APPENDIX B – STUDY ON AIR QUALITY IMPACT

ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON

AIR QUALITY IMPACT OF PROPOSED EXTENSION OF CARRIGTOHILL WASTEWATER TREATMENT PLANT CO. CORK

ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON

AIR POLLUTION AND ENVIRONMENTAL CONSULTANCY

ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON
ENVIROCON

ENVIROCON LTD.
OLD ROAD
KILCARN BRIDGE
NAVAN, CO. MEATH
Tel: (046) 9074135
Fax: (046) 9074055
e-mail: info@envirocon.ie

Date: 11 April 2007

Report By: Michael L. Bailey

1.0 INTRODUCTION

An upgrading and extension of the wastewater treatment plant at Carrigtohill, Cork is proposed, to provide sufficient capacity for the projected increase in municipal and industrial sewage from Carrigtohill and the surrounding area. As part of the evaluation of the likely environmental impact of the planned treatment plant, an assessment of the potential impact of odours from was undertaken by Envirocon Ltd. As part of this assessment a site visit was made to the existing sewage treatment plant in February 2007.

2.0 EXISTING ENVIRONMENT

2.1 Air Quality

The wastewater treatment plant site is located approximately 0.75 km to the south east of the Carrigtohill village with the site accessed from a minor public road running eastwards from the R624. It is located on low-lying ground at about 10m O.D. The Carrigtohill Bypass (N25) runs east-west about 300m to the north of the treatment plant site and is on a raised embankment. There is a pharmaceutical production plant (Millipore) located about 300m from the existing treatment plant and 100m from the Eastern boundary of the extension site. However, there are no significant industrial emissions within the locality of the treatment plant site. The nearest house is located near the junction with the R624, about 225m from the Western boundary of the extension site. There are also a small number of houses about 400m to the SW of the site.

Overall, the air quality in the locality is good with levels of air pollutants in the area substantially below the National Air Quality Standards (NAQS) specified in the Air Quality Standards Regulations 2002 (SI No 271 of 2002). Daily concentrations of sulphur dioxide would be less than 20% of the limit value of 125 μg/m^3 specified in the 2002 Regulations. Ambient concentrations of nitrogen dioxide would be less than 40% of the future NAQS annual limit of 40 μg/m^3, which is to be met by 2010. Corresponding hourly concentrations would also well below the current NAQS hourly limit value of 200 μg/m^3. Carbon monoxide and benzene levels, which are important components of motor vehicle exhausts, would be very low in the area and typically less than 10% of the NAQS limit values.

Dust and airborne particulates, in particular those referred to, as PM_{10} (particulate material with a mean aerodynamic diameter of less than 10 μm) would be below the National Air Quality Standards. The limit values specified in the Regulations 2002, which entered into force in January 2005, give a daily level of 50 μg/m^3 (as a 90.4 percentile of daily average values) and an annual average value of 40 μg/m^3. Annual concentrations would be typically in the region of 10-15 μg/m^3 close to the northern site boundary, with vehicle exhaust emissions and roadside dust along the access road being the principal sources.

No malodours could be detected during the site visit undertaken in February 2007 near the site boundary of the existing treatment plant. The weather conditions were dry during the site visit with winds of about 5m/s from the SW.

2.2 Climate

2.2.1 General Climatology

The climate of the Cork Region is characterised by the passage of Atlantic low pressure weather systems and associated frontal rain belts from the west during much of the winter period. Over the summer months, the influence of anticyclonic weather conditions will result in drier continental air over this part of Ireland, in particular when winds are from the east, interspersed by the passage of Atlantic frontal systems. Occasionally, the establishment of a high pressure area over Ireland will result in calm conditions and during the winter months these are characterised by clear skies and the formation of low level temperature inversions with slack wind conditions at night-time. During the summer months, if anticyclonic conditions become established, then high day-time temperatures may be recorded; as experienced during 2005 and 2006.

2.2.2 Wind

The characteristics of the wind field in terms of wind speed and direction will affect the magnitude of the odour impact at ground level in the surrounding area due to emissions from the tanks and other emission sources within the treatment plant.

