ODOUR NUISANCE IN IRELAND AND THE POTENTIAL USE OF OLFACTOMETRY FOR THE CONTROL OF ODOURS

BY

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Dedication

To my parents,
Paul, Michael
and Mary.

ABSTRACT

Odour nuisance in other European countries has led to the development of techniques which employ panels of human assessors for the determination of environmental odours. Odour measurement is not widely practised in Ireland, yet local authorities are frequently in receipt of odour derived public complaints.

This dissertation examines the fundamentals of odour nuisance in terms of how we perceive odours, common sources of environmental odours, the principles of odour measurement (in particular the Sutch pre-standard on olfactometry) and the extent to which odour nuisance is a problem in Ireland. The intention is to provide a reference document for use by those interested parties in the country who may be variously involved in policy making, legislative development, enforcement of environmental law or any person who has an interest in odours and the public nuisance they can give rise to.

In particular the aim was to provide previously undocumented information on the prevalence of odour nuisance in Ireland, the exercision of the available powers to control odours, and the possible value of odour measurement as part of a regulatory process.

A questionnaire was circulated to all local authorities in the country and 82% responded with information on their experiences and views on the subject of odours. The results of the survey are presented in summary and detailed form.

Declaration

This dissertation has not previously been submitted to this or any other college and, with acknowledged exception, is entirely my own work.

Nicholas F. Kenny

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CHAPTER 1:: INTRODUCTION

1.1 INTRODUCTION

In many European countries environmental legislation exists which is aimed at the control of air pollution. Regulatory processes are designed for the enforcement of this legislation. Successful regulation must of necessity have the access to reliable measuring methods for the determination of air pollutants. The acknowledgement of odour, and the public nuisance it can generate, as an element worthy of inclusion in air pollution regulation, has led to the development of guidelines and methods of measurement that uniquely address the problem of environmental odours.

The method most commonly used to measure odorous emissions is odour threshold determination, expressed in dilutions to threshold numbers. National standard for olfactometric measurement now exist in countries such as Germany, France and the Netherlands. The evolution of these standards indicate the need for assessment of odour nuisance in those countries and the acceptance of olfactometry as a legitimate means of accomplishing that assessment.

Ireland is no different than its european neighbours in respect to odour. Information received from local authorities confirmed that odour nuisance is frequently an issue in this country. However, a review of published literature, together with correspondence with the Department of the Environment and the Environmental Protection Agency revealed that the base of knowledge necessary for the control of odours in generally poor. It is reasonable to suggest that to the uninitiated the concept of regulating odour nuisance can appear problematic. Furthermore that such an opinion reflects the believe that odour is a purely subjective phenomena and that there can be no firm rules for either its assessment or regulation.

One of the aims of this dissertation is to examine odour nuisance and the basic principles of how and why the problem exists. Also to investigate the technique of dynamic olfactometry and how it can be used as a tool in controlling odours. The primary aim is to discover the extent to which odour nuisance is a problem in this country, to examine whether the powers to control odour nuisance are being employed and the possible benefits that could accrue through the greater use of olfactometry.

CHAPTER 2:: PHYSIOLOGICAL ASPECTS OF ODOUR

2.1 INTRODUCTION

The human sense of smell is rarely active on its own. During most of the physiological activities (eating, drinking, sexual activity etc.) it works together with the second chemical sense, taste[1]. Our dislike of bad smells is a deeply ingrained human defence mechanism which is reinforced by the tenets of most civilisations. The human nose, although less sensitive than the noses of some animals species, can detect certain chemical compounds at very low concentrations in the atmosphere, (eg. triethylamine at 0.2ppb)[2].

2.2 WHAT CAUSES THE SENSATION OF SMELL

The odour sensation is initiated in humans by means of between 10 and 25 million olfactory cells called olfactory epithelium, which are situated in the dome of the nasal cavity. Fig 2.1 shows the anatomy of the human nose, the arrows mark the air flow during inhalation. Magnification of the olfactory epithelium in fig 2.1a shows a number of the olfactory cells together with the mucous secreting Bowman glands. Fig 2.1b shows a single olfactory cell in strong magnification, that part of the cell which is exposed to inhaled air is equipped with many tiny hair-like protrudences called olfactory cilia.

Figure 2.1: The anatomy of the nose [3]

a. Sagittal cut through the nose. b. Single olfactory cell in strong magnification.

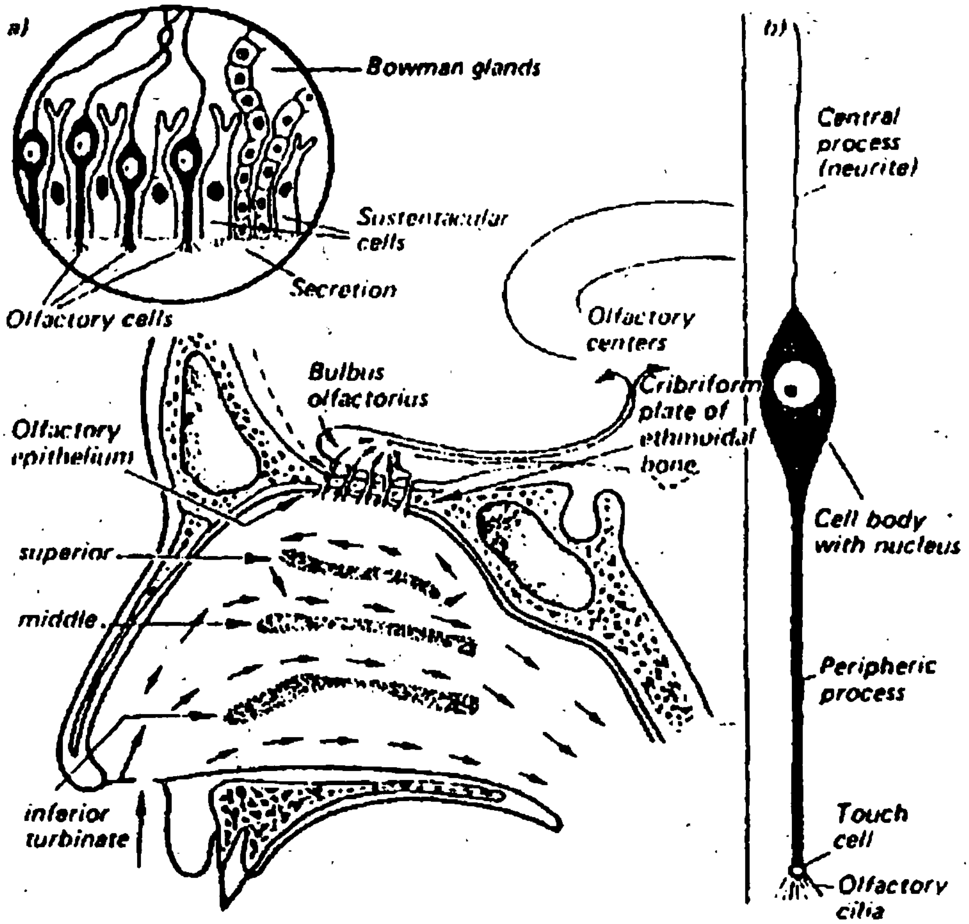


Fig. 2. The anatomy of the human nose

a) Sagittal cut through the nose

b) Single olfactory cell in strong magnification

Modified illustration according to *A.B. McNaught* and *R. Callander* [22] and *K.-H. Plattig* [23]

Inhalation of air causes turbulence in the area of the superior turbinate as the air is en-route from the nostril to the choane (ie. the opening of the nasal cavity into the throat). This turbulence may be intensified by "sniffing", which is an acceleration of inhalation in jerks. While usually only 5%

of the inspired air passes through the olfactory region of the nose, sniffing can increase this figure to as much as 20%, thereby increasing the sensitivity of the olfactory process[2].

The physiological precondition for the excitation of the olfactory cells is the contact of odorant molecules with the mucous covered olfactory cilia. The manifestation of every cell stimulation is the shift in its electrical membrane potential (depolarisation of the olfactory cell membrane). When a critical membrane potential is exceed, the stimulus is conveyed as an action potential via the control process (neurite) to the bulbous olfactorius of the brain. The Bulbous olfactorius conveys information to many subordinate brain areas which eventually result in an associative comparison of the received sensations with accumulated experience, this in turn gives rise to perception and recognition.

The air passage through the nose must not be hampered so that the odorants may reach the olfactory cells. Conditions such as Influenza or the Common Cold can cause blockage of the nasal cavity and severely restrict the functionality of the olfactory system. Furthermore, the odorants must be sufficiently volatile and sufficiently water-soluble to permeate the mucous layer of the olfactory cells. In addition, a certain fat-solubility is required to allow the odorant to penetrate the surface of the lipid-containing membrane of the olfactory cells.

2.3 HOW DO WE RESPOND TO VARIOUS LEVELS OF ODOUR

The strength, or intensity (I) of an olfactory sensation naturally depends on the strength of the stimulus. The strength of the stimulus depends on the concentration (c) of the odorant molecules in the respiration air. The dependence of the sensation intensity on the odorant concentration can be described as a logarithmic function according to *Weber-Fechner*

$$I = k_W \cdot \log(c_{od}/c^*_{od}) \quad (\text{with } c_{od} > c^*_{od})$$

herein:

c^*_{od}	Threshold concentration
k_W	Weber-Fechner coefficient

or as a power function according to *Stevens*

$$I = k_S \cdot c_{od}^{\,n}$$

herein:

k_S Stevens coefficient

n stimulus inherent exponent according to *Stevens*[4,5].

Whichever form is adopted, the relationship between sensation intensity and odorant concentration is not linear. If an assessor were to be in receipt of a particular odour at the threshold concentration then he or she would be just able to detect the odour. If the air concentration of the odorant were to be increased a thousand fold, this would not result in the sensation intensity increasing by the same factor.

With regard to odours (as well as to taste), one can normally distinguish a detection threshold from a recognition threshold. These terms are defined in ISO Standard 5492; Sensory analysis - Vocabulary[6]. The detection threshold is the minimum value of a sensory stimulus needed to give rise to a sensation, the sensation need not be identified. The recognition threshold is the minimum value of a sensory stimulus permitting identification of the sensation perceived.

Both thresholds are odorant specific and assessor specific characteristics. Moreover, there is not alone differences in olfactory sensitivity between individuals but there is also fluctuations in a single individuals sensitivity. A number of conditions have been identified which demonstrate these differences.

For perception to be possible it is necessary for a sufficient number of odour molecules to reach the olfactory epithelium[2]. The minimum perceptible number of molecules in the volume of inspired air (ie. the detection threshold concentration), depends both on the chemical nature of the molecules and the physiology and psychology of the person in receipt of the odour.

Interpersonal variation in responding to odours is a hallmark of olfactory perception. The acuity of the sense of smell increases with age until the early teens, there are then approximately 30 years before the decline of the sense which can sometimes result in anosmia (complete loss of smell) during old age. Anosmia can also occur in younger people but this is usually only selective anosmia because studies with single substances have shown that a few percent of the population are unable to detect specific odorants. There can also be temporary or permanent hyperosmia (heightened sensitivity) or hyposmia (diminished sensitivity). Furthermore there is the condition parosmia when the sense of smell is abnormal in respect to qualitative judgement, or cacosmia where the distorted perceptions are unpleasant. Other factors which have been reported to contribute to interpersonal variations include gender and handedness, with women being marginally better than men at naming and detecting single odours[7].

In the context of odour measurement, these variations do not generally present a problem because such conditions are easily noticed and a handicapped assessor can be omitted from the a testing panel on either a temporary or permanent basis. However, difficulties can arise with regard to short term fluctuations of sensitivity due to adaptation or habituation. Both terms describe the well known fact that a sensation will diminish in spite of the stimulus intensity remaining constant. Excessive stimulation of an odour panellist can thus lead to a shift in their detection threshold[1].

CHAPTER 3:: SOURCES OF ODOUR

3.1 INTRODUCTION

Air, with its characteristic composition dominated by 78% nitrogen and 21% oxygen, does not stimulate the olfactory sensors of the nose. It is what we would typically describe as odourless. This is hardly surprising considering that as a gas mixture it has been cascading past the olfactory organs of the human species since its evolution. Air is essential to our existence, we are totally accustomed to it and it would make little sense for our nervous system to send signals to the brain in recognition of its presence upon every inhalation. Air and water are analogous in that both are essential for life and neither display significant organoleptic attributes detectable by the olfactory or gustatory organs.

Despite its apparent lack of odour, it is curious to note our ability to draw distinction between rural and city air. Most people will have witnessed city dwellers expounding the virtues of "fresh air" during their visits to the country side. It is reasonable to suppose that this demonstrates the phenomenon of sensory adaptation which is the temporary modification of the sensitivity of a sense organ due to continued and/or repeated stimulation. In other words, people who live in cities only become alert to the fumes of hydrocarbons, sulphur dioxide and dust that they are normally exposed to, when their olfactory senses encounter an air mixture in which the offending substances are absent. However, it would be wrong to postulate that people living next to a piggery become oblivious to its odour by reason of adaptation.

Many odours that we perceive are due to very small amounts of volatile substances being present in the air that we inhale. Hydrogen sulphide is reported as being perceptible when present at between 0.0000001x% to 0.000013% of the air (1 - 130 ppb) [9]. As a consequence, even very small amounts can cause substantial olfactory stimulation.

3.2 SOURCES OF ODOUR

Clearly, every odour we perceive in the environment must originate from some distinct source whether they be synthetic or natural in their derivation[10]. Many nuisance odours can give warning of the proximity of an offending facility before such a facility is even visible to the eye.

The interface between an emission source and ambient air can take a number of forms. The odour can come from a point source like a factories emission stack. It can be due to a diffuse source like a field recently spread with slurry. It can even be due to mobile sources like the exhaust fumes from a diesel lorry or the load on the back of a knackers lorry[11].

By definition, odours are airborne and are manifest as volatile substances which impinge on the olfactory senses during inhalation. Various mechanisms can be at work in the release of odorants to the ambient air. Many substances will be released as constituents of industrial process gases in a stack emission. Other odorants will result from volatilisation on the surface of a lagoon in a waste water treatment plant, the extent of this process will be subject to weather conditions like temperature and wind speed. Odorants can be released from the solid substrate of decaying animal parts in the yard of an untidy rendering plant. While the source description and the release mechanisms are of little interest to those who are suffering the aggravation of living nearby, they are of great significance for those who must devise a strategy to remedy a nuisance problem. The following subsections discuss sewage plants, agriculture and industry in terms of their associated odours.

3.2.1 Sewage treatment

With the advent of stricter regulation on the discharge of domestic wastewaters, there has been an increase in the number of sewage treatment plants in Ireland. New plants continue to be developed to keep pace with urban growth. Treatment plants also become increasingly more sophisticated in order to reduce sludge volumes and comply with EU directives which restrict the use of sewage sludge in Agriculture (eg. Council Directive 82/278/EEC on the protection of the environment and particularly the soil, when sewage sludge is used in agriculture). Hence, a premium is now placed on the reduction of sludge volumes through the optimisation of dewatering techniques.

