Appendix 5

Odour Impact Assessment Report

ODOUR monitoring IRELAND

ODOUR & ENVIRONMENTAL ENGINEERING CONSULTANTS

Unit 32 De Granville Court, Dublin Rd, Trim, Co. Meath

Tel: +353 46 9437922
Mobile: +353 86 8550401
E-mail: info@odourireland.com
www.odourireland.com

DESKTOP ODOUR IMPACT ASSESSMENT OF THE CURRENT AND PROPOSED ORGANIC GOLD MARKETING LTD COMPOSTING LOCATED IN WILKINSTOWN, NAVAN, CO. MEATH.

PREPARED BY:	Dr. Brian Sheridan
ATTENTION:	Ms. Lorraine Herity
DATE:	12th January 2005
REPORT NUMBER:	2004.A151
DOCUMENT VERSION:	Draft Document Ver. 005
REVIEWERS:	Mr. Conrad Wilson & Ms. Lorraine Herity

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Odour Monitoring Ireland was commissioned by RPS MCOS Ltd to carry out an odour impact assessment of the current and proposed composting operations located at Organic Gold Marketing Ltd, Wilkinstown, Co Meath. The purpose of this assessment was to determine the potential for the generation of odour impact on the surrounding vicinity. Potential odour sources were identified from consultation with Organic Gold Marketing Ltd and RPS MCOS Ltd and were used to construct the bases of the modelling assessment. Odour emission rates were calculated from library based olfactometry data. Dispersion modelling using ISC ST3 was used to identify the odour impact area of the process and the effects of proposed odour abatement/minimisation strategies. A worst-case meteorological year and worst-case odour emission data was used to predict any potential odour impact in the vicinity of the proposed waste facility. Odour impact potential was discussed for the current and future operation of the composting process. The following conclusions were drawn:

1. It is predicted that minor odour impact will be perceived in the vicinity of the current facility while the odour misting system is in operation when utilising dispersion model ISC ST3. Five residents and one shop will perceive an odour concentration of between 3.0 and 6.0 Ou_E m^{-3} at the 98th percentile in a worst-case meteorological year. All other residents/shops/pubs will perceive an odour concentration less than 3.0 Ou_E m^{-3}. Odour complaints were received about the current operating facility following operational changes such as input product (i.e. addition of gypsum) to the windrows. No recorded complaints were received about the facility when operated in accordance with the proposed operation. It is therefore suggested that an odour impact criterion of 3.0 Ou_E m^{-3} should be suitable for the current and future operating facility.
2. It is predicted that following the implementation of proposed odour minimisation/abatement techniques (i.e. indoor waste acceptance, mixing, in-vessel first stage composting, and mist scrubbing system) odour plume spread is similar to current operations with all residences perceiving an odour concentration of less than 6.0 Ou_E m^{-3} at the 98th percentile In accordance with the odour impact criterion established in *Section 1.7.2*, there some odour impact may be perceived in the vicinity of the facility during meteorological conditions that do not favour odour dispersion. Organic Gold Marketing Ltd will install a biofiltration system if such odour impact occurs.

It was recommended:

1. Ensure a clear and concise odour management plan is developed for the site so as to eliminate any significant odour emissions events,
2. It is suggested that if significant complaints are received about the facility, the sources of odours are characterised and if suitable a biofilter should be installed to eliminate odour complaints.
3. The turning of windrows should maintain appropriate conditions within the composting matrix (i.e. oxygen, moisture and evenly distributed nutrients) and windrows turning should be performed in appropriate meteorological conditions (i.e. unstable, higher wind speeds, clear sky).

4. A closed-door strategy should be incorporated upon the operation of the indoor facility. The specific details are discussed within the document in detail. These doors (rapid roller) should be alarmed to prevent operators from opening for long periods of time. Additionally the surface area of the door open area should be reduced by using flexible heavy-duty plastic curtains. Strict management practices will be required within this building to prevent significant puff odour emissions.
5. Other recommendations are made through the document.

1. Introduction

Like the majority of industrial and processing facilities, the operations of Organic Gold Marketing Ltd located in Wilkinstown, Co. Meath is faced with the issue of preventing odours causing impact to the public at large. The current operations use conventional composting techniques to process solid waste and sludge. In future proposed composting system a new improved in-vessel composting facility will be used at the site for more rapid decomposition of waste material. This odour impact assessment assesses the likely odour impacts associated with those processes located outdoors namely the windrows composting operation. Utilising odour emission data and atmospheric dispersion modelling techniques, the predicted overall odour impact of the current and future outdoor operations can be determined. The key odour impact sources are identified and assessed. Standard library odour emission rates were used for the composting operations. Contours of odour concentrations for the 98th percentile are predicted around the current and future composting operations in order to examine the extent of any odour impact and the effectiveness of utilised and considered odour minimisation/abatement protocols. It is predicted that during current operation, some residences in the vicinity of the composting operations will perceive an odour concentration of between 3.0 and 6.0 Ou_E for less than 175 hours (i.e. 98th percentile) in a worst-case meteorological year for ISC ST3 dispersion models, respectively. Some intermittent complaints may be generated but since the facility is located in an agricultural area, residents are not as sensitive. The proposed future operation should not generate significant odour complaints from local residences with all residences/pubs/shops perceiving and odour concentration of less than 6.0 Ou_E m^{-3} at the 98th percentile. Strict odour management plans will need to be implemented upon the current and future operating site. These are discussed within the document in detail.

1.1 What is an odour unit?

The odour concentration of a gaseous sample of odourant is determined by presenting a panel of selected screened human panellists with a sample of odourous air and varying the concentration by diluting with odourless gas, in order to determine the dilution factor at the 50% detection threshold. The Z_{50} value (threshold concentration) is expressed in European odour units ($Ou_E\ m^{-3}$).

Although odour concentration is a dimensionless number, by analogy, it is expressed as a concentration in odour units per cubic metre ($Ou_E\ m^{-3}$), a term which simplifies the calculation of odour emission rate. The European odour unit is that amount of odourant(s) that, when evaporated into one cubic metre of neutral gas (nitrogen), at standard conditions elicits a physiological response from a panel (detection threshold) equivalent to that elicited by one European Reference Odour Mass (EROM) evaporated in one cubic meter of neutral gas at standard conditions. One EROM is that mass of a substance (*n*-butanol) that will elicit the Z_{50} physiological response assessed by an odour panel in accordance with this standard. *n*-Butanol is one such reference standard and is equivalent to 123ug of *n*-butanol evaporated in one cubic meter of neutral gas at standard conditions (CEN, 2003).

1.2 Characterisation of Odour

The sense of smell plays an important role in human comfort. The sensation of smell is individual and unique to each human and varies with the physical condition of the person, the odour emission conditions and the individual's odourous education or memory. The smell reaction is the result of a stimulus created by the olfactory bulb located in the upper nasal passage. When the nasal passage comes in contact with the odourous molecules, signals are sent via the nerve fibres where the odour impressions are created and compared with stored memories referring to individual perceptions and social values. Since the smell is individual, some people will be hypersensitive and some will be less sensitive (ansomia). Therefore, the sense of smell is the most useful detection technique available as it specialises in synthesising complex gas mixtures rather than analysing the chemical compound (Sheridan, 2000).

1.3 Odour Qualities

An odour sensation consists of a number of inter-linked factors. These include:

- Odour threshold/concentration
- Odour intensity
- Hedonic tone
- Quality/Characteristics

- Component characteristics

The odour threshold concentration dictates the concentration of the odour in $Ou_E\ m^{-3}$. The odour intensity dictates the strength of the odour. The Hedonic quality allows for the determination of pleasantness/unpleasantness. Odour quality/characteristics allow for the comparison of the odour to a known smell (i.e. like dead fish, turnip, flowers). Individual chemical component identity determines the individual chemical components that constitute the odour (i.e. hydrogen sulphide, benzoic acid, benzyl aldehyde). Once odour qualities are determined, the overall odour impact can be assessed.

1.4 Perception of emitted odours

Complaints are the primary indicator that odours are a problem in the vicinity of any facility. Perceptions of odours vary from person to person, each with their own individual fingerprint. Several conditions govern a person's perception of odour:

- **Control:** A person is better able to cope with an odour if they feel it can be controlled.
- **Understanding:** A person can better tolerate an odour impact if they understand its source.
- **Context:** A person reacts to the context of an odour as much as we do to the odour itself.
- **Exposure:** When a person is constantly exposed to an odour they may lose their ability to detect that odour. For example, a plant operator who works in the facility may grow immune to the odour.

From these criteria, we can predict that odour complaints are more likely to occur when:

- A new facility locates in areas where people are unfamiliar with facilities;
- When a new process establishes within the facility;
- Or when an urban population encroaches on an existing facility.

The ability to characterise odours being emitted from the facility will help to develop a better understanding of the impact of the odour on the surrounding vicinity. It will also help to implement and develop better techniques to abate odours using existing technologies and engineering design.

1.5 Characteristics of composting odours

Odours from composting arise mainly from the uncontrolled anaerobic biodegradation of proteins and carbohydrates to produce unstable intermediates. Other odours come directly from accepted septic materials and bad handling/management practices. Odours are generated by a number of different components, the most significant being the sulphur containing compounds (thiols, mercaptans, hydrogen sulphide), volatile fatty acids (butyric acid, valeric acid), amines (methylamine, Dimethylamine), phenols (4-methylphenol), etc. (Dawson et al. 1997). Most of these compounds have very low odour threshold concentrations as illustrated in *Table 1.1*. Different concentrations and mixtures of these compounds can intensify or reduce odour threshold concentration, determined as synergism and antagonism respectively.