There are two meteorological stations within 17km of the Carrigtohill site, one at Cork Airport (17km to the West) and the other at Roches Point (12km to the South). Long-term observations at both meteorological stations indicate that the prevailing wind direction is from a southwesterly direction with a secondary maximum for north-westerly winds. The long-term wind roses indicating the incidence of winds at 10-degree intervals around the compass for the two locations are shown in Figures 1 and 2 for Cork Airport and Roches Point respectively. The meteorological station at Cork Airport is at about 154m O.D., compared to the one at Roches Point, which is located near the mouth of Cork Harbour. However, the station at Roches Point is very exposed to coastal breezes and nocturnal air flows out through the mouth of Cork Harbour during light wind conditions in the area. The site at Carrigtohill is north of Great Island and is less likely to be affected by the coastal sea breeze experienced around the Cork harbour, in particular at the mouth at Roches Point. Prevailing conditions would tend to be comparable to the general wind field over the region in the Cork area and so climatological data for Cork Airport was used in the odour modelling study.

The long-term incidence of winds of 5m/s or less at Cork Airport is about 52% of the year with speeds of <2 m/s (including calms) occurring about 7% of the time. The lowest frequency is for winds from a north-easterly direction, which account for about 8% of the year. The mean annual wind speed is 5.5 m/s with an incidence of 0.5 % of hours for speeds below 1m/s. Climatological data from Roches Point indicate a lower incidence of wind speeds below 5 m/s, with about 45% below this value. The mean annual wind speed at Roches Point is about 6.3 m/s, as a result of the exposed coastal location of this meteorological station. The wind roses for Cork Airport for the modelled years 2005 and 2006 are given in Figure 3, which show the high frequency of winds from a SW and NW direction, compared to the incidence of winds from an easterly direction.

2.2.3 Air Temperature

The annual mean air temperature for the Carrigtohill area is about 9.5C, with a range in daily averages for most of the year of about 2-18.5 C. During warm dry spells in the summer, temperatures may rise to over 25C, as experienced during 2005 and 2006. The greatest potential for odorous emissions is during the summer months when warm dry weather conditions can increase the rate of evaporation from exposed treatment tank surfaces. These weather conditions may also be associated with low-flow sewage conditions from the surrounding area.

3.0 THE PROPOSED DEVELOPMENT

3.1 Odour Emissions from Wastewater Treatment Plants

Fresh sewage arriving at a wastewater treatment plant via a properly constructed sewer system has a slight smell, normally described as musty in character. As long as a certain level of dissolved oxygen is maintained in the sewage anaerobic conditions will not take place. However, if the oxygen content of the sewage is used up then gases such as hydrogen sulphide, nitrogen and sulphur based organic compounds (mercaptans, ketones, amines, indoles and skatoles) are quickly produced and a general septic condition occurs with typical pungent odours being emitted. These conditions may arise where the incoming sewage becomes septic as it is pumped along the rising main and result in strong malodours at the inlet works.

The rate of emissions of malodorous compounds from within a treatment plant depend on the freshness of the incoming sewage, exposed surface areas of treatment tanks, sludge handling procedures and presence and type of odour control measures installed. In most cases, odour nuisance problems are due to the age of the plant, septicity of sewage and overloading conditions during primary or secondary treatment. Modern technology at treatment plants such as enclosing inlet works, high efficiency odour control systems, constant monitoring of flow conditions, diffused aeration for secondary treatment and sludge treatment within enclosed buildings can result in odours being greatly reduced.

Sulphide compounds, especially hydrogen sulphide and mercaptans, have very low levels of odour detection and these gases are a major component of the malodours generated from treatment of sewage. The most common component is hydrogen sulphide, which has a detection threshold of about 0.5-2 μg/m^3. Its characteristic smell of rotten eggs occurs at concentrations about 3-4 times higher with odour nuisance complaints likely at higher levels.

The perception of odour at some point downwind of an emission source depends on the type of odour compound and the air concentrations of the odorous gas. The measure used to quantify odour nuisance potential is the odour concentration (odour unit per cubic metre, o.u./m^3). An odour concentration of 1 o.u./m^3 is the level at which there is a 50% probability that, under laboratory conditions using a panel of qualified observers, an odour may be detected. At levels below 1 o.u./m^3 the concentration of the gaseous compound causing the odour in the air will be less than the detection level and so although the odorous gas is still present in the air no odour will occur.

The intensity of an odour ranges from 1 o.u./m^3 = odour detection, 2= faint odour with the intensity increasing up to 5 o.u./m^3 where the odour is easily identifiable, with higher levels likely to result in nuisance complaints by the local community. The length of time the odour can be detected is an important factor in the likelihood of the odour causing a nuisance. If the odour is recognisable but very infrequent over the year, then again complaints are unlikely. This is especially the case in rural environments where the community has a higher tolerance of odours associated with agricultural activities than those living in an urban area.

