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ODOUR IMPACT ASSESSMENT OF DROGHEDA WASTE WATER TREATMENT PLANT LOCATED IN MARSH ROAD, STAGREENAN, DROGHEDA, CO. LOUTH.

PERFORMED BY ODOUR MONITORING IRELAND ON BEHALF OF IRISH WATER

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1. Executive Summary

Odour Monitoring Ireland Ltd was commissioned by Irish Water to carry out an odour sampling and odour dispersion modelling assessment of odour emissions from Drogheda Waste Water Treatment Plant (WwTP) located in Marsh Road, Stagreenan, Drogheda, Co. Louth. The purpose of this assessment was to determine the potential odour impact of the operational facility on the surrounding population and to ascertain the levels of required odour mitigation to reduce odour impact on the surrounding population. Considered odour mitigation measures are proposed but these can change to alternative methods as long as the same or better outcomes are achieved by alternative proposed methods.

Following a site assessment utilising odour sampling and analysis techniques, two odour emission dataset were developed to determine the potential odour impact from the existing and proposed operational WwTP. These included:

Ref Scenario 1: Predicted overall odour emission rate from existing WwTP during routine operation (*see Table 4.1*) – **Model 1 & 10.**

Ref Scenario 2: Predicted overall odour emission rate from proposed WwTP following the implementation of considered odour mitigation within the existing waste water treatment facility (*see Table 4.2*) – **Model 11 & 18.**

Details of Scenario 1 – Model 1 to 10 and Scenario 2 – Model 11 to 18 are described in *Section 3.2*.

Aermod Prime (21112) was used to determine the overall odour impact of the existing WwTP operations and the odour reduction effect following the implementation of odour mitigation as set out in odour impact criteria presented in *Section 3.5*. The output data was analysed to calculate:

Existing site operation

- **Ref Scenario 1 - Model 1** - Predicted odour emission contribution of overall existing operational WwTP (including 3 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.3*).

- **Ref Scenario 1 - Model 2** - Predicted odour emission contribution of overall existing operational WwTP (including 3 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.4*).

- **Ref Scenario 1 - Model 3** - Predicted odour emission contribution of overall existing operational WwTP (including 2 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.5*).

- **Ref Scenario 1 - Model 4** - Predicted odour emission contribution of overall existing operational WwTP (including 2 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.6*).

- **Ref Scenario 1 - Model 5** - Predicted odour emission contribution of overall existing PST operation (2 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0 Ou_E/m^3 (*see Figure 7.7*).

- **Ref Scenario 1 - Model 6** - Predicted odour emission contribution of overall existing PST operation (2 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50 Ou_E/m^3 (*see Figure 7.8*).

- **Ref Scenario 1 - Model 7** - Predicted odour emission contribution of overall AD tank leakage (1 off tank) during routine operation (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0 Ou_E/m^3 (*see Figure 7.9*).

- **Ref Scenario 1 - Model 8** - Predicted odour emission contribution of overall AD tank leakage (1 off tank) during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50 Ou_E/m^3 (*see Figure 7.10*).

- **Ref Scenario 1 - Model 9** - Predicted odour emission contribution of overall leakage sources located within WwTP during routine operation (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0 Ou_E/m^3 (*see Figure 7.11*).

- **Ref Scenario 1 - Model 10** - Predicted odour emission contribution of overall leakage sources located within WwTP during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50 Ou_E/m^3 (*see Figure 7.12*).

Proposed site operation

- **Ref Scenario 2 - Model 11** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank only (*see Table 4.2*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.13*).

- **Ref Scenario 2 - Model 12** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank only (*see Table 4.2*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.14*).

- **Ref Scenario 2 - Model 13** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank and PST 2 (*see Table 4.2*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0 Ou_E/m^3 (*see Figure 7.15*).

- **Ref Scenario 2 - Model 14** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank and PST 2 (*see Table 4.2*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50 Ou_E/m^3 (*see Figure 7.16*).

- **Ref Scenario 2 - Model 15** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank, PST2 & 3 and sludge processing leakage (*see Table 4.2*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.50, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.17*).

- **Ref Scenario 2 - Model 16** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation (*see Table 4.2*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.18*).

These computations give the odour concentration at each Cartesian grid receptor location that is predicted to be exceeded for 2% (175 hours of exceedence) and 0.5% (44 hours of exceedence) over 5 years of screened hourly sequential meteorological data (Dublin Airport 2015 to 2019 inclusive). The Cartesian receptor grid was 20, 50 and 250 m spaced given a total receptor number of 4,388 over an area of 25.0 km^2.

The following conclusions were gathered from the study:

1. The odour measurement and dispersion modelling assessment was carried out in line with recommended guidance include EPA AG4. Odour sampling and measurement survey was carried out over a three day sampling period on the 5th, 6th and 10th August 2021. Dispersion modelling assessment was carried out utilising the latest USEPA regulatory model Aermod Prime 21112 with five years of hourly sequential meteorological data and appropriate topographical data for the site and surrounding area.

2. With regards to the odour emission rate for the existing Drogheda WwTP, the overall odour emission rate was 103,274 Ou_E/s with PST 2 and 3 in operation. The most significant odour sources in terms of odour character, intensity and hedonic tone were the Primary settlement tanks, Outflow chamber from the Primary settlement tanks, Inlet flow distribution chamber to the Anoxic / Aerobic tanks, Sludge holding tanks, Sludge thickening building, Sludge storage skips and AD tank leakage. With regards to these odour sources, these contribute to 61% of the overall odour load to atmosphere from the existing facility.

3. With regards to Scenario 1 – Model 1 and Model 2 – Existing operations with 3 PST tanks in operation, as can be observed, it is predicted that the levels of odours from the existing Drogheda Waste water Treatment Plant is likely to generate odour impact in the vicinity of the facility. Residential and commercial receptors located to the North, West, East and South of the operational facility will experience odour levels which are likely to give rise to odour complaints (*see Figures 7.3 & 7.4*). Given the nature of the predominant odours on site and given their odour character and hedonic tone, these are likely to elicit strong negative reactions from receptors that detect the odours. Given this fact, stricter odour impact criteria are required to assess this odour impact during existing operations. With regards to detectable odour levels, residential and commercial receptors will perceive maximum odour levels up to 3.58 Ou_E/m^3 for the 98th percentile of hourly averages for worst case meteorological year Dublin 2019 and 9.96 Ou_E/m^3 for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. This is in excess of the proposed odour impact criterion of less than or equal to 1.0 Ou_E/m^3 and 1.50 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019 for existing operations.

4. With regards to Scenario 1 – Model 3 and Model 4 – Existing operations with 2 PST tanks in operation (current situation on site as PST 1 is not in use at present), as can be observed, it is predicted that the levels of odours from the existing Drogheda Waste water Treatment Plant is likely to generate odour impact in the vicinity of the facility. Residential and commercial receptors located to the North, West, East and South of the operational facility will experience odour levels which are likely to give rise to odour complaints (*see Figures 7.5 & 7.6*). Given the nature of the predominant odours on site and given their odour character and hedonic tone, these are likely to elicit strong negative reactions from

receptors that detect the odours. Given this fact, stricter odour impact criteria are required to assess this odour impact during existing operations. With regards to detectable odour levels, residential and commercial receptors will perceive maximum odour levels up to 3.09 Ou_E/m^3 for the 98th percentile of hourly averages for worst case meteorological year Dublin 2019 and 8.96 Ou_E/m^3 for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. This is in excess of the proposed odour impact criterion of less than or equal to 1.0 Ou_E/m^3 and 1.50 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019 for existing current operations.

5. With regards to Scenario 1 – Model 5 and Model 6 – Existing contributions of PST 2 and 3 to overall odour plume (i.e. odour emissions from PST 2 and 3 only as PST 1 is not in use at present), as can be observed, it is predicted that the levels of odours from the operation of PST 2 and 3 is likely to generate odour impact in the vicinity of the facility. Residential and commercial receptors located to the North, West, East and South of the operational facility will experience odour levels which are likely to give rise to odour complaints (*see Figures 7.7 & 7.8*). Given the nature of the predominant odours on site and given their odour character and hedonic tone, these are likely to elicit strong negative reactions from receptors that detect the odours. Given this fact, stricter odour impact criteria are required to assess this odour impact during existing operations. With regards to detectable odour levels, residential and commercial receptors will perceive maximum odour levels up to 1.41 Ou_E/m^3 for the 98th percentile of hourly averages for worst case meteorological year Dublin 2019 and 3.82 Ou_E/m^3 for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. This is in excess of the proposed odour impact criterion of less than or equal to 1.0 Ou_E/m^3 and 1.50 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019 for existing current operations.

6. With regards to Scenario 1 – Model 7 and Model 8 – Existing contributions of AD Tank leakage to overall odour plume (i.e. odour emissions from one AD tank only), as can be observed, it is predicted that the levels of odours from the operation of AD tank is not likely to generate odour impact in the vicinity of the facility. All residential and commercial receptors located to the North, West, East and South of the operational facility will perceive maximum odour levels up to 0.41 Ou_E/m^3 for the 98th percentile of hourly averages for worst case meteorological year Dublin 2019 and 0.21 Ou_E/m^3 for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019 (*see Figures 7.9 & 7.10*). This is within the proposed odour impact criterion of less than or equal to 1.0 Ou_E/m^3 and 1.50 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019 for existing current operations.