Sewage treatment plants frequently give rise to odour nuisance and much of the published literature on odours relates to problems generated at sewage plants.. Testimony to this fact was the attendance in April 1994 of more than 180 delegates at a symposium on Odour Control and Prevention in the Water Industry which was held in Newcastle, UK[12]. A French survey in which air samples were collected from the various unit processes at 12 different sewage plants, produced results which identified the sludge treatment processes (ie. thickening, dewatering and thermal treatment) as being the principle sources of odour generation[13].

Sulphur compounds were found to represent the majority of odorous molecules at the sewage treatment plants. They are mercaptans, organic sulphides and disulphides and above all hydrogen sulphide. When the effluent or sludge has reached septicity, anaerobic bacteria reduce sulphur containing organic compounds to hydrogen sulphide and other reduced sulphurous species. A UK study [14] at Strongford STP found that questionnaires returned by local people described the nuisance odours as being characteristic of rotting cabbage. This is consistent with the presence of organic sulphides. Tests showed that sludge flow and press filtrate were the major sources of malodour, furthermore, the odour levels were increased by the retention of sludge in sewers and sedimentation tanks. Boon [15], provides a thorough examination of research and development into the causes, consequences and methods of controlling septicity in sewers. The low odour thresholds of these compounds explains their propensity to cause odour nuisance. Nitrous compounds may also contribute to the sewage odours. These are mainly ammonia, amine and to a lesser extent indole and skatole[16]. Ammonia stems partly from urine, and partly from the biological degradation of proteins and amino acids. It can also arise through the hydrolysis of nitrous compounds in long term storage facilities. Amines are usually a by-product of the bacterial metabolism of amino-acids in anaerobic conditions. To a lesser extent, compounds belonging to the volatile fatty acid family, aldehydes, alcohols and ketones are sometimes produced during effluent treatment. These compounds are the by-products of carbohydrate fermentation, first transformed into acid (acidification phase) then into alcohol, aldehydes and ketones. It was found that all the above mentioned compounds were present in varying quantities in the vicinity of all treatment structures[16]. However, build-up and degassing of foul smelling compounds are intensified during sludge treatment.

Treatment units which afford a high degree of effluent to air interface, such as aerators and trickling filters, should contribute little to the odour burden. This is because the oxygenation of the effluent prohibits the establishment of anaerobic conditions in which the reduced substances can be generated. However, abnormal operation of these processes, such as overloading or insufficient oxygenation, can give rise to odours.

3.2.2 Agriculture

In this instance the term agriculture refers only to the cultivation of crop and herd in the classical sense. It does not refer to intensive farming which is mentioned under the heading of industrial sources.

The handling of animal slurries and silage production represent the major agricultural sources of odour. However, there are inherent characteristics of farming sources which mitigate their capacity to cause public nuisance. Farms are typically distant from major urban conurbations and odours once generated undergo ample dispersion before reaching residential areas. Other reasons are postulated to support this argument in relation to the land-spreading of pig slurry in Ireland [17]. The population density is low at 41 per square kilometre, animal enterprises tend to be small and farmers generally have sufficient land to avoid frequent gross application of slurry, cattle graze for most of the year and even when housed their effluent is usually handled as solid, wind speeds average 5 m/s and favour rapid dispersal of odours and finally, a high proportion of the population come from rural backgrounds and may therefore find farm odours less objectionable.

Nevertheless, odour problems can arise from the landspreading of slurry. The history of the slurry, the method of application to the land, and factors which affect the transfer rate of odorants all influence the magnitude of the emission. There are differences in the odour generating capacities of slurries. Pig slurries are considered to be responsible for the largest proportion of problems, high dry matter content and long storage periods prior to spreading exacerbate the situation. The machinery used to spread the slurry, while determined in part by the dry matter content, can greatly influence the levels of odour generated. Splash-plate, bandspreading and injection methods reduce the opportunities for odorant emission respectively. The injection method has the added advantage of reducing the loss of nitrogen through volatilisation and the likelihood of surface run-off [18] Once the slurry has been spread, factors such as temperature, and rainfall also have an effect. Landspreading normally takes place during summer months when there is a soil moisture deficit, the warmer temperatures will contribute to the volatilisation processes. The practice of applying prior or during rainfall was found to reduce odours. The influence of weather conditions on the dispersal of odours is discussed more fully in section 3.3.

The ensiling of grass, maize and other vegetable products for use as feed for ruminants is now common practice. The control of odours from silage stores can be difficult due to the large size of the storage silos and the extent of the surface area exposed during use[19]. It is essential, for the purpose of controlling odours, to control the fermentation process with the correct use of additives and silting of the crop. Sources of odour also arise when silage effluent is allowed to flow across open concrete with subsequent evaporation during dry weather. Pain [20], details other sources of agricultural odours including waste storage and feed production.

3.2.3 Industrial sources

Industrial facilities that give rise to odours are many and varied, and it is beyond the scope of this paper to discuss them all individually. Some notable categories, whose propensity to cause nuisance in Ireland is examined in chapter 6, are listed below:

- Animal by-products
- Livestock farming (intensive)
- Brewery/Distilling
- Foundries/Metal processing
- Plastics
- Fish based industries
- Food processing
- Pharmaceutical/Chemical
- Paint/Varnish/Adhesives

Industrial odours originate from process stacks, from general ventilation of work areas and from areas of plant which are not enclosed by buildings[2]. Emissions can be continuous, industrial waste water treatment plants are a common example, or the emissions may coincide with the occurrence of certain process events like the exhausting of cookers at a rendering plant. Odours can also arise from unscheduled events like spillages or leaks of process gases. They may be the result of negligence in respect of cleaning procedures and generally bad housekeeping.

3.3 FACTORS EXTERNAL TO THE SOURCE WHICH INFLUENCE THE IMPACT OF AN EMISSIONS

The single greatest factor which determines whether an odorous emission will cause a nuisance at some distant residence is the prevailing weather conditions. It is because of the considerable ability of the atmosphere to disperse and dilute that odorant concentrations at a source are reduced many thousands of times before they reach the nose of a receptor. Unfortunately the reduction will not always be sufficient to lower the odour concentrations beneath those capable of causing a nuisance. The potential for atmospheric dispersion is not constant and varies with climatic conditions. The influence of topography and buildings can have adverse as well as helpful effects on plume dispersion. Their influence must nonetheless be included with the other variables that impact on ambient odours [2].

To examine these phenomena it is helpful to consider a hypothetical source of odorous emission. For simplicity consider a stack (ie. point source), emitting waste gas the composition of which is constant with time and has an odour concentration (defined in chap. 4) of 1000 odour units per cubic meter (ou/m^3). The air flow from the stack, which is also constant, is 3 m^3/sec. Therefore, odour is being emitted at a rate of 3,000 ou/sec.

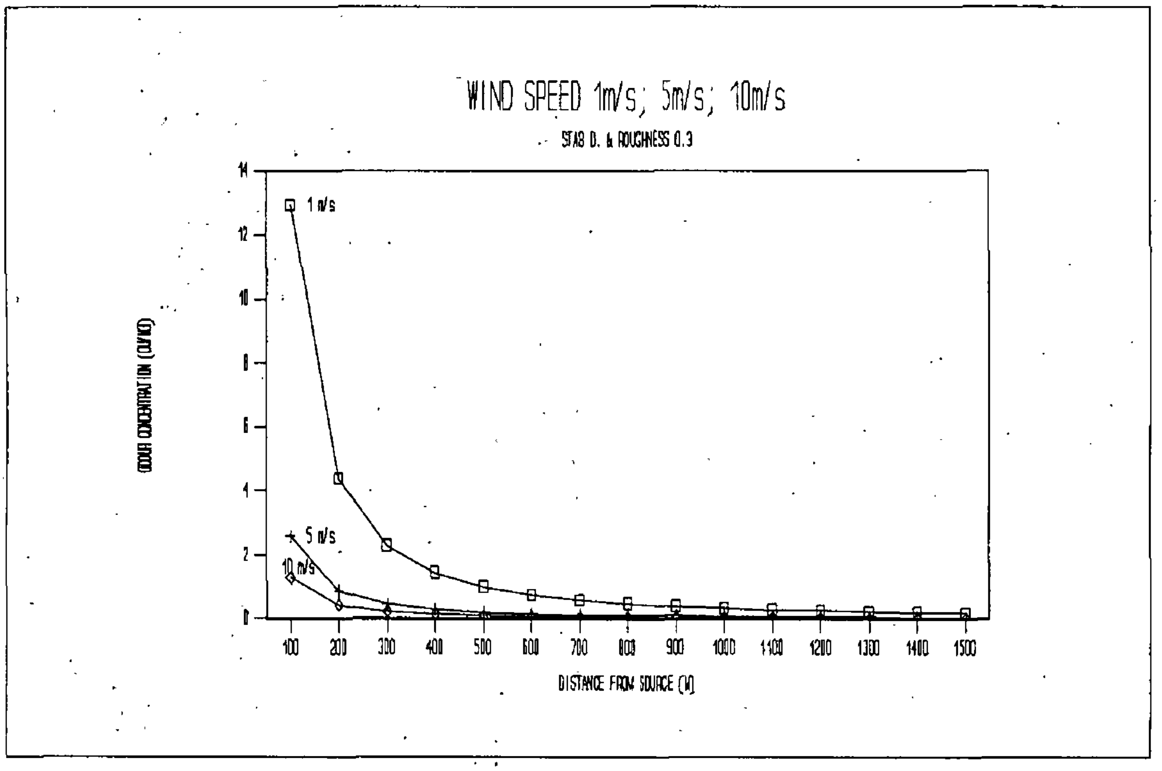
The resultant ambient concentrations can be estimated using a computer dispersion model [20]. Dispersion models are frequently applied to the estimation of ambient odours. There are arguments to support the measurement the odours at source by olfactometry and the use of weather simulating models to advise on ambient levels instead of attempting to measure directly at ambient sites [21]. The dispersal process has the effect of producing a plume of polluted air which, to a first approximation, is roughly cone-shaped and extends in the downwind direction with the apex of the cone pointing toward the emission point. The plume can be described mathematically by a Gaussian equation [2]. The models ability to simulate atmospheric mixing permit it to demonstrate the effects that climate and other variables have on the emission from our hypothetical source.

From a starting point described by the model set-up parameters in table 3.1, the figures 3.1, 3.2, and 3.3 illustrate the effects that wind speed, climatic stability category and ground roughness respectively have on the ground level odour concentrations. The model has been used to calculate the downwind centerline concentrations at distances between 100m and 1500m from the source. The ambient levels are expressed as the average 3 minute concentrations.

Table 3.1

Set-up parameter	Hypothetical scenario
Odour emission rate	3000 ou/s
Stack height	3 meters
Efflux velocity	Negligible
Ambient concentrations (ou/m^3)	3 minute average
Study area	100 to 1500 meters

Figure 3.1 The effects of variation in wind speed



If, for the purpose of demonstration, the possibility of masking due to high background odours is ignored, then it is reasonable to suppose that the emission will be detected at distances from the source where the concentration exceeds 1 ou/m^3. Figure 3.1 demonstrates the increased atmospheric dispersion and consequent reduction in ambient odour levels caused by wind variations between 1 m/s and 10 m/s. The stability category and ground roughness are fixed at

D and 0.3 respectively. At wind speed of 10 m/s the threshold level is only exceeded at distances within 100 meters of the source, while similar levels are possible at 600 meters when the wind speed drops to 1 m/s.

Figure 3.2 The effects of variation in Pasquill stability category

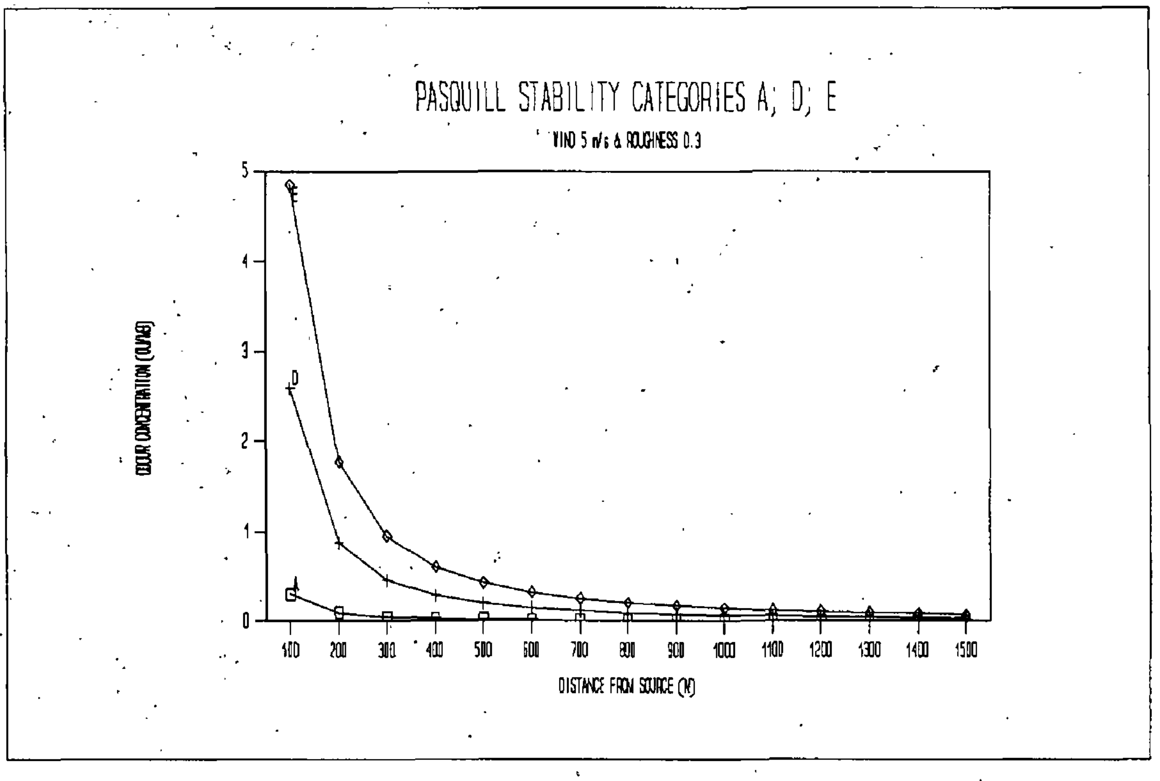


Figure 3.1 demonstrates the effects of variations in the climatic stability category. The wind speed and ground roughness are fixed at 5 m/s and 0.3 respectively. Pasquill categories are classified according incoming solar radiation, wind speed and cloud cover. The sun warmed ground heats the air above it and causes thermal lift due to differences in air densities between the air at ground level and that above it. These processes are described by Pasquill categories and the effects of changes between categories A, D and E are demonstrated. Category E describes temperature inversion. This occurs when cold air close to the ground is trapped by warmer air above. This severely restricts the possibility for thermal lift and consequently higher levels of odour can occur. While the effect is not as marked as for that of wind speed it is nonetheless significant and the coincidence of inversion and low wind can result in excessive odour levels.