3.2 Proposed Extension of WWTP

3.2.1 Introduction

The proposed extension of the existing treatment works at Carrigtohill is designed to provide treatment capacity for a Biological Oxygen Demand (BOD) load for Phase 1 of 45,000 p.e. (person equivalent), compared to the current design capacity of 8,500 p.e. The final design capacity (Phase 2) will be 67,000 p.e. This will require a new inlet works, storm water tank, secondary treatment and sludge treatment facilities.

The construction contract is design/build/operate (DBO). This means that the Contractor will carry out the design of the plant. The DBO contract will contain performance specifications, including odour control. The Contractor will also be required to monitor odorous emissions to ensure compliance with emission limits during the normal routine operation of the plant.

It will be a requirement of the design of the new treatment plant that the following components will be included: -

- The present sewage treatment works will be replaced.
- A new inlet works building housing the inlet sump/flumes and preliminary treatment screening equipment will be constructed.

- A storm-water holding tank will be installed.
- Secondary treatment will be provided by Secondary Batch Reactor Tanks
- A new sludge treatment building will be constructed.
- Odours from the inlet works building and the sludge treatment building will be treated with high efficiency odour control units.

3.2.2 Inlet Works

The inlet works will be housed in a single building and will be designed to operate to a high level of efficiency. This building will be located near in the NE part of the extension area and will be approximately 17m x 10m in dimension. There will be a high degree of control of odorous emissions from the various stages of the preliminary sewage treatment process. All the inlet channels, along with the inlet chamber will be completely covered and the foul air ducted to an odour control unit. The sewage will pass through the mechanical coarse and fine screens housed in this building. Screened material will be washed and classified into covered skips housed within the inlet works building.

The influent will pass to a covered grit trap within the building to remove grit and finer particulates from the influent. This material will be piped into a classification system to remove organic material and excess liquid and then it will be washed and discharged into a covered skip that will be located within the building.

3.2.3 Storm-water Holding Tank

Incoming flows in excess of 3DWF will be stored in an open rectangular storm-water holding tank located adjacent to the Secondary treatment tanks within the eastern part of the extension site. Once high flow conditions have abated, the storm-water liquor will be pumped into the inlet works and the bottom and side-walls of the tank will be manually hosed down to remove debris adhering to the sides. Prompt cleaning of the sidewalls after the storm-water holding tank is emptied will reduce the potential for malodours to be generated from the tank.

3.2.4 Secondary Treatment

Secondary treatment will be provided by four rectangular Secondary Batch Reactor (SBR) tanks, each with estimated dimensions of 14 x 34m. These tanks operate as batch reactors, with a self-contained secondary treatment of equalisation, aeration and clarification in one basin. The typical flow process is that the wastewater enters a partially filled reactor, containing biomass. Once it is full the aeration process commences and mixing takes place with diffused sub-surface aeration. On completion of the aeration process the biomass settles and the treated supernatant is drawn-off. The quantity of sludge produced using this treatment process is substantially less than from conventional treatment systems as no primary sludge is generated. The treatment process within the SBR tank removes the need for separate secondary clarifier tanks.

The batch reaction process within the SBR tank involves both periods of aeration and no aeration (anoxic) and so the aeration equipment supplies air into the tank over a shorter period compared to tank basin by sub-surface cyclonic aeration which reduces the release of large quantities of aerosols and malodours into the air compared to emissions from surface shaft propeller systems observed from secondary treatment plants in older sewage treatment plants around the country.

3.2.5 Sludge Treatment

Sludge removed from the SBR treatment tanks will be transferred to a holding tank before being thickened and dewatered within the dewatering building. The holding and thickening tanks will be enclosed and the sludge dewatering belt presses covered within the dewatering building. Odorous emissions from the sludge treatment building will be treated in a high efficiency odour control unit. The building will be located within the western sector of the site and will have dimensions of approximately 15 x 10m.

3.2.6 Odour Control Units

Two high efficiency odour control units, one for the inlet works and another for the sludge treatment building, are planned to treat contaminated foul air from the various sources within the buildings. The ventilation within both buildings will provide for 5 air changes per hour. These odour emission point sources will be located close to the inlet works building and the sludge treatment buildings respectively.

Each unit will have a very high removal efficiency rate, with odour reduction levels in excess of 95%. Acceptable methods of odour control include biofiltration, charcoal and ozone scrubber systems. It is likely that the odour control units will be sited on the ground with the scrubbed outlet air from the unit ducted to a vertical stack.