7. With regards to Scenario 1 – Model 9 and Model 10 – Existing contributions of odour leakage from Sludge handling processes to overall odour plume (i.e. odour emissions from Sludge thickening building, Sludge holding tank and Storage skips), as can be observed, it is predicted that the levels of odours from the operation of the facility is not likely to generate odour impact in the vicinity of the facility although the odour plume encroaches upon the industrial neighbour due North of the facility. All residential and commercial receptors located to the North, West, East and South of the operational facility will perceive maximum odour levels up to 0.52 Ou_E/m^3 for the 98th percentile of hourly averages for worst case meteorological year Dublin 2019 and 1.19 Ou_E/m^3 for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019 (*see Figures 7.11 & 7.12*). This is within the proposed odour impact criterion of less than or equal to 1.0 Ou_E/m^3 and 1.50 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019 for existing current operations.

8. A number key mitigation technique will be considered for implemented within the Waste water Treatment Plant. These include:

a. Fix all leaks on the existing AD tank providing an odour reduction of 7,311 Ou_E/s.

b. Consider how odour reductions can be achieved on the current operational Primary settlement tanks 2 and 3. In this report it is considered that they will be covered and negatively ventilated to a two stage odour control unit. Other alternative methods can be considered and include:
    i. Reducing septicity in the network, primarily by chemical dosing
    ii. Reducing/addressing odours in the network pumping stations by introducing aeration which will control and prevent further generation of septicity and provide increased odour control on the pumping stations
    iii. Install a pre-aeration tank upstream of the PSTs designed to actively strip out the odours and provide odour control on the off gases
    iv. Cover the primary tanks and provide odour control on the head space.

   There are various operational, maintenance and H&S issues to be evaluated with each of the above options and a combination of options may be the most optimal. The application of mitigation on the Primary settlement tanks (PST) 2 and 3, Primary outflow chambers 2 and 3 and Aeration tanks inlet flow distribution chamber will result in an overall odour reduction of 54,656 Ou_E/s. It is assumed that PST1 will remain not in use and if brought into use, the same considered odour mitigation will be applied to PST 1.

c. Consider how odour reductions can be achieved on the current sludge process activities to include the Sludge thickening building, Sludge holding tanks and Sludge storage skips. In this report it is considered that further negative ventilated will be applied to the Sludge thickening building, Sludge storage tanks and Sludge storage skips. It is also considered that leaks on each of the Sludge holding tanks 1 to 3 will be repaired. All odours will be collected and treated in a to a two stage odour control unit. Other alternative methods can be considered. For example, instead of fully ventilating the sludge thickening building, each centrifugal thickener can be contained within a valance hood and the air around the enclosure can be ventilated at a high rate. The application of mitigation on the Sludge processing activities will result in an overall odour reduction of 16,654 Ou_E/s.

9. Following the implementation of all considered odour mitigation on the existing Drogheda WwTP, the predicted overall odour emission rate from the proposed Drogheda WwTP will be 24,653 Ou_E/s. This equates to an overall odour reduction of 79.31% following the implementation of proposed odour mitigation. It shall be noted that the implementation of odour mitigation will eliminate predominately odour sources which would be considered hedonically extremely offensive and unpleasant

10. With regards to Scenario 2 – Model 3 and Model 4 – Proposed operations, as can be observed, following the implementation of proposed odour mitigation, it is predicted that the levels of odours from the proposed Drogheda Waste water Treatment Plant is not likely to generate odour impact in the vicinity of the facility. Residential and commercial receptors located to the North, West, East and South of the operational facility will experience odour levels which are not likely to give rise to odour complaints. Given the fact that the implementation of odour mitigation in the proposed Drogheda WwTP will minimise the emission of odours which are hedonically very unpleasant (i.e. untreated odours from the Primary settlement tanks, Outlet flow chambers from Primary settlement tanks, Inlet flow distribution chamber to Anoxic and Oxic tanks, Sludge thickening building, Sludge holding tanks and Sludge skips), the guideline odour limit value requires to be less strict (i.e. solely as a result of the hedonic nature of the odours being emitted from the facility). The assessment criterion can revert to a normal assessment criteria of

less than or equal to 1.50 Ou_E/m^3 and 3.0 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. With regards to detectable odour levels, residential and commercial receptors will perceive maximum odour levels up to 1.10 Ou_E/m^3 for the 98th percentile of hourly averages for worst case meteorological year Dublin 2019 and 2.68 Ou_E/m^3 for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. This is well within the proposed odour impact criterion of less than or equal to 1.50 Ou_E/m^3 and 3.0 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. The implementation of odour mitigation will result in a significant reduction in perceived odour levels in the vicinity of the proposed operational facility and given the fact that hedonically offensive odours will be abated; the likelihood of complaints risk is greatly reduced.

The following high level recommendations were formed from the study. Such recommendation maybe implemented in a staged approach over a period of time. Although an approach is discussed within this document, alternative justified mitigation methods can be used to achieve odour reduction whether process change related or other forms of proven technology implementation.

- With regards to the AD tank leakage, repairs / reconstruction of the digester will be required to eliminate this odour source and potential impact of same. When in operation following repairs, it is highly unlikely that any emissions will occur from the digester. This will lead to a reduction in the odour plum spread by approximately 40 to 60 m. More significantly, the nature of the odour been emitted from the digester is very offensive and very detectable and repair should lead to a reduction in odour complaints.

- With regards to the Primary settlement tanks 2 and 3, these will require mitigated. A number of considered options are presented and these can be used in combination to achieve the same odour reduction outcomes that is required to minimise odour impact. These include:

    - Option 1 - Primary settlement tanks 2 and 3 (and also 1 if brought back into duty) to be covered with tight fitting covers with a leakage rate of less than 1 m^3 / m^2 of cover surface at 50 Pa pressure. Primary settlement tank 1 is currently not in use and will remain same for the foreseeable future. Primary settlement tanks 2 and 3 will also require to be negatively ventilated to an odour control system and maintained at a negative pressure of at least negative 50 Pa suction pressure. It is estimated that a ventilation volume of at least 2,100 m^3/hr shall be extracted and this collected air will require to be treated in an odour control system capable of achieving an exhaust odour threshold concentration of less than 500 Ou_E/m^3 (see OCU 1 in *Table 4.2*). It is expected that a two stage odour control system will be required to achieve this requirement (e.g. first stage biological treatment followed by second stage carbon polishing).
    - Option 2 - Reducing septicity in the network, primarily by chemical dosing
    - Option 3 - Reducing/addressing odours in the network pumping stations by introducing aeration which will control and prevent further generation of septicity and provide increased odour control on the pumping stations
    - Option 4 - Install a pre-aeration tank upstream of the PSTs designed to actively strip out the odours and provide odour control on the off gases

- With regards to the Outflow chamber from each of the Primary settlement tanks and Inlet flow distribution chamber to Anoxic / Aerobic tanks, these are located in close proximity to the primary settlement tanks and therefore extracted air from these sources can be treated in this system. In order to be successful in ensure no fugitive odour emissions from these sources, the existing covers will need to be made air tight. In addition, these sources will require to be placed under negative pressure by means of air extraction. It is estimate that a minimum extraction rate of 1,587 m^3/hr of odourous air will be required and treated in OCU 1.

- With regards to the Sludge holding tanks, these tanks are covered but the covers will require to be assessed with respect to integrity. Visual inspection of the covers indicate a number of gaps in the covers which will require to be repaired and / or replaced. These tank cover shall be processed proved to ensure they can achieve a sealing efficiency of 1 m^3 / m^2 of cover surface at 50 Pa pressure. These will also require to be negatively ventilated to an odour control system and maintained at a negative pressure of at least negative 50 Pa suction pressure. It is estimated that a ventilation volume of at least 1,200 m^3/hr shall be extracted from the three tanks and this collected air will require to be treated in an odour control system capable of achieving an exhaust odour threshold concentration of less than 500 Ou_E/m^3 (see OCU 2 in *Table 4.2*). It is expected that a two stage odour control system will be required to achieve this requirement (e.g. first stage biological treatment followed by second stage carbon polishing).

- With regards to the Sludge centrifudge building, this building is currently leaking odours due to the nature of the building fabric and doors. The building shall be made air tight and processed proved to achieve a leakage rate of less than 1.50 m^3 / m^2 clad surface / hr @ 50 Pa. In addition, improved and focused ventilation shall be implemented within the building to improve occupational air conditions within the building. It is estimated that an additional ventilation volume of at least 4,328 m^3/hr shall be extracted and this collected air will require to be treated in an odour control system capable of achieving an exhaust odour threshold concentration of less than 500 Ou_E/m^3 (see OCU 2 in *Table 4.2*). It is expected that a two stage odour control system will be required to achieve this requirement (e.g. first stage biological treatment followed by second stage carbon polishing). Other considered approaches can be utilised to include enclosing around the centrifudge and ventilating these to an odour control system.

- With regards to the Sludge storage skips and conveying system, odours are currently leaking / displaced from this process. In order to prevent / minimise the leakage of odour from these processes, odour extraction shall be applied to the conveying system and sludge storage skips. It is estimated that an additional ventilation volume of at least 1,500 m^3/hr shall be extracted and this collected air will require to be treated in an odour control system capable of achieving an exhaust odour threshold concentration of less than 500 Ou_E/m^3 (see OCU 2 in *Table 4.2*). It is expected that a two stage odour control system will be required to achieve this requirement (e.g. first stage biological treatment followed by second stage carbon polishing).

- Therefore in order to treat the extracted air from these processes, it is proposed that two new odour control systems will be required to treat the collected odourous air. These are noted as new OCU 1 and new OCU 2 within *Table 4.2*. The total minimum treatment capacity of new OCU 1 and new OCU 2 shall be 4,887 m^3/hr and 7,028 m^3/hr, respectively. This minimum ventilation rate may change following detailed design studies of the various options.