Table 1.1. Odour detection thresholds of composting odour precursors.

Chemical component	Threshold Concentration (mg m^{-3})
Ammonia	0.03-37.8
Methylamine	0.0012-6.1
Trimethylamine	0.00026-2.1
Hydrogen Sulphide	0.001-0.27
Methyl mercaptan	0.0000003-0.038
Ethyl mercaptan	0.000043-0.00033
Butyric acid	0.0004-42
Valeric acid	0.0008-0.12

O'Neill & Phillips et al. (1992)

1.6 Odour emissions formation from composting operations

The rate of release of odourous compounds into the atmosphere at composting operations is influenced by:

1. Long residence time of accepted input product in containers and on-site;
2. Temperature of accepted raw materials (increased temperature causes increased anaerobic conditions and volatilisation of odourous compounds);
3. The concentration of odourous compounds in the solid phase exposed to air and exposed surface area;
4. Processes that generate turbulence like mixing processes;
5. Excess moisture;
6. Incorrect Carbon:Nitrogen ratio;
7. Maintenance of oxygen rich levels within the composting operations;
8. Tipping, screening and shredding of raw materials;
9. Non-homogenous aeration and mixing;
10. Inappropriate storage of finished material;
11. This is a non-exhaustive list.

Raw materials for composting can be odourous due to the development of anaerobic zones within the input material. When this raw material is disturbed through tipping, mixing and shredding/mixing operations, pockets of odourous air are released. Inappropriate storage of raw material such as in wet environments can lead to the rapid development of anaerobic material resulting in odourous release. It is important that basic odour management plans are implemented for site operation to prevent such situations from occurring (i.e. get raw material into the process as soon as possible, maintain raw material under enclosed dry area; avoid acceptance of severely septic raw material). These scenarios should be covered within the acceptance procedure documentation developed for the site.

1.7 Atmospheric dispersion modelling of odours: What is dispersion modelling?

Any material discharged into the atmosphere is carried along by the wind and diluted by wind turbulence, which is always present in the atmosphere. This process has the effect of producing a plume of air that is roughly cone shaped with the apex towards the source and can be mathematically described by the Gaussian equation. Atmospheric dispersion modelling has been applied to the assessment and control of odours for many years, originally using Gaussian form ISCST 3 and more recently utilising advanced boundary-layer physics models such as ADMS and AERMOD (Keddie et al. 1992). Once the odour emission rate from the source is known, (Ou_E s^{-1}), the impact on the vicinity can be estimated. These models can effectively be used in three different ways: firstly, to assess the dispersion of odours and to correlate with complaints; secondly, in a "reverse" mode, to estimate the maximum odour emissions which can be permitted from a site in order to prevent odour complaints occurring; and thirdly, to determine which process is contributing greatest to the odour impact and estimate the amount of required abatement to reduce this impact within acceptable levels (McIntyre et al. 2000). In this latter mode, models have been employed for imposing emission limits on industrial processes, odour control systems and intensive agricultural processes (Sheridan et al., 2002).

1.7.1 Industrial Source Complex 3 (ISC ST3).

The model used is BREEZE Industrial Source Complex version 3. This model is recommended in the Environmental Protection Agency (EPA) guideline on Air Quality Modelling for applications to refinery-like sources and other industrial sources. It is a straight-line trajectory, Gaussian-based model. It was also recently recommended (Complex 1 section) by the Irish EPA to model the potential odour impact from intensive agriculture, mushroom composting and tannery facilities (EPA, 2002). It is used with meteorological input data from the nearest representative source. The most important parameters needed in the meteorological data are wind speed, wind direction, ceiling heights, cloud cover, and Pasquill-Gifford stability class for each hour. ISC ST 3 is run with a sequence of hourly meteorological conditions to predict concentrations at receptors for averaging times of one hour up to a year. It is necessary to use many years of hourly data to develop a better understanding of the statistics of calculated short-term hourly peaks or of longer time averages.

1.7.2 Establishment of odour impact criterion for proposed facility.

Odours from composting operations arise mainly from the volatilisation of odourous compounds generated from non-quiescence processes (i.e. waste tipping and mixing operations, etc). Most of the compounds emitted are characterised by their high odour intensity and ease of detection. Odour impact criteria have been developed for composting odours. A sample of a report carried out in the Netherlands ranking 20 generic and 20 environmental odours according to their like or dislike by a group of people professionally involved in odour management is illustrated in *Table 1.2* (EPA, 2002). This allowed for the establishment of odour impact criterion based on the odours specific hedonic tone characteristics.

Table 1.2. Sample of report ranking 20 environmental odours according to like and dislike (i.e. odour character).

Environmental Odours	Mean Ranking
Intensive agricultural farm	12.8 (Limit value 6.0 $Ou_E\ m^{-3}$)
Waste water treatment plant	12.9 (Limit value 3.5 $Ou_E\ m^{-3}$)
Green fraction composting	14.0 (Limit value 3.0 $Ou_E\ m^{-3}$)
Landfill	14.1 (Limit value 3.18 $Ou\ m^{-3}$)
Abattoir/Slaughterhouse	17.0 (Limit value 1.5 $Ou_E\ m^{-3}$)

As can be observed, landfill odours are 8.5% more dislikeable than intensive agricultural odours and wastewater treatment odours and 20% more likeable than Abattoir/Slaughterhouse odours (see *Table 1.2*). Green fraction composting and landfill odours are similar in their dislike ability and therefore it is rational to suggest that a similar odour impact criterion may be used based on these facts. Selection of odour impact criterion can be illustrated through the mean ranking system (i.e. 1.5 $Ou_E\ m^{-3}$ for Abattoir/slaughterhouse odours with a mean ranking of 17 (very dislikeable) to 3.0 $Ou_E\ m^{-3}$ for green fraction composting odour with a mean ranking of 14 (more likeable)).

Commonly used odour annoyance criteria in Ireland, UK and Netherlands are illustrated in *Table 1.3*. Generally, odour concentrations should be below 6 $Ou_E\ m^{-3}$ for 98^{th} percentile in order to prevent complaints arising from existing intensive pig facilities in Ireland. In Holland odour concentrations should be below 3.0 $Ou_E\ m^{-3}$ for the 98^{th} percentile for existing composting facilities. Through extensive intensity relationship studies, an odour impact criterion of 3.0 $Ou_E\ m^{-3}$ was established for the assessment of the proposed extension of Boghborough landfill, London.

Table 1.3. Odour annoyance criteria for dispersion modelling.

Concentration Limit $Ou_E\ m^{-3}$	Percentile value %	Application
Dutch (MPTER and Complex 1 Model)		
≤3.0	98^{th}	Composting facility existing site, rural area or industrial estate.
English (ADMS model)		
≤5	98^{th}	Waste water treatment works Greenfield site,
≤10		Existing WWTP Industrial estate in vicinity
Ireland (ISC ST Complex 1 section)		
≤6.0	98^{th}	Expected level to be achieved by all intensive pig production facilities
≤3.0	98^{th}	Target level to be achieved by all intensive pig production facilities and mushroom compost industry
Germany		
≤4		Waste water treatment works, level at which odour nuisance experienced Frechen (1995).
UK		
≤3.18	98^{th}	Landfill odour impact criterion whereby odour become faint and non-offensive

(McIntyre et al. 2000; EPA, 2002; Longhurst et al. 1998)

If we accept that an odour threshold concentration of 1 $Ou_E\ m^{-3}$ is the level at which an odour is detectable by 50% of the screened panellists. According to research on wastewater treatment works, the odour recognition threshold is approximately 3-5 times this concentration and is liable to cause offence (3-5 $Ou_E\ m^{-3}$). An odour impact criterion of ≤ 5 $Ou_E\ m^{-3}$ is implemented in England for wastewater treatment works (DOE, 1993) and is accepted in planning applications for these facilities to limit odour impact (McIntyre et al., 2000) but this was established with the ADMS software package.

As odours from compost facilities are considered more hedonically unpleasant than odour from intensive agricultural facilities, it would be more prudent to limit the possibilities of odour impact and apply an odour impact criterion of ≤ 3 Ou_E m^{-3}.

The current composting operation is operated outdoors (i.e. waste acceptance, mixing and windrows formation and composting). The future proposed composting operation will be divided into two processes namely indoors and outdoors. All waste acceptance, mixing and 2 week pre-composting will be performed indoors/in-vessel. All second stage composting will be performed outdoors. Second phase composting will be significantly less odourous than phase one composting.

Due to the fact that all phase 1 composting will be performed in an enclosed in-vessel composting system, which in accordance with the manufacturer guarantees will have no odour emissions, it is reasonable to propose an odour impact criterion of 3.0 Ou_E m^{-3} at the 98th percentile for the indoor mixing/blending process and phase 2 maturation process. Any odours emitted from the second phase composting will be greatly reduced in offensiveness potential due to the pre-composting stage carried out indoors. It is therefore reasonable to suggest an odour impact criterion of 3.0 Ou_E m^{-3} at the 98th percentile for this process.

In accordance with the odour annoyance criterion above in *Table 1.3*, it is recommended that all residential dwellings should be located outside the ≤ 3.0 Ou_E m^{-3} contour for the 98th percentile for future operations in one meteorological year as determined by atmospheric dispersion modelling software. It is important to emphasise that the composting facility is surrounded by agricultural activities and hence residences in this area would generally be less sensitive than those residences located in villages/towns/cities. There have been some recorded complaints at the site over a period of time in the past, which were due to a change in operational procedures. These operational changes have since been corrected. Before this change, it is reported that no odour complaints were received. If tabulated data were available then this could be used to calibrate the dispersion model to the odour generation amount once the material-handling amount is known. This could be used to eliminate the use of worst-case estimates and refine the study precisely.