4.0 ODOUR IMPACT OF WWTP EXTENSION

4.1 Odour Model Overview

Short-term ground level odour ground level concentrations downwind of the wastewater treatment plant were computed using the ADMS3 (Version 3.3, July 2005) advanced air quality dispersion model developed in the U.K. by CERC (Cambridge Environmental Research Consultants). This prediction model is used by Regulatory Authorities and the Environment Agency in the United Kingdom and has been approved by the Environmental Protection Agency for modelling studies supporting IPCL applications. It has been widely used in Ireland for evaluating the impact of odours from wastewater treatment plants.

The ADMS3 model takes account of the substantially improved understanding of the plume dispersion within the atmospheric boundary layer by the use of more complex parameterisation, than used in previous generation prediction models. It uses boundary layer theory based on the Monin-Obukhov length and boundary layer height instead of the categories of atmospheric stability used in the older U.S. EPA dispersion models including the ISC3. The model is suitable for modelling odour impacts from area emission sources near the ground, such as wastewater treatment tanks that have emission heights of 2-3m above ground level.

.

4.2 Input parameters

4.2.1 Odour emission estimates

4.2.1.1 Overview

Unlike emission rates for industrial sources such as boiler stacks or process vents, where specific information for a range of emission characteristics is generally available, estimation of emissions from wastewater treatment plants is much harder to quantify. Although measurement of emissions from wastewater plants has been extensively carried out and models to predict emission rates from the various sources produced in the U.S. these relate to volatile organic compounds (e.g. toluene, benzene, and trichloroethylene). These types of pollutants tend to be more inert in the treatment plant process and so a mass balance approach may be used.

For estimating emissions of odours due to inorganic compounds and organic compounds (e.g. mercaptans and other sulphides) that are produced as a result of anaerobic activity during the sewage treatment process, a mass balance approach is unsuitable. Many of the studies citing odour concentrations from existing treatment plants tend to be based on situations where problems exist in old overloaded plants. Hence selection of suitable emission rates needs to be made with due consideration of the type of treatment conditions, such as tank design and method of sludge handling, at the wastewater treatment plant.

The emission rates used in the odour prediction model were expressed in terms of odour release per second. For the secondary treatment tanks, the emission rates were expressed in terms of the odour emission rate per unit area per second (o.u./m^2.s). In the case of emissions from the exhaust stacks of the odour control units the odour emission rate was calculated in terms of o.u/s.

4.2.1.2 Secondary Treatment

A tank surface height of 3m for the rectangular SBR's and an emission plume temperature near to ambient conditions was used in the odour dispersion model. The vertical exit velocities from the surface of the tanks are very low with rates typically below 0.01 m/s reported in the literature and so emission rates from tanks are due primarily to the rate of evaporation from the water surfaces.

The surface area of each of the proposed rectangular tanks is approximately 475 m^2, resulting in an emission rate per tank of 190 o.u./s, based on an emission rate per m^2 of 0.4 o.u./s.

4.2.1.3 Odour control units

The emission rates for proposed odour control exhaust stacks for the inlet works and sludge treatment buildings were set equivalent to 500 o.u./s in the odour impact model. These stacks will be a minimum height of 5m with a typical stack exit diameter of 0.5m. An exhaust flow rate of 8 m/s and exit temperature of 15ºC were used in the odour prediction model for both the inlet works and sludge treatment building odour control units.

4.2.2 Climatological Data

Sequential hourly climatological data from Cork Airport was used in predicting the odour concentrations near the site. The ADMS3 model was run using hourly observations for 2 discrete annual data sets (2005 and 2006) to allow for annual variations in the wind field. Input parameters for wind speed, direction, cloud cover and air temperature provided values to enable the degree of atmospheric turbulence, or stability to be calculated. The wind roses that show the distribution of wind direction/speed for 2005 and 2006 are given in Figure 3. Atmospheric instability occurs due to heating of the ground by solar radiation and this is related to the amount of cloud cover, coupled with the solar inclination, which is a function of the time of year.

4.2.3 Surface Roughness

The vertical wind profile above the ground is an important parameter in determining the structure of the atmospheric boundary layer near the ground. The Monin-Obukhov length provides a measure of the relative importance of buoyancy generated by heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. This frictional effect is related both to the surface roughness length and wind speed. The former parameter is supplied as input to the ADMS3 dispersion model and it can vary from 0.001m over open sea to 1.5m in urban areas. It is used in calculating the boundary layer structure, which determines the rate of dispersion of an emission plume both in the horizontal and vertical plane as the plume travels downwind from the stack. A surface roughness length value of 0.3m, which approximates to general agricultural areas, was used in the ADMS3 to represent conditions around Carrigtohill.

