

In instances where you have surveyed in the vicinity of an odour-producing activity that is not permitted as of right (and where the occupiers of properties are entitled to be free of offensive odour at all times) (Somerville, 1997, p1 citing *Te Aroha Air Quality v Waikato Regional Council (No 2)* A70/93 (1993) 2 NZRMA 57A) indications that people have/are experiencing offensive or objectionable odour indicates that there is an odour problem in the area.

If you have conducted a survey in an area where an odour-producing activity permitted or discretionary activity (where occupiers of properties near that activity

> *"... might perhaps be expected to tolerate the risk of smells arising from error or malfunction if the best practicable options had been taken"* (ibid.)

then there is conceivably a community odour problem if offensive or objectionable odour is experienced at times where odour has not arisen from error of malfunction.

Sometimes one of the conditions of a resource consent may be that a survey is carried out annually, for example (Manawatu-Wanganui Regional Council, 1996). Resource consent conditions need to be enforceable, specific, clear and accurate leading to a measure of certainty ... and not an undue measure of discretion (Ministry for the Environment, 1995, p32), and to be drafted like the rule of a plan (Somerville, 1997, pers. comm.[5]). A resource consent condition would therefore need to clearly and precisely state the purpose of the survey so that survey conclusions can also be clearly and precisely articulated. If one of the conditions of the consent that there is to be no detectable or offensive odour beyond the boundary, for example, then one of the objectives of the survey would presumably be to monitor this other consent condition. Survey conclusions would then be presented within that context.

Standards for acceptable levels of odour need to be developed (Lincoln Environmental, 1997) and these would then be reflected in rules in plans and resource consent conditions. Survey conclusions would then be presented in terms of whether the standards were being adhered to.

3.3 Odour Diaries

3.3.1 What do we mean by 'odour diaries'?

This technique broadly involves people living in the vicinity of a suspected, known, or potential odour source keeping a record of odour occurrences (and sometimes non-occurrences) over a specified period. In addition to the FIDO factors (frequency, intensity,

duration and offensiveness), diarists may be asked to record the time, date, prevailing weather conditions and suspected source.

We found no written information formally or scientifically describing diaries as odour assessment techniques during the course of developing these guidelines. The only reference to diaries found was a definition of diary questioning: *"Selected test subjects are asked for a defined period to keep records in diary form of odours they notice in the surroundings of their homes"* (Verein Deutscher Ingenieure, 1993a, p16). The odour diary technique as it is used in New Zealand appears to embody components of other odour assessment techniques such as community odour panels (see section 3.4), trained independent observers/field inspections, and odour community surveys of the type discussed in section 3.2. **For this reason the guidelines outlined below are based on the authors' interpretation of similarities and differences of odour diaries with these other techniques, and with information gathered during interviews with selected local authority staff who had used odour diaries.**

3.3.2 In what circumstances could odour diaries be used?

- To obtain baseline data on existing odour sources, for example, before a facility is established. The information obtained can be very valuable in future monitoring in the event that complaints are received about the new operation. The outcome would show either a) there is no odour present if there are no other sources in the area, or b) would effectively be monitoring existing sources in the area.

- To monitor consent conditions, including the areal extent and frequency of odour occurrences from an existing facility before and after the installation of new emission control equipment to determine its effectiveness. Odour diaries are a good way of keeping a record of odour occurrences and may show decreases in odour levels due to control equipment installation. Diaries are a relatively insensitive monitoring method and could never be used alone to determine the effectiveness of control equipment. That should be done by some sort of direct emission monitoring such as olfactometry.

- To identify an odour source, particularly when used together with wind trajectory data.

- To demonstrate commitment to an odour management strategy that may be required as part of a resource consent condition/renewal.

3.3.3 How much can it cost to run an odour diary exercise?

Like the other techniques discussed, the scale of an odour diary exercise may be highly variable. It can range from asking a small number of complainants to keep a regular log of the problem, in which case the costs will be similar to those involved in the small-scale telephone or personal interview surveys, to major and very costly exercises. The costs in terms of time involved in a recent exercise carried out by a large urban local authority are shown below. The costs inputed to this study (Lincoln Environmental, 1997) are calculated at the usual charge-out rate of staff although in this case most of the time involved was contributed by Task Force Green workers. Strategies such as the employment of workers under subsidised schemes or students during the summer holidays may well provide a means for local authorities to undertake work which would otherwise be too costly.

In this exercise initial calls were made on 123 households. Although relatively few refused to participate at the outset, completed diaries were collected from 80 households at the end of the survey's duration of three months.

Advice on survey design and sampling	$4000
Co-ordination and preliminary discussions (10 hours @ $50)	$500
Training plus introductory call on participants (188 hours @ $50)	$9,400
Calling on and up-lifting forms from participants (105 hours @ $50)	$5,250
Computer entry and analysis (21 hours @ $50)	$1,050
Mileage (1300 km @ $0.40)	$520
Printing and Stationery	$80
TOTAL COST	$20,800

Had the field work been carried out by students at a cost of $10 per hour the total cost would have been $9,080.

Odour diaries, if properly completed, can provide an excellent *database* for use in assessing the extent and seriousness of odour problems. The staff who had been involved with the exercise described stressed the importance of regular contact between local authority and diarists to maintain interest and ensure that diaries are properly completed. Where a weather recording station is set-up at the outset, the validity of complaints can be checked and the range of conditions under which the problem is experienced can be analysed.

As the examples given in this section show, the costs of implementing techniques for odour assessment are highly variable. Before embarking on specific techniques local authorities need to consider the scale of the problem and the objective of the exercise and the level of resources to be committed.

3.3.4 Planning for odour diaries

3.3.4.1 To use diaries or not to use diaries

Clarifying the objective/s for setting up an odour diary exercise will help you decide whether an odour diary is the most appropriate technique for your purposes. The end use of the information should also influence your decision. If the findings could be used in a legal setting, you should seek legal advice as to whether it would be prudent to engage a recognised expert for diary design, sampling and analysis. Although we are unaware of any case-law pertaining to the admissibility of odour diaries as evidence, we have provided guidelines that are consistent where possible with case-law on the admissibility of surveys as evidence (see section 3.2.4).

The issuing of diaries can give those that are affected and are complaining confidence that the council is taking action. On the other hand, if diaries are randomly distributed, those receiving them who are affected but have not complained may 'become complainers'. You need to avoid raising expectations amongst diarists that diary-keeping will lead to solving odour concerns.

3.3.4.2 Who will be invited to keep a diary?

The next step is to determine the boundary of your population of interest, that is, the area within which you want diaries to be kept. This might be determined through the Council's odour complaint records or odour dispersion modelling, for example.

The size and shape of the assessment area will depend on the objectives of the exercise and on the type of emitter or emission area to be monitored. Instances could include:

- the emission area of a single odour source - the assessment area would be a circle of adequate diameter centred on the emitter. Inspection visits downwind of the emitter need to be made to estimate the necessary size of the circle. (If dispersion modelling with an actual meteorological data set was conducted this could be more clearly defined with more people included in the areas downwind from the predominant wind. Simply looking at a wind rose will tell you a lot as to where to expect the maximum impacts.)

- the impact of one or several sources on a defined area of impact (e.g. an existing or planned residential area). The assessment area will be the defined area of interest.

- emissions may be measured for the purpose of odour mapping. The assessment area will be the area to be mapped (Verein Deutscher Ingenieure, 1993b, p15).

Who you secure to keep a diary and how diarists are selected will depend on the purposes of the exercise.

3.3.4.3 The diary keeping period

This will also be influenced by the purpose for diary keeping. It is important to have specific beginning and end points so that diarists can see that the exercise has a purpose and is not intended to 'fob them off'. They may also be more motivated if they know they are required to assist for say three months, rather than for an indefinite period.

An important issue is whether the emissions from the source in question are at typical rates or not. The assessment period could take at least six months and cover cold and warm seasons in equal parts (Both, 1995, p4).

3.3.4.4 Designing an odour diary

You may want to consider a selection of diaries that have been developed by other councils or companies and select the features that are appropriate to your task.

3.3.4.5 Collecting the data

Decisions as to how frequently you want the diarists to return their completed forms (using prepaid forms that simply need sealing are ideal) need to be made, how you can encourage/

facilitate that process, and whether you have the resources for the diaries to be collected personally by a staff member or someone delegated to do that.

3.3.4.6 Data preparation and analysis

At this stage you will likely consider what other information you may be gathering in conjunction with that from the diaries and how you plan to record the data when it is returned so that it can be analysed at the end of the diary keeping period.

3.3.5 Selecting the diarists

Various means have been used in New Zealand to choose diarists by either local authorities or by private companies perhaps in association with a local authority. These include:

- spatial sampling using statistical methods where areas of land within certain segments of a 3.5 and 5 km radius of a proposed facility were used to develop a grid system from which to make a random selection of people from an irregular landscape. A sample size appropriate to the situation was chosen in order to get reliable results.

- a whole population (anyone likely to discern an odour from a specific source) rather than a sample has been invited to participate with letters and diaries being sent to all householders in the area to be monitored.

- inviting those who make odour complaints to participate.

- placing advertisements in newspapers, newsletters, etc. inviting people to keep diaries.

- sending out letters to selected householders in the area to be monitored.

The first method mentioned above involves drawing a spatial sample over a defined geographical area, whereas the second method used the population of interest as the actual sample. The third and fourth methods can be described as self-selection non-random methods (with a propensity for bias), while the approach used in selecting householders in the last method is not known to the authors and may have been either random or non-random.

.The purposes for which you want to use the data you gather will help determine which approach to use in selecting diarists. If you plan to use the data gathered as evidence for enforcement of consent conditions, you may wish to adopt a rigorous approach using statistical methods. The use of random methods reduces the potential for bias that is inherent in self-selection methods but non-statistical approaches may be acceptable when resources are very limited.

We have outlined below a method of spatial sampling that is used in Germany for determining odour in ambient air by field inspections (Verein Deutscher Ingenieure, 1993b; Department of the Environment, Regional Planning and Agriculture of the Land North Rhine-Westphalia, 1993; Both, 1995) but could be appropriate for situations where odour diaries are wanted. Consult with an expert if the findings have the potential to be used in a legal situation.

Your first step is to develop a basic measurement plan and this will define the assessment area, assessment squares, measuring points (diarists), the assessment period (Both, 1993, p4), and the factors (FIDO) to be assessed. The assessment area (for a single odour source) could be defined as a circle with a radius of 30 times the height of the stack and a minimum radius of 600 metres (Both, 1995, p4). If a plant has diffuse emission sources and emission heights that are less than 10m above the ground, the radius can be determined through ensuring that the shortest distance from the border of the emitting surface is less than 600 m (Department of the Environment, Regional Planning and Agriculture of the Land North Rhine-Westphalia, 1993, p10).

The area you want to monitor needs to be covered by a grid of equidistant measuring points. You only need assessment squares and measuring points for areas where people live permanently/do not stay temporarily (that is, residential areas). Measuring points are at each corner of the assessment squares and the standard distance between those points (grid spacing) is 250m. In special cases the distance can be 1000 m, 500 m or 100 m (Both, 1995, p4). The distance depends on the objective of the monitoring as well as factors such as the size of the assessment area, the desired resolution, the desired sample size, and the behaviour pattern of the odour producer/s. As a rule of thumb, part-squares at the boundary of the assessment area that are greater than 50% are counted fully, while part-squares that are less than 50% are excluded fully.

Figure 3.4 illustrates an example of a pig farm with approximately 4000 pigs. Neighbours live between 750 m and 1500 m of the farm. The grid spacing is 250 m with investigation consisting of 13 assessment squares with 33 measuring points. Figure 3.5 shows the numbering of the measurement points and assessment squares[13].

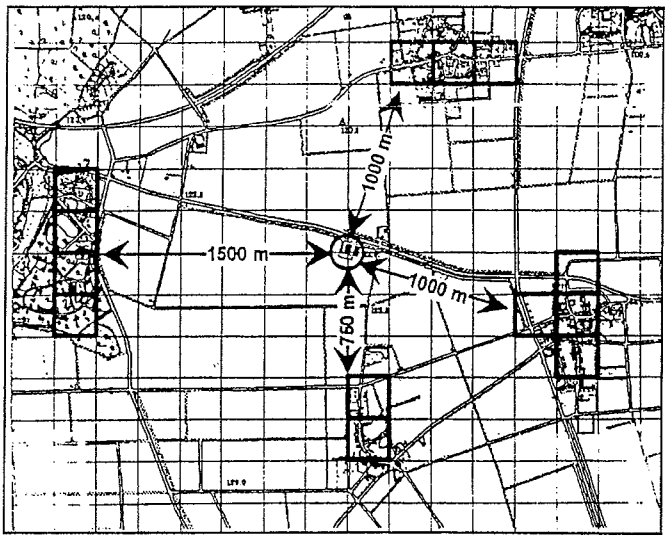


Figure 3.4: Example of an assessment area, assessment squares, measuring points and distance to the source (Source: Both, 1995, pl0)

13 There was no explanation in Both's paper as to why one measuring point was not included and the means by which the measuring points were numbered.

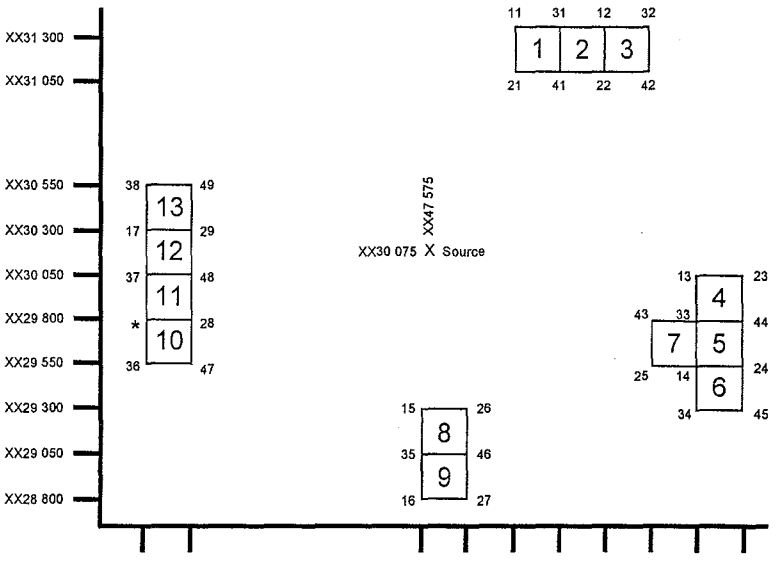


Figure 3.5: Numbering of measuring points and assessment squares (Source: Both, 1995)

In special cases you can use a polar coordinate grid with gridpoints on circles of equidistant radius increment. The remarks on square grids above apply in the same way (Verein Deutscher Ingenieure, 1993b, p15).

The next step is to identify diarists who are to be invited to participate in the monitoring exercise. Those living at or closest to the measuring points can be contacted using either the Habitation Index, Council ratepayer lists if a local authority is setting up the project (see Appendix A4 and AS) or visiting the area on foot. If the household is unwilling to be involved, then the next closest household can be approached. You can then invite the person most often at home (see Appendix A3) to maintain the diary.

3.3.6 Designing the odour diary

Obviously this needs to be 'user friendly' in order to get accurate information and to not deter diarists from participating over the period in question. Provide a very clear written explanation on how to use diaries.

Information generally collected includes: date, time, wind direction and speed, odour strength, duration, and odour description/character. It is helpful to those filling in the diaries if they are given a short list of local characteristics and also minimises a large range of descriptions (Ministry for the Environment, 1995, p40). 'Offensiveness' ratings can also be recorded. The discussion on response scales in section 3.2.8.5 above should be referred to.

(Only collect information that you cannot obtain elsewhere; wind speed and be available from a meteorological station if there is one in the vicinity). Data on odour duration may have limited usefulness, particularly if the diarist was at home for only part of the odour event.

Figure 3.6 provides an example of an odour diary compiled from samples of others. It is common practice to attach a map and if the diary is sent to all householders those who respond can indicate on it where they live. The map should indicate north and degrees from

north. It is a good idea to pre-test the diary form before you start to ensure that diarists are providing information in the way you expect. Filling in the first line with examples demonstrates the way you want the information to be recorded.

Do ensure that all categories of response are on the same piece of paper as they can get lost if they are issued on a separate piece of paper at the outset of the survey. The diary could be in bound form as loose-leaf completed sheets may become lost.