2. Introduction

Odour Monitoring Ireland Ltd was commissioned by Irish Water to perform an odour impact and dispersion modelling assessment of the operational Drogheda Waste Water Treatment Plant (WwTP) utilising odour sampling techniques and dispersion modelling software Aermod Prime (21112). Like the majority of facilities, the operation of the facility is faced with the issue of preventing odours causing impact to the public at large.

Following on from the assessment of the existing facility, the impact of proposed considered odour mitigation techniques on certain odour sources located within the existing facility were assessed. The odour sources considered included primary waste water treatment and sludge processing and handling processes. These were considered due to the odour character, intensity and hedonic nature of these odours in such facilities. The impact on perceived odour concentration levels in the vicinity of the facility were assessed utilising dispersion modelling impact assessment and impact reductions were compared against acceptable odour guideline limit values. Dispersion modelling assessment was carried out in accordance with EPA guidance AG4 (EPA, 2019).

Two odour emission scenarios were developed to take account of the routine operations in the existing Waste Water Treatment Plant and the proposed facility following the implementation of proposed odour mitigation. This odour emission rate and specified source characteristics were inputted into Aermod Prime dispersion model (21112) in order to determine the overall odour impact at and/or beyond the boundary of the facility.

This assessment was performed in accordance with currently recommended international guidance and practice for the assessment of odours (Environment Agency H4 and Irish EPA AG4 guidance documents).

This report will present the Materials and Methods, Results and Discussion, Conclusions and high level considered recommendations gathered throughout the assessment.

3. Materials and Methods

This section will describe the materials and methods used for the odour sampling and dispersion modelling assessment.

3.1. Odour sampling and analysis

This section will provide the materials and methods used to sample and analyse odours from the operational WwTP.

3.1.1. Odour sampling

Point sampling

In order to obtain air samples for odour assessment, a static sampling method was used where air samples were collected in 40 to 60 litre pre-conditioned Nalophan^{NA} bags using a vacuum sampling device over a 15/20 minute period. The sampler operates on the 'lung principle', whereby the air is removed from a rigid container around the bag by a battery powered SKC vacuum pump at a rate of 4 l min^{-1}. This caused the bag to fill through a stainless steel and PTFE tube whose inlet is placed in source air, with the volume of sample equal to the volume of air evacuated from the rigid container. All odour-sampling bags were pre-conditioned and flushed with odourous air to remove any interference from the sample material.

In order to estimate the odour levels from the AD tank process, Irish Water sampled odours from a representative digester located in Leixlip WwTP. This was analysed for Odour units and the estimated gas leakage rate in m^3/s was used to calculate an odour emission rate in Ou_E/s. The source was represented as a discrete point source within the air dispersion model.

Area sampling

In order to measure the flux odour emission rate from area odour surfaces located within the Waste Water Treatment Plant, a calibrated wind tunnel method was used. This calibrated sampling hood allowed for the accurate determination of odour emission rate from the surface of the tanks such as the Primary settlement tanks, Anoxic and Oxic tanks, Final settlement tanks. In combination with the point source static sampling method, a 60-litre sample over a fifteen to twenty-minute period was obtained (Jiang et al., 2002). Area source mass emission rates/flux was presented as $Ou_E/m^2/s^1$.

3.1.2. Olfactometry

Olfactometry using the human sense of smell is the most valid means of measuring odour (Dravniek et al, 1986) and at present is the most commonly used method to measure the concentration of odour in air (Hobbs et al, 1996). Olfactometry is carried out using an instrument called an olfactometer. Three different types of dynamic dilution olfactometers exist:

- Yes/No Olfactometer
- Forced Choice Olfactometer
- Triangular Forced Choice Olfactometer.

In the dynamic dilution olfactometer, the odour is first diluted and is then presented to a panel of screened panellists of no less than four (CEN, 2003) Panellists are previously screened to ensure that they have a normal sense of smell (Casey et al., 2003). According to the CEN standard this screening must be performed using a certified reference gas *n*-butanol. This screening is applied to eliminate anosmia (low sensitivity) and super-noses (high sensitivity). The odour analysis has to be undertaken in a low odour environment such as an air-conditioned odour free laboratory. Analysis should be performed within 30 hours of sampling.

3.1.3. Odour measurement in accordance with the EN13725:2003

An ECOMA TO8 dynamic yes/no olfactometer was used throughout the measurement period to determine the odour threshold concentration of the sample air. The odour threshold concentration is defined as the dilution factor at which 50% of the panel can just detect the odour. Only those panel members who pass screening tests with n-butanol (certified reference gas, CAS 72-36-3) and who adhered to the code of behaviour were selected as panellists for olfactometry measurements (CEN, 2003). Odour measurement was carried out in an odour free laboratory in accordance with EN13725:2003. The analyses were carried out in the laboratory of Odour Monitoring Ireland Ltd in Trim Co. Meath.

3.1.4. 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 odour units ($Ou_E\ m^{-3}$).

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 123µg of n-butanol evaporated in one cubic meter of neutral gas at standard conditions (CEN, 2003).

3.1.5. 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). For an area odour source, this is equal to the odour emission flux ($Ou_E/m^2/s$) multiplied by the total surface area (m^2) of the odour source to provide an odour emission rate in Ou_E/s.

The odour emission rate is used in conjunction with the dispersion model to generate odour concentration contours for comparison with the proposed guideline limit values for the existing and proposed Waste Water Treatment Facility. It will also estimate the approximate radius of impact for the existing and proposed facility (Hobson et al, 1995).

The overall odour emission rates for the existing and proposed Scenarios 1 and 2 are presented in *Tables 4.1* & *4.2*.

3.2. Model assumptions

The following model assumptions were used to construct and generate the output results from the dispersion model. These include:

- The input data used within the dispersion model was obtained from measurements carried out on site on the 05th, 06th and 10th August 2021.
- Two assessment scenarios were assessed to take account of client requirements.

Existing site operation

- **Ref Scenario 1 - Model 1** - Predicted odour emission contribution of overall existing operational WwTP (including 3 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.3*).
- **Ref Scenario 1 - Model 2** - Predicted odour emission contribution of overall existing operational WwTP (including 3 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.4*).
- **Ref Scenario 1 - Model 3** - Predicted odour emission contribution of overall existing operational WwTP (including 2 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.5*).
- **Ref Scenario 1 - Model 4** - Predicted odour emission contribution of overall existing operational WwTP (including 2 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.6*).
- **Ref Scenario 1 - Model 5** - Predicted odour emission contribution of overall existing PST operation (2 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0 Ou_E/m^3 (*see Figure 7.7*).
- **Ref Scenario 1 - Model 6** - Predicted odour emission contribution of overall existing PST operation (2 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50 Ou_E/m^3 (*see Figure 7.8*).
- **Ref Scenario 1 - Model 7** - Predicted odour emission contribution of overall AD tank leakage (1 off tank) during routine operation (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0 Ou_E/m^3 (*see Figure 7.9*).
- **Ref Scenario 1 - Model 8** - Predicted odour emission contribution of overall AD tank leakage (1 off tank) during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50 Ou_E/m^3 (*see Figure 7.10*).
- **Ref Scenario 1 - Model 9** - Predicted odour emission contribution of overall leakage sources located within WwTP during routine operation (*see Table 4.1*), to odour plume dispersal at

the 98th percentile for an odour concentration of less than or equal to 1.0 Ou_E/m^3 (*see Figure 7.11*).

- **Ref Scenario 1 - Model 10** - Predicted odour emission contribution of overall leakage sources located within WwTP during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50 Ou_E/m^3 (*see Figure 7.12*).

<u>Proposed site operation</u>

- **Ref Scenario 2 - Model 11** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank only (*see Table 4.2*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.13*).

- **Ref Scenario 2 - Model 12** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank only (*see Table 4.2*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.14*).

- **Ref Scenario 2 - Model 13** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank and PST 2 (*see Table 4.2*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0 Ou_E/m^3 (*see Figure 7.15*).

- **Ref Scenario 2 - Model 14** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank and PST 2 (*see Table 4.2*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50 Ou_E/m^3 (*see Figure 7.16*).

- **Ref Scenario 2 - Model 15** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank, PST2 & 3 and sludge processing leakage (*see Table 4.2*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.50, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.17*).

- **Ref Scenario 2 - Model 16** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation (*see Table 4.2*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.18*).

- AERMOD Prime (21112) dispersion model was used to assess the predicted odour concentrations on the surrounding area. This is the latest USEPA regulatory model.

- Five years of hourly sequential meteorological data was screened within the dispersion model in order to provide statistical sound predictions for the impact assessment. Dublin Airport 2015 to 2019 inclusive was used for the operation of the dispersion model while Dublin Airport 2019 was determined as worst case impact year. This is in keeping with current national and international recommendations (EPA Guidance AG4 and Environment Agency). In addition, AERMOD incorporates a meteorological pre-processor AERMET PRO. The AERMET PRO meteorological preprocessor requires the input of surface characteristics, including surface roughness (z0), Bowen Ratio and Albedo by sector and season, as well as hourly observations of wind speed, wind direction, cloud cover, and temperature. The values of Albedo, Bowen Ratio and surface roughness depend on land-use type (e.g., urban, cultivated land etc) and vary with seasons and wind direction. The assessment of appropriate land-use type was carried out to a distance of 10km from the meteorological station for Bowen Ratio and Albedo and to a distance of 1km for surface roughness in line with USEPA recommendations

- The 98th and 99.5th percentile of maximum hourly predicted concentrations was used to provide the output data from the dispersion model.

- Emissions to the atmosphere from the operations were assumed to occur 24 hours each day / 7 days per week over a standard year at 100% output for all sources.