4.2.4 Receptor Grid

A receptor grid was used in the ADMS3 model to predict ground level odour concentrations within 1km of the wastewater treatment plant site. The grid covered an area around the site with a grid reference of 180600E, 71800N at the SW corner. Preliminary modelling to assess the extent of the area of the likely maximum hourly and daily ground level impact from the exhaust stack emissions indicated that the highest levels occurred within 0.5km.

4.3 Results of odour dispersion model

Hourly climatological data from Cork Airport, for the years 2005 and 2006 were used to predict the 99.5 and 98 percentile hourly odour concentration values. These percentile calculations give the odour concentration at each receptor location that is predicted to be exceeded for 2% of the year or 175 hours in the case of the 98 percentile. The 99.5 percentile value is the concentration predicted to be exceeded for 0.5% of the time, or 45 hours. The pattern of predicted odour concentration around the plant reflects the annual incidence of certain wind speeds and directions coupled with the different types of atmospheric stability close to the ground

An odour concentration of 1 o.u./m^3 is defined as the level at which there is a 50% probability that, under laboratory conditions using a panel of qualified observers, an odour may be detected. At odour levels below 1 o.u./m^3, the concentration of the gaseous compound causing the odour in the air will be less than the detection level and so although the gas is still present in the air no odour may be detected. Sensitivity to an odour also depends on the location; for example, an odour from agricultural related activities is likely to be tolerated by the community longer in a rural setting than in an urban area.

The results of the odour impact modelling study based on the Phase 1 extension of the wastewater treatment plant are presented as odour concentration contour plots in Figures 1 and 2. These plots show the pattern of the 99.5 percentile and 98 percentile odour concentrations in the locality of the plant and are based on the maximum value predicted at each receptor location over the two years that were modelled.

The predicted 99.5 percentile odour concentrations that are predicted for the planned extension are shown in Figure 4 and the pattern of odour levels indicates that the maximum level at the nearest house to the West of the site boundary will be between 0.25-0.5 o.u./m^3. At the houses to the NE of the site boundary, on the outskirts of Carrigtohill, the predicted 99.5 percentile odour concentration is less than 0.25 o.u./m^3 and to the south the predicted level will also be below 0.25 o.u./m^3. In other words, the odour prediction model predicts that odour levels will generally be below the odour detection level for 99.5 percent of the time at the nearest houses to the site. The predicted 99.5 percentile odour concentrations at the Millipore plant boundary to the NW of the site are predicted to be about 0.5-1 o.u./m^3 near the entrance and 0.25-0.5 o.u./m^3 in the vicinity of the production buildings. At the site boundary adjacent to the public road, the predicted 99.5 percentile odour concentration is predicted to be about 3-4 o.u./m^3. This is due to the proximity of the planned location of the SBR tanks near to the northern site boundary.

The predicted 99.5 odour concentrations at the nearest private properties are very low and although there are no National Standards the predicted odour concentrations would meet the Standards required in other European Countries such as the Netherlands. In the Netherlands a maximum concentration of 1 o.u./m^3, which should be met for 99.5% of the year, has been used as a limit value downwind of new plants.

The odour concentrations in the locality of the wastewater treatment plant that are predicted to be exceeded for 2% of the year, or 175 hours during the year, referred to as the 98 percentile, are shown in Figure 5. At the nearest houses the site, the predicted 98 percentile odour concentration are predicted to be well below 0.1o.u/m^3. The 98 percentile concentration is also predicted to be well below 0.2 o.u./m^3 at the Millipore premises. The odour levels are predicted to be less than 1.5 o.u./m^3 along all boundaries around the planned extension site.

An odour concentration of greater than 5 o.u./m^3 has been widely used as a criteria for determining possible nuisance complaints, typically as a predicted hourly average 98 percentile limit value. This predicted odour concentration has been adopted in the past as an acceptable approach in Ireland and the U.K. to demonstrate that no odour nuisance would occur beyond the site boundary of planned wastewater treatment plants.

Ambient odour limits proposed by the EPA in a report (Odour Impacts and Odour Emissions Control Measures for Intensive Agriculture, EPA 2002) regarding odorous emissions from pig production units propose a more stringent condition in relation to a limit value around new pig production units of 3 o.u./m^3 as a 98 percentile of predicted hourly concentrations. A target value of 1.5 o.u./m^3 also as a 98 percentile has also been proposed to provide a general level of protection against odour nuisance for the general public. A predicted odour concentration of 1.5 o.u./m^3, expressed as a 98 percentile of hourly values, is recommended by the Environment Agency in the U.K. (IPPC H4 Horizontal Guidance for Odour Part 1, 2003) for sources with a potential for offensive odours, including wastewater treatment plants.