Figure 3.3 The effects of variation in ground roughness

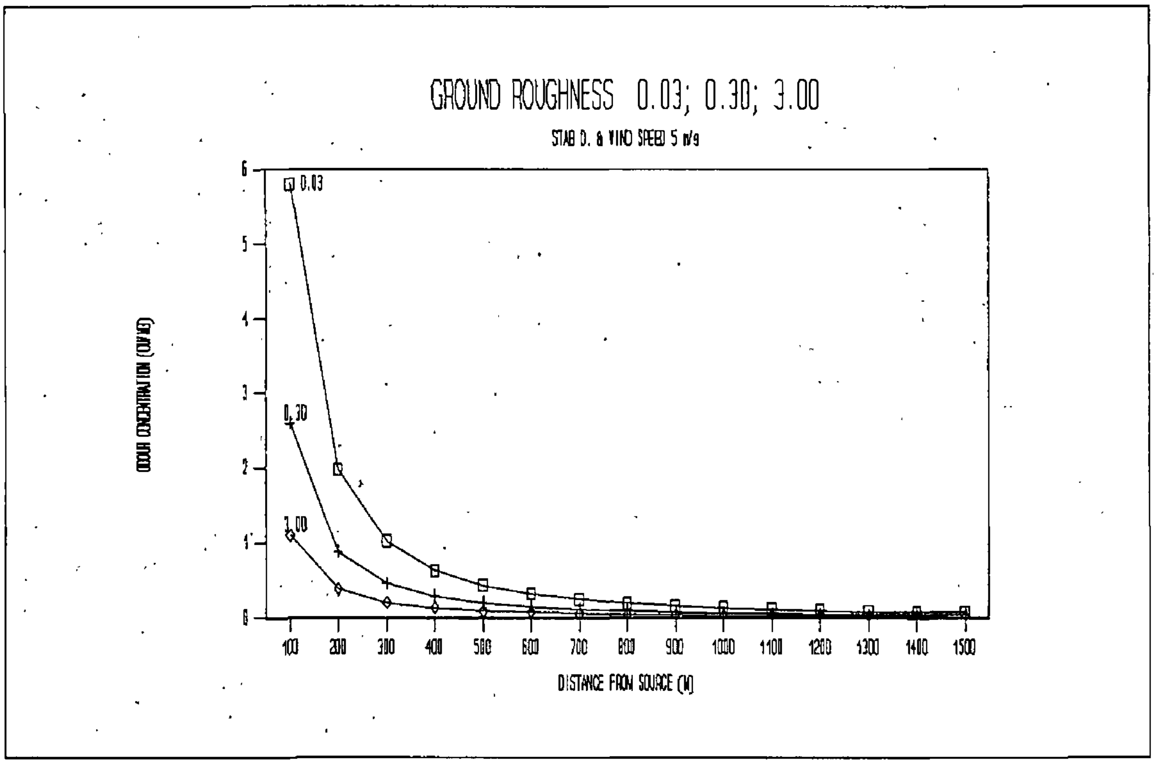


Figure 3.3 demonstrates the effects of variations in ground roughness. The wind speed and stability are fixed at 5 m/s and 0.3 respectively. Roughness elements or obstacles on the ground (eg hedges, trees, buildings and hills) engender mechanical mixing of the air as it passes over them. The intensity of this mechanical turbulence increases with increasing surface roughness and increasing wind speed, and diminishes with height above ground. The roughness score assigns a value to the size of the physical obstructions. The roughness scenarios that are simulated in figure 3.3 are 0.03, flat land; 0.30, cultivated land with bushes and small trees; 3.00, cityscape. The lower the roughness score the lower the possibility of mixing and threshold levels of odour can occur at greater distances from the source.

The atmospheric turbulence or eddies create substantial fluctuations in the concentration of any odorous species present in the plume. Some of these fluctuations have time scales as low as one second of even less and are therefore capable of providing odorous stimuli on this sort of a time scale. It is postulated [2] that concentrations of up to 10 times the 3-minute average and of sufficient duration to stimulate the nose will occur occasionally.

CHAPTER 4:: OLFACTOMETRY - THE MEASUREMENT OF ODOURS

4.1 INTRODUCTION

Olfactometry is the controlled presentation of odorants and the registration of the resulting sensations in humans[1]. The term is now synonymous with the dilution of a test gas to its threshold of detectability as determined by a panel of assessors. The use of human sensory evaluation has long been the preserve of those involved in the testing of wines, teas and perfumes but olfactometric techniques have enjoyed an increase in their application to environmental odours. Those practising the measurement of environmental odours have had to contend with the scepticism of the scientific fraternity because of their reliance on human assessors as the basis of the measuring technique[22]. This cynicism is understandable were one to examine a list of published threshold values for pure substances. The reported concentration at which a pure gas becomes detectable by smell can vary by factors of hundreds and even thousands between laboratories. However, an appreciation of the difficulties in assessing odours without the assistance of the nose has meant that, despite its inaccuracies, the science of olfactometry has persisted as a means of evaluating environmental odours. Improvements in the odour measurement in Europe has been achieved through the publication of a number of national standards, in which efforts were made to reduce interlaboratory variation.

An individual sensing an odour in ambient air is directly aware of only two sensory properties of the odour; intensity (how strong it smells) and character (what it smells like). These sensations jointly determine the extent of the annoyance produced by the odorous air pollution[23]. However, it is another measurable characteristic of the odour, its detectability, which is most commonly employed in the assessment of environmental odours[22]. The reason for this is that the assessment of an odours character is a very subjective exercise and measuring its intensity can give rise to problems because of the tendency of the nose to adapt to compounds which are present at concentrations above threshold levels.

The first olfactometer that used the principle of diluting odorous air with non-odorous air to determine the perception (detectability) threshold was built by Zwaardemaker in the last decade of the 19th century[24]. It was during the late 1970's and the 1980's that national standard methods for the measurement of odours were published in the United States, France, Germany and the Netherlands. A recent development is the establishment of a European working group, which operates under the auspices of the European Committee for Standardisation, and whose task it is to compile a European standard on odour measurement by dynamic olfactometry[24].

4.2 WHY USE OLFACTOMETRIC TECHNIQUES TO ASSESS ODOURS.

The following points explain the rationale behind the development of olfactometric techniques for the assessment of environmental odours[1].

- The introduction of air quality control regulations in some European countries gave rise to a need for objective methods to describe the air pollution generated by odorants and assess their potential to cause odour nuisance.
- Many odorants will cause an odour sensation when present in very low concentrations (eg. the reported thresholds for hydrogen sulphide are between 1 and 130 ppb). These concentrations can be below the limits of detection which are achievable by conventional physical and chemical measuring methods.
- The qualitative and quantitative determination of gaseous mixtures generally involve considerable expenditure. The complexity of the gases which emanate from odorous sources usually makes such an approach financially and practically unfeasible.
- There is an uncertain relationship between the concentrations of the individual gases in an emission and the odour sensation which the mixture is capable of generating. Synergistic and antagonistic effects mean that this relationship can not be found out empirically by reference to the odour thresholds of the individual compounds.

In conclusion, odour nuisance only arises because of the human physiological ability to detect odours, therefore it is logical that any attempt to assess nuisance should employ the same physiological capability.

4.3 TERMINOLOGY

Before proceeding any further it is worthwhile defining some of the terms which are commonly applied to the area of odour measurement.

Dilution Method. The technique used to present odorous gases to a panel of assessors.

Dynamic Olfactometry is the term which describes a sample dilution method in which dilution is achieved by mixing a flow of the odorous gas sample with a flow of non-odorous gas (usually air but sometimes nitrogen). The resulting diluted sample is then presented to panellists at a controlled flow rate. A series of different dilutions are presented to decipher the individual odour threshold for each panellist. The series usually begins with the dilution of lowest odour concentration and ends with that of highest odour concentration, but the dilutions are in certain cases presented in a random order[8].

Odour Concentration, expressed in odour units per cubic meter, (ou/m^3), is the number of dilutions required to reach the detection threshold[25]. The odour concentration is variously described as the "threshold odour number", "dilutions to threshold" or the "dilution number".

Individual Odour Threshold, is that concentration which is perceived by a person in 50% of the cases in which it is presented to them.

Group Threshold is the concentration that is perceived by 50% of a panel of assessors.

Detection and Recognition Thresholds. The odour is sensed at the dilution corresponding to the detection (or perception) threshold, the sample does not smell like odourless air but the character of the odour cannot be recognised. To recognise the odour character a higher concentration of sample is needed. Depending on the odour, the sample concentration at the recognition threshold is higher than it is at the detection threshold by a factor of between 1.5 and 10^5. Most odour control regulations imply detection thresholds.

4.4 AN EXAMPLE OF A DYNAMIC OLFACTOMETRY METHOD (The Dutch Pre-standard NVN 2820).

It has already been mentioned that a number of national standards exist for the measurement of odours. These standards are similar to each other in principle and differ only in details like the number of panellists, the method of dilution presentation, the number of different dilutions presented in a series, the requirements for selection as a panel member, etc. However, a distinction should drawn between single stimulus (yes/no) and multiple stimulus (forced choice) techniques.

The single stimulus method requires the assessor to smell at one port only and then indicate "yes" or "no" as to whether a odour was detected. In the forced choice method the assessor is required to smell at two and sometimes three ports, only one port will contain the diluted sample while the other(s) contain odour free air. As the name of the method suggests, an attempt must be made to identify the correct port even if no difference was perceived. It is not proposed to discuss each method in detail but suffice to say that there is a divergence on how best to measure odours. This divergence has been recognised by the Comité Européan de Normalisation and has been the impetus to the establishment of a European standard. The standard will cover the use of both methods.

The Dutch pre-standard on odour measurement describes a uniform technique for the measurement of odours using a forced choice method of olfactometry, but more importantly, it specifies requirements which must be met to ensure the quality of the measurement results. The quality of the measurements from a particular laboratory is assessed from the results which the laboratory obtains for the measurement of certified.reference gases. The Dutch measuring institute in Delft maintain two gases, n-butanol and hydrogen sulphide, with concentrations in nitrogen of 60 and 20 µmol/mol respectively,as certified reference gases.

The Dutch pre-Standard will be discussed in detail in the following sub-sections. The pre-standard demonstrates how laboratory procedure and quality control are applied to the practice olfactometric measurement. The Dutch pre-standard is the only method of odour measurement practised commercially in Ireland and as such is the most appropriate to this paper.

4.4.1 Principle

By means of an olfactometer a series of dilutions of an air sample containing an odour producing substance or substances is presented to a panel of observers. The panel must indicate whether there is a difference between the diluted sample and odour free air. If no difference is observed, a choice must still be made (forced choice). The odour concentration is calculated from the responses of the panel. The number of times it is necessary to dilute the sample in order to reach the group threshold is numerically equivalent to the odour concentration in the sample.

The odorous gas which is being investigated is collected into a gas sampling bag (normally 80 -

100 liters is sufficient for analysis), and transported to the laboratory where it is connected to the olfactometer to allow the dilutions to be generated. The olfactometer must also be supplied with a stream of odour free air which may be obtained either from cylinders or a compressor source.

4.4.2 Equipment and resources

The olfactometer (dilution apparatus) should permit the mixing of sample air with odour free air and the delivery of the diluted sample to a smelling port at which the it can flow past the nose of the assessor. A second, or in some cases a third, smelling port must be provided through which the odour free air can flow. The olfactometer must have a dilution range of at least 2^{14} (16,384 dilutions) and the step between successive dilutions should be between a factor 1.4 and 3.0 (a factor 2.0 is usually used). The dilution, once set, should be within 20% of the expected dilution and it should remain stable with time. The olfactometer must provide an equal flow from each of the ports and be capable of delivering the diluted sample randomly between any of the ports. The flow from each port must be at least 20 l/min and the ports should be designed in such a way that panellists do not inhale ambient air along with the air being tested. The flow should have an even flow profile and it should not vary with time. The components of the olfactometer which are exposed to the odorous gases must be made of inert materials, (stainless steel, glass or PTFE), to avoid the adsorption of odorous substances. The method requires that the dilutions being set by the olfactometer and their stability with time should be checked at least once a year with the aid of a certified reference gas and a calibrated measuring instrument.

The generation of an odour free air supply for the olfactometer can be achieved using an air cooled rotary compressor unit (oil-lubricated compressors are not recommended). The supply line should be fitted with an air cooling dryer to remove moisture and condensable odours, and a compressed air filter consisting of an aerosol filter combined with an active carbon filter to remove any residual odours. Once the unit has been installed an assessment of whether the dilution air is "odour-free" should be carried out by smelling

The sample bag should be made of PTFE or some other fluoropolymer with a suitable fitting to admit the sample gas. Any material that comes into contact with the odorous gas during sampling should meet those requirements outlined for the olfactometer. To avoid sample contamination by pumps or meters, the sample bag is usually housed in a rigid sample vessel, the lid of the vessel has a fitting which connects to the bag and the gas is sucked into the bag by generating a vacuum within the vessel. Predilution techniques can be used to dilute the sample gas on-site where the odour concentration is so high that the direct presentation via the olfactometer is not possible, or the gases to be sampled are high in moisture and run the risk of condensing on the walls of the bag. Predilution can be achieved either by the use of dry odour free cylinder air to partly fill the bag in advance of sampling, or the use of specially designed in-stack dilution apparatus. It is beyond the scope of this paper to deal in detail with the subject of sampling, but it should be noted that the accurate assessment of an odour source depends not only on reliable analysis but also on the collection of a representative sample.

In olfactometric measurements it is important to realise that the panel of observers form a integral part of the overall measuring system. It is their noses which are collectively employed as the detection mechanism, therefore they can be justifiably classified as equipment. In the framework of the pre-standard it is important to compile a panel which contributes as little as possible to variance between different olfactometers. This means that the panel is not a cross section of the population, but meet certain selection criteria. The panel must consist of at least 8 people and qualifications must be achieved before becoming a panel member. This involves practice on the workings of the olfactometer as well as sensitivity screening through the compilation of at least 12 individual thresholds for n-butanol. A prospective panel member must meet the criteria of having a mean individual threshold for n-butanol of between 20 - 80 ppb and the scatter between the 12 measurements must be within a required criteria. A peculiarity of the pre-standard is the use of certainty scoring during panel selection and its non-use during regular analyses. Certainty scoring requires the panellist to indicate the port at which they believe the sample is located, but also to indicate how certain they are of their response (ie whether; "Certain", "Inkling" or "Guess"). An individual threshold for the purpose of panel selection is the geometric mean of the dilution at which the choice was "correct" and the panellist indicated to be "certain". and the dilution at which the choice was either "incorrect" or "correct" but not "certain". Whereas, an individual threshold for the purpose of analysing an environmental sample is the geometric mean of the dilution at which the choice was "correct" and continued to be "correct" and the dilution at which an "incorrect" choice was made. A graphical demonstration of the differences in individual threshold determination for screening and for regular analyses can be seen in table 4.1.

Table 4.1: Interpretation of the individual threshold from a response series.

Dilutions	16384	8192	4096	2048	1024	512	256
Choice of port + = correct - = incorrect	+	-	+	-	+	+	+
Certainty 1 = guess 2 = inkling 3 = certain	1	1	1	2	2	3	3

When screening with n-butanol the individual threshold is the geometric mean of dilution 1,024 and 512. When the same response sequence is recorded for an environmental sample the individual threshold is the geometric mean of dilution 2,048 and 1,024.

The screening process must be performed on a panellist in advance of every day he/she is used on a panel by determining at least 2 individual thresholds for n-butanol. Rules with which panel members must comply during their hours of employment are the exclusion of smoking, eating and drinking (except water) in advance of a measurement. They must also refrain from the use of perfumes or cosmetics. The panel should be motivated by the provision of information about the sample, provided with a comfortable environment in which to work and adequate payment (ie.motivation).