- All building wake affects were assessed within the dispersion model especially given the nature of the structures located within the WwTP. USEPA regulatory model BPIP 04274 was utilised.

- Terrain effects were accounted within the dispersion model using AERMAP software and digital data from the client and OSI (0.50 and 10 m spaced). Given the complex terrain within and in the vicinity of the WWTP, the client carried out a laser terrain assessment to provide accurate elevations throughout the site. This was added to the OSI 10 m spaced terrain data for elevations outside the site boundary. This provided accurate topographical profile of the surrounding area inside and outside the site boundary. A total area of 25 km^2 was included within the dispersion model.

- Flagpole receptors were established at an elevation of 1.8 m above ground level in order to take account of average breathing level of receptors.

- 43 Individual sensitive receptors were also incorporated within the dispersion modelling assessment for indicative purposes. Results at each of these sensitive receptors are presented in *Section 5* of this report for both the existing and proposed assessment scenarios.

3.3. Dispersion modelling assessment

3.3.1. 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).

3.3.2. AERMOD Prime

The AERMOD model was developed through a formal collaboration between the American Meteorological Society (AMS) and U.S. Environmental Protection Agency (U.S. EPA). AERMOD is a Gaussian plume model and replaced the ISC3 model in demonstrating compliance with the National Ambient Air Quality Standards (Porter et al., 2003) AERMIC (USEPA and AMS working group) is emphasizing development of a platform that includes air turbulence structure, scaling, and concepts; treatment of both surface and elevated sources; and simple and complex terrain. The modelling platform system has three main components: AERMOD, which is the air dispersion model; AERMET, a meteorological data pre-processor; and AERMAP, a terrain data pre-processor (Cora and Hung, 2003).

AERMOD is a Gaussian steady-state model which was developed with the main intention of superseding ISCST3 (NZME, 2002). The AERMOD modeling system is a significant departure from ISCST3 in that it is based on a theoretical understanding of the atmosphere rather than depend on empirical derived values. The dispersion environment is characterized by turbulence theory that defines convective (daytime) and stable (nocturnal) boundary layers instead of the stability categories in ISCST3. Dispersion coefficients derived from turbulence theories are not based on sampling data or a specific averaging period. AERMOD was especially designed to support the U.S. EPA's regulatory modeling programs (Porter at al., 2003)

Special features of AERMOD include its ability to treat the vertical in-homogeneity of the planetary boundary layer, special treatment of surface releases, irregularly-shaped area sources, a three plume model for the convective boundary layer, limitation of vertical mixing in the stable boundary layer, and fixing the reflecting surface at the stack base (Curran et al., 2006). A treatment of dispersion in the presence of intermediate and complex terrain is used that improves on that currently in use in ISCST3 and other models, yet without the complexity of the Complex Terrain Dispersion Model-Plus (CTDMPLUS) (Diosey et al., 2002).

3.4. Odour impact criterion for odours

The odour impact criterion chosen for the analysis of the output data from the dispersion was based on a number of assumptions and agreed guideline limit values. Given the fact that the existing Waste Water Treatment Plant is emission odours of a considered hedonically unpleasant odour which is untreated and emitting directly to atmosphere and are likely to fluctuate in odour character, intensity and hedonic tone, a more strict odour impact criteria is considered appropriate for this facility. The proposed odour impact criteria for the existing Drogheda WwTP will be as follows:

- **Ref Scenario 1 – Models 1 to 10 – Existing facility** – All sensitive receptors shall not be exposed to an odour concentration of greater than to 1.0 and 1.50 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. Models 1, 2, 3 and 4 include the odour contour representation for Irish Waters internal odour standard of less than or equal to 3.0 and 5.0 Ou_E/m^3 contours.

With regards to the proposed Drogheda WwTP operation and depending on the staged abatement strategy that will be applied the assessment criterion will depend on the mitigation strategy and implementation of same. Given that during Stage 1 implementation, only the AD tank leakage will be mitigated, other hedonically unpleasant odours such as PST's and Sludge processing activities will remain active and therefore the assessment criterion will need to be lower in order to take account of potential impacts. Given this fact the proposed Drogheda WwTP will be assessed against the following criterion:

- **Ref Scenario 2 – Model 11 to 14 – Proposed facility** – All sensitive receptors shall not be exposed to an odour concentration of greater than 1.0 and 1.50 Ou_E/m^3 for the 98th and

99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. Models 11 and 12 include the odour contour representation for Irish Waters internal odour standard of less than or equal to 3.0 and 5.0 Ou_E/m^3 contours.

When the full abatement strategy is implemented and given the fact the odour mitigation will be implemented on all hedonically unpleasant odour sources such as the AD tank, Primary settlement tanks, Outflow chambers from Primary settlement tanks, Inlet flow distribution chamber to Anoxic / Oxic tanks, Sludge holding tanks, Sludge thickening building and Sludge storage skips, the potential for the facility generate significantly unpleasant odours is markedly reduced. Given this fact, the proposed odour impact criteria for the proposed Drogheda WwTP will be as follows:

- **Ref Scenario 2 – Model 15 to 16 – Proposed facility** – All sensitive receptors shall not be exposed to an odour concentration of greater than 1.5 and 3.0 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. Models 15, and 16 include the odour contour representation for Irish Waters internal odour standard of less than or equal to 3.0 and 5.0 Ou_E/m^3 contours.

In order to assess the potential for worst case odour impact, five years of hourly sequential met data is screened and the data for the worst case meteorological year is presented. This is in keeping with EPA guidance (AG4, 2019).

3.5. Meteorological data.

Dublin Airport met station 2015 to 2019 inclusive was used for the operation of Aermod Prime 21112. This allowed for the determination of dispersion for 5 years of meteorological data for the determination of overall odour impact from the existing and proposed WwTP operations at and/or beyond the boundary of the facility.

Section 9 presents the windrose and tabular statistics for Dublin Airport meteorological station for years 2015 to 2019 inclusive.

3.6. Terrain data.

Topography affects within and in the vicinity of the site were accounted for in the model utilising topo data as gathered by the client and from Ordnance Survey Ireland (i.e. 0.50m and 10 m spaced). A 0.50 m grid spacing was required in order to take account of the significant topographical features located within the boundary of the facility.

All building wake effects are accounted for in the modelling scenario (i.e. building effects on point sources) as this can have a major effect on the odour plume dispersion at short distances. This was performed using the BPIP Prime algorithm 04247 within the dispersion model.

4. Results

This section will present the results obtained from the odour measurement and dispersion modelling study.

4.1. Odour emission dataset for Scenario 1 – Model 1 to 10 and Scenario 2 – Model 11 to 16

Two data sets for odour emission rates were calculated to determine the potential odour impact of the existing and proposed operational Drogheda WwTP utilising odour emission data as gathered on site and following the implementation of proposed mitigation. These scenarios include:

Ref Scenario 1: Predicted overall odour emission rate from existing WwTP during routine operation (*see Table 4.1*) – **Models 1 to 10.**

Ref Scenario 2: Predicted overall odour emission rate from proposed WwTP following the implementation of odour mitigation within the existing waste water treatment facility (*see Table 4.2*) – **Models 11 to 16.**

Aermod Prime (21112) was used to determine the overall odour impact of the existing and proposed Drogheda WwTP as set out in odour impact criteria's presented in *Section 3.4.*

Table 4.1 illustrates the odour emission input data measured and utilised within the dispersion model for Scenario 1 Models 1 to 10 – Existing Drogheda WwTP.

Table 4.2 illustrates the odour emission input data calculated and utilised within the dispersion model for Scenario 2 Models 11 to 16 – Proposed Drogheda WwTP following the implementation of proposed odour mitigation.

For both Scenarios, the overall odour source characteristics are included for clarity.

The measured overall odour emission rate from the operational existing Drogheda WwTP was 126,438 Ou_E/s on these days of monitoring.

The predicted overall odour emission rate from the proposed Drogheda WwTP when all mitigation measures are implemented will be 24,653 Ou_E/s.

This equates to an overall odour reduction of **80.50**% following the implementation of proposed considered odour mitigation. It shall be noted that the implementation of odour mitigation will eliminate predominately odour sources which would be considered hedonically extremely offensive and unpleasant. A number of considered odour mitigation measures are examined within the document. These are considered and alternative odour mitigation measures can be proposed as long as they achieve the same outcome in terms of odour reduction.

Table 4.1. Predicted overall odour emission rate from operational existing Drogheda WwTP (ref Scenario 1 – Model 1 to 10).