For the Phase 2 design scenario, the predicted 99.5 percentile of short-term odour concentrations is predicted to be 0.25-0.6 o.u./m^3 at the nearest houses to the site, as shown in Figure 6. Predicted odour concentrations are shown to be less than 1 o.u./m^3 in the vicinity of the production building at the Millipore site. The corresponding 98 percentile odour concentrations presented in Figure 7 are less than 0.25 o.u./m^3 at the nearest private properties and near the Millipore plant.

5.0 ODOUR CONTROL MEASURES

The following measures to control and reduce potential sources of malodours are proposed for the extension of the wastewater treatment plant at Carrigtohill:-

- The inlet works channels and screening equipment will be housed in an enclosed building.
- Screened coarse material and grit from the grit trap will be washed and transferred into covered skips located within the inlet works building.
- Odorous emissions from inlet works building will be vented to atmosphere via a high efficiency odour control unit.
- Odorous emissions from the sludge treatment building will be vented to atmosphere via a high efficiency odour control unit.
- The odour control units will operate with removal efficiencies of over 95%. The location and design of the exhaust stacks to these units will ensure that adequate vertical release of emissions is achieved to ensure that there will be no malodours occuring beyond the site boundary from the exhaust stacks.
- The secondary sludge thickening tank will be covered and the headspace air in the tank ducted to the sludge treatment building odour control unit.

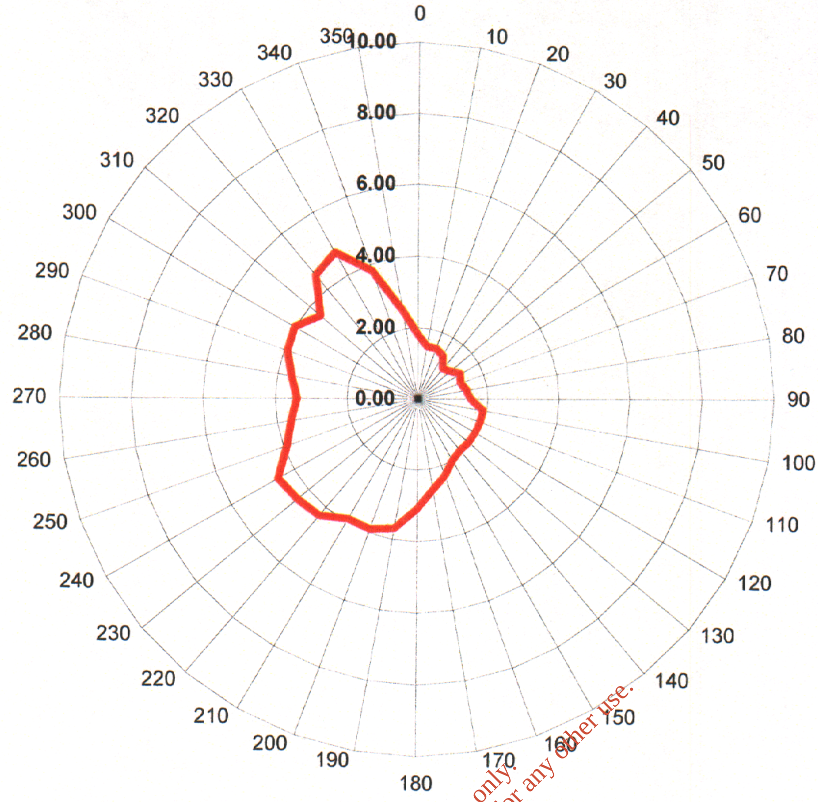
6.0 CONCLUSION

The predicted 99.5 percentile odour concentrations for Phase 1 of the scheme are predicted to be less than 0.5 o.u./m^3 at the nearest housing and so would be unlikely to result in a short-term nuisance odour. Predicted levels are within the range of 3-4 o.u./m^3 near the northern site boundary, adjacent to the access road. The corresponding 98 percentile odour concentrations are less than 0.5 o.u./m^3 beyond about 100m from the site boundary. For the Phase 2 final design stage, with all 6 SBR units in operation, the predicted short-term 99.5 percentile odour levels are also predicted to be less than 0.5 o.u./m^3 at the nearest housing. The corresponding 98 percentile odour concentrations are also well below 0.5 o.u./m^3 at the nearest housing.