It is assumed

- That no septic raw material is accepted on-site so as to cause offensive odour emissions (i.e. treated sludge's should only be considered).
- Raw material is processed and placed within the in-vessel composting system within 24 hours.

- That no raw material is accepted upon site unless sufficient bulking material is on-site to mix with the raw material.
- That good odour management practices are incorporated into the overall running of the facility to prevent any significant odour emission occurring (i.e. limit the occurrence of non-quiescence conditions).
- Meteorological conditions (i.e. unstable, wind speed and wind direction) are considered when carrying out operations upon the site.
- Sufficient pre-composting is carried out to prevent the occurrence of offensive odours that are commonly encountered during composting.
- That the in-vessel composting system contributes no odour emissions to the overall site odour emissions.
- That pre-composting is carried out for at least 2 weeks.
- That the mist scrubbing system is operated continuously and all other proposed odour minimisation protocols discussed within this document are implemented.
- That a closed-door strategy is maintained upon the waste acceptance/mixing/blending building and that only one door is opened for a maximum of 15 minutes per hour.
- That heavy-duty plastic curtains are installed upon the inlet and outlet door of the waste acceptance/mixing/blending building to reduce open area.
- That if any odour impact occurs, a biofiltration system will be installed at the site.

1.8 Proposed methods, processes & Operating Procedures for Composting process

See *Section 5* of details of waste acceptance and waste processing of the proposed development.

1.9 Automated mist scrubbing system

Mist scrubbers are abatement processes that absorb odourous gases into and generally oxidise them within, the liquid phase (i.e. depending on solution used). Mist scrubbers depend on the contact between the odourous gas and small droplets of liquid solution. To achieve adequate contact, there must be sufficient surface area of the droplets, proximity of droplets to odourous gas molecules, and sufficient time for contact to occur. Once the odourous gas has been absorbed into or onto the individual droplets, the reaction liquid being used within the droplets proceed to oxidise or otherwise treat the odourous compounds. Mist particles can leave the reaction vessel either as condensate or within the outlet gas stream. Perhaps the single most important factor in mist system design and operation is the size of the individual droplets of the reaction solution. The typical range of particle sizes for mist systems in odour treatment applications is approximately 1 to 20μm while 20μm is favourable as too small of a droplet size can flash evaporate (Sheridan, 2002).

The nozzles for the application of atomising typically require higher pressure than normal spray nozzles, which provide droplets larger than 100μm in size. Atomizers using compressed air to shatter the reaction solution and produce particles in the order of 1 to 20μm or smaller are typically used in these mist systems but recent advances in nozzle technology do not require air assistance.

As these nozzles are so important to the operation it is advised that:

- The nozzles should be accessed easily for inspection;
- The nozzles should be removable since the orifices are small and may get clogged;
- Use softened water to prevent build up of scale and other materials;
- Filters need to be installed on the individual nozzles and on the tank supplying the reaction solution.

Blockages in the nozzles or in the lines will have the effect of increasing droplet size and therefore reduce the overall performance of the scrubber. The total surface area of reaction liquid droplets may be increased substantially by decreasing the size of droplets. For example decreasing the diameter of droplets from 100 to 50μm increases the effective surface area by a factor of 463%.

One method of producing a smaller droplet without increasing energy consumption involves the use of complex surfactant mixture (CSM). The addition of small amounts of soap to the spray liquid will lower the liquids surface tension, (Sheridan, 2002). Mist particles that impact on the sides of the ventilation chimneys or other surfaces essentially becomes falling film condensate which results in only limited contact with the foul air. Within a few seconds, the majority of particles impact on a wall and thus, are removed from the gas stream. For treatment to occur, the droplets must absorb gaseous components. If solution treatment within droplets does not occur or only occurs to a limited degree, the mist system may be acting primarily as an absorption system in which odourous compounds are absorbed into the condensate liquid and recycled into the system. This may provide adequate removal of odourants from the gas stream.

A mist scrubber may comprise of a number nozzles located on the boundary fence. The sprayers are attached to a tank containing the reaction solution. As the odour air passes through the mist, they are transferred from the gas to the liquid phase.

Mist scrubbing is space saving and advantageous especially in the case of high air flows with low odour concentrations. They are associated in most cases with high running costs. However, if there is only one complainant in the vicinity of a facility, the system can be linked to an on-site weather station and the mister only operates when the wind is blowing in the direction of the complainants dwelling (*Figure 1.1*).

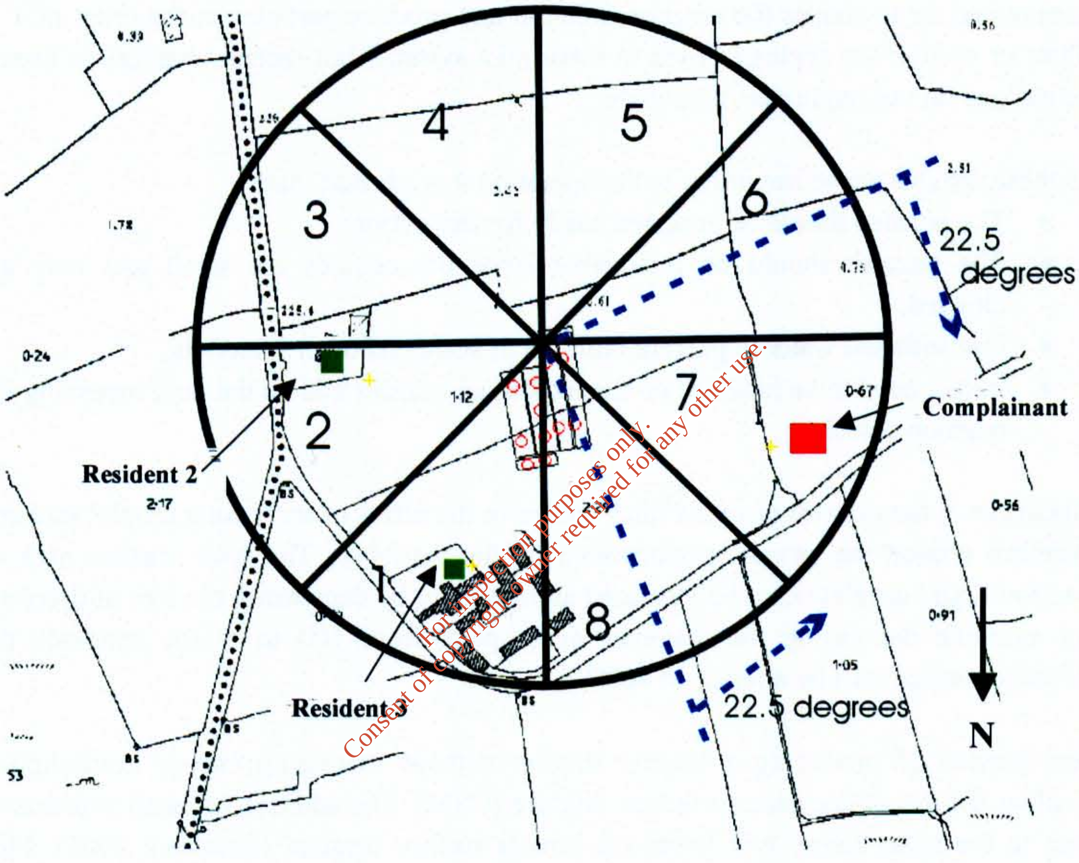

Figure 1.1. Schematic diagram of the operation of meteorological activated mist-scrubber.

The installation of a wind direction clock system on-site allows wind direction to be recorded. A signal line from the wind direction clock to the scrubber will serve to operate the scrubber at a pre-set wind direction (e.g. Sector 7, 270^0 to 315^0 relative to north in this case) and below wind speed (1.7 m s^{-1}) (*Figure 3.1*). To simplify, when the wind direction is between 270^0 to 315^0, the mister is activated. It is only de-activated when the wind direction deviates by 22.5^0 either side of 270^0 to 315^0. The automation of the scrubber ensures efficient control of emissions during potential odour causing episodes.

The connection of the mist scrubbing system to the wind direction clock also reduces reaction solution usage, which improves its overall running cost.

Various surfactants and odour neutralisers are available but it is important to choose a surfactant/neutraliser with a pleasant odour that complex with the odour source. For example, using a hedonically lemon/rosemary odour should complex with compost odours and therefore they should become less perceivable. As odours from the composting are generally acidic (i.e. organic acids), using a slight alkaline solution will allow for greater absorbance of these compounds and increase removal efficiency. Careful attention should be given to the alkaline solution chosen due to health and safety concerns. At 20% odour removal should be achieved from such a technology (Casey, 2001). The facility has already installed an odour misting system, which is located on the boundary wall.

1.10 Odourous compound formation in composting facilities

Odour generation from composting operations can occur at many stages of the overall process. These include:

- Raw material acceptance and type of material,
- Mixing of raw materials,
- Types of materials mixed and use to facilitate heat generation (i.e. gypsum can lead to the formation of H_2S, methyl mercaptan and dimethyl sulphide through oxidation and reduction of excess sulphates),
- Turner type and turning frequency,
- Maintaining pre-compost in aerobic conditions and maintaining correct C:N ratio,
- Handling of leachate.