Location key	Sample description	Average odour threshold conc. (Ou_E/m^3)	Average odour emission flux ($Ou_E/m^2/s$)	Volume flow rate (Am^3/s, 293.15K, 101.3Kpa, wet gas)	Total exposed / open area (m^2)	Odour emission rate (Ou_E/s)	% contribution
K1	Preliminary treatment building headspace	4,505	-	-	-	-	--
K2	Prelim biofilter Outlet (Average) (All three vents combined)	617	-	5.2008	-	3,208	2.54
K3	Primary settlement tank 1	-	27.9	-	823.85	22,985[1]	18.18
K4	Primary settlement tank 2	-	27.9	-	824.54	23,005[2]	18.19
K5	Primary settlement tank 3	-	37.6	-	825.24	31,029[2]	24.54
K6	Primary pump station vents 1	1,287	-	0.004	-	5	0.004
K7	Primary pump station vents 2	1,287	-	0.004	-	5	0.004
K8	Primary settlement tank outlet flume 1 (Average)	37,326	-	0.0048	-	179[1]	0.14
K9	Primary settlement tank outlet flume 2 (Average)	37,326	-	0.0048	-	179[2]	0.14
K10	Primary settlement tank outlet flume 3 (Average)	37,326	-	0.0048	-	179[2]	0.14
K11	Aeration Distribution chamber	39,257	-	0.024	-	942[3]	0.75
K12	Aeration tanks 1 – 6 anoxic zone (Average)	-	8.3	-	285	2,366	1.87
K13	Aeration tanks 1 – 6 aerobic zone (Average)	-	5.0	-	2,123.60	10,618	8.40
K14	Centrifudge biofilter outlet Average	764	-	0.479	-	366	0.29
K15	Centrifudge biofilter inlet	5,792	-	-	-	-	--
K16	Sludge biofilter No 1 outlet (Average)	644	-	0.403	-	259	0.21
K17	Sludge biofilter No1 inlet	6,114	-	-	-	-	--
K18	Sludge biofilter No.2 Outlet (Average)	845	-	1.067	-	901	0.71
K19	Sludge biofilter No2 inlet	5,470	-	-	-	-	-
K20	Centrifudge building headspace (Average)	8,366		1.396	-	11,679[4]	9.24
K21	Final settlement tank 1 (Average)	-	0.9	-	1556.13	1,401	1.11
K22	Final settlement tank 2 (Average)	-	1.2	-	1557.2	1,869	1.48
K23	Final settlement tank 3 (Average)	-	1.0	-	1550.3	1,550	1.23
K24	Supernatant biofilter outlet (Average)	442	-	0.186	-	82	0.07
K25	Supernatant sump biofilter inlet	2,092	-	-	-	-	-
K26	Sludge holding tank 3 headspace (Average)	6,918	-	0.36	-	2,491[5]	1.97
K27	Sludge skip headspace	18,020	-	0.192	-	3,460[6]	2.74
K28	Storm water tanks 1 – 3 (empty)	-	0.5	-	736.8	368	0.29
K31	AD Tank	1,021,745	-	0.0071556	-	7,311[7]	5.78
Total odour emission rate (Ou_E/s)	**-**	**-**	**-**	**-**	**-**	**126,438[8]**	**100.00**

Notes: [1] denotes that Primary Settlement Tank 1 and its associated process links are currently not in operation. Different model runs utilising both the three PST (i.e. PST1, 2 and 3) and two PST (i.e. PST 2 and 3) are accounted for in model runs – see Model 1 and 2.

[2] denotes that PST 2 and 3 are in operation at the facility and are accounted for within model run – see Model 3 and 4

[3] denotes the odour emissions are occurring through leakage from the inlet distribution chamber to the Aeration tanks. This odour would be similar on odour character to the odour emanating from PST 2 and 3.

[4] denotes that this is the odour emission rate leakage from the Centrifudge building.

[5] denotes that this is the estimate odour leakage rate from the Sludge holding tank 3. There is currently no air extraction from this tank. All sludge holding tanks have roof integrity issues which could give rise to odour leakage.

[6] denotes that this is an estimated odour leakage rate from the sludge holding skips. Odour extraction ducting is in place and requires to be assessed in terms of extraction capacity.

[7]denotes that is the calculated odour leakage rate from the one operational AD tank. Digester gas was obtained from a reference digester in Leixlip WWTP and an estimated gas leakage rate was utilised to estimate an overall odour emission rate from the operational tank.

[8] denotes that the overall odour emission rate from Drogheda WWTP with all PST tanks 1 to 3 in operation will be 126,438 Ou_E/s. With PST tanks 2 and 3 in operation, the overall odour emission is 103,274 Ou_E/s.

With regards to the odour emission rate for the existing Drogheda WwTP, the overall odour emission rate was 126,438 Ou_E/s with three PST's in operation or 103,274 Ou_E/s for two PST's in operation (i.e. current situation as PST 1 is not in use at present). The most significant odour sources in terms of odour character, intensity and hedonic tone were the Primary settlement tanks, Outflow chamber from the Primary settlement tanks, Inlet flow distribution chamber to the Anoxic / Aerobic tanks, Sludge holding tanks, Sludge thickening building, Sludge storage skips and AD tank leakage. With regards to these odour sources, these contribute to 79.08% of the overall odour load to atmosphere from the existing facility (i.e. assuming 2 off PST tanks in operation).

In order to eliminate these as significant odour sources, considered odour mitigation is required to be implemented on these odour sources.

With regards to the Primary settlement tanks (PST's), PST 1 shall remain not in use. A number of considered odour mitigation techniques are proposed and can be used in combination with each other.

While the modelling demonstrates that the PSTs are a significant source of odours it also shows that the odours being generated from the PSTs are very high in comparison to that released typically from PSTs. This indicates that the wastewater is already septic and therefore a number of options have to be evaluated to address the odours:

- Reducing septicity in the network, primarily by chemical dosing
- Reducing/addressing odours in the network pumping stations by introducing aeration which will control and prevent further generation of septicity and provide increased odour control on the pumping stations
- Install a pre-aeration tank upstream of the PSTs designed to actively strip out the odours and provide odour control on the off gases

- Consideration shall be given to the covering of PST 2 and 3 with tight fitting covers with a leakage rate of less than 1 m^3 / m^2 of cover surface at 50 Pa pressure. These will also require to be negatively ventilated to an odour control system and maintained at a negative pressure of at least negative 50 Pa suction pressure. It is estimated that a ventilation volume of at least 2,100 m^3/hr (i.e. for 3 off PST's) and 1,400 m^3/hr (i.e. for 2 off PST's) shall be extracted and this collected air will require to be treated in an odour control system capable of achieving an exhaust odour threshold concentration of less than 500 Ou_E/m^3 (see OCU 1). It is expected that a two stage odour control system will be required to achieve this requirement (e.g. first stage biological treatment followed by second stage carbon polishing). Other mitigation methods can be considered to achieve the same outcome but these shall be proven before and upon implementation.

With regards to the Outflow chamber from each of the Primary settlement tanks and Inlet flow distribution chamber to Anoxic / Aerobic tanks, these are located in close proximity to the primary settlement tanks and therefore extracted air from these sources can be treated in this system. In order to be successful in ensure no fugitive odour emissions from these sources, the existing covers will need to be made air tight. In addition, these sources will require to be placed under negative pressure by means of air extraction. It is estimate that a minimum extraction rate of 1,587 m^3/hr of odourous air will be required and treated in OCU 1 – *see Table 4.2*.

With regards to the Sludge holding tanks, these tanks are covered but the covers will require to be assessed with respect to integrity. Visual inspection of the covers indicate a number of gaps in the covers which will require to be repaired and / or replaced. These tank cover shall be processed proved to ensure they can achieve a sealing efficiency of 1 m^3 / m^2 of cover surface at 50 Pa pressure. These will also require to be negatively ventilated to an odour control system and maintained at a negative pressure of at least negative 50 Pa suction pressure. It is estimated that a ventilation volume of at least 1,200 m^3/hr shall be extracted from the three tanks and this collected air will require to be treated in an odour control system capable of achieving an exhaust odour threshold concentration of less than 500 Ou_E/m^3 (see OCU 2 – *see Table 4.2*). It is expected that a two stage odour control system will be required to achieve this requirement (e.g. first stage biological treatment followed by second stage carbon polishing).

With regards to the Sludge centrifudge building, this building is currently leaking odours due to the nature of the building fabric and doors. The building shall be made air tight and processed proved to achieve a leakage rate of less than 1.50 m^3 / m^2 clad surface / hr @ 50 Pa. In addition, improved and focused ventilation shall be implemented within the building to improve occupational air conditions within the building. It is estimated that an additional ventilation volume of at least 4,328 m^3/hr shall be extracted and this collected air will require to be treated in an odour control system capable of achieving an exhaust odour threshold concentration of less than 500 Ou_E/m^3 (see OCU 2). It is expected that a two stage odour control system will be required to achieve this requirement (e.g. first stage biological treatment followed by second stage carbon polishing). Other considered approaches can be utilised to include enclosing around the centrifudge and ventilating these to an odour control system. This will be borne out in detailed design.

With regards to the Sludge storage skips and conveying system, odours are currently leaking / displaced from this process. In order to prevent / minimise the leakage of odour from these processes, odour extraction shall be applied to the conveying system and sludge storage skips. It is estimated that an additional ventilation volume of at least 1,500 m^3/hr shall be extracted and this collected air will require to be treated in an odour control system capable of achieving an exhaust odour threshold concentration of less than 500 Ou_E/m^3 (see OCU 2). It is expected that a two stage odour control system will be required to achieve this requirement (e.g. first stage biological treatment followed by second stage carbon polishing).

Therefore in order to treat the extracted air from these processes, it is proposed that two new odour control systems will be required to treat the collected odourous air. These are noted as new OCU 1 and new OCU 2 within *Table 4.2*. The total minimum treatment capacity of new OCU 1 and new OCU 2 shall be 4,887 m^3/hr and 7,028 m^3/hr, respectively. This minimum ventilation rate may change following detailed design studies of the various options. *Table 4.2* presents the proposed odour mitigation scenarios for Drogheda WwTP.

Table 4.2. Predicted overall odour emission rate from proposed Drogheda WwTP (ref Scenario 2 – Model 11 to 16).