Date	Time	Wind Direction	Wind Speed	Odour Strength	Duration	Odour Description	Offensiveness rating
1.3.97	1.00 pm	SW	3	2	1 hr 15 min	Sulphur	1

Figure 3.6: Example of an odour diary

Wind speed

0 = calm; smoke rises vertically
1 = smoke drifts but wind not felt on face
2 = wind felt on face, grass moves
3 = leaves and small twigs in constant motion, dry clothing on clothesline begins to move
4 = loose paper blows around, small branches sway
5 = small trees sway
6 = large branches move, telephone lines whistle, umbrellas inconvenient to use

Odour strength

0 = no noticeable odour
1 = faint, occasional wafts
2 = noticeable, slight but constant
3 = very noticeable, distinct
4 = frequently strong
5 = very strong, overwhelming

Odour description

List of odour characteristics (limit to 10 options if possible)
- include 'other' category

Offensiveness rating

0 = no odour
1 = not offensive
2 = a little offensive
3 = offensive
4 = very offensive
5 = extremely offensive

Name, address, month, etc.

3.3.7 Instructing the diarists

This is a very important step and can affect the quality and accuracy of information received. Meeting the diarists in person as well as providing them with written instructions would be ideal but may not be possible.

Emphasise:

- that even though the diarist may not be aware of any odour occurrences over a particular period, this is still important information;
- that 'wind direction' means the direction the wind is blowing from not to;
- that all the columns need to be completed each time they make an entry as each piece of information helps to make up an overall picture;
- that if for some reason they are not able to complete the diary fully, any information they have is valuable,
- that it is their impressions you want and not those of other members of the household.

Diarists need to be given clear instructions as to the frequency of recording. It may be at any time an odour is perceived, daily, or even weekly although this latter frequency has been used for community odour panels (see section 3.4.8.1) rather than for diaries.

3.3.8 Strategies for maintaining motivation

Keeping diarists motivated is a major challenge and is especially significant in terms of your response rate. Techniques used to maintain the interest of odour panellists overseas (section 3.4.8.4) include:

- approaching the diarists personally;
- providing a special journal containing information on olfactometry and environmental issues
- giving the diarists a present at Christmas;
- making a special effort to answer questions and address remarks made (Punter *et al.*, source unknown, p147); and
- financial remuneration independent of the type and number of replies (Verein Deutscher Ingenieure, 1993a, p9).

Diarists can become disillusioned; despite their efforts, they may perceive that very few or no apparent improvements seem to be taking place. Explaining the purpose of the exercise as fully as possible and indicating whether change can be expected within a particular timeframe may go some way to addressing this problem.

It seems that elderly people are frequently diarists so make sure the map and the diary print is not too small to deter participation.

3.3.9 Getting the diaries back

Diaries are generally returned to the local authority or odour producer fortnightly or monthly. The inclusion of a pre-paid self-addressed envelope or a specially addressed page that only requires folding encourages people to return them with a minimum of effort. Collecting the diaries in person can help maintain motivation but may be beyond the resources of the company or council (one council [Lincoln Environmental, 1997] used Task Force Green people very successfully in this respect).

3.3.10 Data preparation, analysis and presentation

Response rates can now be calculated by comparing the number of diarists invited to participate in the exercise and those who actually did.

Refer back to section 3.2.11 and its subsections for suggestions as to preparing your data for processing and analysis. Using a computer programme such as SPSS, for example, summarise your data by way of frequency distributions in table format for each variable/category in the odour diary. Visual summaries of frequency distributions can be provided by histograms or frequency polygons, for example. Refer also to section 3.2.13.1 which discusses summary statistical measures of central tendency and dispersion for single variables.

One local authority engaged a consultant to develop a computer programme for analysing diary data. The data was collated (see Figure 3.7) (note that each diarist was identified by a provider number only for reasons of confidentiality) and then reduced to a single page by way of a rose diagram using lines of differing sizes or lengths so that it could be understood by a layperson (see Figures 3.8 and 3.9) (Okell, 1997, pers. comm[14]).

14 Okell, R, South Waikato District Council.

Provider No	Complaint No	Location	Orientation to Kinleith	Distance from Kinleith	Date	Time	Wind Direction	Wind Speed	Odour Strength	Duration	Cloud Cover	Odour Description	Odour Description[2]	Pleasantness Rating	Comments
10		TOKOROA	N	5	14-Feb-96	8:00	SW	3	1	2	3	1		4	the mill
8		LICHFIELD	N	20	25-Mar-96	8:00	0		5	1	0	3	4	6	
8		TOKOROA	N	10	21-Mar-96	8:00	0	0	5	3	0	3	4	7	
28	0	TOKOROA	N	5	01-Feb-96	3:30		0	6	3		4		5	
18		TOKOROA	N	10	27-Feb-96	16:30	S	2	4		1	2		4	
18		TOKOROA	N	10	08-Mar-96	2:00		0	5	5	0	2		4	
18		TOKOROA	N	10	09-Mar-96	6:00		0	5	2	0	2		4	
18		TOKOROA	N	10	10-Mar-96	6:00		0	5	2	1	2		4	
18		TOKOROA	N	10	11-Mar-96	6:00		0	3	2	0	2		3	
18		TOKOROA	N	10	12-Mar-96	6:00		0	1	1	0	2		3	
18		TOKOROA	N	10	13-Mar-96	6:00		0	1	1	0	2		3	
18		TOKOROA	N	10	14-Mar-96	6:00		0	1	1	1	2		3	
18		TOKOROA	N	10	21-Mar-96	5:00		0	3	2	0	2		4	
18		TOKOROA	N	10	25-Mar-96	4:00		0	5	3	0	2		4	
18		TOKOROA	N	10	26-Mar-96	6:00		0	3	1	0	2		3	
18		TOKOROA	N	10	27-Mar-96	6:00		0	1	1	0	2		3	
44	0	WAOTU	NW	25	29-Mar-96	8:30	SE	1	4	2	3	3		5	
0	0			0	19-Jan-96	7:00		1	3	0	0	1		0	

Figure 3.7: Collated odour diary data (Source: South Waikato District Council, 1996)

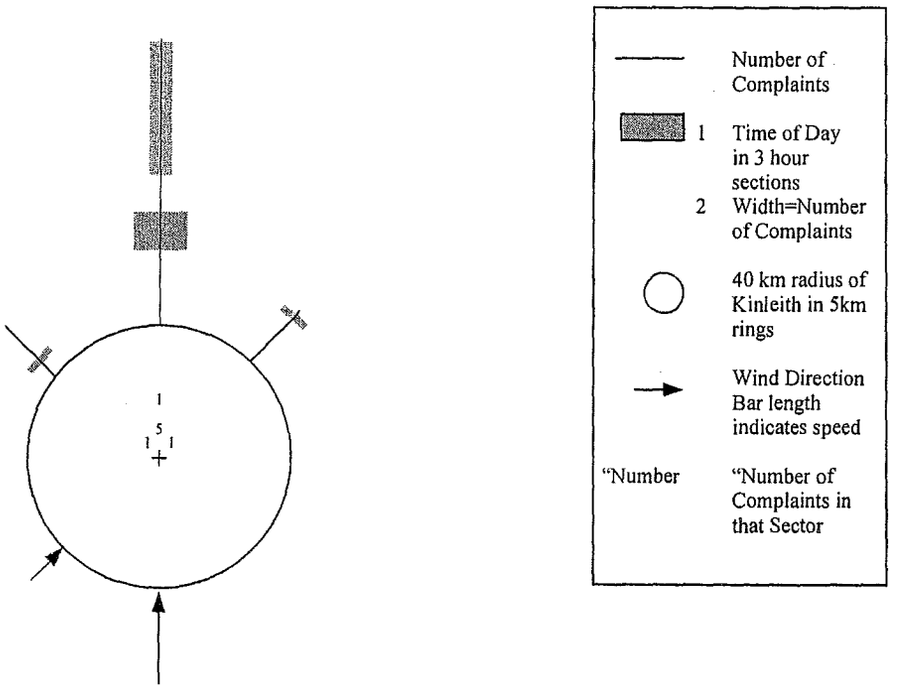


Figure 3.8: Example of daily odour diary data presentation (Source: South Waikato District Council, 1996)

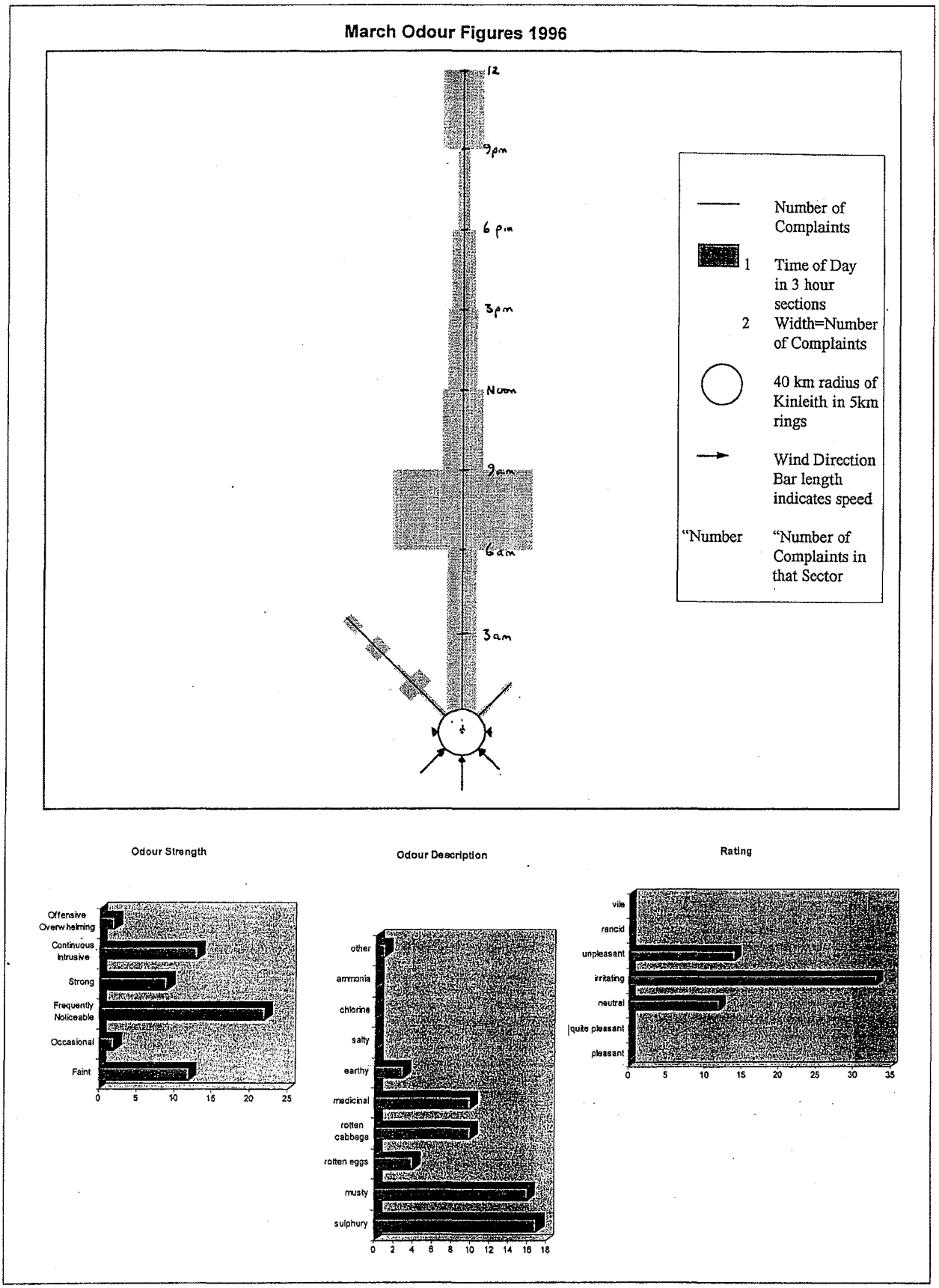


Figure 3.9: Example of monthly odour diary data presentation (Source: South Waikato District Council, 1996)

3.3.11 Feedback to diarists

A summary of the analysis sent out from time to time enables diarists to see how their efforts contribute towards building a bigger picture and can encourage them to continue.

3.4 Community Odour Panels/Community Panel Surveys

3.4.1 What do we mean by 'community odour panels'?

There are several different types of panel with each type being used to achieve particular objectives. These include:

- small panels of volunteers who are invited to have their noses calibrated and to assess odour concentrations through the use of an olfactometer;

- field inspection panels where carefully selected observers are trained to assess odours in ambient air 'in the field' at regular intervals to determine whether odours are discernible (and if so, the type and intensity) (Verein Deutscher Ingenieure, 1993b; Dowell, 1991; Both, 1995);

- a sample of neighbours on the down-wind side of an activity assess whether the size of a proposed buffer zone is sufficient to accommodate adverse effects of odour. In order to strengthen the objectivity of the local sample it may be complemented by out-of-district panellists or people who have no particular interest in the activity, the land in question, or even perhaps the neighbourhood (Sommerville, 1997, p12)[15]; and

- relatively large panels of randomly-selected volunteers who are demographically representative of the population exposed to an odour/s.

It is this last type that we are discussing here. They indicate at regular intervals (generally once weekly at a pre-determined time) from their own homes whether they detect and are annoyed by odours (Verein Deutscher Ingenieure, 1993a; Köster *et al.,* 1984, 1985).

The long term results of community odour panel observations can serve to quantify odour annoyance in a defined area, that is, to measure the frequency of momentary degrees of annoyance using an index of annoyance (IOA) (Verein Deutscher Ingenieure, 1993a, p3).

> *"The annoyance index* Ik *is a stepped scale from 0 to 100 of the annoyance reaction averaged and weighted over all test subjects during a measurement at a certain point in time during a certain investigation period"* (Verein Deutscher Ingenieure, 1993a, p15).

15 It was not possible to include guidelines on this particular approach to odour panels as the research process for this study had been completed before the paper had been written and presented.

"The Odour Annoyance Index (OAI) has been chosen as a measure for the weekly perceived odour annoyance of a population panel because:

- *only annoyance categories are concerned*
- *extreme annoyance has more weight than little annoyance*
- *the measure can be easily interpreted as the 'relative frequency of odour annoyance' ranging from 0 to 100%".*

Depending on the objectives of the investigation, meteorological measurements may also be recorded (ibid., p12).

The guidelines outlined in this section have been derived from approaches used overseas, particularly in Germany, Belgium and Holland (Verein Deutscher Ingenieure, 1993a; Köster *et al,* 1984, 1985; Punter *et al.,* source unknown). **As this approach has not been used in New Zealand, it should be trailed to assess its appropriateness. Note that the approach discussed relates to odour 'annoyance' rather than offensive or objectionable odour. If you anticipate the findings being used in legal proceedings, consult an expert on question and sample design and analysis.**

3.4.2 In what circumstances could community odour panels be used?

This method of measuring odour annoyance over a relatively long period of time enables an Index of Annoyance (IOA) (see section 3.4.9 below) of residents in a particular area to be quantified. It becomes possible:

- *"to measure the distribution in space and time of the annoyance caused within an investigation area,*
- *to demonstrate differences between annoyance occurring in the investigation area and in a neutral control area, as an indication of the need for remedies in an area with complex immissions,*
- *to assess the efficacy of odour reduction or remedies taken,*
- *to measure how the annoyance varies as a function of distance of the resident from a large emitter (in relation to the emission rate),*
- *to obtain clues for identifying odour-relevant emission sources in relation to prevailing wind direction"* (Verein Deutscher Ingenieure, 1993a, p3);

- to develop a basis with which to formulate odour annoyance standards which may be used to indicate whether certain measures should be used to improve air quality in an area (Köster *et al,* 1984, p127);

- to establish whether there is a relationship between annoyance levels and emission concentrations (Punter *et al.,* source unknown);

- to monitor resource consent conditions specifying no annoying (discernible/ objectionable) odour beyond the boundary;

- to assess source and quantity of odour;

- to monitor the accuracy of dispersion model predictions.

However, the complexity of the cause/effect relationship means it is not possible to transfer the annoyance results derived in one locality to a different locality (Verein Deutscher Ingenieure, 1993a, p3).

Additional comments on the use of odour panels include:

- they are sufficiently sensitive and reliable to discriminate annoyance experienced in different sectors of the general population (Köster *et al,* 1984, p127);

- the intervals at which responses are made are controlled by the researcher and therefore independent of refractory periods or extraneous influences that may alter their tolerance for annoyance/offence (such as media publications or pressure groups) and such influences will be smaller than in the case of complaints;

- as the time and frequency of panellists' assessment is known, it becomes possible to relate responses to independent measurements of pollution such as simultaneous emission measurements or general information about prevailing meteorological conditions at the time of their assessment;

- the use of the scale of the panel (see section 3.4.7.4 below) can be calibrated regularly through judgement of odour samples prepared in a laboratory (Köster *et al,* 1984, p100);

- annoyance profiles and variation over time are measured without losing data on individual events;

- regular and simultaneous questioning of panel members allows checks for plausibility of response behaviour (Verein Deutscher Ingenieure, 1993a, p5).