The design and operation of the proposed upgrading and extension of the wastewater treatment plant at Carrigtohill minimises the potential for malodours to be detected beyond the site boundary. Based on the results of the odour dispersion modelling study carried out, no significant impact on the ambient air quality of the area is predicted due to odour emissions from the wastewater treatment plant.

FIGS 1-7

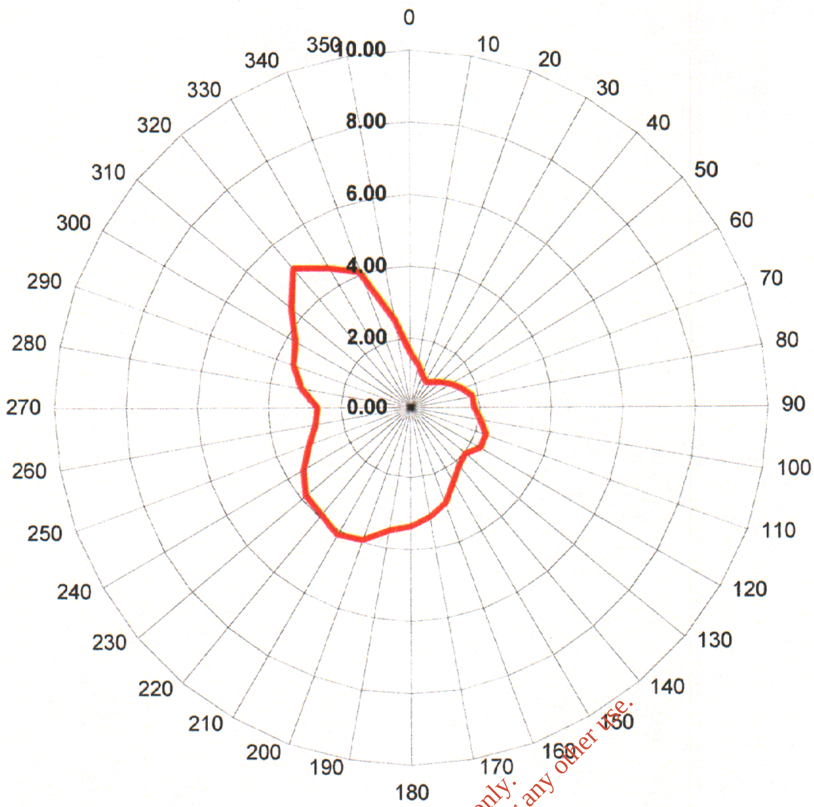
WIND ROSES AND AIR QUALITY DISPERSION MODELLING RESULTS



HOURLY WIND DIRECTION FREQUENCY - ALL WIND SPEEDS

Direction	Percentage Occurrence of Wind Speeds (m/s)						
	<2	2-3	3-5	6-8	9-11	>11	All
350-10	0.6	1.2	1.9	1.6	0.4	0.0	5.7
20-40	0.6	1.1	1.3	1.0	0.2	0.0	4.0
50-70	0.3	0.8	1.4	1.1	0.3	0.0	3.9
80-100	0.3	0.6	1.3	1.6	0.5	0.5	4.8
110-130	0.5	0.9	1.5	1.7	0.7	0.3	5.6
140-160	0.6	0.9	1.3	1.9	0.8	0.7	6.2
170-190	0.7	1.4	2.2	2.9	1.3	0.8	9.3
200-220	0.6	1.4	2.7	3.9	1.8	1.7	12.1
230-250	0.6	1.7	3.4	4.4	1.7	0.9	12.8
260-280	0.7	2.1	3.3	3.1	0.9	0.5	10.6
290-310	0.8	2.3	3.5	3.3	1.1	0.4	11.4
320-340	0.7	2.3	4.8	3.9	1.0	0.3	13.0
Calms	0.5						0.5
Total	**7.3**	**16.8**	**28.5**	**30.3**	**10.8**	**6.3**	**100.0**