Location key	Sample description	Average odour threshold conc. (Ou_E/m^3)	Average odour emission flux ($Ou_E/m^2/s$)	Volume flow rate (Am^3/s, 293.15K, 101.3KPa, wet gas)	Total exposed / open area (m^2)	Odour emission rate (Ou_E/s)	% contribution
K1	Preliminary treatment building headspace	4,505	-	-	-	-	-
K2	Prelim biofilter Outlet (Average) (All three vents combined)	617	-	5.2008	-	3,208	13.01
K3	Primary settlement tank 1	Whether not in use or in operation	-	-	0	See new OCU 1	-
K4	Primary settlement tank 2	-	-	-	0	See new OCU 1	-
K5	Primary settlement tank 3	-	-	-	0	See new OCU 1	-
K6	Primary pump station vents 1	1,287	-	0.004	-	5	0.02
K7	Primary pump station vents 2	1,287	-	0.004	-	5	0.02
K8	Primary settlement tank outlet flume 1 (Average)	-	-	0	-	See new OCU 1	-
K9	Primary settlement tank outlet flume 2 (Average)	-	-	0	-	See new OCU 1	-
K10	Primary settlement tank outlet flume 3 (Average)	-	-	0	-	See new OCU 1	-
K11	Aeration Distribution chamber	-	-	0	-	See new OCU 1	-
K12	Aeration tanks 1 – 6 anoxic zone (Average)	-	8.3	-	285	2,366	9.60
K13	Aeration tanks 1 – 6 aerobic zone (Average)	-	5.0	-	2,123.60	10,618	43.07
K14	Centrifudge biofilter outlet Average	764	-	0.479	-	366	1.48
K15	Centrifudge biofilter inlet	5,792	-	-	-	-	-
K16	Sludge biofilter No 1 outlet (Average)	644	-	0.403	-	259	1.05
K17	Sludge biofilter No1 inlet	6,114	-	-	-	-	-
K18	Sludge biofilter No.2 Outlet (Average)	845	-	1.067	-	901	3.65
K19	Sludge biofilter No2 inlet	5,470	-	-	-	-	-
K20	Centrifudge building headspace (Average)	8,366	-	0	-	See new OCU 2	-
K21	Final settlement tank 1 (Average)	-	0.9	-	1556.13	1,401	5.68
K22	Final settlement tank 2 (Average)	-	1.2	-	1557.2	1,869	7.58
K23	Final settlement tank 3 (Average)	-	1.0	-	1550.3	1,550	6.29
K24	Supernatant biofilter outlet (Average)	442	-	0.186	-	82	0.33
K25	Supernatant sump biofilter inlet	2,092	-	-	-	-	-
K26	Sludge holding tank 3 headspace (Average)	6,918	-	0	-	See new OCU 2	-
K27	Sludge skip headspace	18,020	-	0	-	See new OCU 2	-
K28	Storm water tanks 1 – 3 (empty)	-	0.5	-	736.8	368	1.49
K29	New OCU 1	500	-	1.36	-	680	2.76
K30	New OCU 2	500	-	1.95	-	975	3.95
K31	AD tank	0	0	0	0	0	0
Total odour emission rate (Ou_E/s)	**-**	**-**	**-**	**-**	**-**	**24,653**	--

4.2. Results of odour dispersion modelling for Scenario 1 – Models 1 to 10 and Scenario 2 – Models 11 to 16.

Aermod Prime (21112) was used to determine the overall odour impact of the existing and proposed Drogheda WwTP as set out in odour impact criteria in *Section 3.4*. The output data was analysed to calculate:

Existing site operation

- **Ref Scenario 1 - Model 1** - Predicted odour emission contribution of overall existing operational WwTP (including 3 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.3*).

- **Ref Scenario 1 - Model 2** - Predicted odour emission contribution of overall existing operational WwTP (including 3 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.4*).

- **Ref Scenario 1 - Model 3** - Predicted odour emission contribution of overall existing operational WwTP (including 2 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.5*).

- **Ref Scenario 1 - Model 4** - Predicted odour emission contribution of overall existing operational WwTP (including 2 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.6*).

- **Ref Scenario 1 - Model 5** - Predicted odour emission contribution of overall existing PST operation (2 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0 Ou_E/m^3 (*see Figure 7.7*).

- **Ref Scenario 1 - Model 6** - Predicted odour emission contribution of overall existing PST operation (2 off PST's) during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50 Ou_E/m^3 (*see Figure 7.8*).

- **Ref Scenario 1 - Model 7** - Predicted odour emission contribution of overall AD tank leakage (1 off tank) during routine operation (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0 Ou_E/m^3 (*see Figure 7.9*).

- **Ref Scenario 1 - Model 8** - Predicted odour emission contribution of overall AD tank leakage (1 off tank) during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50 Ou_E/m^3 (*see Figure 7.10*).

- **Ref Scenario 1 - Model 9** - Predicted odour emission contribution of overall leakage sources located within WwTP during routine operation (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0 Ou_E/m^3 (*see Figure 7.11*).

- **Ref Scenario 1 - Model 10** - Predicted odour emission contribution of overall leakage sources located within WwTP during routine operation (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50 Ou_E/m^3 (*see Figure 7.12*).

Proposed site operation

- **Ref Scenario 2 - Model 11** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank only (*see Table 4.2*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.13*).

- **Ref Scenario 2 - Model 12** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank only (*see Table 4.2*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.14*).

- **Ref Scenario 2 - Model 13** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank and PST 2 (*see Table 4.2*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.0 Ou_E/m^3 (*see Figure 7.15*).

- **Ref Scenario 2 - Model 14** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank and PST 2 (*see Table 4.2*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 1.50 Ou_E/m^3 (*see Figure 7.16*).

- **Ref Scenario 2 - Model 15** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation to AD tank, PST2 & 3 and sludge processing leakage (*see Table 4.2*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.50, 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.17*).

- **Ref Scenario 2 - Model 16** - Predicted odour emission contribution of overall proposed WwTP following the implementation of odour mitigation (*see Table 4.2*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 3.0 & 5.0 Ou_E/m^3 (*see Figure 7.18*).

These computations give the odour concentration at each Cartesian grid receptor location that is predicted to be exceeded for 2% (175 hours of exceedence) and 0.5% (44 hours of exceedence) over 5 years of screened hourly sequential meteorological data (Dublin Airport 2015 to 2019 inclusive). The Cartesian receptor grid was 20, 50 and 250 m spaced given a total receptor number of 4,388 over an area of 25.0 km^2.

This will allow for the predictive analysis of any potential impact on the neighbouring sensitive locations while the facility is in operation. It will also allow the operators of the facility site to assess the effectiveness of their odour abatement/minimisation strategies. The intensity of the odour from two or more sources from the facility 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.

5. Discussion of results

This section will discuss the results obtained during the dispersion modelling study.

5.1. Odour plume dispersal for Scenario 1 – Model 1 to 10

The plotted odour concentrations of ≤ 1.0 and 1.50 Ou_E m^{-3} for the 98th and 99.5th percentile of hourly averages for the worst case meteorological year Dublin Airport 2019 is illustrated in *Figures 7.3 to 7.12*. Models 1, 2, 3 and 4 include the odour contour representation for Irish Waters internal odour standard of less than or equal to 3.0 and 5.0 Ou_E/m^3 contours.

With regards to the odour impact from the existing Drogheda WwTP with 3 off Primary Settlement tanks (PST's) in operation, the odour plume spread is approximately 350 to 450 m radial spread from the boundary of the operational facility. A number of sensitive receptors located towards to North, South and West of the facility will perceive odour concentrations in excess of the guideline odour limit values of 1.0 Ou_E/m^3 for the 98th percentile of hourly averages for meteorological year Dublin 2019 (*see Figure 7.3*). *Figure 7.4* illustrates the odour plume spread for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. As can be observed, the odour plume spread is approximately up to 1100m from the facility boundary. A number of sensitive receptors located to the North, South, East and West of the facility boundary will perceive odour concentrations in excess of the guideline odour limit value of 1.50 Ou_E/m^3 for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019.

With regards to the odour impact from the existing Drogheda WwTP with 2 off Primary Settlement tanks (PST's) in operation, the odour plume spread is approximately 350 to 450 m radial spread from the boundary of the operational facility. A number of sensitive receptors located towards to North and West of the facility will perceive odour concentrations in excess of the guideline odour limit values of 1.0 Ou_E/m^3 for the 98th percentile of hourly averages for meteorological year Dublin 2019 (*see Figure 7.5*). *Figure 7.6* illustrates the odour plume spread for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. As can be observed, the odour plume spread is approximately up to 1000m from the facility boundary. A number of sensitive receptors located to the North, South, East and West of the facility boundary will perceive odour concentrations in excess of the guideline odour limit value of 1.50 Ou_E/m^3 for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019.

With regards to the contribution odour impact from the existing Drogheda WwTP 2 off Primary Settlement tanks (PST's), the odour plume spread is approximately 220 to 350 m radial spread from the boundary of the operational facility. A number of sensitive receptors located towards to the North of the facility will perceive odour concentrations in excess of the guideline odour limit values of 1.0 Ou_E/m^3 for the 98th percentile of hourly averages for meteorological year Dublin 2019 (*see Figure 7.7*). *Figure 7.8* illustrates the odour plume spread for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. As can be observed, the odour plume spread is approximately up to 900m from the facility boundary. A number of sensitive receptors located to the North, South and West of the facility boundary will perceive odour concentrations in excess of the guideline odour limit value of 1.50 Ou_E/m^3 for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. The predicted maximum odour concentration detected at the worst case sensitive receptor was 1.41 Ou_E/m^3 and 3.82 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for the worst case meteorological year Dublin 2019 (*see Table 5.1*).