The measurement room should be kept odour-free and constructed in such a way that the panel members can not receive any impression of how the measurement results are progressing. Odour-free areas can be created by proper ventilation and the use of carbon filters. It is recommended that a slight positive pressure be maintained in the room.

4.4.3 Procedure

For each presentation the panellists must sniff from each of the available ports and choose the port he/she considers to contain the odour. If no distinction is possible, a choice must still be made. The assessment time should be at least 10 seconds and not more than 20 seconds.

The dilution series should contain at least 5 concentration stages in a sequence that provides the lowest concentration first and the highest concentration last (increasing concentrations). A dilution series is only valid for the calculation of odour concentration if no more than one panel member has failed to give a positive response to the lowest concentration or has responded positively to all concentrations. A demonstration of the requirements for a series to be valid can be seen in tables 4.2 and 4.3. One measurement must contain at least 2 individual odour thresholds per panel member, therefore a measurement must involve at least 2 series.

Table 4.2: An invalid analytical series

Dilutions	16384	8192	4096	2048	1024	512	256
Panellist A	-	+	-	+	-	+	+
Panellist B	+	-	-	-	+	-	+
Panellist C	+	+	+	-	+	+	-
Panellist D	-	-	+	-	-	+	+
Panellist E	-	+	+	-	+	+	+
Panellist F	+	-	+	+	+	+	+
Panellist G	+	+	-	-	+	+	+
Panellist H	+	+	+	+	+	+	+

Panellist C failed to give a correct response at the lowest dilution and panellist H gave all correct responses. Therefore more than one panellist is discounted and the series is invalid.

Table 4.3: A valid analytical series

Dilutions	16384	8192	4096	2048	1024	512	256
Panellist A	-	+	+	-	+	+	+
Panellist B	-	+	+	-	+	-	+
Panellist C	+	+	-	-	-	+	-
Panellist D	+	-	+	-	+	+	+
Panellist E	+	+	-	-	+	+	+
Panellist F	-	+	+	+	-	+	+
Panellist G	+	-	-	+	+	-	+
Panellist H	-	+	-	+	-	+	+

Panellist C again failed to give a correct response at the lowest dilution. Because this was the only deviant, no more than one panellist is discounted and the series is valid.

4.4.4 Calculation of the odour concentration

Various methods for the calculation of the odour concentration are permitted by the pre-standard provided the results do not deviate significantly from the those obtained using the Dravnieks method (1975). All methods use a statistical approach to determine the odour concentration, based on a normal distribution of the individual odour thresholds of the panel members.

4.4.5 Quality control

The two main facets of quality control which is required in the pre-standard is in relation to dilution device calibration and the sensory or overall calibration of the measurement procedure.

The instrument calibration is carried out in order to check if the olfactometer and the predilution apparatus make dilutions in an accurate and reproducible way. A certified reference gas and a measuring instrument calibrated by a authorised body need to be used for this purpose. It is common to use carbon monoxide as a tracer, in combination with an infrared CO monitor which measures the dilutions delivered to the smelling port[27].

The sensory calibration is an umbrella activity in that it allows the total odour measurement procedure to be examined for repeatability and reproducibility. Sensory calibration is carried out with a certified reference gas, n-butanol is recommended and is the gas most commonly used. The targeted quality criteria were set as follows:

(i) The geometric repeatability; r' is the ratio between two single measured values obtained using the same method, applied to the same sample, and under the same conditions in terms of laboratory, tester, apparatus and small interval, (intra-laboratory comparison). The pre-standard requires that r' be less than 2.

(ii) The geometric reproducibility; is the ratio between two single measured values obtained using the same method, applied to the same sample, and under different conditions in terms of laboratory, tester, apparatus and/or interval, (inter-laboratory comparison). The pre-standard requires that R' be less than 4.

4.5 RING TESTS

Ring tests are inter-laboratory surveys which are designed to evaluate the effectiveness (and the workability) of the standard methods. Certified cylinders of reference gases (typically n-butanol and hydrogen sulphide) are distributed to the participating laboratories on a regular basis.

The Netherlands: With the Netherlands Normalisation Institutes (NNI) publication of the Dutch pre-standard in January 1990 and the inherent quality requirements with respect to repeatability and reproducibility, the NNI became part sponsors of a long duration ring test involving 11 laboratories that were implementing the pre-standard[28]. The objectives of the ring test were as follows:

(i) to examine if the requirements of the method could be met in practice.
(ii) to get an insight into the causes of variations in results.
(iii) to, based on the outcome of the test, improve the method where needed.
(iv) to accumulate data upon which the certification of participating laboratories could be based.

The results of the ring test identified regular instrumental calibration, together with the reduction in personal variability of the panellists through the implementation of more stringent panel selection, to be most influential in the improvement of measurement quality. Brennan [22] (1994), states that an April 1993 revision of the pre-standard modifies these quality criteria targets to $r' \leq 3$ and $R' \leq 4$.

Germany: Under the supervision of the VDI (Association of German Engineers) several interlaboratory tests were conducted to check the effect of the german guideline on olfactometry, VDI 3881 [29].(could include example of German ring test using VDI method and outlined in Hangartners paper. A number of conclusions were suggested following the 3rd of the four rounds[29]. They are as follows:

- the main reason for variation is due "the human factor" instead of olfactometer type.
- response type is important, forced choice technique gives lower threshold values than yes/no.
- sensory calibration with standard odorants helps although considerable variation of results still remains.

Ireland: A ring test involving 1 Irish laboratory, 1 Dutch laboratory and 3 UK laboratories is currently underway. The procedures are (as far as possible) in accordance with the Dutch pre-standard and the recommendations of the Dutch ring test mentioned above[22].

4.6 CEN - EUROPEAN STANDARDISATION

At present there is no universally accepted rules for the design of dynamic olfactometers. Commercially available olfactometers differ significantly and this alone can contribute to interlaboratory variation in results[23]. Other factors have been identified as being important in terms of their capacity to cause divergence[24]. These include the following:

(i) the sample holder or bag, different fluorocarbon materials vary, both in their contribution to the odour and in their ability to prevent loss of odour during storage.

(ii) the sensitivity of the panel members obviously differ, so too does the selection methods and the criteria required to become a panellist.

(iii) the odour room in which the measuring environment must be maintained to provide the reference level for the panellists.

(iv) the data processing and method of calculation which is used to determine the threshold value from the panellists responses.

Recognising the need to improve the quality of measurements and pressurised by the demand for results that bore comparison between laboratories, efforts began in the 1980's to achieve standardisation[24]. Several standard methods were published in the USA, Germany, France and the Netherlands. Ring tests were an integral part of the development process. Results of interlaboratory tests showed that results were still lacking in agreement although a certain convergence was being achieved.

In 1985, a combined FAO/COST 681 workshop on odour prevention and control was organised at ATRC Engineering, Silsoe, UK. As part of the workshop a group of experts from different countries reached agreement on recommendations on olfactometric measurements[30,31]. The group reconvened in 1988 in Zurich to review the progress that had been achieved in the interim[25].

In 1991 a working group was established by the comité Européen de Normalisation (CEN) to draft a European standard for olfactometry[24]. The working group is subscribed to by some 13 European countries including Ireland. The intention is that a draft standard should be completed by the end of 1994. Then after an initial validation period and with a consensus being reached among the EU member states, a full standard will be established which will replace existing national standards. It is speculated that the establishment of such a standard might be an incitement to environmental regulators to use olfactometric measurement as a basis for their policies concerning odours[24].

CHAPTER 5:: THE APPLICATION OF ODOUR MEASUREMENT TO THE ASSESSMENT AND CONTROL OF ENVIRONMENTAL ODOURS

5.1 INTRODUCTION

To appraise odour measurement as an option in the control of environmental odours, it is necessary to examine the manner of its application. This chapter explains the use of odour measurement in assessing the significance of individual emission sources. It examines the use of dispersion modelling to determine the capacity of a source, or group of sources, to impact on the surrounding locality, and the difficulties in effecting the direct measurement of ambient odours. Details are given of a number of alternative techniques which were found during a review of the available literature. Finally, the inclusion of odour measurement as part of government policy on odour control in other EU states is examined by considering the situation in the Netherlands and Denmark.

5.2 ODOUR EMISSION RATE (OER)

While the concept of dilutions to threshold and the expression of odours in concentration terms is central to the evaluation of odours, it is not in itself sufficient to describe the capacity of a particular emission source to impact on the local air quality. The odour emission rate (OER) considers not only the concentration of odour at an emission point but also the volume flow of gas from the emission. The OER is the product of the odour concentration (ou/m^3) and the volume emission (m^3/s). It can be expressed as "ou/s" or "ou/hr" and is analogous to the mass emission (kg/hr) used in the control of substance emissions.

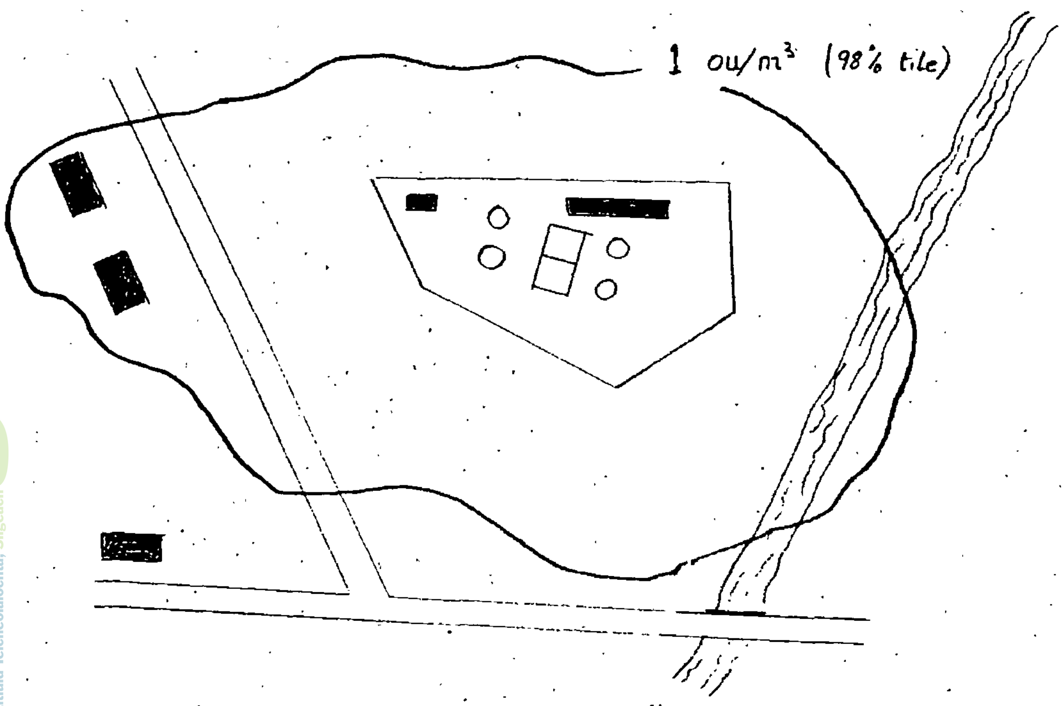
The determination of the OER from stack emissions is a relatively straightforward exercise. It involves the sampling and olfactometric analysis of the stack gases, and use of standard methods to measure the volumetric flow rate in the duct. The determination of the OER from larger area sources is more difficult. Two categories of area source exist, those with outward flow like the surfaces of trickling filters or biofilters, and those without outward flow like settlement tanks and the surface of landfills. Sampling strategies do exist which allow the OER to be calculated from area sources, but this has been recognised as an area that requires further research[24].

5.3 DISPERSION MODELLING

Air dispersion modelling is the prediction of ambient air quality based on details of the local meteorological conditions, topography and the emission source(s) under investigation. The process involves the consideration of the odour emission rate from a source and the simulation of weather and other effects that determine the levels of odour that are likely to result at some point removed from the source. The accurate measurement of odours is therefore a prerequisite for reliable prediction. Practical models used for the prediction of odour dispersion are all based on the gaussian plume model[2]. Dispersion models are commonly computer software packages that are available in varying degrees of sophistication. Pluym[20] is a simple model which has already been discussed in section 3.3. It provides estimates of ambient odour concentrations that will ensue downwind of a single point source under specific conditions of wind speed and atmospheric stability. Other input parameters include the stack height and the roughness of the surrounding terrain. The model output furnishes the expected odour concentrations at distances downwind from the source in excess of 100 meters. At distances less than 100 meters, specifics relating to stack efflux velocity, turbulence at emission point and building- wake effects have a significant influence. Pluym does not permit such details to be regarded and therefore is not used for the prediction of odour levels close to the source. A graphical display of Pluym's results for a hypothetical source can be seen in figures 3.1, 3.2 and 3.3 of chapter 3.

Exposure to an odorants in ambient air embodies two elements, the level of exposure (odour concentration) and the length of time for which the exposure takes place. There are two variables which influence the length of time for which a particular level of odour occurs at an ambient site. Firstly, the Odour Emission Rate will usually vary unless in exceptional circumstances where a process might operate on an around the clock basis and emit the same odours throughout. Secondly, the dispersive properties of the weather differ with time. The Dutch LTFD model[33] is a more advanced model which takes these factors into account. It also allows the modelling of entire facilities like sewage treatment plants in which there are multiple sources (some of which are area sources) that are spacially separated. Input parameters include, the number of minutes operating time of each source per day, the coordinates of each source on a map of the area, and the meteorological history of the site in the form of hourly data on wind speed, wind direction and atmospheric stability over a number of years. The model output is again in the form of expected odour concentrations at various distances from the source, but it also gives information about the regularity of occurrence. An example of the models output can be seen in fig. 5.1. The figure shows a hypothetical map of the area surrounding an odour source in which a concentration of 1 ou/m^3 is expressed as the 98 percentile contour. This contour joins all those points on the map at which an odour concentration of 1 ou/m^3 is likely to occur 2% of the time, lower levels of odour will occur more frequently and higher levels will occur less frequently.

Figure 5.1: Example of LTFD model output



An interim air quality standard has been in use in the Netherlands since 1984. The standard implies ambient percentile limits and prescribes the use of olfactometric measurement in combination with the LTFD model[34].

The Complex-1 model is similar to the LTFD and has been employed by Northumbrian Water Limited as an aid to the design of abatement measures for some of it sewage treatment plants[35]. It was also used for the prediction of odours that would arise at proposed sites. When submitting for planning permission in respect of new sewage treatment facilities, the company found itself in a position of having to prove to the local authority that odour problems would not arise. To this end they employed dispersion modelling combined with estimates of emission rates based on existing facilities.

5.4 THE MEASUREMENT OF AMBIENT ODOURS

There are a number of reasons why source measurements and the use of dispersion modelling is preferred over the direct measurement of odours at ambient sites:

- There are inherent problems in the sampling of ambient odours[23]. The collection of an odour sample at an ambient site is only meaningful if accompanied by detailed data on the weather conditions that prevailed during sampling. Wind speed, wind direction, temperature and climatic stability can significantly influence the ambient air quality. In contrast, strategies for the sampling at emission sources are designed to be uninfluenced by weather conditions and attention need only be paid to representivity of the sample with respect to fluctuations in the emission itself.
- Odour samples collected at an ambient site may contain contributions from many sources, so they could not be relied upon to evaluate the effects that a particular source has on the ambient air quality.
- The bag material and sampling equipment can make small contributions to the levels of odour in a sample, the error is generally irrelevant when sampling at source but can be significant when attempting to measure the relatively low levels found at ambient sites.