1.11 General rules for reduction of odour emissions from Composting operation by design.

- Ensure that relatively non-septic raw material is accepted into the facility,
- Utilise raw materials within 24 hours and eliminate excess water within raw materials as anaerobic conditions will prevail quickly,
- Accept relatively stable sludge,
- Avoid the use of gypsum for heat generation if possible as excess sulphates will generate mercaptans, hydrogen sulphide and sulphides,
- Carry out mixing indoors if possible,
- Avoid turbulent conditions and excess handling during windrows formation;
- Maintain windrow and pre-composting materials at correct moisture content, oxygen, nutrients and C:N ratio to avoid formation of anaerobic conditions and formation of odourous side products,

- Apply recycled leachate in appropriate manner and avoid conditions that facilitate large inter facial area with recycled liquor (i.e. spraying leachate upon windrows using splash plate or other such techniques) The recycled leachate should be applied evenly and in close proximity to the windrows,
- Ensure clear and concise odour management plans are produced for plant operation and abatement systems (i.e. system operation and maintenance) (Sheridan, 1998, 2000, 2002). These should be integrated into any existing environmental management system where applicable.

2. Materials and methods

2.1 Site

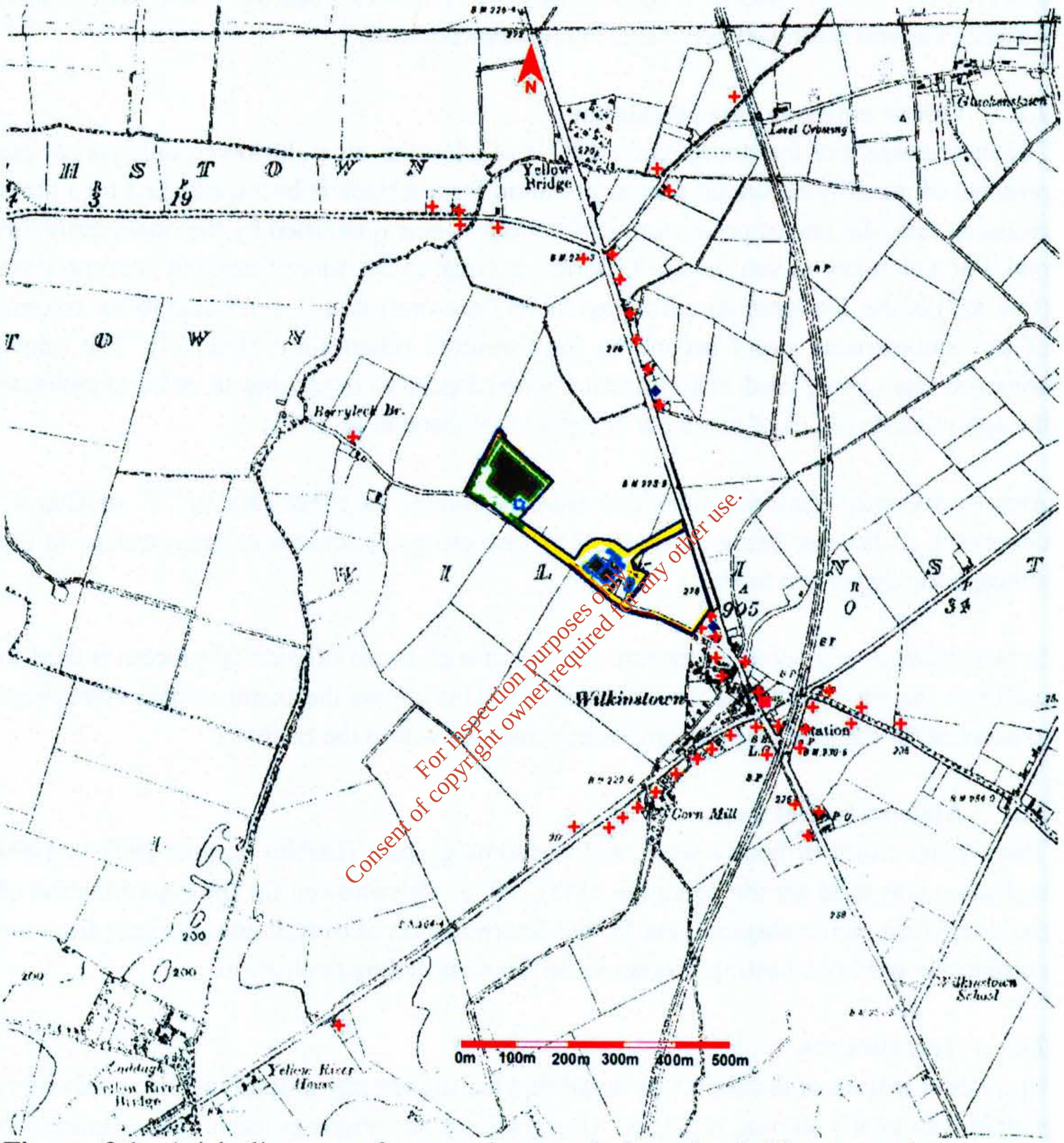

Figure 2.1. Arial diagram of current/proposed Organic Gold composting process, proposed boundary (▬), residents (×) school (□) shops (♦).

The different distances and directions that the current/proposed composting operation is located from the neighbouring dwellings are represented in *Figure 2.1*. As can be observed the closest resident is approximately 270 metres from the windrows compost surface in a west north-westerly direction (meteorologically).

2.2 Odour emission rate calculation.

The measurement of the strength of a sample of odourous air is, however, only part of the problem of quantifying odour. Just as pollution from a stack is best quantified by a mass emission rate, the rate of production of an odour is best quantified by the odour emission rate. For a chimney or ventilation stack, this is equal to the odour threshold concentration ($Ou_E\ m^{-3}$) of the discharge air multiplied by its flow-rate ($m^3\ s^{-1}$). It is equal to the volume of air contaminated every second to the threshold odour limit ($Ou_E\ s^{-1}$). The odour emission rate can be used in conjunction with dispersion modelling in order to estimate the approximate radius of impact or complaint (Hobson et al, 1995).

Area source mass emission rates/flux were calculated as either $Ou_E\ m^{-2}\ s^{-1}$ or $Ou_E\ s^{-1}$ depending if they are being represented as discrete point sources or area sources in the atmospheric dispersion model.

In this situation, the odour generation amount of each tonne of material process is used to calculate the site-specific odour emission rate. This allows the odour impact assessment to account for the handling and processing amounts within the facility.

2.3 Meteorological data.

Three years worth of hourly sequential meteorology data (Dublin Airport 1997 to 1999 inclusive) was used for the operation of ISC ST 3. This allowed for the determination of the worst-case meteorological year for the determination of overall odour impact from the current/proposed composting operations on the surrounding population.

2.4 Terrain data.

Upon examination of terrain it was noted that the topography around the proposed site is simple with gently sloping contours. All significant deviations in terrain are examined in modelling computations through terrain incorporation using AerMap software. All building wake effects are accounted for in the modelling scenarios (i.e. building effects on point (diffuse) sources) as this can have a significant effect on the odour plume dispersion at short distances. All high walls around the facility are treated as a building source. Residents in the vicinity of the facility are enabled as flagpole receptors at a height of 1.8 metres (i.e. normal breathing height).

3. Results

3.1 Odour emission data

Four data sets for odour emission rate were used to determine the potential odour impact of the current/proposed composting operation and design utilising the individual source odour emission data in *Table 3.1*. This scenario included:

1. Predicted overall odour emission rate from current composting operations (Scenario 1) (*Table 3.2*).
2. Predicted overall odour emission rate from current composting operations following implementation of existing odour misting system (Scenario 2) (*Table 3.3*).
3. Predicted overall odour emission rate from proposed indoor/in-vessel composting operations and outdoor second phase windrows maturation (Scenario 3) (*Table 3.4*).
4. Predicted overall odour emission rate from proposed indoor/in-vessel composting operations, outdoor second phase windrows maturation and implementation of existing odour misting system (Scenario 4) (*Table 3.5*).

A worst case odour-modelling scenario was chosen to estimate worst-case odour impact from the current/proposed Organic Gold Marketing Ltd operations.

3.2 Odour emission rates from overall composting processes during operation.

Table 3.1 illustrates the specific odour emission per unit tonne processed used to determine an overall odour emission rate (Ou s^{-1}) from the current/proposed operations. Each odour source emission factor is presented as an emission per unit tonne of material processed (Ou s^{-1} $tonne^{-1}$) Tonnage amount is used as the multiplying factor.

Table 3.1. Odour emission rate for each individual process within current/proposed Organic composting operations.

Odour source	Odour emission flux ($Ou\ s^{-1}\ tonne^{-1}$) [1]
Acceptance of waste	57
Mixing and Pre-treatment	104
Windrows formation and Composting	61
Windrows turning	61
Storage of final product	0.6

Note: [1] EPA, 2002, Desktop odour impact study for a biological treatment facility, near Roscommon, Ireland (TES101A); EPA, 2002, Odour report Galway composting plant

3.3 Odour emission rates from current/proposed Organic Gold composting operations for atmospheric dispersion modelling Scenarios 1, 2, 3, and 4

Table 3.2, *3.3*, *3.4*, and *3.5* illustrates the overall odour emission rate from the current and proposed Organic Gold Marketing Ltd composting operations with and without odour minimisation.

Table 3.2. Predicted overall odour emission rate from current composting operation (Scenario 1).