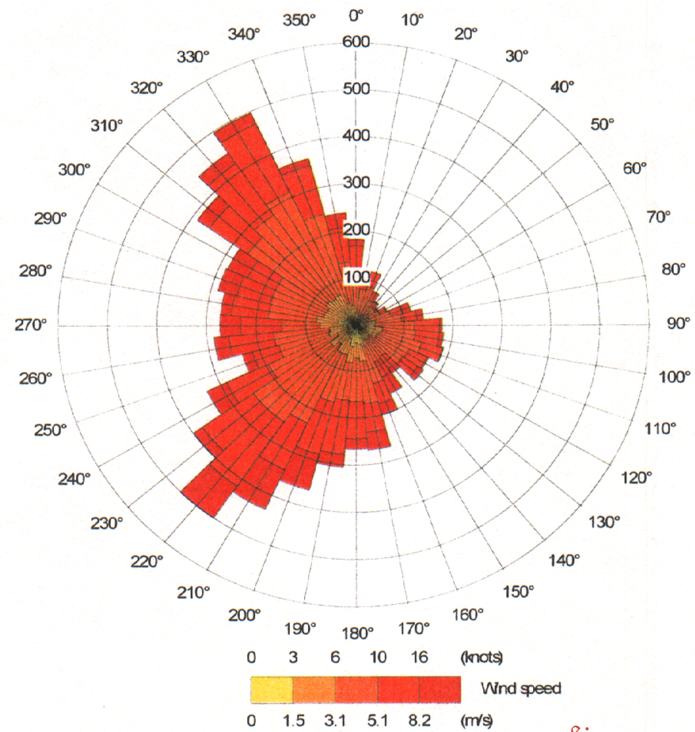
FIGURE 1: FREQUENCY OF WIND DIRECTION AND WIND SPEED FOR HOURLY OBSERVATIONS AT CORK AIRPORT, CO. CORK (1962-91)



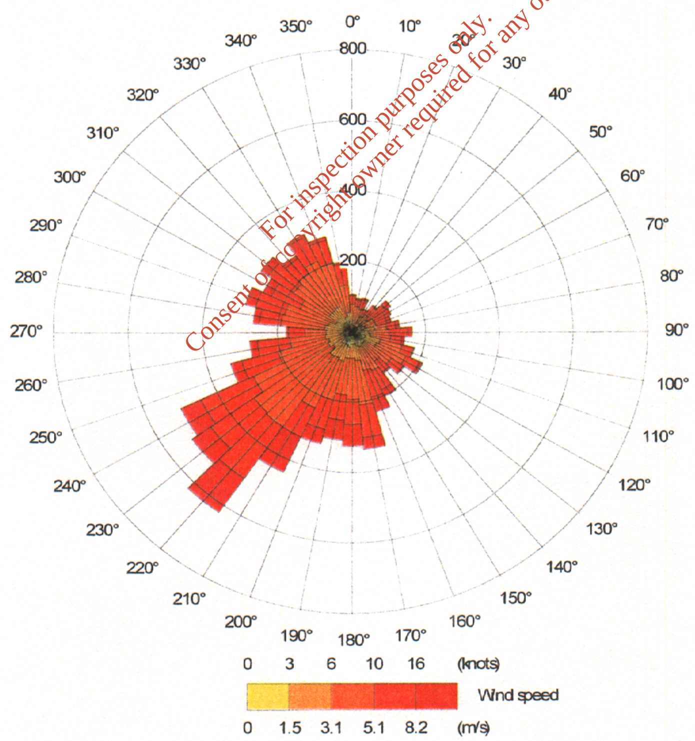
HOURLY WIND DIRECTION FREQUENCY - ALL WIND SPEEDS

Direction	Percentage Occurrence of Wind Speeds (m/s)					
	<2	2-3	3-5	6-8	9-11	>11	All
350-10	0.7	1.0	1.5	1.4	0.4	0.3	5.3
20-40	0.3	0.6	1.1	0.8	0.1	0.0	2.9
50-70	0.3	0.6	1.2	1.2	0.4	0.2	3.9
80-100	0.3	0.6	1.5	2.0	0.8	0.2	5.4
110-130	0.6	1.0	1.9	2.1	0.7	0.3	6.6
140-160	0.6	1.0	1.6	2.0	1.1	0.8	7.1
170-190	0.7	1.1	2.1	2.8	1.5	1.7	9.9
200-220	0.6	1.1	2.3	3.8	2.1	2.1	12.0
230-250	0.4	0.7	2.2	3.8	1.7	1.5	10.3
260-280	0.3	0.7	2.1	3.2	1.3	0.8	8.4
290-310	0.7	1.1	2.4	3.8	1.9	1.8	11.7
320-340	1.7	2.0	2.8	4.1	1.7	1.4	13.7
Calms	2.8						2.8
Total	10.0	11.5	22.7	31.0	13.7	11.1	100.0

FIGURE 2: FREQUENCY OF WIND DIRECTION AND WIND SPEED FOR HOURLY OBSERVATIONS AT ROCHES POINT (1962-91)



2005



2006

FIGURE 3: WIND ROSES OF HOURLY OBSERVATIONS AT CORK AIRPORT, DURING MODELLED YEARS 2005 AND 2006