3.4.3 How much would it cost to establish an odour panel?

We have no explicit examples that we could provide costings for, but assume that costs associated with odour panels are likely to include:

- question design
- sample design
- sample selection
- invitation letter, envelopes and postage (if personally addressed) or payment to someone to carry out a letter drop
- printing of postcards (number of panellists by number of weeks)
- second letter, envelopes, postage
- address and panellist code labels
- pre-paid postage for postcards
- motivation expenses
- data analysis

3.4.4 Planning for an odour panel

3.4.4.1 To set up or not to set up an odour panel...

As suggested in the other techniques discussed so far, clarify the kind of information you need and determine whether an odour panel is the most appropriate means of getting that information. The end use of the information will also presumably influence your decision.

3.4.4.2 Establish objective/s for the odour panel

Read or re-read section 3.2.5.2 on establishing objectives.

3.4.4.3 Who will participate in the panel?

As in the other techniques outlined above, the purposes for which you plan to gather information will help you determine who is to participate (refer to Appendix A2, A3 and A4).

3.4.4.4 When will the panel be involved?

The period over which the panel is to run needs to be determined; is it to be a short term investigation covering two to three months or is it to cover a period of say 12 months? The choice of observation times over either of these time frames will be influenced by the purpose of your investigation.

3.4.4.5 How will the panel be involved? - gathering your data

There appears to be one main approach to gathering data via community odour panels and that is through their responding to two or three questions printed on a postcard that is usually sent to them each week. The postcard questions need to be developed and the process for the issuing and gathering of postcards clearly established.

3.4.4.6 Maintaining panelists' motivation

Refer to section 3.3.8 which gives ideas for maintaining motivation for odour diarists.

3.4.4.7 Data preparation

At this stage you will want to clarity who will be checking and processing the data as the postcards are returned and that it will be in a form that is easily accessible when the time comes to analyse it.

3.4.4.8 Analysing your data

The analyses you choose to carry out will mainly depend on the objectives of the investigation.

3.4.4.9 Accompanying Meteorological Measurements

> *"The type and extent of accompanying meteorological measurements depend on the objective of the investigation (e.g searching for the emitter of an odour immission, or establishing an odour inventory of an area with many emitters). Unless the object is expressly to find an emitter, the meteorological data obtained can for the time being remain largely unused.*

Wind direction and speed for the investigation period and as a representative mean over many years can be obtained by asking a nearby authorised weather station... otherwise both parameters should be measured simultaneously to each test time by the testers themselves and enclosed with the investigation results." (Verein Deutscher Ingenieure, 1993a, p12)

3.4.5 Odour panel objectives

Refer back to section 3.2.5 to determine whether an indicative or definitive approach is appropriate.

3.4.6 Sample design

Read section 3.2.7 before commencing this exercise.

3.4.6.1 Defining your population of interest

The first stage is to define your population of interest (refer to Appendix A2). The steps involved include: determine the *emission or environmental load area* which is the total geographical area where odour emissions can occur. This might be determined through the Council's odour complaint records, odour diary data, and/or odour dispersion modelling. Then the *investigation area* (the area within the emission load area that will be covered by the investigation) needs to be identified. It is likely to have within its boundaries an *investigation zone* and a *control zone* (see example in Figure 3.10)

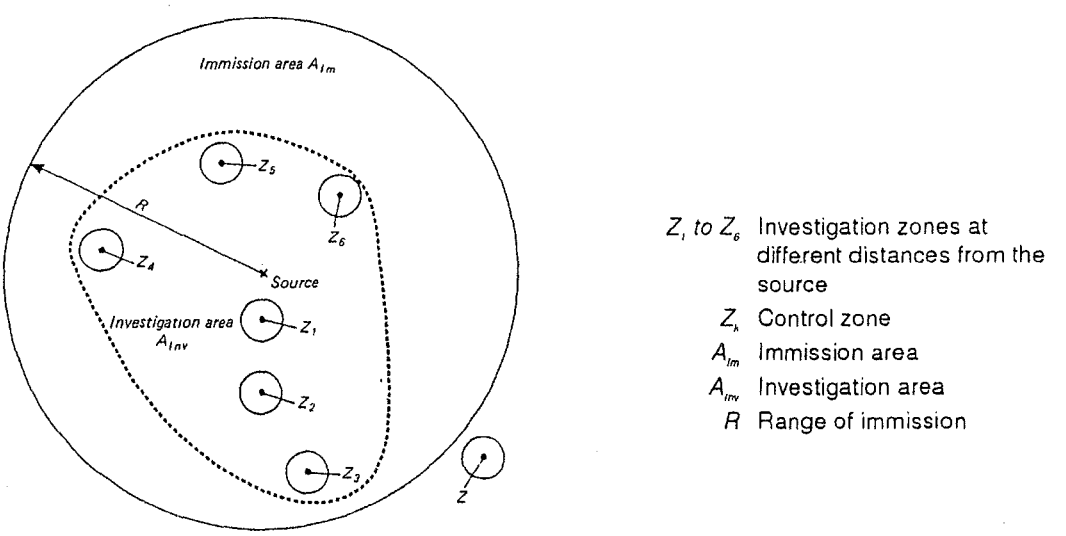


Figure 3.10: Schematic showing immission areas, investigation area and investigation zones (assuming a single emission source) (Source: Verein Deutscher Ingenieure, 1993a)

The *investigation zone* is the part of the emission load area where a sufficiently homogeneous emission load from one or more sources can be isolated or assumed. You will not always be able to select one or more investigation zones on the basis of a homogeneous load as the load depends on meteorological conditions. However you should aim for homogeneity in terms of building types and density, road traffic density, and other such factors.

You will then need to select a *control zone* which will be outside the emission load area and will have comparable type and density of buildings but with no air quality load due to other odour sources. No control zone may be needed in instances such as rural areas because an investigation zone upwind of odour emitters can serve that purpose (Verein Deutscher Ingenieure, 1993a, p6). People living in this area (the control zone) should not differ demographically in any substantial way from those living in the investigation zone/s.

3.4.6.2 Determining your sampling frame

No guidance on determining a sampling frame was given in the overseas literature. You should therefore refer to Appendix A4.1, A5.1, A6.1, A7.1 or A8.1.

3.4.6.3 Selecting the sample - choosing your panellists

The next task is to choose the panel from people who live in the investigation and control zones. Although this technique may be a new one for New Zealand with no relevant case-law on methods as there is for community surveys, we still recommend using a scientific approach so that the data collected may be used in a legal setting (see section 3.2.4). In this instance, consult an expert on sample design and statistical analysis.

One approach that had been used overseas was a letter drop to every house in each zone but unpersonalised requests can result in a low response rate and there is the possibility of neighbours influencing each other. Non-random methods such as recruitment by phone or by placing advertisements in local newspapers were suggested if the response rate to the letter drop is low. Personalised letters may produce a higher response rate (Verein Deutscher Ingenieure, 1993a, p6) but, again, no specific instructions were provided as to how the recipients of the letters were to be selected. An alternative option has been to carry out a letter drop at every fifth (or *n*th) house in a number of pre-selected streets in each zone; this approach can avoid the issue of direct neighbour influence (Köster *et al.*, 1984, p107). This approach resembles the systematic sampling method outlined in Appendix A4.2.

You should also refer to the approaches referred to in Appendix A5.2, A6.2, A7.2 and A8.2.

3.4.6.4 Representing the community's views

There are at least two means of representing the community's views.

One is outlined in section Appendix A3 where the 'person most often at home' was recommended as being the best person to participate in a community survey.

Another has been described by the Verein Deutscher Ingenieure (1993a), Köster *et al* (1984), and Punter *et al* (source unknown). They recommend that the panel should be made up of a random selection of people who are representative of the investigation and control zones and who will be available at certain times of the day. Representativeness should be based on age (18 upwards), sex, socio-economic status, schooling, number of years living in the area, dependency on industry, and attitudes towards environmental matters (Punter et al., source

unknown, p147) and/or age (IS upwards), sex, marital status, and education (Verein Deutscher Ingenieure, 1993a, p6).

As this approach requires a multi-stage selection process, refer to Appendix A3 on the advantages and disadvantages. Personalised invitations (see Figure 3.11) are sent to those residents who might be suitable as panel members although there is no guidance as to what the selection criteria are and how people potentially meeting the criteria might be identified A question form (get an expert's advice on modifying this form for your particular use) for selecting subjects (see Figure 3.12) is included with the initial letter together with a pre-paid return envelope. Addresses of panellists allow you to choose an appropriate geographical distribution (Verein Deutscher Ingenieure, 1993a, p7) although no details are provided as to what could constitute an appropriate geographical distribution.

Sender's address

Person to contact
C/o Test Institute

.....

Recipient's name and address *Place, date*

Dear Sir or Madam,

The (Institute) *, under contract to* (investigator) *has started an investigation of smell/odour experiences in the area in which you live. This investigation is being performed in collaboration with* (2nd institute if applicable) of (place) *. The purpose of the investigation is to find out how the residents of your area experience odours present in the environment. Facts about this are very important for controlling pollution.*

The investigation aims not just to determine the air quality at one isolated moment in time, but to get an impression of how people perceive odours present in the air over a longer period. In this way it is possible, for instance, to investigate the effects of weather and seasonal variations on the odour in ambient air. To do this, around (number) *men and women in* (place) *are needed to assess once per week the odour in the ambient air near their home. This produces a reliable basis of data on the extent of air pollution and what overall factors affect it.*

.../2

Figure 3.11: Example of a letter to panel members (Source: Verein Deutscher Ingenieure, 1993a)

-2-

From next (month) *onward for a period of* (number) *months, a group of* (number) *persons will be asked to take part as panel members in such an investigation. Based on the results from the group of* (number) *persons, a decision is to be made by* (time) *on whether air pollution prevention measures need to be taken.*

Volunteer panel members are asked to undertake, for the entire period of (number) *months (excluding holidays, of course), to make an assessment of the quality of the outdoor air once per week on* (weekday) *between* _____ *and* _____ *am/pm. The test takes only about three minutes. Each panel member is asked at* (time, weekday) *every week to go outside, breathe in the outdoor air, and mark against a rating scale his assessment of the odour present in the ambient air. A postcard for recording the answer will have been sent to the panel on the previous day. This prepaid reply card should be sent back to us the very same day.*

For this investigation, which is of great importance for improving the environmental air quality in our area, we are looking for men and woman volunteers. If you are willing to give your services for this investigation for the entire period, you are requested to kindly fill in the enclosed form and return it to us in the prepaid envelope (number) *forms have been sent out to each* (street, block) *. Any resident aged 18 or over who is willing to take part can fill out a form and return it. For our planning, please return the form before* (date) *. Your reply and your personal data will be treated in strict confidence.*

At the beginning of (month) *you will then receive further details from us. At the end of* (month) *an introductory meeting will be held in* (place) *to get acquainted and to give you further information.*

I hope that many volunteers are willing to give their help in this project.

Yours faithfully,

Enclosure

(cont'd) Figure 3.11: Example of a letter to panel members (Source: Verein Deutscher Ingenieure, 1993a)

Sender (panel member)

Name and address of institute

Question Form

This form contains a number of questions on your personal data and life circumstances. This enables us to select a panel of persons truly representative of the population. If you are willing to take part in the investigation, please fill in the form and return it to us in the prepaid envelope before ___(date)_____.

Some of the questions need to be answered on the dotted lines, for the others please mark a circle around the relevant answer number.

Question 1. *Surname, first name* .....
Address .....
.....
Telephone .....

Questiion 2. *How old are you?* .....*years*

Question 3. *Sex?* *1. male* *2. female*

Question 4. *What are your present living circumstances?*
1. single *a) single-person household*
2. married *b) household with two or more persons*
3. divorced
4. widowed

Question 5. *What level of school or further education have you completed?*
1. Elementary school
2. Junior high school
3. Grammar school / high school
4. Technical college
5. University, polytechnic
6. Other .....

Question 6. *How long have you lived at this address?* ..... *years*
If less than five years:
Where did you live before? .....

Question 7. *Where do you spend the greater part of your day?*
1. office
2. factory
3. at home
4. outdoors

Question 8. *In your opinion, do people in general*
1. pay far too little attention to the environment?
2. pay too little attention to the environment?
3. pay sufficient attention to the environment?
4. pay more than enough attention to the environment?

Figure 3.12: Example of a question form for selecting subjects (Source: Verein Deutscher Ingenieure, 1993a)

It is assumed that you would then derive a breakdown of the population of interest through the use of Supermap (referred to in Appendix A8.4) according to the demographic characteristics mentioned above. The sample would then presumably be drawn on the basis of those breakdowns although you would require a high initial response rate to be able to fulfil the demographic quotas. When you have selected your sample you could send a consent declaration (see Figure 3.4.4) to ensure that privacy legislation requirements are observed (Verein Deutscher Ingenieure, 1993 a, p7). Check that the declaration is consistent with the *Privacy Act 1993.*

Subject's name and address

Address of institute

Subject: "Effects and assessment of odours; repeated brief questioning of neighbour panellists", to be performed by (institute) *in* (place) *from* (dates) .

Declaration of consent

As a participating panel member, I agree that personal data (name, address, age, sex) on myself can be collected and stored within the scope of the above investigation.

After completion of the investigation or if I withdraw from the investigation, my name and address will be erased. I consent to the use of the remaining data in anonymised form for scientific purposes.

.....
Date and place of signing

.....
Signature

Figure 3.13: Example of consent declaration by test subject (Source: Verein Deutscher Ingenieure, 1993a)

In the overseas literature reviewed for the purposes of this section (Lincoln Environmental, 1997), the testers aimed to select 75 people for each zone although they gave no explanation as to how they had determined such a sample size (Punteret *et al.*, source unknown, p146).

3.4.6.5 Estimation and non-response

Refer to Appendix A4.3, A4.4, A5.3, A5.4, A6.3, A6.4, A7.3, A7.4, A8.3 and A8.4 as appropriate for guidance on estimates and dealing with non-response.

3.4.7 Designing the Data Collection Instrument

Figure 3.14 illustrates the information that is contained on the postcard that panellists complete daily/weekly (depending on the duration of the investigation). Comments on the need for rigorous development of response scales that meet appropriate criteria (see section 3.2.8.5) should be referred to.

DO SMELL ATTENTIVELY (Circle one)

DO YOU SMELL ANYTHING? NO

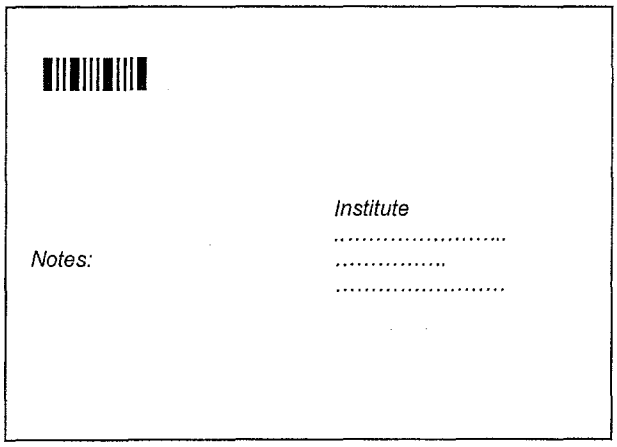
YES

(If yes) IS THE SMELL WHICH YOU PERCEIVE NOW:

1. NOT ANNOYING
2. A LITTLE ANNOYING
3. ANNOYING
4. VERY ANNOYING
5. EXTREMELY ANNOYING

Figure 3.14: Annoyance response scale (Source: Köster *et al.*, 1985, p300)

Figure 3.15(a), (b) and (c) (Verein Deutscher Ingenieure, 1993a, p10) illustrates an example of the envelope and postcard that is sent out for each test time.



Prepaid reply postcard addressed to the institute performing the investigation, with only a bar code as sender's address. The bar code contains the panel member's number, the calendar week number (in case of weekly questioning), and a code for the investigation zone (no uncoded personal data).