Process identity	Specific odour emission factor (Ou s^{-1} $tonne^{-1}$).	Tonnage amount per 1 week	Total odour emission rate (Ou s^{-1})	% Contribution
Acceptance of waste	57	208	11,856	**25.10**
Mixing and Pre-treatment	104	208	21,632	**45.80**
Windrows formation and Composting	61	208	12,688	**26.80**
Windrows turning[1]	61	208	952 (Emission factor 0.075)	**2**
Storage of final product	0.6	156	94	**0.2**
Total	-	-	**47,221**	**100**

Notes: [1] denotes that turning lasts from 30 to 45 minutes per windrows. A total of 4 windrows are currently on-site. Windrows are turned 2-3 times per week for 3 weeks and every 4 days for a remaining 5 weeks. The odour emissions from this process are cyclic and intermittent. A large percentage of odour emission will occur during the first 3 weeks of turning whereby the raw material is within it's pre composting stage. Dispersion models will not account for the cyclic emission effectively so the odour emission rate is lumped over a 1-week period. Windrows turning should occur when meteorological facilitate greatest dilution. An emission factor of 0.075 was used to account for this turning frequency. This is a normal and accepted methodology for such operations as we are examining odour impact over long-term period (i.e. number of years).

Table 3.3. Predicted overall odour emission rate from current composting operation with the implementation of mist odour minimisation system (Scenario 2).

Process identity	Specific odour emission factor (Ou s^{-1} $tonne^{-1}$).	Tonnage amount per 1 week	Odour misting system abatement efficiency (%)[2]	Total odour emission rate (Ou s^{-1})	% Contribution
Acceptance of waste	57	208	20	9,485	**25.1**
Mixing and Pre-treatment	104	208	20	17,306	**45.8**
Windrows formation and Composting	61	208	20	10,150	**2.8**
Windrows turning[1]	61	208	20	761 (Emission factor 0.075)	**2**
Storage of final product	0.6	156	-[3]	94	**0.3**
Total	-	-	-	**37,796**	**100**

Notes: [1] denotes that turning lasts from 30 to 45 minutes per windrows. A total of 4 windrows are currently on-site. Windrows are turned 2-3 times per week for 3 weeks and every 4 days for a remaining 5 weeks. The odour emissions from this process are cyclic and intermittent. A large percentage of odour emission will occur during the first 3 weeks of turning whereby the raw material is within it's pre composting stage. Dispersion models will not account for the cyclic emission effectively so the odour emission rate is lumped over a 1-week period. Windrows turning should occur when meteorological facilitate greatest dilution. An emission factor of 0.075 was used to account for this turning frequency. This is a normal and accepted methodology for such operations as we are examining odour impact over long-term period (i.e. number of years).[2] denotes a maximum assumed 20% odour minimisation efficiency can be achieved by the current odour misting system.

[3] denotes that mist scrubbing system achieves no odour abatement on stored product as this will be stored indoors and away from the misting system as this will increase the moisture content of the product and essentially allow for the development of anaerobic zones.

Table 3.4. Predicted overall odour emission rate from proposed composting operation (Scenario 3).

Process identity	Specific odour emission factor (Ou s^{-1} $tonne^{-1}$).	Tonnage amount per 1 day continuously	Volumetric air flow rate (m^3 s^{-1})	Total process odour emission rate (Ou s^{-1})	% Contribution
In-vessel composting system[1,5]	0 Ou_E m^{-3}	500	0 m^3 s^{-1}	0	0
Waste acceptance[2,5]	61	100	5 m^3 s^{-1}	5338	14.30
Blending and mixing[2,5]	104	100	5 m^3 s^{-1}	9100	24.38
Compost maturation and formation[3]	30.5	481/week	-	14,670	39.30
Windrows turning[4]	61	481/week	-	8,215 (Emission factor 0.28)	22.01
Total	-	-	-	**37,323**	**100**

Notes: [1] denotes that according to manufacturer information and Organic Gold Marketing Ltd, there will be no odour emissions from the in-vessel composting system. The pre-compost will be composted for a minimum period of 2 weeks.

[2]denotes that waste acceptance and blending and mixing is carried out indoors within enclosed building. It is assumed that the building door is kept closed (rapid roller door & plastic curtains (to reduce open area) and only opened for 15 minutes in each hour to accept waste material. Only one door shall be opened at once. A conservative building fabric odour reduction efficiency of 30% is assumed based on experience. Using this information and the formula of Albright and Hellickson, 1990, Baptista et al., 1999, Chow et al., 2000 a volumetric airflow rate of 5 $m^3\ s^{-1}$ is calculated. Knowing odour emission rate of each process within the building and knowing process parameters the overall odour emission rate of the building can be calculated. For example for waste acceptance, 60 Ou $tonne^{-1}\ s^{-1} \times 100$ tonnes per day acceptance $\times$ 5 $m^3\ s^1$ = 30,500 Ou $s^{-1} \times 0.25$ (15 minutes per hour door opening) $\times$ 0.7 (30% building fabric odour reduction efficiency) = 5338 Ou s^{-1} emission rate from building. The same calculation is used to calculate blending and mixing odour emission rate. The odour source is represented as a volume sources within the dispersion model and emission factors and source characteristics are calculated from known operation (i.e. 8AM to 6 PM) and Volume Source Inputs" in the EPA's User's Guide for the Industrial Source Complex (ISC3) Dispersion Models Volume I - User Instructions (EPA-454/B-95-003a) for guidelines on estimating the initial lateral dimension of various types of volume and line sources.

[3] denotes that an odour removal efficiency of 50% is assumed following pre-composting within in-vessel composting system.

[4] denotes that turning lasts from 30 to 45 minutes per windrows. A total of at least10 maturation windrows are proposed on-site. Windrows are turned approximately 5 times for a 6 week period or as temperature dictates. The odour emissions from this process are cyclic and intermittent. Dispersion models will not account for the cyclic emission effectively so the odour emission rate is lumped over a 1-week period. Windrows turning should occur when meteorological facilitate greatest dilution. An emission factor of 0.28 was used to account for this turning frequency. This is a normal and accepted methodology for such operations as we are examining odour impact over long-term period (i.e. number of years).

[5] denotes that biofilter will be installed upon those processes considered to contribute significantly to any odour impact.

Table 3.5. Predicted overall odour emission rate from proposed composting operation with the implementation of mist odour minimisation system (Scenario 4).

Process identity	Specific odour emission factor (Ou s^{-1} $tonne^{-1}$).	Tonnage amount per 1 day continuously	Volumetric air flow rate (m^3 s^{-1})	Total process odour emission rate (Ou s^{-1})	20% Odour misting system odour removal efficiency [6]	% Contribution
In-vessel composting system[1,5]	0 Ou_E m^{-3}	500	0 m^3 s^{-1}	0	0	0
Waste acceptance[2,5]	61	100	5 m^3 s^{-1}	5338	4270.4	14.30
Blending and mixing[2,5]	104	100	5 m^3 s^{-1}	9100	7280	24.38
Compost maturation and formation[3]	30.5	481/week	-	14,670	11736	39.30
Windrows turning[4]	61	481/week	-	8,215 (Emission factor 0.28)	6572	22.01
Total	-	-	-	**37,323**	**29858.4**	**100**

Notes: [1] denotes that according to manufacturer information and Organic Gold Marketing Ltd, there will be no odour emissions from the in-vessel composting system. The pre-compost will be composted for a minimum period of 2 weeks.

[2]denotes that waste acceptance and blending and mixing is carried out indoors within enclosed building. It is assumed that the building door is kept closed (rapid roller door & plastic curtains (to reduce open area) and only opened for 15 minutes in each hour to accept waste material. Only one door shall be opened at once. A conservative building fabric odour reduction efficiency of 30% is assumed based on experience. Using this information and the formula of Albright and Hellickson, 1990, Baptista et al., 1999, Chow et al., 2000 a volumetric airflow rate of 5 m^3 s^{-1} is calculated. Knowing odour emission rate of each process within the building and knowing process parameters the overall odour emission rate of the building can be calculated. For example for waste acceptance, 60 Ou $tonne^{-1}$ s^{-1} × 100 tonnes per day acceptance × 5 m^3 s^1 = 30,500 Ou s^{-1} × 0.25 (15 minutes per hour door opening) × 0.7 (30% building fabric odour reduction efficiency) = 5338 Ou s^{-1} emission rate from building. The same calculation is used to calculate blending and mixing odour emission rate. The odour source is represented as a volume sources within the dispersion model and emission factors and source characteristics are calculated from known operation (i.e. 8AM to 6 PM) and Volume Source Inputs" in the EPA's User's Guide for the Industrial Source Complex (ISC3) Dispersion Models Volume I - User Instructions (EPA-454/B-95-003a) for guidelines on estimating the initial lateral dimension of various types of volume and line sources.

[3] denotes that a odour removal efficiency of 50% is assumed following pre-composting within in-vessel composting system.

[4] denotes that turning lasts from 30 to 45 minutes per windrows. A total of at least 10 maturation windrows are proposed on-site. Windrows are turned at least 5 times for a period of 6 weeks or as temperature dictates. The odour emissions from this process are cyclic and intermittent. A large percentage of odour emission will occur during the first 3 weeks of turning whereby the raw material is within its pre composting stage. Dispersion models will not account for the cyclic emission effectively so the odour emission rate is lumped over a 1-week period. Windrows turning should occur when meteorological facilitate greatest dilution. An emission factor of 0.28 was used to account for this turning frequency. This is a normal and accepted methodology for such operations as we are examining odour impact over long-term period (i.e. number of years).

[5] denotes that biofilter will be installed upon those processes that are considered to contribute significantly to any odour impact.

[6] denotes a maximum assumed 20% odour minimisation efficiency can be achieved by the current odour misting system. All finished compost will be immediately removed off-site for end customer use. Additionally natural screening will be provided around the perimeter of yard, this has taken place at the site with the planting of tree saplings. A palisade fencing (creating additional wind-break) will be erected on-site to act as a windbreak to hinder the transport of odours downwind.