With regards to the contribution odour impact from the existing Drogheda WwTP AD tank leakage, the odour plume spread is approximately 80 m radial spread from the boundary of the operational facility. Sensitive receptors in the vicinity of the facility will not perceive odour concentrations in excess of the guideline odour limit values of 1.0 Ou_E/m^3 for the 98th percentile of hourly averages for meteorological year Dublin 2019 (*see Figure 7.9*). *Figure 7.10* illustrates the odour plume spread for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. As can be observed, the odour plume spread is approximately up to 80m from the facility boundary. Sensitive receptors in the vicinity of the facility will not perceive odour concentrations in excess of the guideline odour limit values of 1.5 Ou_E/m^3 for the 99.5th percentile of hourly averages for meteorological year Dublin 2019. The predicted maximum odour concentration detected at the worst case sensitive receptor was 0.14 Ou_E/m^3 and 0.21 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for the worst case meteorological year Dublin 2019 (*see Table 5.1*).

With regards to the contribution odour impact from the existing Drogheda WwTP Sludge handling processes leakage (excluding AD tank), the odour plume spread is approximately 130 m radial spread from the boundary of the operational facility. Sensitive receptors in the vicinity of the facility will not perceive odour concentrations in excess of the guideline odour limit values of 1.0 Ou_E/m^3 for the 98th percentile of hourly averages for meteorological year Dublin 2019 (*see Figure 7.11*). *Figure 7.12* illustrates the odour plume spread for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. As can be observed, the odour plume spread is approximately up to 140m from the facility boundary. Sensitive receptors in the vicinity of the facility will not perceive odour concentrations in excess of the guideline odour limit values of 1.5 Ou_E/m^3 for the 99.5th percentile of hourly averages for meteorological year Dublin 2019. The predicted maximum odour concentration detected at the worst case sensitive receptor was 0.52 Ou_E/m^3 and 1.19 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for the worst case meteorological year Dublin 2019 (*see Table 5.1*).

A number of discrete sensitive receptors were incorporated into the model (R1 to R43). A number of receptors will perceive an odour concentration greater than 1.0 and 1.50 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for the worst case meteorological year Dublin 2019. *Table 5.1* presents the predicted odour concentration at each of these receptor locations for each of the Model scenarios 1 to 10 and also the maximum predicted odour level at all screened sensitive receptors.

Table 5.1. Predicted ground level odour concentrations at identified sensitive receptors located in the vicinity of Drogheda WwTP for Scenario 1 Models 1 to 10.

Receptor ID	X coordinate (m)	Y coordinate (m)	Existing 98%ile all sources (3 PST's) odour conc. (Ou_E/m^3)	Existing 99.5%ile all sources (3 PST's) odour conc. (Ou_E/m^3)	Existing 98%ile all sources (2 PST's) odour conc. (Ou_E/m^3)	Existing 99.5%ile all sources (2 PST's) odour conc. (Ou_E/m^3)	Existing 98%ile PST 2 & 3 odour conc. (Ou_E/m^3)	Existing 99.5%ile PST 2 & 3 odour conc. (Ou_E/m^3)	Existing 98%ile AD tank leakage odour conc. (Ou_E/m^3)	Existing 99.5%ile AD tank leakage odour conc. (Ou_E/m^3)	Existing 98%ile Leakage sources excluding AD tank odour conc. (Ou_E/m^3)	Existing 99.5%ile Leakage sources excluding AD tank odour conc. (Ou_E/m^3)
R1	711295	774624	0.33	1.01	0.26	0.81	0.17	0.56	0.02	0.02	0.05	0.08
R2	711075	774682	0.53	2.48	0.42	2.00	0.28	1.38	0.03	0.05	0.07	0.11
R3	710907	774711	0.70	2.76	0.56	2.00	0.38	1.51	0.04	0.06	0.09	0.15
R4	710727	774746	0.98	2.55	0.75	1.93	0.51	1.35	0.05	0.08	0.12	0.20
R5	710588	774780	1.08	2.86	0.80	2.00	0.55	1.35	0.05	0.09	0.12	0.22
R6	710472	774798	0.99	2.37	0.71	1.81	0.45	1.06	0.04	0.08	0.10	0.19
R7	710367	774827	0.83	1.89	0.62	1.44	0.40	0.83	0.03	0.07	0.08	0.17
R8	710257	774809	0.58	1.28	0.44	0.97	0.28	0.59	0.02	0.04	0.06	0.11
R9	710066	774769	0.33	0.72	0.25	0.54	0.16	0.35	0.01	0.03	0.04	0.07
R10	709944	774746	0.25	0.56	0.19	0.42	0.13	0.28	0.01	0.02	0.03	0.06
R11	710211	774624	0.29	0.75	0.22	0.56	0.14	0.34	0.01	0.03	0.04	0.08
R12	710466	774618	0.45	1.19	0.34	0.87	0.22	0.55	0.02	0.05	0.06	0.11
R13	710675	774612	0.54	1.30	0.41	0.98	0.27	0.67	0.03	0.06	0.07	0.13
R14	710947	774595	0.49	1.65	0.39	1.35	0.26	0.96	0.02	0.05	0.06	0.11
R15	711144	774566	0.37	1.79	0.28	1.39	0.19	0.98	0.02	0.03	0.05	0.08
R16	711226	775401	0.71	1.59	0.57	1.28	0.36	0.87	0.04	0.06	0.10	0.14
R17	711452	775499	0.42	0.97	0.34	0.76	0.21	0.54	0.02	0.02	0.05	0.08
R18	711892	775209	0.21	0.47	0.16	0.37	0.11	0.27	0.01	0.01	0.03	0.03
R19	711840	775615	0.22	0.51	0.18	0.40	0.12	0.29	0.01	0.01	0.03	0.04
R20	711695	775726	0.24	0.62	0.19	0.49	0.13	0.32	0.01	0.01	0.03	0.04
R21	710449	775366	3.58	9.96	3.09	8.96	1.41	3.82	0.14	0.21	0.52	1.19
R22	710234	775314	1.91	4.66	1.50	3.44	0.86	2.20	0.06	0.10	0.17	0.33
R23	709991	775151	0.79	2.17	0.59	1.58	0.40	1.13	0.03	0.03	0.07	0.09
R24	709979	775302	0.84	2.03	0.64	1.53	0.40	1.06	0.03	0.03	0.07	0.12
R25	709904	774966	0.42	1.01	0.32	0.73	0.21	0.53	0.02	0.03	0.04	0.08
R26	709637	774850	0.22	0.54	0.17	0.41	0.10	0.26	0.01	0.02	0.02	0.05
R27	709677	775482	0.40	1.10	0.31	0.84	0.20	0.58	0.01	0.02	0.04	0.05
R28	710020	775552	0.73	1.75	0.56	1.44	0.36	0.91	0.03	0.03	0.07	0.09
R29	710280	775639	0.95	2.25	0.78	1.78	0.45	1.14	0.04	0.06	0.10	0.16
R30	710524	775726	0.71	2.20	0.59	1.75	0.32	1.09	0.04	0.07	0.12	0.19

Table 5.1 continued. Predicted ground level odour concentrations at identified sensitive receptors located in the vicinity of Drogheda WwTP for Scenario 1 Models 1 to 10.

Receptor ID	X coordinate (m)	Y coordinate (m)	Existing 98%ile all sources (3 PST's) odour conc. (Ou_E/m^3)	Existing 99.5%ile all sources (3 PST's) odour conc. (Ou_E/m^3)	Existing 98%ile all sources (2 PST's) odour conc. (Ou_E/m^3)	Existing 99.5%ile all sources (2 PST's) odour conc. (Ou_E/m^3)	Existing 98%ile PST 2 & 3 odour conc. (Ou_E/m^3)	Existing 99.5%ile PST 2 & 3 odour conc. (Ou_E/m^3)	Existing 98%ile AD tank leakage odour conc. (Ou_E/m^3)	Existing 99.5%ile AD tank leakage odour conc. (Ou_E/m^3)	Existing 98%ile Leakage sources odour conc. (Ou_E/m^3)	Existing 99.5%ile Leakage sources odour conc. (Ou_E/m^3)
R31	710692	775801	0.57	1.72	0.47	1.36	0.27	0.88	0.04	0.06	0.10	0.12
R32	710930	775859	0.49	1.37	0.40	1.07	0.23	0.73	0.03	0.03	0.07	0.11
R33	711197	775899	0.35	0.92	0.29	0.72	0.18	0.52	0.02	0.02	0.05	0.07
R34	710970	776062	0.33	1.00	0.26	0.79	0.16	0.53	0.02	0.02	0.05	0.07
R35	710733	776004	0.36	1.17	0.29	0.92	0.18	0.58	0.02	0.03	0.06	0.07
R36	710379	775853	0.47	1.61	0.39	1.30	0.23	0.83	0.03	0.04	0.07	0.12
R37	710170	775726	0.70	1.68	0.55	1.32	0.34	0.87	0.03	0.03	0.07	0.10
R38	709909	775772	0.46	1.28	0.37	0.99	0.23	0.63	0.02	0.02	0.04	0.06
R39	709648	775813	0.33	0.97	0.26	0.78	0.16	0.49	0.01	0.02	0.03	0.05
R40	709689	776015	0.27	0.80	0.22	0.62	0.13	0.42	0.01	0.01	0.03	0.03
R41	710043	776033	0.36	1.11	0.29	0.86	0.17	0.56	0.01	0.02	0.03	0.06
R42	710396	776149	0.25	0.88	0.20	0.72	0.13	0.47	0.02	0.02	0.04	0.07
R43	710657	776160	0.25	0.87	0.20	0.65	0.12	0.48	0.02	0.02	0.04	0.06
Predicted maximum Odour conc. (Ou_E/m^3)	-	-	**3.58**	**9.96**	**3.09**	**8.96**	**1.41**	**3.82**	**0.14**	**0.21**	**0.52**	**1.19**
Guideline Odour Limit value (Ou_E/m^3)	-	-	**<1.0**	**<1.5**	**<1.0**	**<1.5**	**<1.0**	**<1.5**	**<1.0**	**<1.5**	**<1.0**	**<1.5**

As can be observed in *Table 5.1*, the levels of odours predicted at a number of sensitive receptor locations are in excess of the proposed limit value for the existing facility operations.