Figure 3.15(a): Prepaid reply postcard

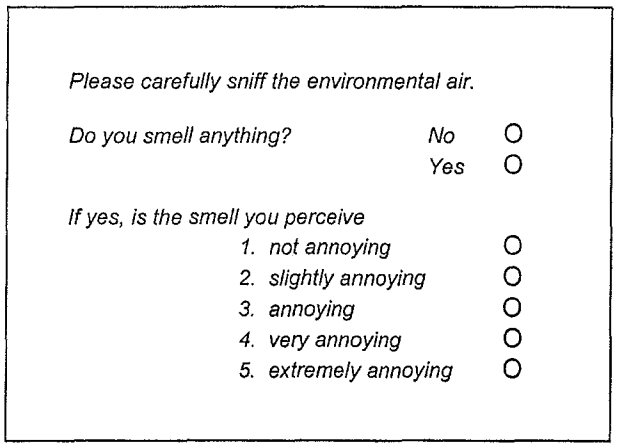


Figure 3.15(b): Reply postcard text

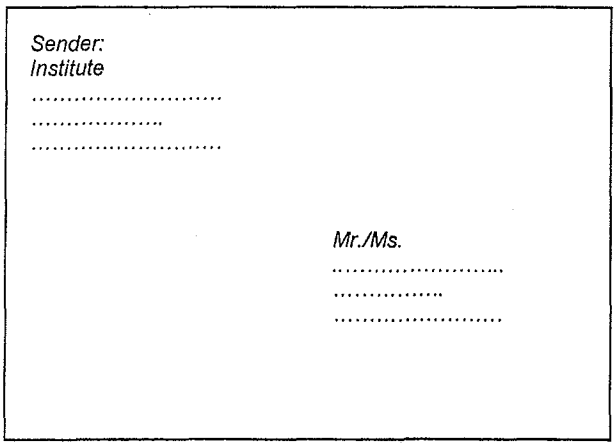


Figure 3.15(c): Postcard envelope

3.4.8 The data collection phase

3.4.8.1 Data collection time-frame

The choice of *observation times* will be influenced by the purpose of the investigation. If the odour source is clearly identifiable, obviously the time and day chosen should coincide with the operating hours of the plant. The observation that odour nuisance outside normal working hours is socially more undesirable than within them should also be taken into account. By keeping to a fixed day and time of day across investigation and control areas the panellists get used to a particular time and helps avoid measurement errors attributable to confusion if test times are varied.

The *duration* of the investigation will also depend on the purpose/objectives (e.g. monitoring of a short-term resource consent condition). A short-term investigation could cover a period of say two to three months (with at least one test time per day) whereas a long-term investigation could cover 12-14 months (with regular test times of at least once per week, on the same day and at the same time. The potential risk of slight inaccuracy because panellists are away on holiday has to be accepted (Verein Deutscher Ingenieure, 1993a, pp7-8).

High frequency measurements may also need to planned for. Overseas experience has shown that panel members may believe that odour pollution seems lower at the times they register their judgement (Köster *et al.*, 1984, p119), or it might be suspected that the odour emitter knows the standard test time and reduces emissions then. The daily or weekly frequency of measurements can be increased over say a six week period to check. This approach can also be used to measure peak emissions. However these extra tests must not interfere with the standard test. In order to get a reliable result a satisfactory response rate is needed (Verein Deutscher Ingenieure, 1993a, pp7-8), but no guidance was given as to a satisfactory rate (refer to Appendix A4.4 for a discussion on response rates).

3.4.8.2 Briefing the panel

When you have identified the panel members you need to brief them before the investigation begins. As long-term motivation is critical to the success of the monitoring, try to arrange a preliminary meeting (several might be held in different areas depending on the scope of the investigation) in order to inform them of:

- the sense and purpose of the investigation
- how the project fits into pollution prevention per se
- the necessity of the investigation, and
- the importance of his/her participation

The interest generated in the meeting could be enhanced through the presence of a speaker to explain the structure and working of the human sense of smell, and other aspects of odour management such as olfactometry, for example.

Explicit verbal and written instructions regarding their task should cover the following points:

- Each week panellists will receive a pre-paid postcard (or several if the investigation is short-term requiring more frequent assessment) containing his/her personal code number and the date of the test (see Figure 3.15 above).

- The card needs to be kept safely until the test day and time.

- At the agreed time the panellist goes outside to an agreed point (x metres from the front or back door, for example).

- He/she inhales the ambient air strongly through the nose and answers the question on the card straight away.

- The card should be posted immediately after it has been completed if that is practical, or no later than the following day (Verein Deutscher Ingenieure, 1993a, ppl0-11).

Impress on panellists that:

- Their response must be their momentary assessment at the stated test time ONLY;

- If they have any observations or comments they want to make about odour experienced at times other than the test time, they can do so on the 'Notes' section of the card;

- Other chance odours that are not relevant to the assessment (e.g. cooking or painting work in the house, or domestic fires if they are not the subject of the investigation) should be ignored;

- If such odours make a proper assessment impossible at the stated test time, then they should make the test 30 minutes later;

- They are not to ask anyone else's opinion as to whether there is an odour and/or how annoying it is - it is their opinion only that is wanted.

3.4.8.3 Collecting the data

Each week the panellists are to be sent the pre-paid postcard. On it they are to indicate whether they smelt anything or not, and if so, how annoying the smell was. They should also be encouraged to include any ideas they have as to the nature and source of the odour. The information received may be collated on a weekly basis and preliminary summaries prepared at regular intervals to provide to the panellists.

If there is doubt as to whether panellists in an odorous area are rating odours differently to those in the control zone, an expensive and complex check can be carried out to verify or dispel the doubt. This involves sending out odour samples for the panellists to assess (Verein Deutscher Ingenieure, 1993a, p11).

3.4.8.4 Maintaining panellists' motivation

A lot of attention needs to be devoted to maintaining motivation throughout the assessment period in order to enhance the response rate. Suggestions include:

- Providing a special journal/newsletter containing information about related environmental matters and about olfaction;
- Providing answers to questions that may be included on the postcards;
- Give them a present at Christmas (Punter *et al.*, source unknown, p147);
- Approaching pannelists on a personal basis as much as possible (e.g. individual letters, personal approach at meetings of panel members);
- Constructing a summary of feedback to date from time to time, including response rates;
- Organising meetings to provide progress reports on the investigation (Köster *et al.*, 1984);
- Reminding participants of the importance of their individual contributions.

3.4.9 Analysing the ratings

Calculate response rates by comparing the number of panellists who participated over the whole period with those who were invited to participate by way of random selection.

Section 3.2.11 and its subsections contain suggestions on preparing your data for processing and analysis. The variables you are likely to have include: an identification number for each panellist, a yes/no response as to whether they could smell an odour at the prescribed time, their annoyance/offensiveness response rating, and their suggestions as to source. Data would be entered weekly into a file in preparation for analysis.

At the end of the assessment period data can be analysed using a computer programme such as SPSS. Section 3.2.13 and its subsections provide guidance on data analysis. Derive frequency distributions for each variable and cross tabulations (see section 3.2.12) incorporating the variable on whether the panellist smelt an odour by the variable relating to suspected odour source.

If a weekly Odour Annoyance Index is wanted, it can be calculated from the returns as the following study summary demonstrates:

> Each week the panellists were asked two questions "Do you smell anything?" If the answer was 'yes', then they were asked "Is the smell which you perceive: (1) Not annoying; (2) a little annoying; (3) Annoying; (4) Very annoying; or (5) Extremely annoying?". Weekly responses of the individual panel scores were represented by a single typical value using a linear combination of the weighted categorical frequencies. That figure represented the characteristic measure of a panel's odour annoyance in a certain week. Possible measures for expressing annoyance included: arithmetic mean, relative frequency of category 2 (a little annoying) or higher, relative frequency of category 3 (annoying) or greater, and an Odour Annoyance Index (OAI) (see Table 3.14 below) (Köster *et al.*, 1985, pp300-302). The index ranged from 0 to 100; the index has a value of 0 if none of the panel members smell anything and a value of 100 if all members smell an extremely annoying odour (Punter *et al*, source unknown, p147).

Table 3.14: Possible annoyance measures (Source: Köster et al., 1985, p302)

Response Category	Weight*	Arithmetic Mean	Relative Frequency >Cat.2	Relative Frequency >Cat.3	Odour Annoyance Index (OAI)
0. No odour	W0	0	0	0	0
1. Not annoying	W1	1	0	0	0
2. A little annoying	W2	2	100%	0	25%
3. Annoying	W3	3	100%	100%	50%
4. Very annoying	W4	4	100%	100%	75%
5. Extremely annoying	W5	5	100%	100%	100%
* This is an empirically derived factor for quantitatively weighing the subjects' responses (Verein Deutscher Ingenieure, 1993a, p16)					

Panellists who responded for less than 20% of the total period were not included in the analysis for statistical reasons. No demographic differences were found between those who responded both more and less than 20% of the total period. Response behaviour did not depend on whether panellists lived in a polluted or non-polluted area. Emission measurements were carried out in one of the locations at the same time as panellists made their judgements.

Figure 3.16 illustrates a sample calculation of odour annoyance for a single week, and Figure 3.17 shows weekly annoyance indices.

The annoyance indices for each week can be incorporated into a bar chart (see Figure 3.17) which shows visually how frequently a certain annoyance index I_k was exceeded during the assessment period (Verein Deutscher Ingenieure, 1993a, p17). Weekly scores can also be plotted on a map and expressed as vectors in terms of wind direction at the time of measurement. Annoyance sources can then be identified on the basis of the results.

Results Matrix from one Observation Week

n number of test subjects (here: $n = 10$)
k calendar week 14
i annoyance category
W_i weighting factor for category i $(0 \leq i \leq 5)$
N_{ik} number of subjects rating category I in the k-th week

Test subject	Annoyance category					
	no odour 0	not annoying 1	slightly annoying 2	annoying 3	very annoying 4	extremely annoying 5
1	x					
2					x	
3		x				
4			x			
5				x		
6						x
7					x	
8		x				
9				x		
10						x
N_{ik}	1	2	1	2	2	2
W_i	0	0	25	50	75	100
$\Sigma N_{ik} W_i$	0	0	25	100	150	200

$$\frac{1}{N}\sum N_{ik} \cdot W_i = 1/10(25+100+150+200) = 475 \cdot 0.1 = 47.5$$

The annoyance index I_{14} found in calendar week 14 is 47.5.

Figure 3.16: Sample calculation of odour annoyance (Verein Deutscher Ingenieure, 1993a, p17)

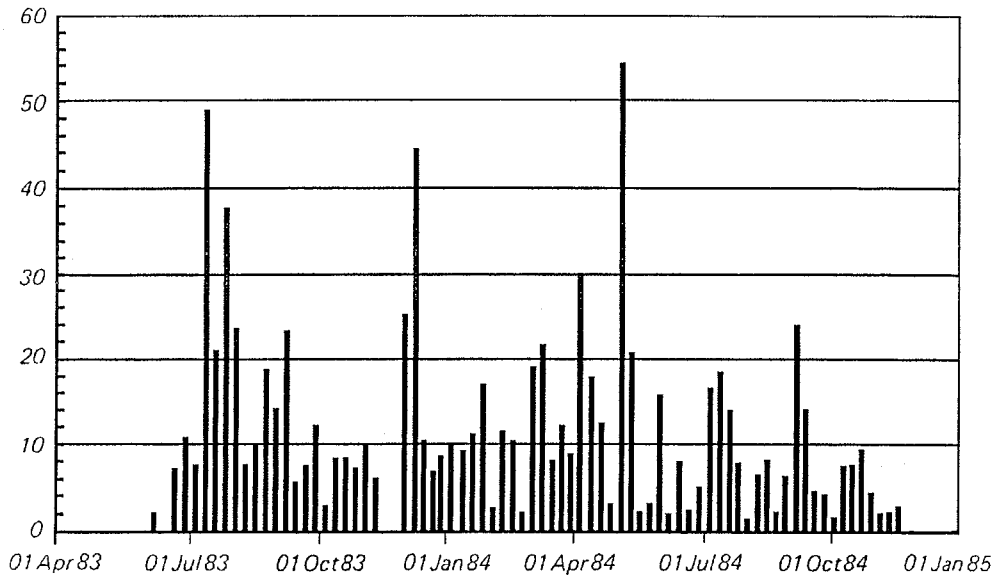


Figure 3.17: Example of the weekly annoyance indices during an investigation covering several months (Source: Verein Deutscher Ingenieure, 1993a)

3.5 Meetings

3.5.1 What do we mean by 'public meetings'?

The term 'public meeting' is self-explanatory and implies meetings that are called for a particular purpose and are open to any interested person.

3.5.2 Circumstances in which public meetings have been used

The following instances were cited in the local authority survey (Lincoln Environmental, 1997):

- District Plan preparation, to determine source conditions;
- to discuss serious odour problem (by-products)

3.5.3 How much can it cost to run a public meeting?

The costs of a public meeting may be met by any of the three parties involved. They are frequently organised by members of the affected community. It is likely that for Council staff attending there will be relatively little preparation work other than that which would be required for the consent process so the costs will be simply those of attending the meeting and some mileage.

Other costs will include publicity - mail box drop, public notice etc., hall hire which is likely to be minimal unless a very large meeting is held, design and preparation of publicity material, catering if a cup of tea is to be offered and the costs of designing and delivering any follow-up material. Typical costs include:

Publicity (2 pamphlets delivered to 300 households)	$190
Two notices in local newspapers	$150
Hall hire	$25
Catering	$25
TOTAL COST	$390

Additional costs will be incurred if professional design services are used or follow-up material delivered. Unless the local authority organises the meeting it will incur only the costs of those attending the meeting at approximately $200 per staff member. The advantages of a public meeting are that a large number of individuals can be drawn together at one time to address an issue and that it is a relatively cheap way of gauging public opinion. However, those who attend public meetings and those who are prepared to express their views in such a forum may well not represent the community as a whole.

3.5.4 Planning a public meeting

- Clarify the purpose of the meeting and then consider who will be interested in or affected by the matters that you want to be considered.
- Use more than one means of advertising so that those who are likely to be interested will hear of it.
- Give the community sufficient notice of the date but not too far ahead that they may forget.
- Use a neutral venue if possible, so that no-one feels disadvantaged.
- A cup of tea before the meeting starts gives an opportunity for people to talk to each other.
- Invite a person to facilitate the meeting who has facilitation skills and is seen to be independent by the community.
- State the purpose of the meeting on the meeting notice and at the outset of the meeting, and what you hope to achieve by the end of the meeting.
- Plan the agenda so that the purpose can be achieved.
- Agree upon a 'where to from here' at the end of the meeting so that people know what to expect and that their on-going interest and participation is valued.
- A cup of tea after the meeting provides a valuable opportunity for informal discussion once various parties have heard each other's point of view during the meeting.

The principles set out in section 3.8 are relevant to a successful public meeting.

3.6 Working Parties

3.6.1 What do we mean by 'working parties'?

A Working Party is a group that is set up generally as a problem-solving entity with a specific task or tasks in mind. It may act as the driving force behind various techniques that are used to investigate issues.

3.6.2 Circumstances in which working parties have been used

Local authorities (Lincoln Environmental, 1997) have used working parties for:

- consultation on plant upgrades and resource consents;
- determining ways to mitigate problems.

3.6.3 What costs are involved in establishing a working party?

Like the other techniques described the costs of working parties are highly variable and are often met largely by the consent holder. They are generally convened to deal with odour problems generated by larger-scale operations.

Where the working party is on-going (probably a consent condition) and meets six monthly or annually to review issues of concern, the costs are usually low. Participants would generally include 2 or 3 company representatives, 1 or 2 council staff and up to 10 community members. It is probable that there is no payment of community members although this is seen as an increasingly contentious issue in resource management generally. Minimal catering and hall-hire costs are usually met by the company and local authorities incur the costs of approximately 4 hours time for each staff member involved and some mileage (approximately $250 if one staff member attends or $450 if two are involved).

Much more costly are working parties which meet frequently over a finite period of time to resolve particular issues. The costs of such exercises may also be borne by the companies involved. One such example involved a total of 10 meetings, each of 3 hours duration. Costs to the company involved included:

Independent facilitation of meetings plus press releases and design of publicity material	$6,000
Petrol vouchers for 9 community members	$1,800
Publicity excluding design	$400
Catering	$200
TOTAL COST	$8,400

The use of an independent facilitator, particularly in a situation where the working party will meet frequently to discuss contentious issues is particularly valuable in achieving an outcome acceptable to all parties. While local authority staff may well have the expertise to run such groups they are unlikely to be seen as totally independent by the company or the community.

Both the district and regional councils involved (Lincoln Environmental, 1997) sustained costs of staff time (5 hours per meeting at $50 per hour = $250 per meeting) and mileage (50 km per meeting at 40 cents per km = $20 per meeting) which totalled $2,700 per council over the ten meetings held. Thus the total cost for ten meetings, excluding the time of company representatives, was $13,800 ($8,400 plus $2,700 plus $2,700) or $1,380 per meeting held.