3.4 Results of odour dispersion modelling for the current/proposed Organic Gold composting operation and design

ISC ST3 was used to determine the overall odour impact of the current/proposed composting operation in Organic Gold Marketing Ltd, Wilkinstown, Co. Meath, as set out in odour annoyance criteria *Table 1.2* and *1.3*. The output data was analysed to calculate:

- Predicted odour emission contribution of overall current composting operation (Scenario 1) (*Table 3.2*), to odour plume dispersal at the 98^{th} percentile for an odour concentration of 3.0 Ou_E m^{-3} using ISC ST3 dispersion model (*Figure 8.1*).
- Predicted odour emission contribution of overall current composting operation with odour misting system (Scenario 2) (*Table 3.3*), to odour plume dispersal at the 98^{th} percentile for an odour concentration of 3.0 Ou_E m^{-3} using ISC ST3 dispersion model (*Figure 8.2*).
- Predicted odour emission contribution of overall proposed indoor/in-vessel composting operation and windrows maturation (Scenario 3) (*Table 3.4*), to odour plume dispersal at the 98^{th} percentile for an odour concentration of 3.0 Ou_E m^{-3} using ISC ST3 dispersion model (*Figure 8.3*).
- Predicted odour emission contribution of overall proposed indoors/in-vessel composting operation and windrows maturation and implementation of odour misting system (Scenario 4) (*Table 3.5*), to odour plume dispersal at the 98^{th} percentile for an odour concentration of 3.0 Ou_E m^{-3} using ISC ST3 dispersion model (*Figure 8.4*).

These computations give the odour concentration at each 50-meter x y Cartesian grid receptor location that is predicted for 98% (175 hours) of the year.

This will allow for the predictive analysis of any potential impact on the neighbouring sensitive locations while the current/proposed composting system is in operation. It will also allow the operators of the composting site to assess the effectiveness of their considered odour abatement/minimisation strategies and consider further abatement on those odour sources contributing significantly to odour plume spread. The intensity of the odour from the two or more sources of the composting operation will depend on the strength of the initial odour threshold concentration from the sources and the distance downwind at which the prediction and/or measurement is being made. Where the odour emission plumes from a number of sources combine downwind, then the predicted odour concentrations may be higher than that resulting from an individual emission source. It is important to note that various odour sources have different odour characters. This is important when assessing those odour sources to minimise and/or abate. Although an odour source may have a high odour emission rate, the corresponding odour intensity (strength) may be low and therefore it is easily diluted. Those sources that express the same odour character, as an odour impact should be investigated first for abatement/minimisation before other sources are examined as these sources are the driving force behind the character of the perceived odour.

4. Discussion of results

4.1 Odour plume dispersal for Scenarios 1 and 2

The plotted odour concentrations of ≤ 3.0 Ou_E m^{-3} for the 98th percentile for the current Organic Gold composting operation utilising ISC ST3 dispersion model is illustrated in *Figure 8.1* (Scenario 1). As can be observed, it is predicted that odour plume spread without odour abatement follows the predominant wind direction with minimum and maximum distances of 200 to 600 metres plume spread from the composting flag in a south and north east direction. Seven residences and one shop are incorporated within the 3.0 Ou_E m^{-3} plume with these residents/shop perceiving an odour concentration of between 3 and 10 Ou_E m^{-3} for the 98th percentile. In accordance with odour annoyance criterion in *Table 1.3*, and in keeping with currently recommended odour annoyance criterion in this country for outdoor composting operations (i.e. mushroom composting industry), these residences may generate odour complaints especially during meteorological conditions that do not facilitate odour dispersion.

Figures 8.2 illustrate the odour plume spread from current operations when the odour misting system is in operation. As can be observed five resident locations and one shop are incorporated within the 3.0 Ou_E m^{-3} plume with these residents and shop perceiving an odour concentration of between 3.0 and 6.0 Ou_E m^{-3} at the 98th percentile. The odour plume spread ranges from 40 to 450 metres from the facility boundary. The possibility of odour complaint is reduced significantly due to the incorporation of an odour misting system. As this facility is located in a predominant agriculture area odour complaints may be intermittent depending on worst-case meteorological conditions.

4.2 Odour plume dispersal for Scenarios 3 and 4

The plotted odour concentrations of ≤ 3.0 Ou_E m^{-3} for the 98th percentile for the future proposed Organic Gold Marketing Ltd composting operation utilising ISC ST3 dispersion model is illustrated in *Figure 8.3* (Scenario 3). The future proposed operation will facilitate waste acceptance, mixing and blending process indoors with implemented odour minimisation strategies implemented. A 2-week pre-composting process will be carried out in emission free in-vessel composting units. Maturation of compost will occur outdoors. As can be observed, it is predicted that odour plume spread following the implementation of indoors waste acceptance/blending and in-vessel composting achieved similar plume spread as the current composting process even though composting production tonnage amount is roughly doubled. Five residences, and one shop are incorporated within the 3.0 Ou_E m^{-3} plume with these residents/shop/ perceiving an odour concentration of between 3.0 and 6.50 Ou_E m^{-3} for the 98th percentile. The odour plume spread ranges from 40 to 500 metres from the facility boundary. In accordance with odour annoyance criterion in *Table 1.3*, and in keeping with currently recommended odour annoyance criterion in this country, odour complaints could be generated by these residences/shop especially during meteorological conditions that do not facilitate odour dispersion (i.e. stable slow wind speeds).

Figures 8.4 illustrate the odour plume spread from future proposed operations following the implementation of the mist scrubbing system and operational practices. As can be observed 4 residences and one shop are incorporated within the 3.0 Ou_E m^{-3} plume with these residents and shops perceiving an odour concentration of between 5.0 and 3.0 Ou_E m^{-3} at the 98th percentile. The odour plume spread ranges up to 480 metres from the facility boundary. The possibility of odour complaint is reduced due to the incorporation of a misting system. Some odour complaints could be received by the regulatory agency during meteorological conditions that do not favour odour dispersion. Odour management practices will need to be precise to eliminate odour impact. Organic Gold Marketing Ltd have agreed in principle that a biofilter will be installed if such odour impact occurs. Incorporation of a bioflter into the proposed process is considered but will not be installed as the current composting facility (which has generated no significant complaints) has a similar odour impact area. Guidance on operational strategies pertaining to odours can be obtained from this document, the BAT notes for the Waste licensing sector, EPA, County Wexford (www.epa.ie) and the Environment Agency odour guidance and waste management guidance documents, Bristol, UK (www.environment-agency.gov.uk).

5. Conclusions

A worst-case odour emission scenario was modelled using the atmospheric dispersion models ISC ST 3 with three years worth of hourly sequential meteorology data representative of the study area. A worst-case meteorological year and worst-case odour emission data was used to predict any potential odour impact in the vicinity of the proposed waste facility. Odour impact potential was discussed for the current/proposed operation of the composting operations. The following conclusions are drawn:

1. It is predicted that minor odour impact will be perceived in the vicinity of the current facility while the odour misting system in operation when utilising dispersion model ISC ST3. Five residents and one shop will perceive on odour concentration of between 3.0 and 6.0 Ou_E m^{-3} at the 98th percentile in a worst-case meteorological year. All other residents/shops/pubs will perceive an odour concentration less than 3.0 Ou_E m^{-3}.
2. It is predicted that following the implementation of proposed composting facility and odour minimisation/abatement techniques (i.e. indoor waste acceptance, mixing, in-vessel first stage composting, and mist scrubbing system) odour plume spread is similar to current operations with all residences perceiving an odour concentration of less than 6.0 Ou_E m^{-3} at the 98th percentile. In accordance with the odour impact criterion established in *Section 1.7.2*, some odour impact may be perceived in the vicinity of the facility during meteorological conditions that do not favour odour dispersion. Organic Gold Marketing Ltd will install a biofiltration system if such odour impact occurs.

6. Recommendations

The following recommendations are presented:

1. Ensure a clear and concise odour management plan is developed for the site so as to eliminate any significant odour emissions events,
2. The turning of windrows should maintain appropriate conditions within the composting matrix (i.e. oxygen, moisture and evenly distributed nutrients) and windrows turning should be performed in appropriate meteorological conditions (i.e. unstable, higher wind speeds, clear sky).
3. Other recommendations are made through the document.