5.2. Odour plume dispersal for Scenario 2 – Model 11 to 16

The plotted odour concentrations of ≤ 1.0 and 1.50 Ou_E m^{-3} for the 98th and 99.5th percentile of hourly averages for the worst case meteorological year Dublin Airport 2019 is illustrated in *Figures 7.13 and 7.14*. The dispersion modelling run examines the impact reduction associated with the implementation of odour mitigation on the AD tank. As can be observed in *Figure 7.13*, the odour plume spread is approximately 300 to 350 m radial spread from the boundary of the proposed operational facility. Sensitive receptors located to the North and West of the facility will perceive odour concentrations greater than the guideline odour limit values of 1.0 Ou_E/m^3 for the 98th percentile of hourly averages for meteorological year Dublin 2019 for the proposed facility following the mitigation program on the AD tanks. *Figure 7.14* illustrates the odour plume spread for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. As can be observed, the odour plume spread is approximately up to 850m radial spread from the facility boundary. A number of sensitive receptors located to the North, West and South of the facility will perceive odour concentrations greater than the guideline odour limit values of 1.50 Ou_E/m^3 for the 99.5th percentile of hourly averages for meteorological year Dublin 2019 for the proposed facility. The predicted maximum odour concentration detected at the worst case sensitive receptor was 2.49 Ou_E/m^3 and 6.47 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for the worst case meteorological year Dublin 2019 (*see Table 5.2*).

With regards to implementation of additional odour mitigation on a single PST (i.e. PST 2), as can be observed in *Figure 7.15*, the odour plume spread is approximately 250 m radial spread from the boundary of the proposed operational facility. Sensitive receptors located to the North of the facility will perceive odour concentrations greater than the guideline odour limit values of 1.0 Ou_E/m^3 for the 98th percentile of hourly averages for meteorological year Dublin 2019 for the proposed facility following the mitigation program on the AD tanks and PST 2. *Figure 7.16* illustrates the odour plume spread for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. As can be observed, the odour plume spread is approximately up to 750m radial spread from the facility boundary. A number of sensitive receptors located to the North and West of the facility will perceive odour concentrations greater than the guideline odour limit values of 1.50 Ou_E/m^3 for the 99.5th percentile of hourly averages for meteorological year Dublin 2019 for the proposed facility. The predicted maximum odour concentration detected at the worst case sensitive receptor was 1.96 Ou_E/m^3 and 5.10 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for the worst case meteorological year Dublin 2019 (*see Table 5.2*).

With regards to the implementation of a odour mitigation plan on the AD tank, PST 2 and 3 and odour leakage from a number of sludge processing activities (i.e. Sludge thickening building, Sludge holding tanks and Sludge storage skips), as can be observed in *Figure 7.17*, the odour plume spread is approximately 50 to 60 m radial spread from the boundary of the operational facility. All identified sensitive receptors located in the vicinity of the facility will perceive odour concentrations less than the guideline odour limit values of 1.50 Ou_E/m^3 for the 98th percentile of hourly averages for meteorological year Dublin 2019 for the proposed facility. *Figure 7.18* illustrates the odour plume spread for the 99.5th percentile of hourly averages for worst case meteorological year Dublin 2019. As can be observed, the odour plume spread is approximately up to 70m radial spread from the facility boundary. All identified sensitive receptors located in the vicinity of the facility will perceive odour concentrations less than the guideline odour limit values of 3.0 Ou_E/m^3 for the 99.5th percentile of hourly averages for meteorological year Dublin 2019 for the proposed facility. The predicted maximum odour concentration detected at the worst case sensitive receptor was 1.10 Ou_E/m^3 and 2.68 Ou_E/m^3 for the 98th and 99.5th percentile of hourly averages for the worst case meteorological year Dublin 2019 (*see Table 5.2*).

A number of discrete sensitive receptors were incorporated into the model (R1 to R43). *Table 5.2* presents the predicted odour concentration at each of these receptor locations for Model 11 to 16 scenarios.

Table 5.2. Predicted ground level odour concentrations at identified sensitive receptors located in the vicinity of Drogheda WwTP for Scenario 2 Models 11 to 16.

Receptor ID	X coordinate (m)	Y coordinate (m)	Proposed 98%ile including uncovered PST tanks 2&3 sources odour conc. (Ou_E/m^3)	Proposed 99.5%ile including uncovered PST tanks 2&3 sources odour conc. (Ou_E/m^3)	Proposed 98%ile including uncovered PST 3 sources odour conc. (Ou_E/m^3)	Proposed 99.5%ile including uncovered PST 3 sources odour conc. (Ou_E/m^3)	Proposed 98%ile all proposed sources abated odour conc. (Ou_E/m^3)	Proposed 99.5%ile all proposed sources abated odour conc. (Ou_E/m^3)
R1	711295	774624	0.23	0.77	0.16	0.54	0.06	0.20
R2	711075	774682	0.37	1.93	0.25	1.31	0.09	0.52
R3	710907	774711	0.49	1.86	0.34	1.24	0.12	0.40
R4	710727	774746	0.66	1.81	0.44	1.17	0.14	0.37
R5	710588	774780	0.72	1.92	0.46	1.21	0.16	0.43
R6	710472	774798	0.64	1.64	0.43	1.09	0.18	0.44
R7	710367	774827	0.55	1.31	0.38	0.93	0.17	0.42
R8	710257	774809	0.39	0.88	0.26	0.56	0.11	0.24
R9	710066	774769	0.22	0.47	0.14	0.32	0.06	0.13
R10	709944	774746	0.17	0.38	0.11	0.25	0.04	0.10
R11	710211	774624	0.19	0.49	0.13	0.34	0.05	0.13
R12	710466	774618	0.29	0.79	0.20	0.52	0.07	0.22
R13	710675	774612	0.36	0.91	0.24	0.61	0.08	0.23
R14	710947	774595	0.34	1.27	0.24	0.79	0.08	0.26
R15	711144	774566	0.25	1.33	0.17	0.96	0.06	0.34
R16	711226	775401	0.49	1.18	0.35	0.84	0.13	0.35
R17	711452	775499	0.28	0.72	0.20	0.49	0.08	0.22
R18	711892	775209	0.15	0.35	0.11	0.24	0.04	0.09
R19	711840	775615	0.16	0.38	0.11	0.25	0.04	0.12
R20	711695	775726	0.17	0.47	0.12	0.33	0.05	0.13
R21	710449	775366	2.49	6.47	1.96	5.10	1.10	2.68
R22	710234	775314	1.27	3.20	0.89	2.18	0.44	1.07
R23	709991	775151	0.53	1.53	0.35	1.02	0.15	0.43
R24	709979	775302	0.58	1.47	0.41	1.01	0.18	0.47
R25	709904	774966	0.28	0.66	0.19	0.45	0.08	0.19
R26	709637	774850	0.15	0.36	0.10	0.25	0.04	0.09
R27	709677	775482	0.28	0.82	0.19	0.56	0.08	0.26
R28	710020	775552	0.52	1.35	0.36	0.92	0.17	0.43
R29	710280	775639	0.67	1.67	0.48	1.20	0.23	0.57
R30	710524	775726	0.49	1.63	0.36	1.17	0.17	0.54
R31	710692	775801	0.41	1.28	0.29	0.91	0.14	0.42

Table 5.2 continued. Predicted ground level odour concentrations at identified sensitive receptors located in the vicinity of Drogheda WwTP for Scenario 2 Models 11 to 16.

Receptor ID	X coordinate (m)	Y coordinate (m)	Proposed 98%ile including uncovered PST tanks 2&3 sources odour conc. (Ou_E/m^3)	Proposed 99.5%ile including uncovered PST tanks 2&3 sources odour conc. (Ou_E/m^3)	Proposed 98%ile including uncovered PST 3 sources odour conc. (Ou_E/m^3)	Proposed 99.5%ile including uncovered PST 3 sources odour conc. (Ou_E/m^3)	Proposed 98%ile all proposed sources abated odour conc. (Ou_E/m^3)	Proposed 99.5%ile all proposed sources abated odour conc. (Ou_E/m^3)
R32	710930	775859	0.34	1.02	0.24	0.72	0.11	0.33
R33	711197	775899	0.25	0.69	0.18	0.49	0.07	0.22
R34	710970	776062	0.23	0.76	0.16	0.53	0.07	0.25
R35	710733	776004	0.26	0.86	0.18	0.60	0.08	0.28
R36	710379	775853	0.34	1.23	0.25	0.89	0.11	0.43
R37	710170	775726	0.50	1.27	0.35	0.89	0.16	0.42
R38	709909	775772	0.33	0.96	0.23	0.69	0.11	0.36
R39	709648	775813	0.23	0.71	0.16	0.52	0.07	0.23
R40	709689	776015	0.20	0.60	0.14	0.42	0.06	0.20
R41	710043	776033	0.26	0.82	0.19	0.58	0.09	0.30
R42	710396	776149	0.17	0.68	0.13	0.49	0.05	0.20
R43	710657	776160	0.18	0.61	0.13	0.42	0.06	0.18
Predicted maximum Odour conc. (Ou_E/m^3)	-	-	**2.49**	**6.47**	**1.96**	**5.10**	**1.10**	**2.68**
Guideline Odour Limit value (Ou_E/m^3)	-	-	**<1.0**	**<1.50**	**<1.0**	**<1.50**	**<1.50**	**<3.0**