5.5 OTHER TECHNIQUES USED TO ASSESS ENVIRONMENTAL ODOURS

By way of completing this chapter on the applications of odour measurement, a number of papers will be discussed that demonstrate the diversity of approach which have arisen out of peoples attempts to assess environmental odours. No attempt has been made to comment on the merits of the individual techniques.

Laing and Barnett, 1992 [36], detail a study designed to establish whether residents living close to the Glenfield Sewage Plant in outer Sydney were exposed to higher levels of odour than residents in Wahroonga at a location distant from any sewage plant, industries and dense traffic.

The fear was that people living at the former location may be exposed to odours which they could not detect because of olfactory adaptation, and that such exposure might be detrimental to their health. Accordingly, air samples were collected at each of the sites and analyzed by forced choice dynamic olfactometry. The results showed that there was no significant difference between the levels of odour to which residents at Glenfield and Wahroonga were exposed, the levels being 4.4 and 4.8 odour dilution units respectively. The levels were deemed to be significantly higher than the control sample (Medical air, 2.8 dilution units). It was concluded that the residents at Glenfield were not, with the exception of occasional short lived incidents, exposed to levels of odour that could be detrimental.

Bonnin, Laborie and Paillard, 1990 [37], describe the study undertaken at 12 different sewage treatment plants in France. The study concentrated on the identification of individual substances which were contributing to the odours but also included olfactometric analysis of gases emanating from the various treatment processes. The olfactory testing used the PAS system which involves the combining of two distinct sensory tests to define the Nuisance Threshold "N" of the various sources. Threshold determinations were performed and these were followed by hedonistic testing to describe the quality of the odours based on the assessors classification of the odours from least to most unpleasant. The Nuisance Threshold was then calculated as:

N = (Hedonistic.score * Olfactive threshold)/3

Both types of test were performed on a three mask dynamic olfactometer. Processes which scored a negative value for N were considered capable of causing an odour nuisance.

Sorel, Gauntt, Sweeten, Reddell and McFarland, 1983 [38] describes a portable system which was developed to quantify odours in the atmosphere. Panellists compare the intensity of ambient odours with those of discrete levels of 1-butanol provided by an olfactometer, they then indicate whether the intensity of the odour was "stronger", "weaker", or "equal" to that of the butanol (ie intensity scaling). The paper identifies what it considers are the deficiencies of threshold methods for the determination of ambient odours. It states that the advantage of suprathreshold intensity comparison lies principally in eliminating the threshold variability of observers.

5.6 ODOUR MEASUREMENT AS AN INTEGRAL PART OF ODOUR CONTROL POLICY IN THE NETHERLANDS AND IN DENMARK

The Dutch policy document on Offensive Odours (1992)[39], states that, at that time, 21% of the Dutch population experienced some degree of irritation from offensive odours, whilst 5% were seriously affected. The policy document expands on a course of action initiated in the countries National Environment Plan, NMP 1988/89, to set "norms" for offensive odours. Quality objectives were set to reduce the numbers affected by odour to 12 % of the population by the year 2000. The means by which the objectives were to be met were through licensing, regulations and zoning.

The odour concentration norms give the maximum permitted ambient odour for residential areas which can occur as a result of a number of categories of plant. The odour concentration norms for residential areas are:

1 ou/m^3	as 98th percentile	for existing sources
1 ou/m^3	as 99.5th percentile	for new sources
10 ou/m^3	as 99.99th percentile	for discontinuous and fluctuating sources

These values have been derived from an empirical relationship between odour concentration and its nuisance value. The odour concentration is normally determined through measuring at source and using dispersion modelling to calculate its contribution to ambient levels. However the policy document also acknowledges the possibility of determining the perceptibility of the odour through the use of measurements made by air pollution detection teams.

The policy document states that legislation is not at present (1992) regarded as necessary to the achievement of policy objectives. Rather, to prevent offensive odours, the preferred course of action is to specify actual methods to be used to achieve the concentration norm when issuing business permits. Enforcement will then be a matter of insuring that the abatement system is being used and that it is functioning properly. Meanwhile, where specific methods of abatement are not known for a particular source, the norm must be set as a target. Enforcement will thrn entail emission measurement and dispersion modelling to assess compliance.

The odour abatement policy in Denmark is based upon the guidelines issued in 1985 by the

Danish Environmental Protection Agency; "Guidelines for the abatement of odour pollution"[40]. In these guidelines uniform regulations concerning the measurement, assessment, prevention and emission of odour sources have been set[41]. The guidelines prescribed that the calculated ground level concentration (odour immission) should not exceed 5-10 ou/m^3 as a 99 percentile value, depending on the location of the source (residential or urban). The method of calculation is stipulated in the guidelines and the averaging time is 1 minute. In order to minimize the variations in measured odour thresholds due to the use of different olfactometers and panels, the guidelines introduce a sensitivity factor. This involves a test laboratory analysing standard mixtures of n-butanol and hydrogen sulphide together with the samples. The values obtained for the standards determine the factor that must be applied to the measured values for the samples. Boholt [41] states that characterising sources using odour threshold measurements combined with dispersion model calculations and odour concentration standards have been used successfully in Denmark.

In 1992 the Danish Environmental Protection Agency issued their Industrial Air Pollution Control Guidelines[42]. These guidelines are intended to provide guidance to Local Authorities when issuing approvals, permits and licenses in respect to industrial emissions. The guidelines are "substance based" and stipulate emission limits and the immission concentration contribution (C-values) for a number of pollutants. The guidelines recommend that immission levels are estimated by using the OML air dispersion model. These C-values are an expression of the agencies knowledge of a substance and are determined on the grounds of health evaluation. However, some of the substances have an odour related C-value, these substances have a factor of ten or more between the C-value and the value they would have been assigned purely on the grounds of health evaluation alone.

CHAPTER 6:: ODOUR NUISANCE IN IRELAND

6.1 INTRODUCTION

The impetus for this dissertation was two-fold. Firstly, to examine the principles of odour nuisance and the techniques used to measure odours. Secondly, to explore the extent to which odours are a problem in Ireland, the utilisation of the legislative provisions to control odours in this country and the attitude of local authorities to the use of odour measurement as a tool to aid in that control.

Neither the Department of the Environment or the Environmental Protection Agency had any documented information on odour nuisance. However, the contacted representatives of both authorities expressed an interest in obtaining the results of any investigation of the subject[43]. A review of published literature suggested that, in Ireland, their was only a very limited number of people who had expertise in the field of odours. Much of the work that had been done was in the area of agricultural odours. Carney,1988[44] completed a Ph.D thesis on the measurement and dispersion of agricultural odours. Carney and Dodd presented two papers at AG ENG 88 in Paris 1988 and these were subsequently published in the Journal of Agricultural and Engineering Research in 1989. The first paper[45] deals with the on the measurement of agricultural malodours and describes the olfactometer which was built in the Agricultural and Food Engineering Department of University College Dublin and used to study the odour characteristics of various animal slurries and the influence that land spreading techniques had on the emission of odours. The second of the two papers [46] deals with an experiment to compare between predicted and measured values for the dispersion of malodours from slurry. Teagasc, the Agriculture and Food Development Authority, conducted studies on methods to reduce odours from land spreading in 1993 but results have yet to be published. SmithKline Beecham (formerly Penn Chemicals) in Ringaskiddy, have in the past, used both an olfactometer and a scentometer to monitor source and ambient odour levels, at and in the vicinity of their plant [47]. Callan has published a number of odour related articles in industry journals[48,49].

Bord na Móna Environmental Products Division in Newbridge Co Kildare have provided a commercial odour measurement service since 1990. The odour laboratory is operated in accordance with the Dutch pre-standard NVN2820[26]. The company is nominated by the

National Standards Authority of Ireland as its representative on the European Committee for Standardisation's working group on odours. Dr Breda Brennan, formerly of Bord na Móna, has presented a number of papers in scientific journals including those on the "Recent advances in odour measurement"[22] and "Biofiltration as an odour control technology" [50] which were presented to the IWEM symposium on Odour Control and Prevention in the Water Industry, at Newcastle upon Tyne in April 1994.

6.2 LEGISLATIVE PROVISION FOR THE CONTROL OF ODOURS

The Air Pollution Act 1987[51] and its associated Licensing of Industrial Plant Regulations 1988[52], have been the main statutory provision for the control of air pollution in this country.

The pertinent sections of the Air Pollution Act includes section 24(1) which requires "*the occupier of any premises, other than a private dwelling*" to "*use the Best Practicable Means to limit and, if possible, to prevent an emission from such premises*" . An emission is defined as "*an emission of a pollutant into the atmosphere*" (Sec. 7) and a subsequent amendment to the act altered the definition of *pollutant* to include "*a substance which gives rise to odour*" (Sec. 7). Therefore the implication is that Best Practical Means must be employed to control odours. Furthermore, the definitions of a *private dwelling* and a *premises* suggest that an agricultural holding would fall subject to the requirement for BPM. Section 24(2) requires that the occupier of a premises shall not cause or permit an emission "in such a quantity, or in such a manner, as to be a nuisance. Also, section 26 empowers a local authority to serve notice on the occupier of a premises to require measures to be taken to prevent air pollution. The Department of the Environment Bulletin no. 19 [53] lists the number of investigations, warnings and notices which were issued under sections 24 and 26 for the year 1992, but no details are available on how many related to odour problems.

Section 30 of the act requires certain scheduled industries to obtain a licence for emissions to atmosphere. A review of the air emission licenses that have been issued to industries under the licensing regulations of 1988 reveals the vast majority of them include a clause to prevent odours occurring beyond the boundary fence of the facility. Thus, the local authorities are bestowed with the power to regulate odour emissions, but their appears to be little guidance available on the form this regulation should take.

The Environmental Protection Agency Act 1990, which provides for the transfer of responsibility for pollution control from the Local Authorities to the recently formed EPA on a phased basis, also provides for the regulation of air pollution. The act adopts an Integrated Pollution Control (IPC) licensing system to be operated by the agency in respect of those activities specified in the first schedule of the act. Planning control of all development and pollution control of activities not specified in the first schedule will remain with the local authorities. Agency representatives have indicated in the media that up to 20 IPC licenses are due to be issued during the summer of 1994. It is likely that the EPA will become increasingly involved in the regulation of odours, particularly those from industrial sources.

6.3 QUESTIONNAIRE ON ODOUR NUISANCE IN IRELAND

Research into odour nuisance in Ireland was conducted by way of a questionnaire which was sent to all 33 (recently increased to 34 following the division of Dublin County Council into three and abolition of Dunlaoghaire Corporation) local authorities in the country. The objective of the questionnaire was to establish information on the following:

- The prevalence of odour nuisance problems and the types of facilities that cause the problems.
- The regulation of odours under the Air Pollution Act.
- The opinions of the local authorities on the usefulness of odour measurement techniques.

6.3.1 Methodology

The objectives of the study having been decided, there were a number of considerations in the designing of the questionnaire. The principal consideration was to ask the right questions so that the desired information would be obtained. To formulate the questions so that the task of answering would not be laborious and thus achieve a high response rate. The questions also needed to be structured so that responses were easily interpreted and the resultant data could be presented in an uncomplicated manner.

A trial questionnaire was sent to the Department of the Environment, the Environmental Protection

Agency and the county councils of Tipperary SR and Meath. The feedback from the four institutions was used to formulate the final draft of the questionnaire. A number of questioning strategies were employed. None of the questions demanded a scripted answer because it would complicate the presentation of results. Many of the questions required ticking the appropriate box or boxes and others ask for estimates in terms of percentages. The logic was to keep the time required to complete the questionnaire as short as possible and to encourage those respondents who did not possess the required information to at least make an estimate.

6.3.2 Results

The questionnaire comprised 18 questions (see appendix A). Each question is reproduced in the following sections together with the percentage response rate and a summary of the responses in either tabular or graphical form. A complete listing of the responses, on a county by county basis, is given in appendix B.

General

Of the 33 questionnaires that were circulated a total of 27 responses were received (82% response rate). Everyone of the 27 had received the attention of the authorities environment department. The respondents were asked to indicate if they would like to receive a summary of the results of the survey and all but one availed of the offer. The results for the Dublin councils of Fingal and South county were returned on a single questionnaire and are presented together. Because some of the questionnaires were only partially completed, not every question gave rise to 27 useable responses. The response rate quoted for each question is calculated as a percentage of the total number of local authorities in the country, (eg 27 of the 33 authorities returned but only 25 answered question 1, therefore, the results for that question represent the views of 76% of the authorities).

Question 1.

Does your council keep a record of public complaints relating to odour nuisance.

Response rate 73%

Yes: 19 No: 5

A number of respondents pointed out that it was common practice to keep records of public complaints but that no special register was kept for those which related to odours. The main purpose of this question was to get an indication whether the responses given in the other 17 questions were based on information that had been chronicled by the local authority.

Question 2

In terms of their propensity to cause public complaint, arrange the following items in decreasing order of importance.

Noise nuisance
Local authority housing
Roads/potholes
Odour nuisance
Sewage/refuse service
Smoke/dust nuisance
Domestic water supply

Response rate 51%

A large number of respondents remarked that neither roads or housing were the responsibility of the environment department and they could not comment on complaints relating to those topics. In the analysis of the data, both roads and housing were omitted and the remaining five items were scored 1 through 5 in terms of importance, (ie the most common cause of complaint was scored 1 and the least common was scored 5). Table 6.1 summarises the results and displays that on average the order of importance is: 1.Water supply; 2.Sewage; 3.Odour; 4.Smoke/dust; 5.Noise.