7. References

1. Baptista, F.G., Bailey, B.J., Randall, J.M., and Meneses, J.F., (1999). Greenhouse ventilation rate: Theory and measurement with Tracer gas techniques. J. Agricultural Engng Resource. 72, 363-374.
2. Callan, B.T., (1993). Noses Knows Best. In malodour measurement and control. Proceedings of the International Tydnall School, September. 134-145.
3. Casey J.C., (2003). Desktop odour impact assessment of the proposed WWTP located in Co. Wexford. Jones Environmental Ireland Ltd. City west Business Park, Naas Rd, Dublin. Performed in accordance with tender specifications and Wexford Co. Co. requirements. Odour Monitoring Ireland.
4. CEN, (2003). prEN13725-Air-quality-Determination of odour concentration by dynamic olfactometry. Brussels, Belgium.
5. Chow. W.K., Fung, W.Y., Wong, L.T. (2002). Preliminary studies on a new method for assessing ventilation in large spaces. Buildings and Environment, 37. 145-152.
6. DOE, (1993). Report by the Inspector on a Public Inquiry into the Appeal by Northumbrian Water Limited for Additional Sewage treatment facilities on land adjacent to Spitial Burns, Newbriggin-by-the-Sea, Northumberland in March 1993. DoE ref APP/F2930/A/92/206240.
7. Dravniek, A., (1986). Atlas of odor character profiles. ASTM Committee on sensory evaluation of materials and products, ASTM data series. Baltimore, MD, USA.
8. EPA, (2001). Odour impacts and odour emission control measures for intensive agriculture. Commissioned by the Environmental Protection Agency (Ireland). OdourNet UK Ltd.
9. Longhurst, P., (1998). Odour impact assessment of an extension to the Brogborough landfill site. IREC, Cranfield University, England.
10. McIntyre, A., (2000). Application of dispersion modelling to odour assessment; a practical tool or a complex trap. Water Science and Technology, 41 (6). 81-88.
11. Sheridan, B.A. (2002). In house odour intensity and hedonic tone profile data of different odourous sources. Unpublished.
12. Sheridan, B.A., (2001). Controlling atmospheric emissions-BAT Note Development, UCD Environmental Engineering Group, Department of Agricultural and Food Engineering, UCD, Dublin 2.
13. Sheridan, B.A., Chadwick, P., (2000). Environmental Impact Statement-Air quality chapter for Clareabbey Wastewater treatment plant. Enfo Head Office, Suffolk Street, Dublin 2, Ireland.
14. Sheridan, B.A., Curran, T.P., Dodd, V.A., (2004). Biofiltration of air: current operational and technological advances. In review. Reviews in Environmental Technology.

15. Sheridan, B.A., Hayes, E.T., Curran, T.P., Dodd, V.A., (2003). A dispersion modelling approach to determining the odour impact of intensive pig production units in Ireland. Bioresource Technology. Published.

8. Appendix I-Dispersion modelling contour results using ISCST3 dispersion model.

8.1 Predicted odour emission contribution of current composting operation (Scenario 1) (*Table 3.2*), respectively to odour plume dispersal at the 98th percentile for an odour concentration of 3.0 $Ou_E\ m^{-3}$ using ISC ST3 dispersion model.

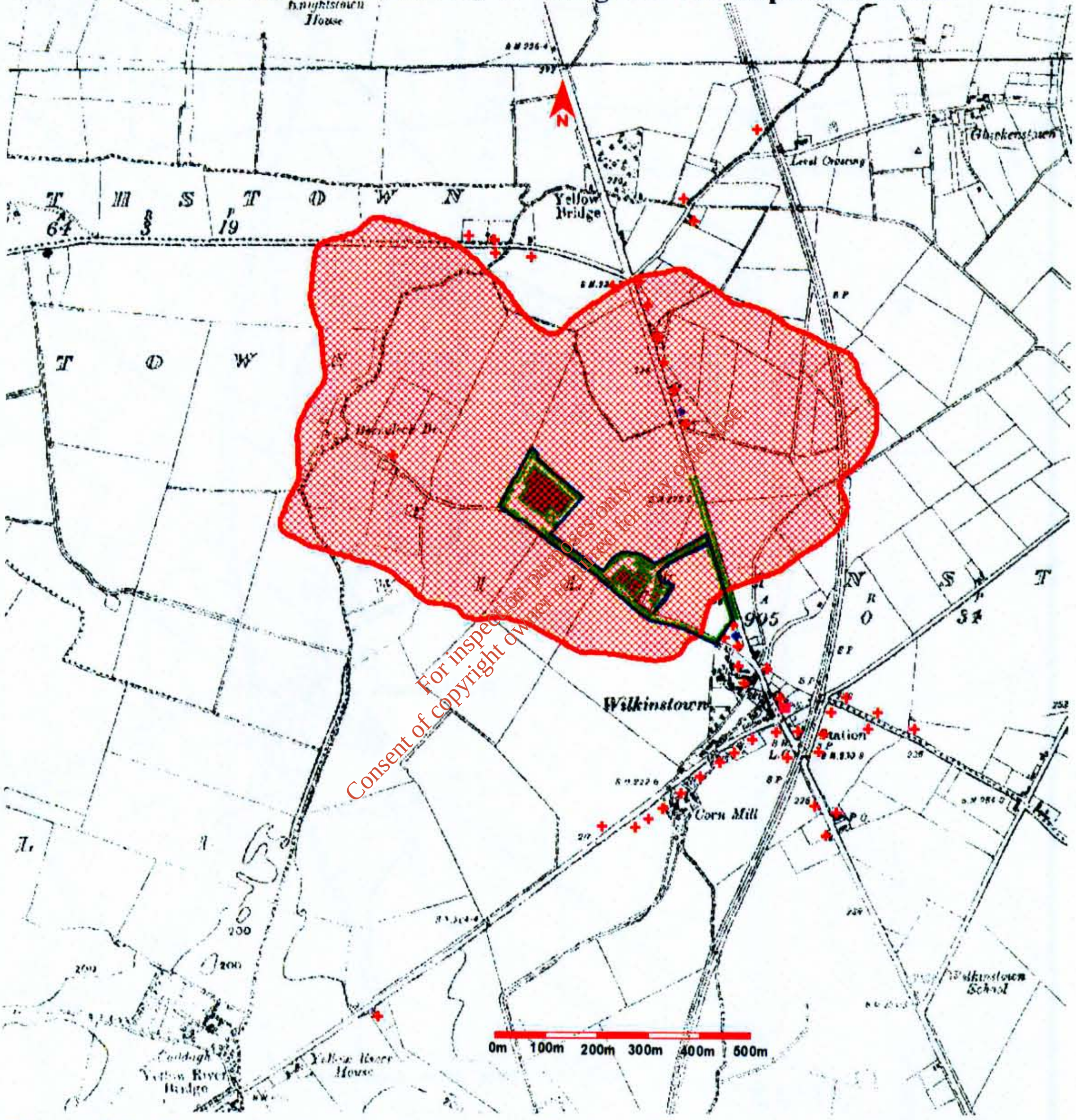

Figure 8.1. Predicted odour emission contribution of current composting operation to odour plume dispersal for Scenario 1 at the 98th percentile for odour concentrations ≤ 3.0 $Ou_E\ m^{-3}$ (—).

8.2 Predicted odour emission contribution of current composting operation following operation of existing mist scrubbing system (Scenario 2) (*Table 3.3*), respectively to odour plume dispersal at the 98th percentile for an odour concentration of 3.0 Ou_E m^{-3} using ISC ST3 dispersion model.

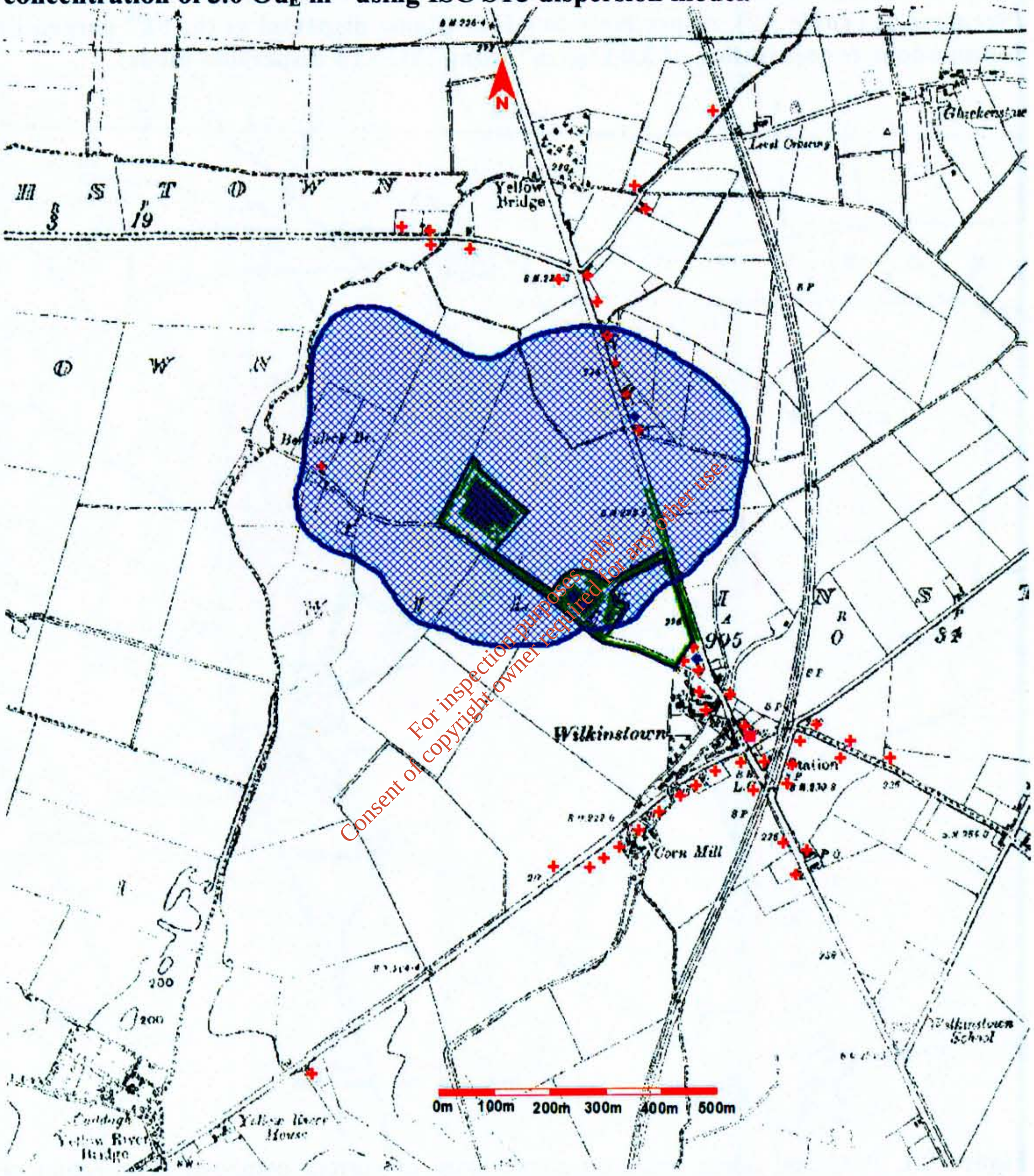

Figure 8.2. Predicted odour emission contribution of current composting operation following operation of existing mist scrubbing system to odour plume dispersal for Scenario 2 at the 98th percentile for odour concentrations ≤ 3.0 Ou_E m^{-3} (——).