The advantages of working parties include the development of a relationship between the company involved and the surrounding community which enables them to work together to solve a problem without confrontation. The disadvantages include the fact that such small groups may not fairly reflect the community, the heavy demands on community members' time and the possibility of intimidation of community members by the company (Lincoln Environmental, 1997).

3.6.4 Setting up a working party

Issues that need to be addressed before establishing a working party can include:

- A statement of purpose or working brief.

- How will membership be constituted?
  - Community representatives - will they have an equal or greater number than company representatives so that they do not feel overpowered?
  - Marae, whanau, rohe, hapu and iwi representatives;
  - Company/facility representatives;
  - Regional and district council representatives.

- Will an independent facilitator that is acceptable to all parties be appointed?

- Try and determine what kind of costs might be incurred and who will pay them.

- How will community liaison take place?

- When will meetings be held in order to convenience as many members as possible?

- Establish protocols - e.g. what happens when one group leaves and wants to rejoin later or new groups join later in the process after decisions have already been made or agreements reached?.

- Would the deliberations of the working party benefit from having an external independent audit group?

Adoption of the principles outlined in section 3.8 will enhance the way a working party can function.

3.7 Consultation with the Tangata Whenua

Legislative requirements to consult with the tangata whenua are specified *in* the RMA. The observations made in this section came from representatives of groups that have been involved in odour issues (Lincoln Environmental, 1997).

The expectations of Maori people with regard to odour are the same as for everyone else. In addition, it is degrading for offensive odour to be present in proximity of the marae through the impact that it has on marae hospitality. In the past, Maori thought it was a fact of life and that they had to put up with odour. Now they accept that there are problems that odour producers cannot necessarily remedy immediately (for existing systems) but for new systems they want no odours beyond the boundary as there is a lot of new technology available.

Maori people do not always know who to complain to and are reluctant 'to cause problems'. Local hapu/whanau/rohe groups may go to their Trust Board to participate on their behalf so that the name of the local group and its relationship with the community is maintained. A Trust Board may be experienced in approaching resource management concerns and find it easier to make contact with the appropriate people.

Where there are likely to be problems with odour a combination committee could be established comprising the consent holder, the broader community, and Maori who are likely to be impacted. This way an individual cannot be 'isolated' (this can be a problem particularly in a rural community).

In a number of consent applications the consultant will hold a complaints log - this approach gives a factual basis to the odour situation and demonstrates integrity of information. This relies on the goodwill of the company to record all complaints - possibly there is a need for an independent body to be involved.

Consultation should be earlier rather than later; Maori are appreciative of the opportunity to try hard to work through the issues. They feel offended when they are not contacted early enough because those doing the consulting know they (the tangata whenua) are there. If existing Maori organisations are in the area the consent holder needs to talk to them; sometimes consultants only speak to Maori people/organisations they know.

The Parliamentary Commissioner for the Environment's guidelines on tangata whenua consultation are supported and should be observed (Cooper, 1996, pers. comm.[16]).

The (Wastewater 2000) Workshop was excellent from the point of view of the tangata whenua who were invited to nearly everything regarding land and environmental issues. It enabled them to establish a line of communication with the Plant itself and provided an avenue for all parties after the workshop. They had a meeting on the marae with people from the Workshop to put forward their concerns. Tangata whenua representatives from the marae also visited the plant to witness construction that was going on; this was appreciated after having spent 2 years going to meetings once a month.

16 Cooper, C, Huakina Development Trust.

Workshop meetings work well in that they have knowledgeable members to express concerns. In this situation the Maori side is not left out - there is comfort in knowing who is there, and at any time to be able to draw information from them and also get help - it provides a 'bank' of people. The tangata whenua do not have resources and the resources to get in touch with people so to have access to others and to plant representatives themselves is valuable.

The success of participation also depends on the person who is representing tangata whenua. A lot depends on what his or her people want and not his or her own feelings.

Even though the Trust Board managed the interests of the marae on the working party for an interim period, marae representatives raised matters with the working party and rejoined when it was clear that major decisions had been made on a small number of options.

Through participation on the working party this tangata whenua group became aware of the emergency call line at the plant for complaints for the public in general and that all complaints are logged (Roberts, 1996, pers. comm.[17]).

3.8 Community Consultation

The Ministry for the Environment's publications on odour management discuss the role of community consultation.

Direct consultation can be carried out with those adjacent to the site and these people may be offered the opportunity to maintain odour diaries. The community can be shown round the plant so that company representatives can explain the technical work being undertaken to address odour problems if that is the case.

A range of approaches can be used when consulting the community. One approach (Meek, 1993, pp111-117) termed the 'LUCAT' approach emphasises *'listening', 'understanding', 'credibility' and 'trust'*. It is based on seven principles of good consultation.

Principle One - The 'good neighbour' principle

Company representatives are encouraged to appreciate the views of their neighbours.

Ask yourself: *"Would I really like to live next door or close to our plant?"*
"Can I honestly say we never have any off-site effects?"

17 Roberts, D, Makaurau Marae.

Principle Two - The 'accept the perception' principle

Company representatives may believe they are misunderstood, especially if they are operating in a responsible manner.

Ask yourself: *"Does the community know we have a well-run operation?"*
"Has it enough information, accurate information, does it feel powerless, etc.?"

Accept that community perceptions are real for those people - the key is to understand and work with their perceptions.

Try to understand why the community has developed the perceptions it has.

Principle Three - The 'shut up and listen' principle

Telling people what you are going to do early on in the process may not alleviate their concerns.

Ask them: *"Tell me about your concerns"* or *"What are your concerns?"*

Even if you feel you are being misrepresented, LISTEN.

You don't have to agree with what is said, but you need to demonstrate that you are willing to understand their views and concerns.

Principle Four - The 'don't think you know everything' principle

Ask yourself: *"Can I honestly say that we do or will know absolutely everything about the risks involved in using the technology we have?"*

If the answer is 'no', then don't tell the community that you do.

Principle Five - The 'conflict is healthy' principle

Conflict is not easy and it can be very unpleasant if you are abused by an angry group of people.

Try to avoid an 'us versus them' approach by acknowledging that there is likely to be overt conflict at the outset and to allow for 'blood letting'. Keep listening.

Principle Six - The 'joint ownership' principle

This principle can be practised more successfully if the community is involved earlier rather than later in the process.

Share your tentative ideas and strategies with the community rather than imposing them on the community.

Find out who might be affected by what you have in mind and then approach those people to find out what they think.

The community can respond positively at being recognised as a resource in the process.

Principle Seven - The 'give it enough time' principle

Involving the community early in the process requires planning which requires time.

Time is also needed to reach a consensus on various issues but it can pay off in the longer term if the community becomes supportive of your plant's activities.

The principles outlined in this final technique can in fact be adopted for any of the techniques presented in previous sections. Success can require a lot of work, patience and commitment initially, but can produce both tangible and intangible results and rewards such as long-term cost savings and enhanced relationships between and amongst the parties involved.

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APPENDIX A:

Sample Design

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APPENDIX A: *SAMPLE DESIGN*

A1 Introduction - How to Use this Appendix

To use this appendix, you will need to know some basic statistics - a good pass in sixth form statistics or mathematics should be enough. You should first read section 3.2.5 of this report, and then sections A2 to A4 of this appendix. These sections are about survey objectives, defining a population of interest, how to represent a community's views, and some general principles of sample design. Once you have read these sections, you will know which of the specific sample designs (sections A5 to A8) is going to be of most use. If you're planning an indicative survey, you will find appropriate sample designs in sections A5 and A7. Sample designs for definitive surveys are discussed in sections A6 and A8, but we strongly recommend that you seek the advice of an expert in sample design if you think the results of your survey could be used in legal proceedings (see sections 3.2.4 and 3.2.7).

Section 3.2.5 of this report covers the different objectives councils and odour producers may have when surveying a community. While a council could also be an odour producer, in general there will be three parties: a council, an odour producer, and the rest of the community. Both councils and odour producers need to select a sample of people to represent the community. A council often has a list of ratepayers from which it can draw its sample. An odour producer will typically not have this sort of information. So, councils and odour producers will tend to use different sorts of surveys because their objectives differ, and because councils already know where people live and work in the community.

Section A2 of this appendix is about how to define a population of interest. The population of interest is the group of people whose opinions you want to record. Obviously, if you define your population as those living within a certain area, and this area is very large, then the proportion of people who perceive an odour problem may be very small. So this definition of your population is crucial to the subsequent use you can make of your survey's results.

Section A3 of this appendix is about how to represent the community's views. While it is relatively easy to sample households and businesses in an area, sampling individuals within each household or business adds another layer of complexity to the sampling process. You need to consider whether this added complexity is necessary.

Section A4 of this appendix is about general principles of sample design - the statistical aspects of running a survey. Four major steps in the sample design process are: developing a sampling frame (a list of those in the population of interest), selecting people for the survey, estimation (calculating results once the survey is completed) and adjusting results for non-response. Sample design takes place in conjunction with questionnaire development and survey management planning. Each of these three operations affects the others. Statistics New Zealand's 'A guide to good survey design' (Statistics New Zealand, 1995) is full of good practical advice on running a survey.

A2 Defining a Population of Interest

The starting point for any survey is a definition of the population of interest. The definition should be clearly stated. The definition will most likely include statements about an area in

which the community to be surveyed lives, and about a time period of interest. The aim is to define an area and a time period within which a community is likely to have found odour offensive.

Those planning a definitive survey must take care that the definition used can withstand legal challenge. For example, if odour quickly dissipates with distance from its source, increasing the area of interest will reduce the proportion in the survey who perceive a problem. A survey at the end of the summer is not a sensible way to assess an odour problem that occurs only in winter.

To decide on a population of interest, and to later defend that decision, you could use: addresses and dates of complaints received; results of atmospheric dispersion modelling (Ministry for the Environment, 1995, p54); documented visits by you or others to different areas; populations of interest used elsewhere for similar problems; discussion of how local climate and topography influence odour dispersion. Much of this information can be displayed using maps.

The Ministry for the Environment suggests that 'an offensive odour generally becomes noticeable when its concentration reaches 5-10 OU' (odour units) (Ministry for the Environment, 1995, p11). So atmospheric dispersion modelling, which gives contours in odour units, could be used to set a boundary to an area of interest. However, since models generally assume constant climatic conditions and crudely approximate topographical features, the addresses of those complaining will be the better guide *(ibid.*, p54).

For a definitive survey, it may be necessary to survey outside your population of interest as well. This is to demonstrate that you have done a good job in defining those likely to find odour a nuisance.[1] However, you can use different sampling fractions in and outside the population of interest, sampling fewer outside the population of interest in order to keep the total sample size down.

A2.1 *Given the addresses of complaints you've received, you define a population of interest as those living or working inside a circle with a radius of 1.0 km. At the centre of the circle lies a factory you suspect is causing an odour problem. To show that few people outside this area find odour offensive, you also survey those living between 1-2 km away from the centre of the circle.*

A3 Representing a Community's Views

A community consists of those living and working in an area, those visiting an area and those investing in an area. But individuals in these last two categories will be hard to identify. In most cases, it should be enough to survey just those living and working in an area, and make some comment about how these other two groups could be affected in the light of your survey's results. In special circumstances (perhaps a large park, tourist attraction, or shopping centre), surveying these other two groups may be necessary. These guidelines do not address how to survey visitors nor investors.

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1 Conditions under which survey results would be judged admissible have included 'That the proper universe was examined' or 'interviewees must be selected so as to represent a relevant cross-section of the public' - *Auckland Regional Authority v Mutual Rental Cars*. (1987) 2 NZLR, p680.

So you will need to sample both businesses and households. It is relatively easy to tell how many businesses and households are in an area. You might use a list of ratepayers, a list of telephone numbers, aerial photographs or electoral role information (the 'Habitation Index'). And you can then sample some of these businesses and households. But you need to talk to individuals, and so you need some way of choosing which person or people to interview within each of the businesses or households in your sample. This means, in sampling terms, a second stage of selection: the first stage is to sample households and businesses; the second stage, to sample individuals from within the previously selected households and businesses. If possible, you want to avoid this second stage of selection for two reasons.

Firstly, you don't know how many people are in each primary sampling unit (the business or household). So the interviewer has to find this out, and then choose at random a person to interview. This means more (and difficult) work for the interviewer, and interviewers will need more training as a result.

Secondly, estimates from a survey are not enough. You need to show how precise your estimates are. To do this, you need to calculate the variance in what you are trying to measure. With two stages of sampling, both stages contribute to the variance (Sarndal *et al.*, 1993, p137). But to estimate the contribution to the variance from the second stage, you need to interview more than one person in each household. This is difficult to do without the answers of the first person interviewed influencing the answers of the second person interviewed (Kish, 1965, p398).

One way around the problem is to always interview 'the household member who is most knowledgeable' (Fowler, 1985, p33). We suggest 'the person most often at home' should be the most knowledgeable member of the household on matters of offensive odours, and a Health and Safety Officer (if on site) should be the most knowledgeable employee in a business. That is, if the business has such a person on site: you would have to approach the CEO first, and ask to speak to the most appropriate person (the person who would receive any complaints about odour from those employed by the business).

However this solution means that the results of your survey will be in terms of households (and businesses), not individuals. That is, '15% of households within 500 metres of the source found the odour offensive', not '15% of the individuals living within 500 metres'. And you will need to explain your procedure for choosing someone to represent the views of each household or business (particularly if it is a definitive survey).

Selecting individuals this way has some real practical advantages. Firstly 'the person most often at home' will be available for an interview more often than someone chosen at random from those in the household. This will reduce the number of households you have to visit (or phone) a second time in order to interview the person you want. Secondly the survey may be repeated some time in the future, if estimates of change are required. It is more accurate to use the same sample (both 'before' and 'after') so that the change is not partly due to a difference between two different samples. If the same sample is used, a sample of differences ('after' minus 'before') is then used to estimate the average difference in the population. Finding 'the person most often at home' in a second survey (and this person could legitimately change between surveys) is much easier than finding some specific individual, chosen at random in the first survey.

On the other hand, a community is really made up of individuals, not households and businesses. 'The person most often at home' is more likely to find an odour offensive than

someone chosen at random from the household. So using the 'person most often at home' approach will over-estimate how many individuals perceive a problem. Of course, as an odour problem becomes more and more obvious, this bias disappears because it won't matter who you talk to in the household - everyone will tell you there's a problem!

If you are running an indicative survey, a slight over-estimate won't really matter. With a small sample, the bias (the difference, on average, between what the survey tells you and the true value) will be small compared to the variance in the estimate. When the variance is large, this is saying the estimate isn't known precisely anyway. Selecting individuals this way will actually be an advantage to the odour producer who wishes to gather information in order to better manage odour. In this case, you want to talk to those who think there is a problem.

In a definitive survey, an over-estimate of the individual's views will not be a problem if it does not help your cause. For example, the odour producer who wishes to show there is a low level of community concern will not benefit from using results from 'the person most often at home' as representing the level of individual concern.

However, if a definitive survey of individuals is necessary and an over-estimate is going to be to your advantage, then you may need to randomly sample individuals within households and businesses. At this point, consult a professional. Briefly, the common method of selecting the individual who has the next birthday is not recommended.[2] Kish gives a better method: the interviewer ranks household members by increasing age (the interviewer doesn't actually need to know these ages), then uses a random number table to choose one person from this list (Ministry for the Environment, 1995, p11). Estimates need to be adjusted to take account of the variable selection probabilities. The variance in these estimates can be calculated as if there were no second stage of sampling. This will under-estimate the true variance (Sarndal *et al.*, 1993, pp139-140), but Kish (1965, pp400, 403) suggests the difference will not be large provided most households and businesses are about the same size (say one to six people). An appreciable number of larger businesses in the population of interest means that businesses should be treated differently. A sample of people will need to be selected from each business, and second stage variances calculated for the business component of the community. Alternatively, businesses could be sampled with replacement (see section A4.2) and then there is no need to calculate second stage variances (Sarndal *et al.*, 1993, p 151).

A4 General Principles of Sample Design

A4.1 Sampling frame

The sampling frame is a list of all households and businesses available for selection. If you are lucky, this list will consist of every household and business in your population of interest. Often there is some mismatch between the sampling frame and the population of interest. For example, a household without a phone or with an unlisted phone number will not be in a sampling frame compiled from the telephone directory. Duplicates in the sampling frame will cause results to be biased towards the opinions of the duplicated group. It is good

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2 Asking for the household member with the nearest birthday gives too much control to the person first contacted. This person often claims to be the person with the nearest birthday when they are not; this person may not know the birthdays of all the others in the house; or they may decide that visitors are not part of the household. Or the interviewer may decide that it is easier to interview this first contact rather than someone else who isn't perhaps at home. Other methods of selecting a household member force the interviewer to do a proper job.

practice to report any mismatch between sampling frame and the population of interest and discuss how this could affect results. As a result of this mismatch, do you expect estimates to be too high or too low for certain questions?