Table 6.1: Propensity to cause public complaint

	Noise	Odour	Sewage	Smoke	Water supply
Number of 1 scores	0	2	5	2	9
Number of 2 scores	3	4	4	3	4
Number of 3 scores	3	5	3	6	1
Number of 4 scores	2	7	3	4	1
Number of 5 scores	10	0	2	3	2
Average score	4.00	3.00	2.59	3.17	2.00

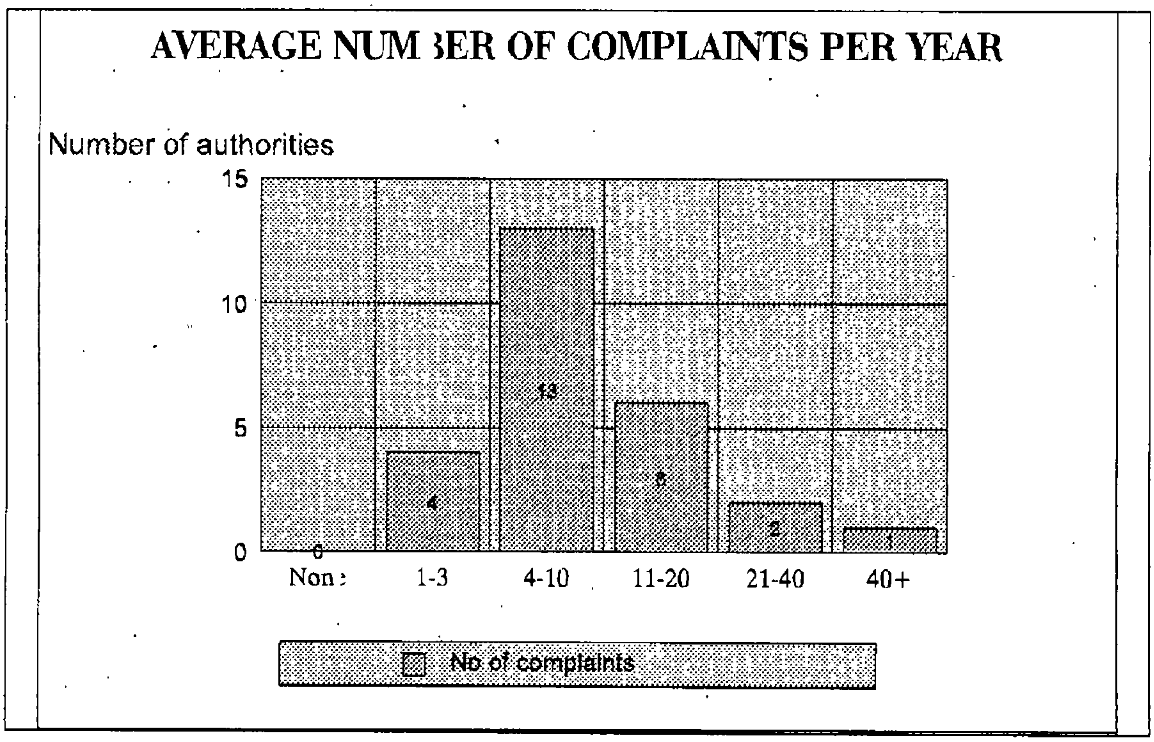
<u>Question 3</u>

What total number of complaints relating to odour nuisance would your council receive on average every year.

Response rate 76%

A summary of the responses is displayed in figure 6.1 below.

Figure 6.1



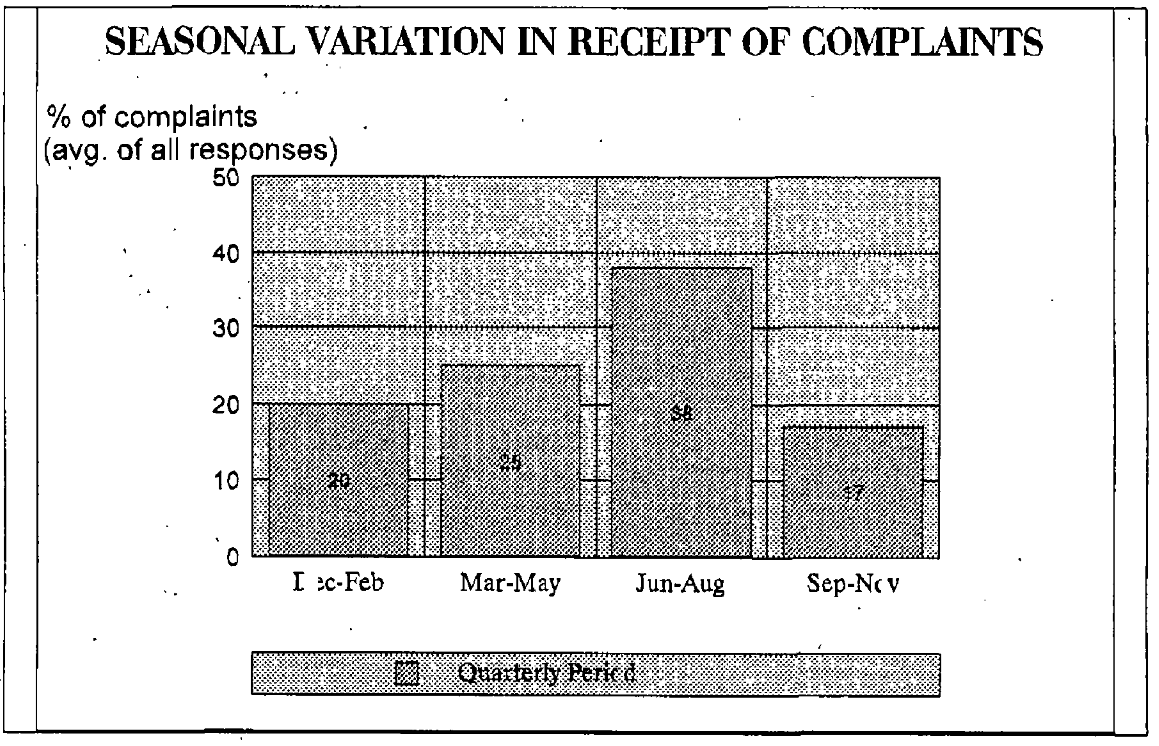
Question 4.

Does your receipt of complaints show any seasonal trends. (Out of a total of 100%, assign the correct fraction of the total to each category)

Response rate 67%

For each of the four quarterly periods, the average of all percentages attributed to that period was calculated and presented in figure 6.2.

Figure 6.2



Question 5.

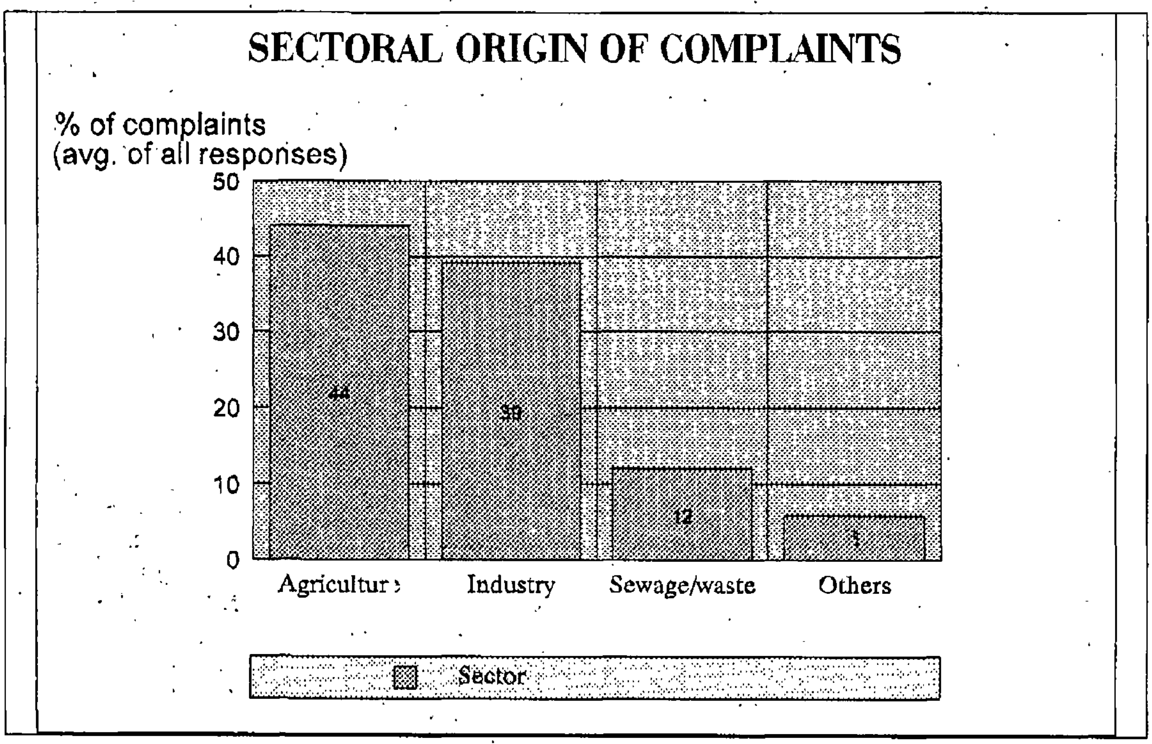
What percentage of the total number of complaints are the result of activities in the following sectors. (Out of a total of 100%, assign the correct fraction of the total to each category)

Agriculture
Industry
Sewage/Waste
Other

Response rate 76%

For each of the four sectors, the average of all percentages attributed to that sector was calculated and presented in figure 6.3.

Figure 6.3



Question 6.

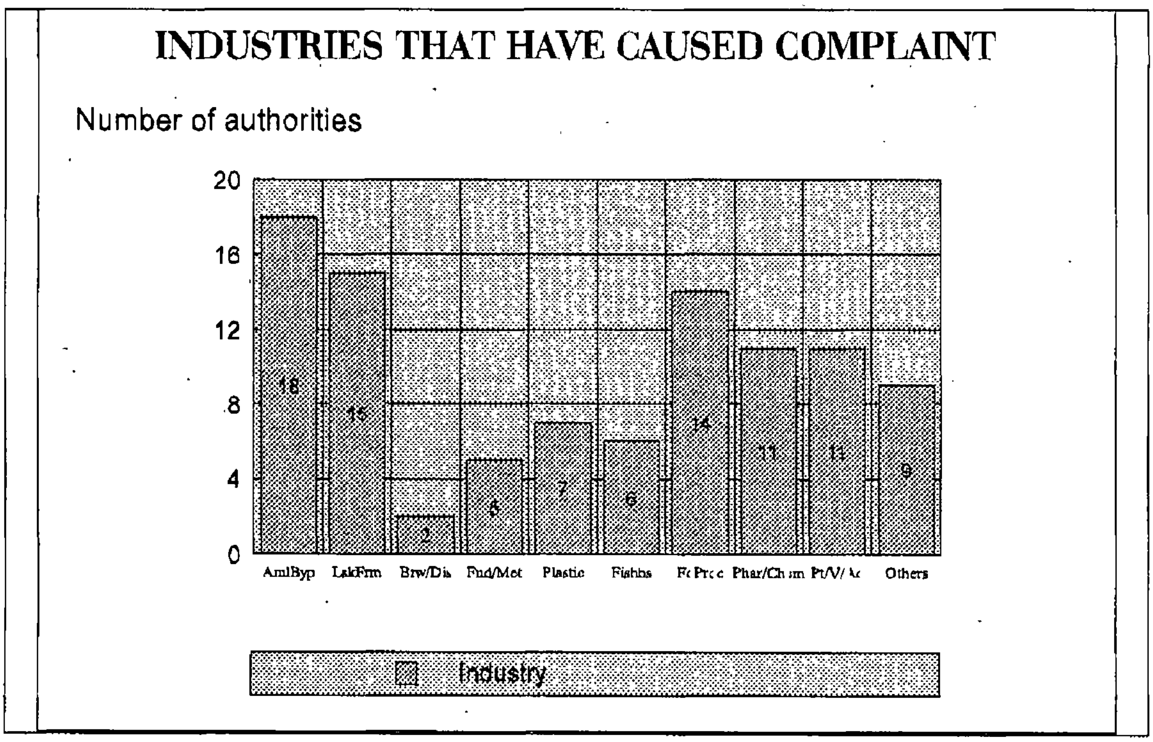
Of all those complaints relating to the industrial sector, indicate any of the following activities which have been the subject of complaint. (tick the appropriate boxes)

Animal byproducts	*Fishbased Ind.*
Livestock farming	*Food processing*
Brewing/Distilling	*Pharmaceutical/Chemicals*
Foundry/Metals	*Paint/Varnish/Adhesives*
Plastics	*Others (specify)*

Response rate 79%

The number of authorities that had received complaints regarding each of the industrial activities were totalled and presented in figure 6.4 below. The industries that were specified under the heading "others" were gas cylinders, cotton drying, rubber, refuse, textiles, printing, tarmacadam and maggot production.

Figure 6.4



Question 7.

When compared with 5 years ago, what change has their been in the number of odour complaints received per year. (choose one option only)

An increase of	*0-50%*	*50-100%*	*100-200%*	*>200%*
A decrease of	*0-50%*	*50-100%*	*100-200%*	*>200%*
No change				

Response rate 61%

The table below lists the number of local authorities that chose each of the available options to represent the change in odour complaints over the past five years.

Table 6.2: Change in the number of odour complaints over the last 5 years

Change in the number of odour complaints over the past five years	Down 0-50%	No change	Up 0-50%	Up 50-100%	Up 100-200%	Up > 200%
Number of Local authorities	1	8	2	5	2	2

Questions 8 through 13 investigate the Local Authorities experiences with odours in the year 1993 alone.

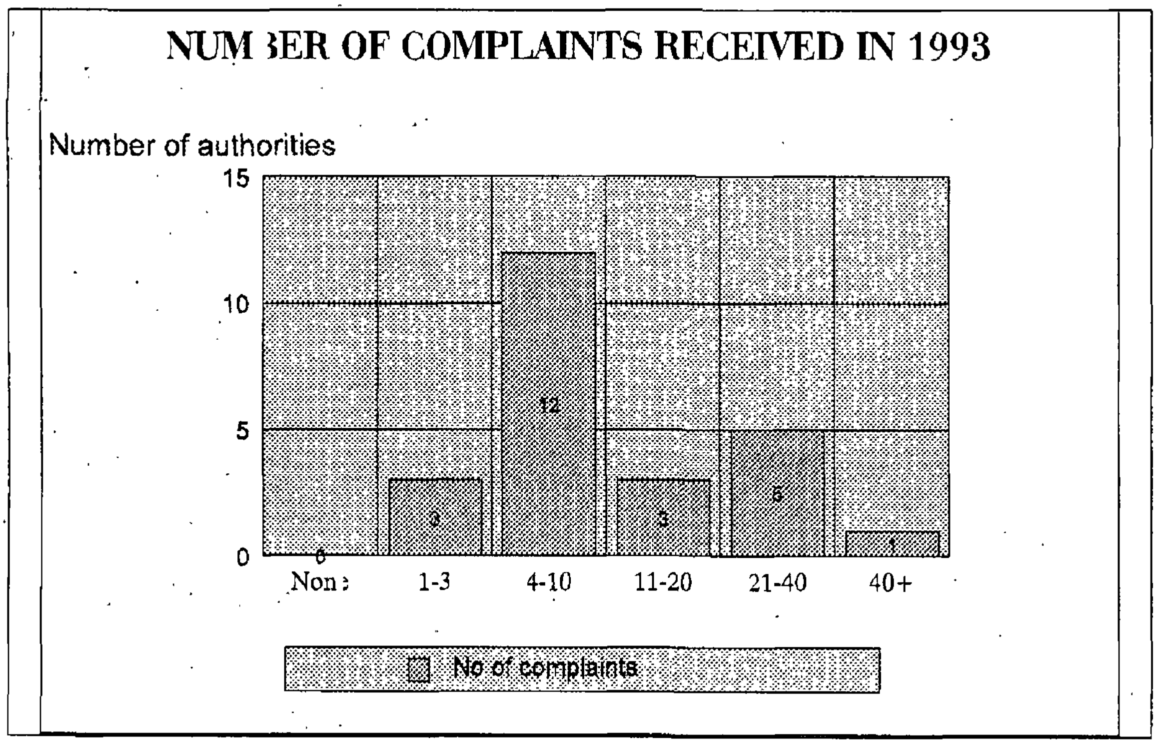
Question 8.

What was the total number of complaints relating to odour nuisance received by your council in the year 1993.

Response rate 73%

A summary of the responses is displayed in figure 6.5.