8.3 Predicted odour emission contribution of proposed partially indoor/in-vessel composting operation (Scenario 3) (*Table 3.4*), respectively to odour plume dispersal at the 98th percentile for an odour concentration of 3.0 $Ou_E\ m^{-3}$ using ISC ST3 dispersion model.

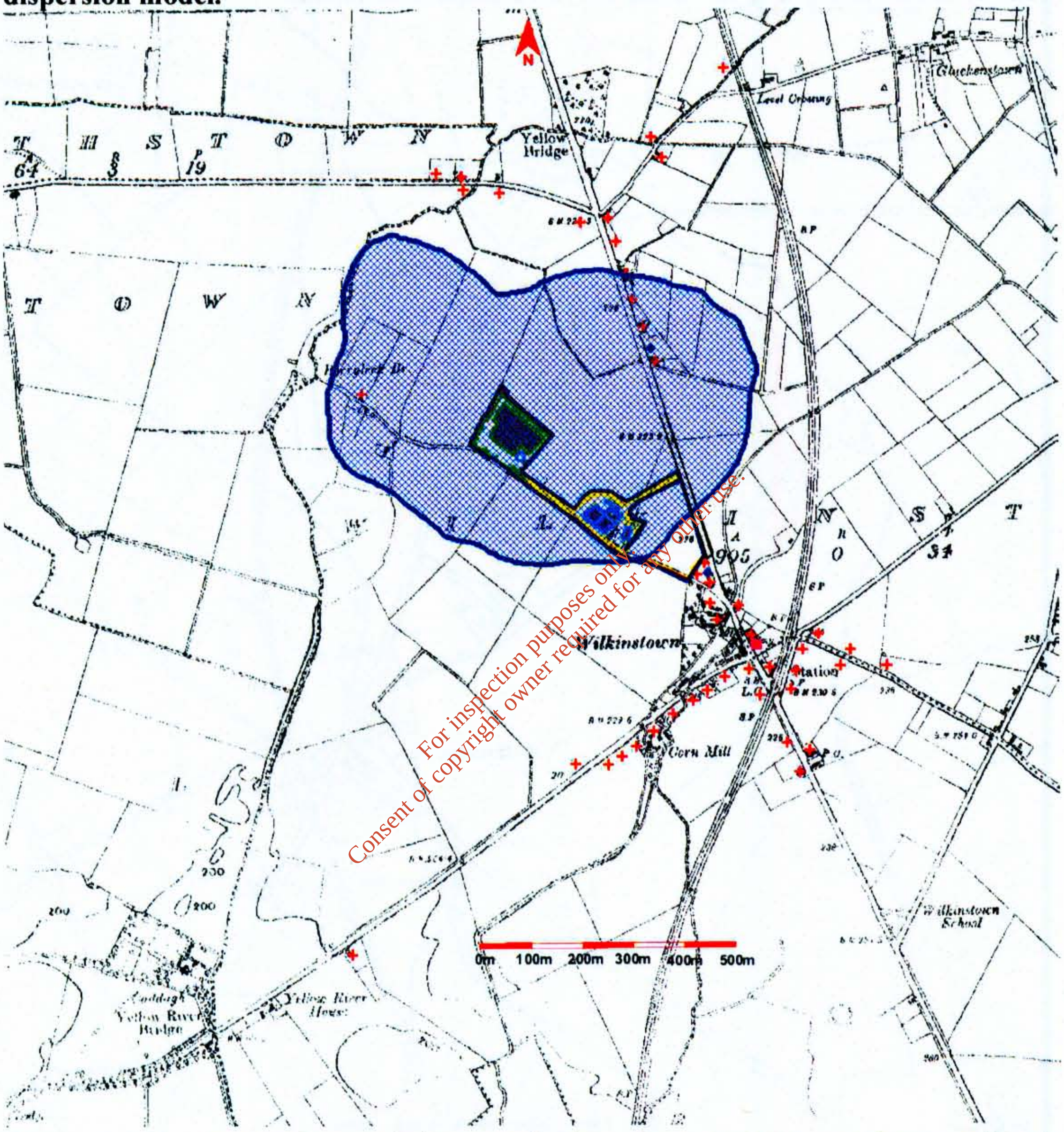

Figure 8.3. Predicted odour emission contribution of proposed composting operation to odour plume dispersal for Scenario 3 at the 98th percentile for odour concentrations ≤ 3.0 $Ou_E\ m^{-3}$ (━).

8.4 Predicted odour emission contribution of proposed partially indoor/in-vessel composting operation and operation of existing mist scrubbing system (Scenario 4) (*Table 3.5*), respectively to odour plume dispersal at the 98th percentile for an odour concentration of 3.0 Ou_E m^{-3} using ISC ST3 dispersion model.

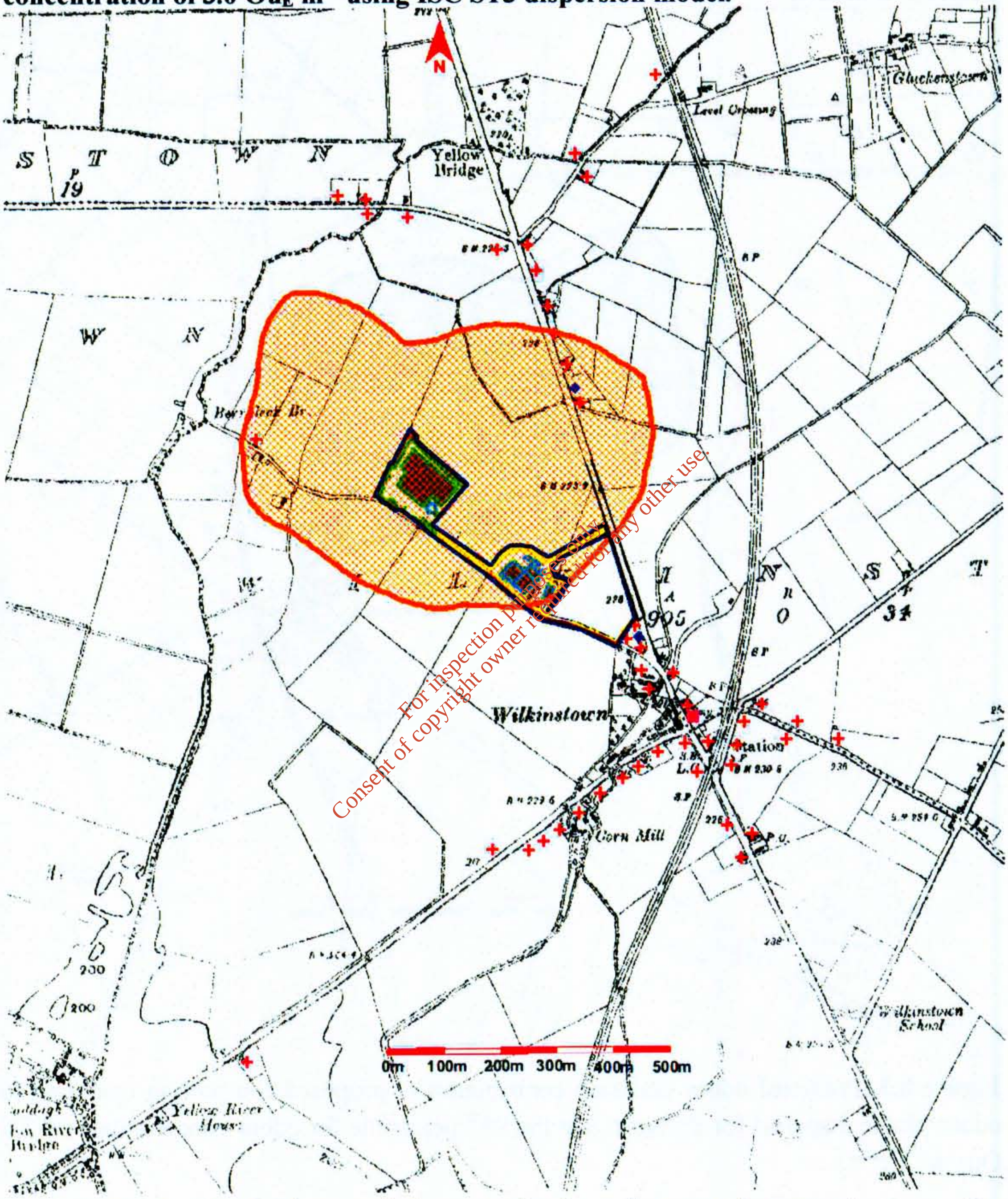

Figure 8.4. Predicted odour emission contribution of proposed composting operation following operation of existing mist scrubbing system to odour plume dispersal for Scenario 4 at the 98th percentile for odour concentrations ≤ 3.0 Ou_E m^{-3} (——).