Some sort of sampling frame is necessary in any survey. A district or city council will be able to use a list of ratepayers. A regional council or odour producer may have to use some other sort of list. In what follows, we will refer to a *'council'* as though all councils can use a list of ratepayers as a sampling frame, and we will refer to an *'odour producer'* as though all odour producers cannot use a list of this sort. This is not true and so a council may find itself using a sample design more commonly used by an odour producer and the other way around.

A survey's objectives (see section 3.2.5) and the sampling frames available strongly influence sample design. So each combination of *'council'* or *'odour producer'* and *'indicative'* or *'definitive'* survey will require a different sort of sample design.

A4.2 Selecting the sample

A sample is then selected from the sampling frame. Random sampling ensures that one can estimate (without bias) the properties of the population of interest from the sample. In a simple random sample, each item in the sampling frame has an equal chance of being selected for the survey. Other sorts of random sampling are more efficient than simple random sampling. That is, for a given sample size, other sorts of random sampling can give more precise estimates (precision is measured by the variance of the estimate - see section A4.3). So before selecting the sample, you need to calculate a suitable sample size but this calculation depends on the sort of random sampling you're going to use. Appropriate methods of random sampling will be introduced as needed, together with how to calculate a suitable sample size.

The simple random sample (without replacement) is a component in many of the more complicated methods of random sampling. Sampling with replacement means that when an household or business is selected from the population for the sample, it is observed and then returned to the population before the next draw. Sampling without replacement ensures that once an household or business is selected for the sample, it cannot be selected a second time. Simple random sampling is usually without replacement because it is more efficient (Sarndal *et al.*, 1993, p73).

The easiest way to take a simple random sample (without replacement) is to use a computer program (such as a spreadsheet or statistical package) to select your sample. You could read your sampling frame into the computer program and then select the sample. Alternatively, you could create a column of numbers inside the computer program, so that each number represents one item in your sampling frame; then select numbers from this column and use these numbers to identify the items in your sampling frame that are in the sample. Most computer programs will have simple random sampling without replacement as the default, but it pays to check.

If you can't use a computer to draw the sample, you can take a systematic sample from your sampling frame by hand. To draw a systematic sample of roughly size n, choose a random number between one and k, and then select every k^{th} ratepayer from the sampling frame starting with the ratepayer corresponding to the random number. Calculate k as the integer part of N/n, where N is the total number of ratepayers in the sampling frame.

A4.2.1 *You calculate the required sample size to be 60. There are 893 ratepayers in the sampling frame, so k = 893/60 = 14.88 $\Rightarrow$ 14. You now need to find a random number between 1 and 14, as a starting point for sampling from the list. You get a scientific calculator to choose a random number between 0 and 1: the calculator selects 0.271. Multiply this number by k; add one; and then just use the integer part of the answer: (0.271'14) +1 = 4.794 $\Rightarrow$ 4. So select the fourth ratepayer in the list, and then every 14th ratepayer after that, until you get to the end of the list.*

A systematic sample from a list arranged alphabetically can be treated as if it were a simple random sample (Cochran, 1977, pp212-213). If the list is not in alphabetic order, make sure the order is essentially random. Particularly watch out for any order in the list that roughly coincides with the frequency of sampling from the list (*ibid.*, pp217-219).

A4.2.2 *In the example above (section A4.2.1), suppose the sampling frame consisted mainly of households but every 14th ratepayer in the sampling frame was the owner of a business. The systematic sample would then either have no businesses in it at all or would consist entirely of businesses, depending on the random starting point chosen. While an exact periodic effect like this is unlikely, roughly periodic variation in the list is a possibility and this could lead to biased estimates. If in doubt, take a simple random sample instead.*

A4.3 Estimation

With a simple random sample, the sample average is an unbiased estimate of the population average. This is not true for most other random sampling methods. Once results are in, estimates of population averages or totals must be calculated. Mostly, estimate of averages will be required: 'on the last occasion odour was perceived as annoying, the odour lasted on average for 1.8 hours'. Note that a proportion is a special sort of average. Proportions are converted to percentages by multiplying the proportion by 100. So '15% of respondents felt the odour was offensive' is a statement about a proportion. If each person who feels odour is offensive is recorded as a one, and a zero is recorded otherwise, adding up the ones and zeros and dividing by the number of respondents yields a proportion. Yet this process is just finding an average.

The likely variation in estimates must also be calculated. This 'variance' is a measure of how precisely answers are known. In statistics, precision refers to how much estimates would vary about an average value if you repeatedly sampled your population - but if the estimate is biased, its average value will not be the true value. In general, one can calculate the precision of an estimate but not its bias.

For legal purposes, knowing the precision of the estimate is as important as knowing the estimate itself. If a survey is to be used as evidence, details may be required of 'any tests applied and the results of any tests applied to determine the extent to which the survey or

results of the survey can be trusted' (*Auckland Regional Authority v Mutual Rental Cars* (supra)).

One appropriate test is the 95% confidence interval. This interval is approximately the estimate (of an average, total or proportion) plus or minus two times the square root of the variance of the estimate.

$$\text{i.e. } 95\%\ \text{CI} = \text{estimate} \pm 2.\sqrt{\text{variance of estimate}} \qquad (1)$$

The interpretation of this interval is that for 95% of all possible samples, the true value for the population of interest will lie within the interval. Hence the true value is to be found within this interval with a high degree of confidence. As a general rule, to be reliable a confidence interval needs to be based on a sample size of at least 30 (Cochran, 1977, p27; Berenson *et al.*, 1988, p227).

A4.3.1 *You take a simple random sample of 30 households from a population of 2000. In five of these 30 households, the person 'most often at home' says that odour is a problem. Therefore the proportion of households where odour is perceived as a problem is 5/30 or 0.17 (17%). Let's say the variance of this proportion is 0.0047 (you'd use equation 11 in section A5.3). The 95% confidence interval is then 0.17 ± (2×0.07), or from 0.03 to 0.31. That is, in 3% to 31% of households in the population of interest, the 'person most often at home' says that odour is a problem.*

Other higher or lower percentage confidence intervals could be useful. Most statistics textbooks give examples of how to do this. The 95% confidence interval has a long history of use in science, and should be acceptable for legal purposes. But there's nothing magic about this 95% confidence interval - for indicative surveys, 90% or 80% confidence intervals may well be more useful. Indicative surveys are likely to use small samples. The result will be 95% confidence intervals that are very wide: perhaps so wide as to be rather uninformative (as in section A4.3.1 above). The 80% interval will give you a narrower interval within which the true value is likely to lie, although you cannot be quite so certain that the true value is within this interval. The 80% confidence interval is approximately the estimate (of an average, total or proportion) plus or minus 1.3 times the square root of the variance of the estimate:

$$\text{i.e. } 80\%\ \text{CI} = \text{estimate} \pm 1.3.\sqrt{\text{variance of estimate}} \qquad (2)$$

A4.4 Non response

Finally, those who do not respond to a survey are often different to those who do. Non-response introduces a bias: on average estimates from the survey differ from the true values for the population. Many things can be done, as part of survey management, to reduce non-response. With a definitive survey, you should try to contact those not at home at least three times before giving up. With an indicative survey, try to contact those not at home at least twice (or at least try some them a second time - see section A5.4). Other ways to reduce non-response include contacting people in advance to arrange an interview time, assurances of privacy and confidentiality, providing some small incentive (Department of Statistics, 1992, p33). Good questionnaire design helps too. But there will always be some degree of non-

response. Once answers are in, statistical methods can be used to adjust estimates so they are less biased.

You should always report your survey's response rate. As a rule of thumb, the response to your survey should be 70% or better. Otherwise 'most researchers would have more accurate and useful estimates if they reduced the sample size and devoted the saved resources to obtaining responses from a higher percentage of the sample' (Fowler, 1985, p147).

A5 Council: Indicative Survey

A5.1 Sampling frame

A list of ratepayers (both households and businesses) in the area of interest will be the best sampling frame. Those selected from the list will be contacted, and the person most often at home will be asked a short series of simple questions.

A telephone survey will be the quickest and cheapest way to reach those selected (*ibid.*, pp68-9). Postal surveys are not recommended because of their low response rates (*ibid.*, pp66-67). A telephone survey needs a short questionnaire and simple questions. A short questionnaire is a good selling point when you're trying to persuade someone to participate in your survey. Simple questions are needed for telephone interviews; otherwise the respondent may have difficulty understanding what is being asked. [In face to face interviews, it's easier to tell if the respondent doesn't understand the question and needs additional information from the interviewer. The respondent can also see a copy of a long question, or the choice of answers as the question is being asked by the interviewer.]

Treat flats as businesses. In the first instance, interview the owner (as the CEO): he or she may then suggest you speak to a tenant (as a more appropriate person to answer your questions) and may help you contact this person. For an indicative survey, it won't really matter if you have to interview the owner when you'd rather interview a tenant (see comments in section A3 about bias versus variance in estimates from indicative surveys).

A5.2 Selecting the sample

Take a simple random sample (or systematic sample) from your list of ratepayers (section A4.2). To calculate the required sample size, identify the most important question or questions in your survey. For each question, consider the width of the confidence interval you want to end up with. Calculate an approximate sample size for each question as (Berenson *et al.*, 1988, pp259-261):

$$n_0 = \frac{Z^2\sigma^2}{\partial^2} \qquad (3)$$

n_0 = first approximation to required sample size;

Z = 2.0 for a 95% confidence interval;

= 1.3 for an 80% confidence interval;

∂ = half the width of the desired confidence interval;

σ^2 = population variance (as yet unknown).

Now adjust this approximate sample size given the number in the sampling frame (N) (Berenson *et al.*, 1988, pp266-268; Cochran, 1977, p76):

$$n = \frac{n_0 N}{n_0 + N} \tag{4}$$

n = required sample size;
N = population size (number in the sampling frame).

Do this for each important question and take the largest value of n as the sample size required for your survey. Remember, you need a sample size of at least 30 to be able to calculate reliable confidence intervals (section A4.3).

Of course you don't know the population variance before surveying, and the trick is to make an intelligent guess. If you are going to estimate an average, think of the largest and smallest values you are likely to get in answer to your question. The population variance is then roughly: [3]

$$\sigma^2 = \left[\frac{(\text{largest} - \text{smallest})}{6}\right]^2 \tag{5}$$

A5.2.1 *You are going to ask respondents: 'Think back to the last time you were annoyed by odour. How long did the odour last?'. You want to estimate how long offensive odours last. You think the answers you'll receive will range from 0 to 15 hours. Your rough estimate of the population variance is then* $[(15-0)/6]^2 = 6.25$. *If you decide you want to calculate an 80% confidence interval for this mean with width plus or minus half an hour, your initial sample size is* $1.32 \times 6.25/0.52 = 42$. *If there are 2000 ratepayers in your sampling frame, the required sample size is adjusted to* $(42 \times 2000)/(42+2000) = 41$. *Select say 60 people to allow for a 70% response rate. Note that in this example, using equation 4 doesn't really change the sample size because here the sample size is small relative to the population size.*

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[3] Equation 5 follows if what you are trying to measure is distributed according to a normal distribution. Then 99.9% of observations (ie. almost all) lie within 3 standard deviations on either side of the mean. So the range of what you observe is about 6 standard deviations - and the variance is just the square of a standard deviation. If you think that what you are trying to measure should follow a rectangular or triangular distribution, use similar methods - see Cochran, Working Group (1977): *Sampling techniques (third edition).* New York: John Wiley, p81.

If you are going to estimate a proportion, note that the population variance for n variable that can only take the values zero or one is approximately:[4]

$$\sigma^2 = P.(1-P) \qquad (6)$$

This equation is at a maximum when the population proportion (P) is 0.5 (that is, 50%). So think of what the population proportion is likely to be; then choose a value closer to 0.5. Without any information at all, you might use P = 0.5; but you risk being too conservative and ending up with a much larger sample size than you really need.

A5.2.2 *You think around 10% of the population will find a particular odour offensive. You want a 95% confidence interval with width plus or minus 10%. [That is, if the estimate of this proportion turns out to be 0.12, you want to end up with a 95% confidence interval from 0.02 to 0.22.] To be slightly conservative, you assume that the population proportion (P) is 0.15. Your initial sample size is 2.02×0.15×0.85/0.12 = 51. Notice that if you'd assumed P = 0.5, your initial sample size would be 100. If there are 200 ratepayers in your sampling frame, the required sample size is adjusted to 51×200/(51+200) = 41 - say 60 people to allow for a 70% response rate.*

A5.3 Estimation

Once the survey has been completed, estimate an average as (Cochran, 1977, pp20-21):

$$\bar{\hat{Y}} = \bar{y} = \frac{\sum_{i=1}^{n} y_i}{n} \qquad (7)$$

$\bar{\hat{Y}}$ = estimate of population average;

$\bar{y}$ = sample average;

$\sum_{i=1}^{n} y_i$ = add up each sample observation;

n = sample size.

[4] For a variable taking only values zero or one (see section A4.3), the population variance is $N/(N-1) \times P \times (1-P)$. Since N/(N-1) will be close to one, the population variance is therefore approximately $P \times (1-P)$ - see Cochran, 1977, p51.

The variance of this estimate is (*ibid.*, p26):

$$v(\bar{y}) = \frac{(N - n)}{N} \cdot \frac{s^2}{n} \tag{8}$$

$v(\bar{y})$ = variance of sample average;
N = population size;
s^2 = sample variance.

Use the statistical function of a scientific calculator to find the sample variance (s^2), or calculate this by hand as:

$$s^2 = \frac{\sum_{i=1}^{n} y_i^2 - \frac{\left(\sum_{i=1}^{n} y_i\right)^2}{n}}{n-1} \tag{9}$$

$\sum_{i=1}^{n} y_i^2$ = add up the square of each sample observation;

$\left(\sum_{i=1}^{n} y_i\right)^2$ = add up each sample observation, then square the result.

A5.3.1 *Each person in a sample of 40 tells you how long (in hours) the odour lasted in their most recent experience of an offensive odour (see section A5.2.1). The sum of each sample observation is 72, and the sum of each sample observation squared is 320. The variance is therefore [320-(722/40)]/39 = 4.88. The mean is 72/40 = 1.8 hours, the variance of the mean (equation 8) is [(2000-40)/2000]×(4.88/40) = 0.12. From section A4.3, an 80% confidence interval for this mean is 1.8 ± (1.3×0.35) - that is 1.3 to 2.3 hours.*

Estimate a proportion (see section A4.3) and its variance as (Cochran, 1977, p51):

$$p = \frac{a}{n} \tag{10}$$

p = sample proportion (see section 3.2.6.3.3);
a = number in sample with value one rather than zero;
n = sample size.

The variance of this proportion is (*ibid.*, p52):

$$v(p) = \frac{(N-n)}{N} \cdot \frac{p(1-p)}{(n-1)} \qquad (11)$$

$v(p)$ = variance of sample proportion;
N = population size.

If you then calculate a confidence interval (section A4.3) and find that zero or one is included in this interval, you will need to use a more accurate method (*ibid.*, pp57-60).

A5.3.2 *You ask a sample of 40 people (from the 200 in your sampling frame - see section A5.2.2) if they have experienced any offensive odours in the last year. Of the 40, 5 answer 'yes'. Your estimate of the proportion is 5/40 = 0.125 and the variance of this proportion is [(200-40)/200]×(0.125×0.875/39) = 0.0022. From section A4.3, a 95% confidence interval for the proportion experiencing offensive odours is 0.125 ± (2×0.047) = [0.03, 0.22] - that is, 3 to 22%.*

A5.4 Non response

If you have the resources, you should make at least two attempts to contact 'the person most often at home'. One way to save resources in this process is follow up just a simple random sample of those who weren't contacted in the first attempt.

You take a sample of n people: you have contacted n_1 of these people but you haven't been able to reach n_2 ($n_1 + n_2 = n$). Take a simple random sample (or systematic sample - see section A5.2) of size r from the n_2 people you haven't contacted. Make a major effort to get responses from these r people. Instead of using the sample average, estimate the population average as:

$$\bar{y}' = \frac{(n_1\bar{y}_1 + n_2\bar{y}_r)}{n} \qquad (12)$$

$\bar{y}'$ = adjusted sample average;
$\bar{y}_1$ = average for those contacted initially;
n_1 = number contacted initially;
n_2 = $n - n_1$;
$\bar{y}_r$ = average for the r respondents contacted subsequently.

The difference between this estimate and the normal sample average should be reported. This difference is a measure of the bias that results from being unable to contact some people.