Figure 6.5



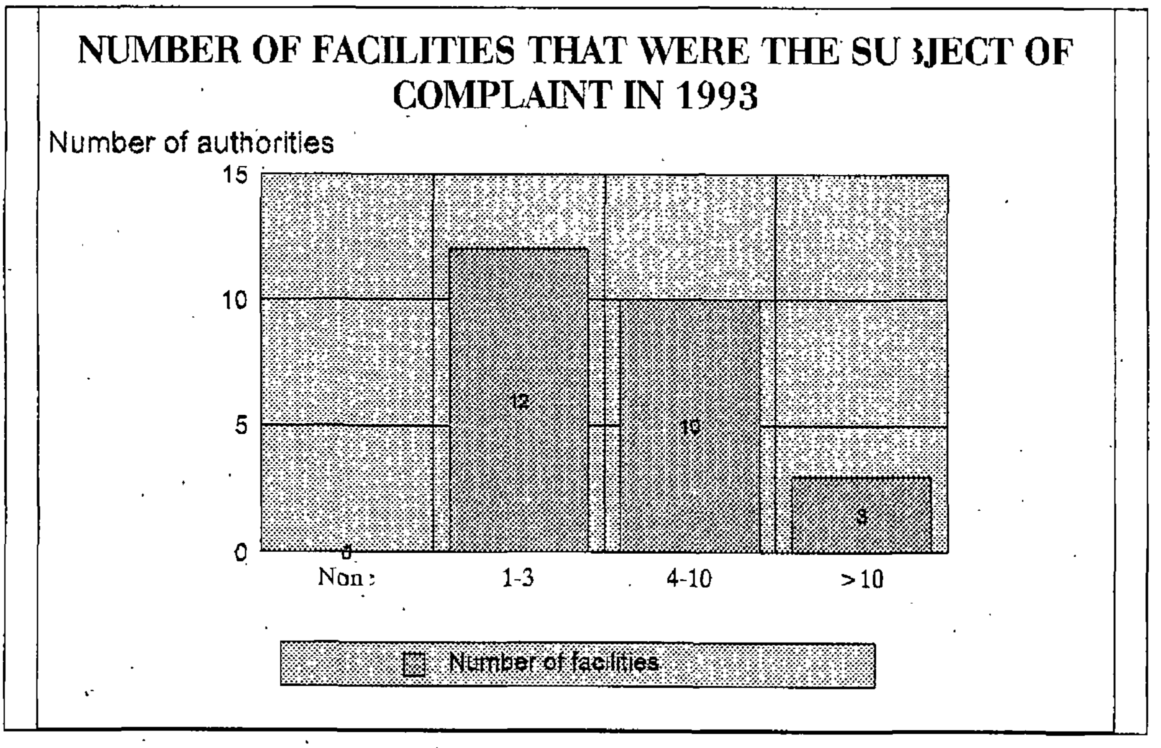
Question 9.

Where a certain industry or activity is giving rise to odour nuisance, it will often be the subject of repeated complaints by a relatively small number of people. Of the total number of complaints received last year, how many different facilities did they relate too.

Response rate 76%

A summary of the responses is displayed in figure 6.6.

Figure 6.6



Questions 10, 11, 12 and 13 were designed to examine the extent to which the regulatory powers for the control of odours are being enforced. These questions are presented together and a summary of the results are displayed in table 6.3.

<u>Question 10.</u>

Section 24 (1) of the Air Pollution Act requires to the use of BPM. How many advice/warnings did your council issue last year, and how many involved a problem with odours.

Response rate 67%

<u>Question 11.</u>

Section 24 (2) of the Air Pollution Act prohibits emissions that would cause a nuisance. How many advice/warnings did your council issue last year, and how many involved a problem with odours.

Response rate 67%

<u>Question 12.</u>

Section 26 of the Air Pollution Act empowers a local authority to require measures to be taken to prevent air pollution. How many notices did your council serve last year and how many involved a problem with odours.

Response rate 67%

<u>Question 13.</u>

How many times last year did your council take court action against an offending facility for the purpose of reducing air pollution, and how many involved a problem with odours.

Response rate 67%

The number of actions, taken under each of the sections of the Air Pollution Act (APA), were totalled and are listed in the table below. The number which related to a problem that involved odours is also listed and the percentage of the total number which they represent. The 67%

response rate means that the results represent 22 of the 34 local authorities.

Table 6.3: Regulation of air pollution and odours in 1993

Relevant section of the APA.	Total number	Number involving odour	Percentage of total involving odour
Section 24(1) Advice/Warnings requiring the use of BPM	154	40	26%
Section 24(2) Advice/Warnings prohibiting an emission that would cause nuisance	191	60	31%
Section 26 Notices requiring measures to be taken to prevent air pollution	43	20	47%
Court actions taken for the purpose of reducing air pollution	5	2	40%

Questions 13 through 18 examine the extent to which odour measurement has been employed in this country and solicits the opinions of the local authorities on the value of odour measurement.

Question 14.

When dealing with odour problems, has your council or has a plaintiff at the behest of your council, ever employed:

a. A specialist consultant in odour control

Response rate 76%

Yes: 11 No: 14

b. Odour measurement techniques

Response rate 76%

Yes: 9 No: 16

Questions 15, 16 and 17, and a summary of the results are presented in table 6.4.

Question 15.

Odour measurement can be used to evaluate the gases entering and leaving an abatement system and thus evaluate its efficiency. How valuable does your council consider the use of such techniques in the assessment of BPM.

Response rate 79%

Question 16.

Odour measurement combined with air dispersion modelling can predict the impact that a particular plant has on the surrounding locality. How valuable does your council consider the use of such techniques.

Response rate 76%

Question 17.

Data on existing sites, combined with air dispersion modelling, can predict the environmental impact of a proposed development such as a sewage treatment plant or a landfill. How valuable does your council consider the use of such techniques.

Response rate 73%

Each question required the respondents to rate their opinion of odour measurement an as aid. They were asked to indicate whether they considered it would be, *Very useful; Useful; No use; No opinion.* A summary of the results is listed in table 6.4.

Table 6.4: Perceived value of odour measurement for the control of odours

The perceived value of odour measurement for:	Very useful	Useful	No use	No opinion
Measuring the removal efficiency of abatement systems and the assessment of BPM	3	16	1	6
In combination with dispersion modelling to predict the impact of a facility on the surrounding locality	7	17	0	1
Provision of odour data from existing sites which combined with dispersion modelling can be used to predict the impact of a proposed development like a new sewage treatment plant	5	18	0	1

Question 18.

Current air pollution legislation sets an Air Quality Standard (AQS) for Smoke/Dust. This fixes limit concentrations which should not be exceeded in ambient air and specifies the methods by which the Smoke/Dust levels should be measured. Where an AQS is being or is likely to be exceeded, the local Authority is required to take appropriate steps to secure compliance with the limit. Does your council believe that a similar approach to odour control would assist in the prevention of odour nuisance.

Response rate 70%

Yes: 6 No: 10 No opinion: 7

6.3.3 Discussion of results

The following discussion is an interpretation of the results of the survey. Reference is made to both the summary treatment of results in this chapter and the detail presentation on a county by county basis in appendix B.

There is a degree of variation between counties in terms of the topics that cause public complaint. While water supply is on average the most important and is rates number 1 by 9 of the 18 counties that responded, it is also the least important in 2 of the counties. Odours, as a subject of complaint, lay in third on average but was the most important in the counties of Cork and Longford.

The majority of authorities received an average of between 4 and 10 odour complaints in a year. Only one authority, Cork County Council, received an average of greater than 40 in a year. The greatest number of odour complaints are lodged during the quarterly period of June to August. However, 7 of the 23 respondents indicated no seasonal variation in the receipt of complaints, and the neighbouring counties of Clare and Galway receive the greater number of complaints during December to February. Many factors could be at work in determining these seasonal variations. The higher temperatures in the summer months will favour the volatilisation of odorants which are bound in solid or liquid substrates. The counties that register a high proportion of agriculturally derived odours are most likely to receive complaints at the time of year when slurry spreading is prevalent. Seasonal differences may be due to variations in the weather rather than anything to do with the sources of odour. Periods in which climatic inversion and low wind speeds are common will accentuate an odour problem because the dispersive properties of the weather will be at a minimum.

The question which requested a division of the total number of complaints into the sectors of agriculture, industry, sewage/waste and other, resulted in significant variation from county to county. The agricultural sector was, on average, the sector that caused the greatest proportion of complaints. Four counties indicated that agriculture accounted for more than 90% of complaints, and it was not surprising that the city corporations of Dublin, Limerick and Waterford had little or no complaints regarding agricultural sources. Industrial sources accounted for more than 90% of complaints in only two counties, and unlike the other three sectors, industrial activities were a source of complaint in every one of the responding counties. Sewage/waste sources was rated third on average and was not a source of complaint in seven of the responding counties.

Those industries that have traditionally been regarded as sources of odour nuisance were the most common subjects of complaint. There were 26 respondents to the question on industries that had in the past been the subject of complaints. The two highest scorers were animal byproducts and livestock farming for which their were 18 and 15 counties respectively that had experienced complaints.

The most popular opinion on the change that had occurred in the numbers of odour complaint over the past five years was that there had been no change. Only one council (Westmeath) reported a decrease and the other eleven respondents said that there had been an increase of between 0% and greater than 200%.

Questions 8 through 13 examined the extent of the odour problem and the exercision of regulatory powers to control odours, for the year 1993 alone. The purpose of examining the situation in a single year was to achieve data that would allow a more accurate inter-county comparison. Questions that required estimates about the odour problems experienced by a local authority "in the past", made no allowance for the differences in longevity of employment of the officers filling in the questionnaire. Therefore some answers might be based on the experiences of a year or two and others might be based on ten or twenty years experience.

By requesting the number of facilities that were subject to complaints as well as the total number of complaints received an indication was obtained of the prevalence of repeated complaints about the same facility. Most respondents estimated the total number of complaints in 1993 to be greater than the number of facilities about which the complaints were lodged. Half of the 24 respondents reported the number of complaints in 1993 as been in the range 4-10. Half of the respondents reported the number of facilities that had been the subject of complaint in 1993 as been in the range 1-3. Dublin Corporation, and the county councils of Kildare and Kilkenny reported the number of facilities that had been the subject of complaint in 1993 to have been greater then 10.

In 1993, the reported utilization of powers under the auspices of the Air Pollution Act show that, of the authorities that responded, Dublin Corporation accounts for the overwhelming majority of the total. This may reflect a profusion of pollution incidents in the area, or it may be that Dublin Corporation has a particular penchant for the enforcement of the act. The figures reported for questions 10 and 11 (these are shown in detail in table 4 of Appendix B) suggest that many local authorities issue advice/warnings under section 24 of the act without discriminating between subsections 24(1) and 24(2) which deal with the requirement for BPM and the prevention of emissions that could cause a nuisance. This is particularly apparent in the case of Dublin Corporation which reports a total figure of 114 advice/warnings with 15 involving odour for both subsections.

A significant number of the advice/warnings related to problems involving odours. If the figures for Dublin Corporation are omitted, then the number of advice/warnings that involved odours account for 62% in the case of section 24(1) and 58% in the case of section 24(2). It is also clear that many authorities either, did not have occasion to, or failed to, implement their powers under the act. Of the 22 authorities that responded, 10 did not use section 24(1), 9 did not use section 24(2) and 12 did not use section 26. A total of 5 court actions were taken under the act and 2 of these involved odour. A significant point, which was remarked upon by the representative of the Fingal/South Dublin council is that some odour complaints are dealt with under the Public Health (Ire) Act 1878.

With regard to the authorities employment of specialist advice on odour control or the use of odour measurement, the figures for 1993 show that less than half of the respondents availed of either facility. These figures might be regarded as low when one considers that every one of the authorities had received odour related complaints for that year. However, their could be many reasons for the failure to employ specialist services. For example, the complaints might not be so impassioned as to justify the cost, the authority may have been either unaware or unconvinced of the value of odour measurement in a particular situation, or they may have dealt successfully with the complaints without having recourse to external consultants.

Notwithstanding the limited use of odour measurement techniques in 1993, the responses received for questions 15, 16 and 17 show that their is a general opinion that odour measurement would be useful and sometimes very useful in certain circumstances. The majority of respondents believed that olfactometry would be of value for measuring the efficiency of abatement systems and the assessment of BPM. Furthermore, that it would be valuable when used with air dispersion modelling to predict the impact of an existing emission, or of a proposed development, on the ambient air quality of a locality.

Finally, the notion of applying an odour Air Quality Standard, like that used for smoke and sulphur dioxide met with disapproval from the majority of authorities. Asked if such an approach would assist in the prevention of odour nuisance, 6 respondents expressed the opinion that it would, 10 that it would not, and 7 had no opinion on the matter. The representative from Cork County Council believed that odour nuisance was too subjective and hence it would be difficult to standardise an approach, they felt that it would be preferable to reduce and eliminate odours through public and source involvement. Wexford County Council believed that such an approach to odours would be very complicated, and while it might be beneficial in industrial areas, it is debatable whether the costs would justify the benefits in rural situations. The representative from Galway County Council thought that an AQS approach would be of assistance, but pointed out the current absence of an Irish standard and the difficulty of deciding what was an acceptable level of odour in rural areas, where unpleasant smells are a normal consequence of in-house farming (eg. slurry, blood and offal spreading).

CHAPTER 7:: CONCLUSION

7.1 CONCLUSIONS

Local Authorities in Ireland, in common with their counterparts in Europe, are in receipt of public complaints due to odours. These complaints originate from many industry sources and to a great extent from agricultural sources.

Generally speaking odours are detrimental only in terms of their ability to cause nuisance but they can be perceived by the public as health hazards. The increasing public awareness of environmental matters could lead to more plentiful and fervent public complaints in the future.

Statutory provision for the control of odours in this country does exist by virtue of the inclusion of odour under the definition of pollutant in the Air Pollution Act 1987. However their is little or no guidance given on the practicalities of enforcing odour control.

The continuing transfer of pollution control responsibilities from the local authorities to the EPA should allow for greater proficiency in odour control because a single regulatory body can afford to develop expertise in specialist areas in a way that was impractical for the local authorities.

The new Integrated Pollution Control licenses which will be introduced by the EPA could mean that industries which traditionally met the conditions of an effluent license through the maintenance of their Waste Water Treatment plant may now also have to concern themselfs with the prevention of effluent odours.

Characterisation of sources using odour threshold measurements, combined with dispersion models and odour concentration standards appear to be the most straightforward approach to regulation. This approach has been employed successfully in both Denmark and the Netherlands in spite of the historical inaccuracies of olfactometry. Recent improvements in the repeatability and reproducibility of olfactometry strengthens its merit as a valuable tool for the assessment and management of odour problems.

To date, odour measurement had not been widely used in Ireland. The general consensus among local authorities was that it would be useful in various situations involving odours.

Odour measurement, in combination with dispersion modelling is an effective tool for:

- The prediction of odour emissions from a new plant as a feature of the EIS process.
- The determination of removal requirements when designing an abatement system for new or existing facilities.

The use of standard olfactometric methods and the demonstration of a testing laboratories competence in respect of standard mixtures must be established before any authority attempts to regulate on the basis of olfactometric results.

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APPENDIX A

Local Authority questionnaire.

ODOUR NUISANCE IN IRELAND QUESTIONNAIRE

Survey for MSc. thesis by Mr. Nicholas Kenny.