Note that since a proportion is just a special sort of average (section A4.3), you can replace averages in the above equation with the appropriate proportions.

A5.4.1 *You carry out the survey described in section A5.2.2. The response rate in your survey is lower than the 70% you hoped for. Of the 60 ratepayers in your sample, you manage to contact only 35 on your first attempt. Of these 35, 4 say they have experienced offensive odours in the last year. From the 25 non-respondents you choose 10 at random, and pursue these people until at last you make contact. Of these 10, 3 answer 'yes' to your question. Your proportion adjusted for non-response is [35×(4/35)+ 25×(3/10)]/60 = 0.19 (19%). Note that if you had not contacted some of the non-respondents, you would have estimated the proportion answering 'yes' as 4/35 = 0.11 (11%). Calculate the variance of the proportion as if you hadn't contacted the non-respondents. Using equation 11, the variance is therefore [(200-35)/200] ×(0.11×0.89/34) = 0.0024. From section A4, a 95% confidence interval for the proportion experiencing offensive odours is then 0.19 ± (2×0.049) = [0.09, 0.29] - that is, 9 to 29%. This confidence interval will be a bit wider than it should be - it's possible to calculate a variance that takes account of the contacted non-respondents but it's a little more complicated and with an indicative survey, there's really no point in being that accurate when calculating the variance* (Cochran, 1977, pp370-371).

A6 Council: Definitive Survey

A6.1 Sampling frame

A list of ratepayers (households and businesses) in the area of interest will be the best sampling frame. You could still take a simple random sample (or systematic sample) from this list, and then simply follow the guidelines in section A5 above. You would probably take a larger sample for a definitive survey, to increase the accuracy of estimates for legal purposes. [Indicative surveys typically use small samples and as a result, 95% confidence intervals are likely to be rather uninformative - see section A4.3.] Remember that if a definitive survey of individuals is necessary and an over-estimate of the severity of an odour problem will help your cause, then you should consult a professional. You may need to randomly sample individuals within households and businesses (see section A3).

In a definitive survey you may wish to interview people face-to-face rather than phoning, so you can ask more complex questions (perhaps on the FIDOL factors) (Ministry for the Environment, 1995, p14). In this section, we will assume you have decided to visit households and businesses, interviewing 'the person most often at home' from each selected household and a suitable representative from each selected business (see section A3). If a selected address turns out to be a flat, then you will end up interviewing a tenant rather than the owner of the property. The tenant 'most often at home' will usually be the most appropriate person to answer your questions.

Often you will want to make estimates for different parts of a population - perhaps for both those inside and outside an affected area. The easiest way to do this efficiently is by using stratified random sampling (section A6.2). You divide the population up into parts (strata), so that later you can make estimates for each stratum. Ideally each stratum is as similar within and as different between strata as possible (that is, similar and different in terms of the community's perception of odour).

In practice, the result might be something like this: you form say three strata as concentric rings around a point source (assuming local topography does not affect odour or its influence is unknown). The closest stratum is the area in which most of those who have complained live. The second stratum out has the odd complainant. And the third stratum is an area outside your population of interest, so you can show you have covered everyone likely to find odour a problem (see section A2). You might divide up some or all of these circles into sectors, making more strata, based on your knowledge of the prevailing winds. Do complaints seem more prevalent 'down-wind' of a suspected odour source? Remember, the trick is to form another stratum only if a those living in a particular area are likely to have a very different perception of the problem.

A6.2 Selecting the sample

It does not pay to have too many strata, because you now have to list all the ratepayers in each stratum. You then take a simple random sample (or systematic sample) of ratepayers in each stratum, using the methods given in section A4.2. Use a different random number to start each systematic sample.

The big advantage of stratified sampling is that it can be far more efficient than simple random sampling (that is, a smaller sample size can give estimates of the same precision). To calculate the overall sample size, first identify the most important question or questions in your survey. For each question, you need to consider the width of the confidence interval you want to end up with. For each question, you need to guess the population variance in each stratum, using the methods in section A5.2. Once you have this information, you can calculate the overall sample size. Having done this for those questions you consider important, you take the largest overall sample size as the required sample size and allocate this sample among the strata.

Calculate the overall sample size for a given question as (Cochran, 1977, p98):

(13)

$$n = \frac{\left(\sum_{h=1}^{L} N_h \sigma_h\right)^2}{(N^2 \partial^2 / Z^2) + \sum_{h=1}^{L} N_h \sigma_h^2}$$

n = overall sample size;
N = overall population size;
N_h = population size in stratum h (h = 1, ..., L);
Z = 2.0 for a 95% confidence interval;
∂ = half the width of the desired confidence interval;
σ_h^2 = population variance in stratum h;
σ_h = square root of σ_h^2.

Now allocate this sample size among the strata (Cochran, 1977, p98):

(14)

$$n_h = n.\frac{N_h \sigma_h}{\sum_{h=1}^{L} N_h \sigma_h}$$

n_h = sample size alloated to stratum h.

Note that sometimes n_h turns out to be larger than N_h. If this happens, you'll need to make a slight adjustment to this method (*ibid.*, p104).

This method of allocation means that if you are taking systematic samples, each stratum will have a different value of k (the integer part of N_h/n_h). There are other methods of allocating the overall sample size which keep k constant, but the method shown here (known as Neyman allocation) ensures that strata where responses are more varied are sampled more intensively. This improves sampling efficiency (Cochran, 1977, pp370-371).

Simple random sampling within each stratum ensures that you can make estimates (of averages or proportions) for any single stratum, as well as overall estimates for all those surveyed. However, if you want to find a confidence interval for a single stratum, as a rule of thumb that stratum needs a minimum sample size of 30 (section A4.3).

A6.2.1 *You are going to ask respondents if they have experienced any offensive odours in the last year. You want a 95% confidence interval (with width plus or minus 5%) for the proportion that answer 'yes' to this question. You form three strata - concentric rings around the factory you believe is releasing odours. The first column in the table below gives your conservative guess of the proportion likely to answer 'yes' to your question in each stratum. You can then estimate the variance in each stratum as $P_h.(1-P_h)$ - see equation 6. The third column shows the population in each stratum - the total population is 600. Using equation 13, the total sample size is (231.72)/(225+94) = 168. The fourth column in the table shows how equation 14 allocates the total sample size among the three strata. Note that the sampling fraction (n_h/N_h) is highest in the stratum where you think more people are finding odour offensive. Note too that the sample size in each stratum is over 30, so you will be able to calculate confidence intervals for each of your strata. You will want to increase the sample size in each stratum to allow for non-response (see section A5.2.2).*

Stratum	Ph	σh2	Nh	nh
Inner ring	0.5	0.25	100	36
Middle ring	0.3	0.21	200	67
Outer ring	0.1	0.09	300	65
Total			600	168

A6.3 Estimation

Once the survey has been completed, estimate an average as (Cochran, 1977, p91):

$$\hat{\bar{Y}} = \bar{y}_{st} = \frac{\sum_{h=1}^{L} N_h \bar{y}_h}{N} \qquad (15)$$

$\hat{\bar{Y}}$ = estimate of population average;
$\bar{y}_{st}$ = average of a stratified random sample;
$\bar{y}_h$ = sample average in stratum h.

The variance of this average is (*ibid.*, p95):

$$v(\bar{y}_{st}) = \frac{1}{N^2} \sum_{h=1}^{L} \frac{N_2}{n_2} . (N_h - n_h) . s_h^2 \qquad (16)$$

$v(\bar{y}_{st})$ = variance of $\bar{y}_{st}$;
s_h^2 = sample variance in stratum h.

Use the statistical function of a scientific calculator to find the sample variance in each stratum (s_h^2), or calculate this by hand using equation 9 in section A5.3.

Estimate a proportion as (*ibid.*, p107):

$$p_{st} = \frac{\sum_{h=1}^{L} N_h p_h}{N} \qquad (17)$$

p_{st} = proportion for a stratified random sample;
p_h = sample proportion in stratum h.

The variance of this proportion is (Cochran, 1977, p108):

$$v(p_{st}) = \frac{1}{N^2} \sum_{h=1}^{L} \frac{N_h^2 (N_h - n_h)}{(N_h - 1)} . \frac{p_h (1 - p_h)}{(n_h - 1)} \qquad (18)$$

$v(p_{st})$ = variance of p_{st}.

When using equations 7, 9 or 10 - to calculate the sample average, variance or proportion in stratum h - just use sample observations from stratum h. That is:

(19)

$$\bar{y}_h = \frac{\sum_{i=1}^{n_h} y_{hi}}{n_h}, \quad p_h = \frac{a_h}{n_h}$$

A6.3.1 *You carry out the survey described in section A6.2.1. In the inner ring, 12 out of 30 respondents answer 'yes', they have experienced offensive odours in the last year. In the middle ring 15 out of 60 respondents say 'yes', and in the outer ring 5 out of 60 respondents say 'yes'. Your estimate of the overall proportion is (40+50+25)/600 = 0.19. The variance of this proportion is (58.5+89.4+93.5)/6002 = 6.706 x 10-4. So a 95% confidence interval for the proportion is 0.19 ± (2.0x0.026) = [0.14, 0.24]. You could also calculate a 95% confidence interval (section A5.3) for say the inner ring as 0.40 ± (2.0x0.076) = [0.25, 0.55].*

A6.4 Non-response

To allow for those you cannot contact, use the procedure outlined in section A5.4 to adjust your estimate of the average. Take a random sample of those who were not available in your first attempts to get an interview. You could do this in just one stratum or take a random sample in each of several strata. Make a real effort to interview these non-respondents. Adjust the estimate of the stratum average using the procedure in section A5.4. Use adjusted stratum averages instead of the normal stratum averages when combining estimates from each stratum to give the average of a stratified random sample (in section A6.3). This works for proportions too.

You can use a similar adjustment to account for those who refuse to be interviewed. This method is called the 'basic question' approach (Bethlehem and Kersten, 1985, pp287-300). You should identify one question (maybe two questions at most) that best summarises what your survey is about. Because this question needs to be asked to both respondents and non-respondents in as similar circumstances as possible, ideally this 'basic question' is one of the first you ask in your questionnaire. This approach will not be possible if the most important question is 'buried' in the questionnaire to de-sensitise the issue.

When someone refuses to participate, you ask them to answer just this one 'basic question'. Later adjust each stratum average (or proportion) and use adjusted stratum averages instead of the normal stratum averages in your calculation of the average for a stratified random sample. The adjustment to be made to each stratum average is:

A6.4.1 *For the survey described in section A6.2.1, your sample size calculations suggest you need a sample of 36 from the inner ring. You increase this to a sample of 50 to allow for a 70% response. But when you carry out the survey, you manage to complete 20 full interviews in the inner ring. Of the remaining 30, 15 were not at home the <u>three</u> times you called, 5 refused to talk to you and 10 refused an interview but gave answers to just the 'basic question'. This question was whether they had experienced any offensive odours over the last year. In the full*

interviews, 15 out of 20 said 'yes', but only 2 of the 10 answering just this 'basic question' said 'yes'. Your adjusted estimate of the proportion answering 'yes' in the inner ring is then [20x(15/20)+15x(2/10)]/(20+15) = 0.51. If you had just used information from full interviews, you would have estimated this proportion as 15/20 = 0.75. You now need to repeat this process for the other two strata, and then you can use these adjusted proportions in equation 17. You can use the data from both sources when calculating the variance (equation 18) - in the inner ring, you have data for your 'basic question' from 20+10 = 30 respondents in total.

For both overall and single stratum estimates, compare the adjusted average for this 'basic question' with an average calculated the usual way. The comparison will indicate whether non-response is likely to cause appreciable bias in estimates for other questions. If appreciable bias seems likely, you can get a statistician to adjust estimates for other questions. [Estimates for other questions can be adjusted by regression, using the information you have just collected about your 'basic question' (Cochran, 1977, p107).]

A6.4.2 *For the survey described in section A6.2.1, you require estimates for each ring (as well as overall estimates). Section A6.4.1 shows that in the inner ring, there's a large difference between estimates for the 'basic question' with and without the extra information (0.51 versus 0.75). This difference suggests appreciable bias is possible in estimates for other questions. You should get a statistician to adjust the estimates for these other questions. Otherwise you could be seriously over-stating the problem.*

A7 Odour producer: Indicative Survey

A7.1 Sampling frame

As an odour producer, you will not have a list of ratepayers from which you can draw a sample. A telephone survey will be quicker and cheaper than household interviewing. Remember to keep your questionnaire short and simple (section A5.1). If you are lucky, your population of interest will coincide with a local calling area. You can simply take a systematic sample from a phone book. More commonly, the population of interest will be only a small part of a local calling area, or spread over several local calling areas. In this case talk to Telecom Directories, Directory Information Services. They can select all the phone numbers within a certain geographic area. They may not be able to exactly match your area of interest - you should ask for the smallest area that completely includes your area of interest. They will sell you a list of phone numbers, without names and addresses (because of the Privacy Act 1993), and at the time of writing their prices seemed reasonable.[5] The rest of section A7 covers this situation.

One other alternative is to contract a council to run the survey for you, using a questionnaire that is acceptable to both you and the council. [The council is unlikely to be able to give you a sample of their ratepayers, because of the Privacy Act 1993.]

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5 On 1/11/96 the cost (GST exclusive) of selecting phone numbers was 3.5 cents per number with a set up cost of $150. Alternatively, Directory Information Services would take a random sample for you, for 18.5 cents per number and with no set up cost. With both these alternatives you had to buy a minimum of 3000 numbers. So if you need only a small sample for an indicative survey, these prices aren't really relevant - phone 0800-501-515 for price and product options. Some time in the future, you may be able to specify your area of interest using Statistic New Zealand's meshblock classification system (see section A8.1).

A7.2 Selecting the sample

Your population of interest is contained within a local calling area in a phone book, or within a list provided by Telecom's Directory Information Services. The problem is some of the numbers in your sampling frame are for people living outside the area you are interested in. You need to take a sample of telephone numbers, and just telephone those in your population of interest. But even if you have an address as well as a phone number, you may not know if a particular household is in your population of interest. In this case, when you phone you have to find this out first, before you ask the rest of your questions. You only want to record answers for those who are in your population of interest. This situation is called sampling a subpopulation or domain (Cochran, 1977, p34).

To calculate the required sample size, identify the most important question or questions in your survey. For each question, consider the width of the confidence interval you want to end up with. Calculate an approximate sample size for each question as:

$$n_0 = \frac{Z^2\sigma^2}{\partial^2} \qquad (20)$$

n_0 = first approximation to required sample size;
Z = 2.0 for a 95% confidence interval;
= 1.3 for an 80% confidence interval;
∂ = half the width of the desired confidence interval;
σ^2 = population variance (as yet unknown).

Of course you don't know the population variance before surveying, and the trick is to make an intelligent guess. Some ideas on how to do this are in section A5.2.

Now you need to adjust this approximate sample size given the number in your population of interest (N_j). You probably won't know what this number is: work out the number of phone numbers in your sampling frame (N), and roughly estimate the proportion of these that belong to households in your population of interest (p_j). Multiply these two numbers together as an estimate of N_j. You will be conservative if you make N_j slightly larger than you think it probably is:

$$n_j = \frac{n_0 N_j}{n_0 + N_j} \qquad (21)$$

n_j = required sample size;
N_j = size of population of interest,
= $N.p_j$.

Remember, n_j should be at least 30 so that later you can calculate reliable confidence intervals (section A4.3).

You now know how many households you want to sample from the population of interest. But to find these households, you need to take a sample from the sampling frame and then reject those households that turn out not to be in your population of interest. So the sample you initially select (n) needs to be larger than the sample you want to end up with (nj):

$$n = \frac{n_j}{p_j}. \qquad (22)$$

A7.2.1 *You think around 10% of the population will find a particular odour offensive. You want a 95% confidence interval with width plus or minus 10%. To be slightly conservative (section A5.2.2), you assume that the population proportion (P) is 0.15. Your initial sample size is 2.02x0.15x0.85/0.12 = 51. There are 300 phone numbers in your sampling frame, and you expect 80% of these numbers to belong to those in your area of interest. So the size of the population of interest (Nj) is 300x0.80 = 240. The required sample size is then adjusted to 51x240/(51+240) = 42. But to find these 42 people, you will need to select 42/0.8 = 53 phone numbers from the sampling frame - say 75 phone numbers to allow for a 70% response.*

You need to follow through this process for each important question and take the largest value of n as the sample size required for your survey.

Now take a simple random or systematic sample of size n from the N phone numbers in your sampling frame (section A4.2). When you phone each number in the sample, first check that the household you've called is in your population of interest. You'll never get exactly the sample size you planned (n_j), but you should get close enough. But if your population of interest makes up only a small percentage of the sampling frame, you'll need to phone a lot of numbers to get the (roughly) n_j you need.

A7.3 Estimation

You can treat this sample as a simple random sample. Use the equations in section A5.3 to calculate averages, proportions and their variances. Provided you just collect responses from those in your population of interest, these equations work if you replace n with nj, and N with Nj (Bethlehem and Kersten, 1985, pp287-300). That is, use the sample size and population size of your population of interest, not the sampling frame sample size and population size. Now that you have selected the sample, you are in a position to make a better estimate of N_j:

$$N_j = \frac{n_j}{n}.N. \qquad (23)$$

A7.3.1 *Of the 75 phone numbers in section A7.2.1, you make contact with 60 households, and 45 of these turn out to be in your population of interest. In 10 out of the 45 households, 'the person most often at home' had noticed an offensive odour during the last year. Your estimate of Nj is therefore (45/60)x300 = 225 - your estimate before taking the sample was 240. Your estimate of the proportion is 10/45 = 0.22 (equation 10) with variance [(225-45)/225]x0.22x0.78/44 = 0.0031*

(equation 11). An 80% confidence interval (equation 2) is 0.22 ± (1.3x0.06) = [0.15, 0.29].

A7.4 Non-response

You may wish to sample some of those you are initially unable to contact. By finding some of these people, you can adjust estimates to reduce the bias that results from non-response. The method is a variation on equation 12 and it's not that easy. At this point you either consult your friendly statistician, or try to make some sense out of the following example.

A7.4.1 *Of the 75 phone numbers in section A7.2.1, you manage to make contact with only 40 households, of which 30 turn out to be in your population of interest. Of these 30, 6 have noticed an offensive odour during the last year. From the remaining 35 phone numbers, you take a simple random sample (or systematic sample) of 15 and pursue these at length. Of these 15, 10 households turn out to be in your population of interest, and of these 10, 3 have noticed an offensive odour. Your estimate of the proportion (equation 12) is [30x(6/30) + n2 x (3/10)]/[30+n2]. The trouble is, you don't know n2 - the number in your population of interest among those you haven't contacted. Your best estimate of n2 is 35x(10/15). This makes your estimate of the proportion (6+7)/53.3 = 0.24. If you hadn't sampled non-respondents, you would have estimated this proportion as 6/30 = 0.20. Calculate the variance of the proportion as if you hadn't sampled non-respondents. The resulting confidence interval will be a bit wider than it needs to be - it's possible to calculate a variance that takes account of the non-respondents you finally contacted but things are complicated enough already (Cochran, 1977, p51).*

A8 Odour Producer: Definitive Survey

A8.1 Sampling frame

You could use the indicative sampling frame (section A7.1) for a definitive survey. You would probably take a larger sample for a definitive survey, to increase the precision of estimates for legal purposes. [Indicative surveys typically use small samples and as a result, 95% confidence intervals are likely to be rather uninformative - see section A4.3.]

In a definitive survey you may wish to interview people face-to-face rather than phoning, so you can ask more complex questions (perhaps on the FIDOL factors) (Cochran, 1977, p52). In this section, we will assume you have decided to visit households and businesses, interviewing 'the person most often at home' from each selected household and a suitable representative from each selected business (see section A3).

There are a number of ways you can construct a sampling frame with addresses; no one method will suit all circumstances. The size of the area you want to survey will largely determine which of the following methods is most suitable. In order from small scale to large, possible sampling frames are: (1) a list of houses and businesses from aerial photographs; (2) a list of houses and businesses for each streets in a town or city suburb; (3) the phone book for a local calling area; (4) the 'meshblock' classification system used by Statistics New Zealand.

The first method is very small scale. Using aerial photos, simply number the houses in the area of interest. Take a simple random sample of these numbers using a computer.

The second method requires a list of all the addresses of households and businesses for each street in your area of interest. It will be easiest to assemble this sampling frame in a computer spreadsheet. You can get all the streets (for your population of interest) off a map, and then visit each street to find the last number in the street. This will tell you roughly how many houses there are in the street. Or if this is too much work, visit a Registrar of Electors (New Zealand Post) and look at the 'Habitation Index' for the electorate. The 'Habitation Index' has streets in alphabetical order, and the names and addresses of registered voters who live in each street.6 Find each street of interest in the 'Habitation Index', and record the last address in the street. Obviously, the 'Habitation Index' will not be very useful for a new subdivision. Once you know roughly the last address in the street, you know roughly how many households are in the street. With a spreadsheet, you can then generate a number for every household in every street and this is your sampling frame.

This trick of using the last address to tell you how many households are in a street is not exact - but often you'll be close enough. In a mathematical sense, the number of the last address in the street will under-estimate the number of households in the street. If the 'Habitation Index' does not contain a high percentage of all the addresses in the street, use the following unbiased estimate (Rayner, 1994):

$$\hat{N}_s = \left(\frac{(m+1)Y_{max}}{m}\right) - 1 \qquad (24)$$

$\hat{N}_s$ = an estimate of the number of houses in a particular street;
Y_{max} = the largest number among the m numbers listed in the Habitation Index for that street.

In a practical sense, even this alternative (equation 24) is likely to under-estimate the number of households in the street - because multiple households at the same street number will be more frequent than parks and empty sections. So your sampling frame will under-represent those living in flats and retirement villages and if these households represent a significant part of your population, you will just have to visit those streets where there are a lot of multiple households at the same street number and record all the letter box numbers in these streets. You can get a pretty good idea of whether a street has a high proportion of flats or a retirement village from the names and addresses in the 'Habitation Index'.[7]

A sampling frame of this sort will contain some street addresses that simply do not exist, and will miss out some addresses that do exist. The best you can do is to ensure that these additions and subtractions are as 'random' as possible. That's why you should visit and

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6 The 'Habitation Index' itself is not suitable as a sampling frame - too many eligible voters do not register, and so many households are missing. But from the 'Habitation Index' you can get an idea of how many households are in each street, and using this information you can put together your own sampling frame.

7 You could also use Supermap (section A8.4) to find areas with a high proportion of flats or retirement villages. 'Dwelling type' data include percentages for 'flats or houses joined together' and for 'homes for the elderly'.

amend your sampling frame with actual letter box numbers where multiple households are prevalent or in newly subdivided areas. Remember to document your procedures so that later you can explain what you did and why. You should also 'post-stratify' estimates (see section A8.4). If your sampling frame under-represents certain groups, estimates may be biased - with sensible 'post-stratification', adjusted estimates will be less biased.

The third method uses the phone book. Since the phone book gives addresses, you could use this for a sampling frame. But it's more likely your population of interest does not lie within a single local calling area; or your population of interest is only a small part of a local calling area; or you want to make estimates for different parts of your population of interest. In each case, the phone book is not going to be a satisfactory sampling frame. [Telecom's Directory Information Services can only supply you with phone numbers, not addresses.]

The fourth method is surveying on a large scale. Statistics New Zealand uses a 'meshblock' classification system to divide the country up into areas roughly the size of a city block (rural meshblocks tend to be larger). In theory, you could take a sample of meshblocks from those containing your population of interest, then list all the households in each of the sampled meshblocks, and sample some of these households and businesses. This is called cluster sampling. Several stages of sampling are involved: first a sample of meshblocks, then a sample of houses and businesses within each sampled meshblock. While this is the best way to survey a large or high density area (such a city), you are going to need a statistician. Calculating the required sample size, calculating averages, proportions and their variances are all more difficult with a cluster sample.

One other alternative is to contract a council to run the survey for you, using a questionnaire that is acceptable to both you and the council. [The council is unlikely to be able to give you a sample of their ratepayers, because of the Privacy Act 1993].

A8.2 Selecting the sample

With numbered houses on an aerial photo, use a computer to draw a simple random sample. Do not use a systematic sample in this situation because you are unlikely to number the houses in a random order (see section A4.2). On the other hand, take a systematic sample if you are using the phone book as the sampling frame. Use section A5.2 to calculate the sample size for a simple random or systematic sample.

If you construct a sampling frame of street names and house numbers in a spreadsheet, you could take a simple random sample, or use a systematic sample provided the streets are in alphabetical order. Or you could arrange the streets into strata, and take a simple random sample (or systematic sample) from each stratum. Each stratum should be as similar within and as different between as possible (that is, similar and different in terms of the community's perception of odour). Read section A6.1 on how to divide a population up into strata; read section A6.2 on how to calculate the sample size for a stratified random sample.

A8.3 Estimation

Use section A5.3 to calculate estimates from a simple random or systematic sample. Use section A6.3 to calculate estimates from a stratified random sample.

A8.4 Non-response

To account for those you cannot contact, use the method described in section A5.4 (for simple random sampling) and in section A6.4 (for stratified random sampling). A random sample of those not available in first attempts at an interview is used to adjust the estimate of an average or proportion.

You can use a similar adjustment to account for those who refuse to be interviewed. This 'basic question' approach is described in section A6.4. You should identify one question (maybe two questions at most) that best summarises what your survey is about. Because this question must be asked of both respondents and non-respondents in as similar circumstances as possible, this 'basic question' has to be one of the first you ask in your questionnaire. When someone refuses to participate, ask if they will just answer this one question. Answers from those who complete a full interview and from those who answer just the 'basic question' are then combined to give an adjusted estimate of an average or proportion.

The next method of adjustment can reduce not only the bias due to non-response (section A4.4), but also the bias in estimates due to inadequacies in a sampling frame. So this method of adjustment will be particularly useful if you've had to construct the sampling frame yourself, using a street map and the 'Habitation Index' (see section A8.1).

This third method is called 'post-stratification'. But you need to think about its use before you survey, because you have to find out which 'post-strata' each respondent belongs to by asking the appropriate questions in your survey. 'Post-strata' typically involve groups based on say age, sex or ethnicity. Like the usual sort of geographically based strata (section A6.1), 'post-strata' should be as similar within the group and as different between groups as possible - similar and different with respect to perceptions of odour. While you could form 'post-strata' within geographical strata, this would involve a large overall sample size. Each 'post-stratum' needs a sample size of at least 20 (Sarndal *et al.*, 1993, p267), so you are most likely to use 'post-stratification' in conjunction with simple random sampling. There is a more efficient way to 'post-stratify' across (rather than within) geographical strata, but the calculations are not for the faint-hearted (*ibid.*, pp268-269). We will just consider 'post-stratification' as it applies to simple random sampling.

You need to know the frequency with which each group occurs in your population of interest. The easiest way to find this out is using Supermap - a Statistics New Zealand database on CD ROM. You will find Supermap at major public libraries, polytechnics and universities. Using Supermap, you can identify the meshblocks (see section A8.1) that make up your population of interest. Supermap will give the number of people in the meshblock at the last Census, by age, sex, ethnicity and many other variables.

So to use this method, perceptions of odour should vary between groups and you have to be able to get data from Supermap for each of these groups. Groups based on age or on work status (full time, part time, or not in the labour force) are likely to fit these two criteria. [Even if perceptions don't vary between groups, 'post-stratification' won't increase the bias in estimates.] If those in flats and retirement villages make up a significant part of your population and you think they are likely to be under-represented in your sampling frame (and this may bias estimates), then form groups based on age. If you are more concerned about bias in estimates because of low response rates, then form groups based on work status. You might form groups based on other variables - it depends on what sort of people you think are under-represented in your sample (either because of problems with your sampling frame or because of non-response). Since you have to ask questions in your survey to establish group

membership, you could look at the way these questions were asked in the last Census. You may also need to check the definitions used in the last Census - for concepts such as 'part time' or 'not in the labour force' (Department of Statistics, 1991).

To adjust estimates, replace the usual sample average ($\bar{y}$ 1 in equation 7) with (Cochran, 1977, p134):

$$\bar{y}_w = \sum_{g=1}^{G} \frac{N_g}{N} \cdot \bar{y}_g \qquad (25)$$

$\bar{y}_w$ = post – stratified estimate of the sample mean;
N_g = number of people in group g;
N = add up number of people in all G groups;
$\bar{y}_g$ = sample average for those in group g.

Since a proportion is just a special sort of average, you can replace the averages in the above equation with the appropriate proportions.

The 'post-stratified' estimate weights each group average by the frequency with which that group occurs (N_g/N). That's why it doesn't matter too much if meshblock boundaries don't coincide exactly with the boundaries of your population of interest. If there's a slight mismatch, it probably won't change the group frequencies much. 'Post-stratification' reduces both the bias in estimates, and the variance. So you can use the usual variance calculation (equation 8 or 11) because the result will be conservative. You could get a statistician to calculate a more accurate variance or to 'post-stratify' using several variables (perhaps using both age and work status) or to 'post-stratify' across geographical strata (Cochran, 1977, p107) .

A8.4.1 *You are going to ask respondents if they have experienced any offensive odours in the last year. You identify all the streets and part streets in your population of interest from a street map. You use the 'Habitation Index' and visits to construct a sampling frame, and you then take a simple random sample of 80 out of 400 households. You think your sampling may under-represent flats in this lower socio-economic area. From Supermap, you find that the area you're interested in includes most of six meshblocks. You add up the people in these six meshblocks, for each of three age groups: 0-29, 30-59, 60 and over. In your questionnaire, you ask respondents which age group they belong to and after the survey, you estimate a sample proportion for each age group (pg). The data are in the table below. The 'post-stratified' estimate for the proportion who say 'yes' is (0.50x0.33)+(0.30x0.24)+(0.20x0.18) = 0.27. The usual sample proportion is 20/80 = 0.25.*

'Post-stratum'	Ng	Ng/N	'yes'	n	p_g2
0-29	600	0.50	7	21	0.33
30-59	360	0.30	10	42	0.24
60+	240	0.20	3	17	0.18
Total	1200	1.00	20	80	

APPENDIX B:

Calculating the Chi-Squared Statistic[1]

Table of Contents:

1 Includes contributions from Debbie Singh, Department of Sociology, University of Auckland.

APPENDIX B: *CALCULATING THE CHI-SQUARED STATISTIC*

In this appendix we show how to calculate the chi-squared statistic and its p-value. The data in Table 3.11 (section 3.2.13.3) is used as an example:

Origin of Odour	Offensiveness		
	'Not at all'	'A little'	'Very'
Source of interest	4 (8.1)	15 (16.7)	15 (9.2)
Other sources	3 (3.1)	8 (6.4)	2 (3.5)
Don't know	8 (3.8)	8 (7.9)	0 (4.3)

There are three steps involved:

1. Calculate the expected counts for each cell;
2. Calculate the chi-squared statistic from observed and expected counts;
3. Use a chi-squared table in a statistical textbook to find the p-value.

B1 Expected Counts

The expected count in each cell is given by:

$$E_{ij} = \frac{R_i \times C_j}{n},$$

E_{ij} = expected count in row i column j,

R_i = total count in row i,

C_j = total count in column j,

n = total count in table.

So for the cell in the first row and first column, the expected count is (4+15+15) × (4+3+8) / 63 = 8.1 as shown. Note adding up all the observed counts gives the total count for the table as n = 63.

B2 Chi-Squared Statistic

The chi-squared statistic (symbol χ^2) is calculated as:

$$\chi^2 = \sum_{ij} \frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}},$$

O_{ij} = observed count in row i column j.

The chi-squared statistic adds up contributions from each cell. Each cell's contribution is the squared difference between observed and expected counts, divided by the expected count. For the first cell, the contribution is $(4\text{-}8.1)^2 / 8.1 = 2.08$. Contributions for all nine cells are 2.08, 0.17, 3.66, 0.00, 0.40, 0.64, 4.64, 0.00, 4.30 and these add up to 15.89.

B3 P-Value

A computer programme uses a complicated formula to calculate the p-value. This is not something that is easily done by hand. But most statistical textbooks have a chi-squared table at the back in an appendix. The table will have rows labelled 'Degrees of freedom' or 'DF'; the columns will be for different values of probability; and the cells of the table give the value of chi-squared for that combination of DF and probability.

The appropriate degree of freedom is given by DF = (I-1) × (J-1), where I is the number of rows in your table and J is the number of columns. So for this example DF = (3-1) × (3-1) = 4. Having calculated the DF, find the appropriate row in the textbook's table, look along the row to find chi-squared values higher and lower than the one you calculated, and then look up to see the probabilities associated with these higher and lower values.

For DF = 4 in Berenson, Levine and Rindskopf (1988), the row starts with chi-squared 0.2 for probability 0.995 and finishes with chi-squared 12.8 for probability 0.005. At 15.9, the calculated chi-squared statistic is larger than the last value in this row, so all we can say is that the probability of the calculated chi-squared is less than 0.005. So with a textbook we would conclude that the p-value was $p < 0.005$. A computer program would calculate a p-value of $p = 0.003$.