This copy was issued to, and completed by, representatives of the local authority known as: ______________________________

The questionnaire received the attention of the following:

- ***Representative(s) of the Environment dept.*** ☐
- ***Telephonist(s) in receipt of public complaints*** ☐
- ***Others (please specify)*** ______________________

This local authority would like to receive details of the survey results.

Yes ☐ ***No*** ☐

The name and address of the person to which the results of the survey should be sent:

____

____

____

____

GENERAL

1. Does your council keep a record of public complaints relating to odour nuisance.

☐ Yes ☐ No

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2. In terms of their propensity to cause public complaint, arrange the following items in decreasing order of importance, (eg: if roads are the greatest source of complaint then put the figure 1 in the space opposite, etc)

A - Noise nuisance ______

B - Local authority housing ______

C - Roads/potholes ______

D - Odour nuisance ______

E - Sewage/refuse service ______

F - Smoke/dust nuisance ______

G - Domestic water supply ______

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3. What total number of complaints relating to odour nuisance would your council receive on average every year.

☐ None ☐ 1-3 ☐ 4-10 ☐ 11-20 ☐ 21-40 ☐ >40

Does your receipt of odour complaints show any seasonal trends. (Out of a total of 100%, assign the correct fraction of the total to ach category).

Dec-Feb ______% Mar-May ______% Jun-Aug ______% Sep-Nov ______%

What percentage of the total number of odour complaints are the result of activities in the following sectors. (Out of a total of 100%, ssign the correct fraction of the total to each category).

Agriculture ______% Industry ______% Sewage/waste ______% Others ______%

Of all those odour complaints relating to the industrial sector, indicate any of the following activities which have given rise to mplaint. (tick the appropriate boxes)

☐ Animal by-products ☐ Fish based industries

☐ Livestock farming (intensive) ☐ Food processing

☐ Brewery/Distilling ☐ Pharmaceutical/Chemical

☐ Foundries/Metal processing ☐ Paint/Varnish/Adhesive

☐ Plastics ☐ Other (specify)____________

When compared with 5 years ago, estimate what change their has been in the number of odour complaints received per year. (tick ıe box only)

a. An increase of	☐ *0-50%*	☐ *50-100%*	☐ *100-200%*	☐ *>200%*
a. A decrease of	☐ *0-50%*	☐ *50-100%*	☐ *100-200%*	☐ *>200%*
c. No change	☐			

HE EXTENT OF THE PROBLEM IN 1993

'he following questions 8 - 13 address only your councils experiences in the year 1993)

What was the total number of complaints relating to odour nuisance received by your council last year.

☐	☐	☐	☐	☐	☐
None	*1-3*	*4-10*	*11-20*	*21-40*	*>40*

Where a certain industry or activity is giving rise to odour nuisance, it will often be the subject of repeated complaints by a relatively ıall number of people. Of the total number of complaints received last year, how many different facilities did they relate too.

☐	☐	☐	☐
None	*1-3*	*4-10*	*>10*

). Section 24 (1) of the Air Pollution Act requires to the use of BPM. How many advice/warnings did your council issue last year, and ɔw many involved a problem with odours.

a. Total ____________________

b. Number involving odour _______

'. Section 24 (2) of the Air Pollution Act prohibits emissions that would cause a nuisance. How many advice/warnings did your council sue last year, and how many involved a problem with odours.

a. Total ____________________

b. Number involving odour _______

'. Section 26 of the Air Pollution Act empowers a local authority to require measures to be taken to prevent air pollution. How many tices did your council serve last year and how many involved a problem with odours.

a. Total ____________________

b. Number involving odour _______

. How many times last year did your council take court action against an offending facility for the purpose of reducing air pollution, d how many involved a problem with odours.

a. Total ____________________

b. Number involving odour _______

LFACTOMETRY AND THE CONTROL OF ODOUR NUISANCE

lfactometry is the method of measuring odours. The most common approach uses a panel human assessors to evaluate the strength an odorous gas. It allows an emission from a particular source to be assigned an odour concentration.

. When dealing with odour problems, has your council, or has a plaintiff at the behest of your council, ever employed the services of e following:

a. A specialist consultant in odour control

☐ Yes ☐ No

b. Odour measurement techniques

☐ Yes ☐ No

. Odour measurement can be used to evaluate the odour content of gases entering and leaving an abatement system, and thus evaluate removal efficiency. How valuable does your council consider the use of such techniques in the assessment of BPM.

☐ Very useful ☐ Useful ☐ No use ☐ No opinion

. Odour measurement combined with air dispersion modelling can predict the impact that a particular plant has on the surrounding cality. Thereby, a judgement can be made as to whether a nuisance is likely to occur. How valuable does your council consider the e of such techniques.

☐ Very useful ☐ Useful ☐ No use ☐ No opinion

. Data from existing sites, combined with air dispersion modelling, can predict the environmental impact of a proposed development ch as a sewage treatment plant or a landfill. How valuable does your council consider the use of such techniques.

☐ Very useful ☐ Useful ☐ No use ☐ No opinion

. Current air pollution legislation sets an Air Quality Standard (AQS) for Smoke/Dust. This fixes limit concentrations which should not exceeded in ambient air and specifies the methods by which the Smoke/Dust levels should be measured. Where an AQS is being or likely to be exceeded, the local Authority is required to take appropriate steps to secure compliance with the limit. Does your council lieve that a similar approach to odour control would assist in the prevention of odour nuisance.

☐ Yes ☐ No ☐ No opinion

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ank you very much for your patience and cooperation in carrying out this survey. If you wish to make further comments please do so the reverse side of the page.

APPENDIX B

Tabulated results of Local Authority responses on a county by county basis.

TABLE B.1

County Identification	Q1 Records kept ?		Q2 Propensity to cause nuisance (Rate 1 to 5 in decreasing order of importance)					Q3 Average number of complaints per year (indicate one of the following ranges)						Q4 Seasonal trends in odour complaints (out of a total of 100%, divide appropriately)			
	Yes	NO	Noise	Odour	Sewage	Smoke	Water S	None	1-3	4-10	11-20	21-40	>40	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
Carlow		1							1					25	25	25	25
Cavan	1		5	4	2	3	1			1				10	25	50	15
Clare	1		5	4	2	3	1			1				50	10	30	10
Cork Co. Co.	1		2	1	5	3	4						1	25	25	25	25
Cork Co. Boro																	
Donegal	1										1			17	17	50	17
Dublin (Fingal & South Dublin)																	
Dublin (Dunlaoghaire/Rathdown)																	
Dublin Corp.	1		2	3		1						1		10	20	50	20
Galway											1			70	10	10	10
Galway Corp.																	
Kerry	1									1							
Kildare	1		3	4	5	2	1				1			10	40	40	10
Kilkenny	1		5	3	2	4	1					1		15	35	15	35
Laois	1		5	3	1	4	2			1				25	25	25	25
Leitrim		1	4	3	2	5	1		1					10	40	40	10
Limerick	1		5	4	1	3	2			1				25	25	25	25
Limerick Corp.	1		4	5	1	3	2			1				25	25	40	10
Longford		1	2	1	3	4	5			1							
Louth																	
Mayo	1									1				25	25	25	25
Meath	1		3	2	4	5	1				1			5	40	55	0
Monaghan																	
Offaly	1		5	4	3	2	1			1				5	10	75	10
Roscommon	1								1					25	25	25	25
Sligo		1								1				10	10	70	10
Tipperary NR																	
Tipperary SR	1		3	2	4	5	1			1				10	40	40	10
Waterford		1	5	2	4	3	1				1			15	50	15	20
Waterford Co. Boro	1		5	4	1	2	3			1				20	30	30	20
Westmeath	1		4	2	3	1	5		1					25	25	25	25
Wexford	1									1				0	5	90	5
Wicklow	1		5	3	1	4	2				1						

TABLE B.2

County Identification	Q5 Sectoral variation of complaints (out of a total of 100%, divide appropriately)				Q6 Industries that have caused odours (indicate any of the following)									
	Agriculture	Industry	Sewage/ waste	Others	Animal Byproducts	Livestock farming	Brewing/ Distilling	Foundry/ Metals	Plastics	Fishbased	Food processing	Pharm/ chemical	Paint/varnish /adhesives	Others (specify)
Carlow	50	50									1			
Cavan	30	40	25	5	1	1		1			1	1		
Clare	9	60	20	11					1			1		refuse
Cork Co. Co.	15	50	10	25	1	1	1	1	1		1	1	1	
Cork Co. Boro														
Donegal	5	90	5	0	1	1				1		1	1	Textile
Dublin (Fingal & South Dublin)					1	1		1	1		1	1	1	
Dublin (Dunlaoghaire/ Rathdown)														
Dublin Corp.	0	40	0	60			1		1		1		1	Printing
Galway	90	10			1	1				1	1			
Galway Corp.														
Kerry	95	4	0	1							1	1		
Kildare	60	15	25	0	1	1			1		1		1	
Kilkenny	70	15	14	1	1	1					1	1	1	Tarmac
Laois	50	45	5	0	1								1	
Leitrim	0	100	0	0										Maggots
Limerick	50	25	25	0	1	1		1			1		1	
Limerick Corp.	0	40	40	20	1					1				Rubber
Longford	60	20	30	0	1	1								
Louth														
Mayo	20	80	0	0	1	1				1				
Meath	50	40	5	5	1	1					1	1	1	
Monaghan														
Offaly	70	20	5	5	1	1					1	1		
Roscommon	33	33	33	0							1			
Sligo	70	30	0	0					1				1	Rubber
Tipperary NR														
Tipperary SR	50	50	0	0										
Waterford	90	8	1	1	1									
Waterford Co. Boro	10	80	10	0	1	1		1				1	1	
Westmeath	25	50	15	10	1	1			1	1				
Wexford	95	5	0	0										Cotton
Wicklow	50	20	20	10	1	1				1	1	1		Gas btls

TABLE B.3

County identification	Q7 Percentage change in number of complaints over the last 5 years	Q8 Number of complaints last year; 1993 (indicate one of the following ranges)						Q9 Number of different facilities that the complaints related to. (indicate one of the following ranges)			
	No change	None	1-3	4-10	11-20	21-40	>40	None	1-3	4-10	>10
Carlow	none		1						1		
Cavan	up 0-50%			1						1	
Clare	none			1						1	
Cork Co. Co.							1			1	
Cork Co. Boro											
Donegal					1				1		
Dublin (Fingal & South Dublin)											
Dublin (Dunlaoghaire/Rathdown)											
Dublin Corp.						1					1
Galway					1				1		
Galway Corp.											
Kerry	none			1					1		
Kildare	up >200%					1					1
Kilkenny	none					1					1
Laois	up 50-100%			1					1		
Leitrim	none		1						1		
Limerick	up 50-100%			1						1	
Limerick Corp.	up 50-100%			1						1	
Longford											
Louth											
Mayo	none			1					1		
Meath	up 100-200%				1				1		
Monaghan											
Offaly	up 50-100%			1						1	
Roscommon	none		1						1		
Sligo				1					1		
Tipperary NR											
Tipperary SR	up >200%			1					1		
Waterford	up 100-200%					1				1	
Waterford Co. Boro	up 0-5-%								1		
Westmeath	down 0-50%			1						1	
Wexford	none			1						1	
Wicklow	up 50-100%					1				1	

TABLE B.4

County identification	Q10 APA section 24(1) requires the use of BPM. The number of advice/warnings issued in 1993 (total and odour related)		Q11 APA section 24(2) prohibits emissions that would cause nuisance. The number of advice/warnings issued in 1993 (total and odour related)		Q12 APA section 26 empowers Loc. Auth. to require measures to be taken to prevent air pollution. The number of notices issued in 1993 (total and odour related)		Q13 The number of times court action was taken to prevent air pollution. (total and odour related)	
	Total	Odour related	Total	Odour related	Total	Odour related	Total	Odour related
Carlow	0	0	3	3	1	0	1	0
Cavan	0	0	4	3	0	0	0	0
Clare	0	0	0	0	0	0	0	0
Cork Co. Co.	5	3	5	5	3	0	0	0
Cork Co. Boro								
Donegal	0	0	0	0	1	1	1	1
Dublin (Fingal & South Dublin)								
Dublin (Dunlaoghaire/Rathdown)								
Dublin Corp.	114	15	114	15	16	5	0	0
Galway	0	0	0	0	0	0	0	0
Galway Corp.								
Kerry								
Kildare								
Kilkenny	6	2	23	10	0	0	0	0
Laois	1	1	1	1	0	0	0	0
Leitrim	0	0	0	0	1	1	0	0
Limerick	3	1	11	5	0	0	0	0
Limerick Corp.	16	4	16	4	0	0	0	0
Longford	0	0	0	0	0	0	0	0
Louth								
Mayo	1	1	0	0	0	0	0	0
Meath	10	7	10	8	12	9	0	0
Monaghan								
Offaly	1	0	5	3	0	0	0	0
Roscommon	0	0	0	0	0	0	0	0
Sligo	0	0	0	0	0	0	0	0
Tipperary NR								
Tipperary SR								
Waterford	0	0	6	0	0	0	1	0
Waterford Co. Boro	2	2	2	2	2	2	0	0
Westmeath	3	1	2	1	2	0	0	0
Wexford	4	3	0	0	1	1	0	0
Wicklow	4	4	5	4	4	1	2	1

TABLE B.5

County identification	Q14a Have employed a specialist in odour control in the past		Q14b Have employed odour measurement techniques in the past		Q15 Perceived value of olfactometry for measuring the removal efficiency of abatement systems and the assessment of BPM				Q16 Perceived value of olfactometry combined with dispersion modeling to predict the impact of a facility on the surrounding locality.				Q17 Perceived value of odour data from existing sites combined with dispersion modelling to predict the impact of a proposed development (eg sewage plant or landfill).				Q18 That a similar approach to that adopted for smoke/dust (ie air quality stds) would assist in the control of odour		
	Yes	No	Yes	No	Very useful	Useful	No use	No opinion	Very useful	Useful	No use	No opinion	Very useful	Useful	No use	No opinion	Yes	No	No opinion
Carlow								1	1					1					1
Cavan		1		1				1		1				1			1		
Clare		1		1				1				1				1			1
Cork Co. Co.	1		1			1			1				1					1	
Cork Co. Boro																			
Donegal					1				1				1				1		
Dublin (Fingal & South Dublin)	1		1					1		1				1				1	
Dublin (Dunlaoghaire/Rathdown)																			
Dublin Corp.		1		1		1				1				1				1	
Galway		1		1		1				1				1			1		
Galway Corp.																			
Kerry		1		1		1				1				1			1		
Kildare	1		1		1				1				1						
Kilkenny	1		1			1				1			1					1	
Laois	1			1		1				1				1					1
Leitrim		1		1		1				1				1				1	
Limerick		1		1		1			1					1				1	
Limerick Corp.	1		1				1			1				1				1	
Longford	1		1			1				1				1			1		
Louth																			
Mayo	1			1				1		1				1				1	
Meath		1		1		1				1				1					1
Monaghan																			
Offaly		1		1		1				1				1			1		
Roscommon		1		1				1											
Sligo		1		1	1					1									
Tipperary NR																			
Tipperary SR	1		1															1	
Waterford		1		1		1				1				1				1	
Waterford Co. Boro		1	1			1				1				1					
Westmeath	1		1			1			1				1						1
Wexford		1		1		1				1				1					1
Wicklow	1			1		1			1					1					1