REPORT

Odour impact assessment of the permitted area of Queensferry WwTW

Client:
Dwr Cymru Welsh Water

Report Number:
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Executive Summary

Dŵr Cymru Welsh Water (DCWW) are currently applying to Natural Resource Wales (NRW) for an EPR[1] permit for the sludge treatment operations at Queensferry WwTW. The permit is required following reinterpretation of the Industrial Emission Directive (IED) which brings such processes into the Environmental Permitting regulatory regime.

As part of the application, NRW requested a quantitative odour impact assessment be conducted to assess the current risk of impact posed by odours released from the permitted activities on nearby sensitive receptors in keeping with the requirements of NRW's odour guidance H4[2]. The findings of the assessment were then used to identify what further measures are required to minimise such risk, in keeping with the requirements of EPR and BATc, which are summarised as follows:

- BAT14(A) requires '*minimisation of the number of diffuse (odour) emission sources*' (e.g. ensuring odorous materials which pose a risk of impact are contained or conducted within a building).
- BAT14(B) requires selection of high integrity equipment such as pipework, pumps and gaskets and to minimise leakage of odours or odorous materials.
- BAT14(D) requires containment, collection and treatment of diffuse emissions including control of odours by '*maintenance of an adequate pressure*' within buildings or enclosures and '*directing emissions to an appropriate abatement system*'.
- BAT34 requires a reduction in channelled '*emissions to air of dust, organic compounds and odorous compounds, including H_2S and NH_3*' to meet specific Achievable Emission Levels (BAT-AELs). E.g. odour treatment systems.
- A general requirement to provide an equivalent level of environmental protection by demonstrating compliance to odour exposure benchmarks at nearby sensitive receptor(s), as determined through odour dispersion modelling

The study was conducted using dispersion modelling techniques which have an established history of application for assessing odour impact and comply with the requirements of current Environment Agency guidance. The dispersion model included all sources of odour associated with the permitted operations which have the potential to travel offsite, including reception of imported sludge, storage and thickening of indigenous and imported sludges and the storage, dewatering and removal of digested sludges. Odour emissions from each source were defined using a combination of site specific survey data and library data from the Olfasense emission database.

The findings of the assessment are as follows:

[1] Environment Permitting Regulations (England and Wales) 2016
[2] Environmental Permitting: H4 Odour Management – How to comply with your environmental permit. April 2011. https://www.gov.uk/government/publications/environmental-permitting-h4-odour-management

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1. Odour emissions from the permitted site are currently predicted to pose a risk of impact up to 0.8 km from the site boundary, which includes residential properties to the north, south and east of the site, the traveller park to the north of the site, and a number of commercial premises to the west of the site across the A494.
2. The main contributors to the predicted exposure levels are fugitive odours from the raw sludge holding tanks, imported sludge tanks and sludge thickening building, all of which are highly offensive in nature and account for an estimated 85% of total site emissions.
3. In order to mitigate offsite impact risk and reduce exposure to below the applicable odour impact benchmark, the following mitigation measures are recommended:
    a. Refurbish/replace the covers on the raw sludge holding tanks, digestor feed tank and imported sludge tanks to minimise any leakage routes.
    b. Provide active extraction to the following tanks to ensure they are maintained under negative pressure under all normal foreseeable operational conditions include filling and inspection.
        i. Imported sludge tank.
        ii. Screened imported sludge tank.
        iii. Sludge holding tank 1.
        iv. Sludge holding tank 2.
        v. Digestor feed tank.
        vi. Sludge thickener building.
    c. Install a new odour control system to treat the extracted air from the sources above.

Table of Contents

1 Introduction

1.1 Background

Dŵr Cymru Welsh Water (DCWW) are currently applying to Natural Resource Wales (NRW) for an EPR[3] permit for the sludge treatment operations at Queensferry WwTW. The permit is required following reinterpretation of the Industrial Emission Directive (IED) which brings such processes into the Environmental Permitting regulatory regime.

As part of the application, NRW requested a quantitative odour impact assessment be conducted to assess the current risk of impact posed by odours released from the permitted activities on nearby sensitive receptors in keeping with the requirements of NRW's odour guidance H4. The findings of the assessment were then used to identify what further measures are required to minimise such risk, in keeping with the requirements of the NRW's odour guidance H4[4] and BAT as defined in the 2018 waste treatment BAT reference document (BREF).

1.2 Odour control requirements under EPR

Under the Environmental Permitting Regulations 2016 (EPR), operators of permitted processes must ensure compliance to the odour condition contained within the permit. The typical form of this odour condition is as follows:

'Emissions from the activities shall be free from odour at levels likely to cause pollution outside the site, as perceived by an authorised officer of Natural Resources Wales, unless the operator has used appropriate measures, including, but not limited to, those in an approved odour management plan, to prevent or where that is not practicable to minimise the odour.'

The operator must therefore employ appropriate measures to prevent odour pollution (at nearby sensitive receptors) or minimise it where prevention is not practicable.

For wet anaerobic digestion processes, appropriate measures are defined in the form of BAT conclusions (BATC), which were published in the Waste Treatment BAT Reference Document (BREF) in August 2018[5]. In addition to implementation and regular review of an Odour Management Plan (OMP) the BAT conclusions which are relevant to odour are as follows:

- BAT14(A) requires '*minimisation of the number of diffuse (odour) emission sources*' (e.g. ensuring odorous materials which pose a risk of impact are contained or conducted within a building).
- BAT14(B) requires selection of high integrity equipment such as pipework, pumps and gaskets and to minimise leakage of odours or odorous materials.

[3] Environment Permitting Regulations(England and Wales) 2016
[4] H4 Odour Management, Environment Agency, March 2011
[5] Best Available Techniques (BAT) Reference Document for Waste Treatment Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control) Antoine Pinasseau, Benoit Zerger, Joze Roth, Michele Canova, Serge Roudier 2018

- BAT14(D) requires containment, collection and treatment of diffuse emissions including control of odours by '*maintenance of an adequate pressure*' within buildings or enclosures and 'directing emissions to an appropriate abatement system'.
- BAT34 requires a reduction in channelled '*emissions to air of dust, organic compounds and odorous compounds, including H2S and NH3*' to meet specific Achievable Emission Levels (BAT-AELs). E.g. odour treatment systems.
- A general requirement to provide an equivalent level of environmental protection by demonstrating compliance to odour exposure benchmarks at nearby sensitive receptor(s), as determined through odour dispersion modelling.

Determining what measures are appropriate is also dependent upon site specific circumstances and should take cost and benefits into account. In some circumstances, it may be necessary to apply additional measures that go beyond BATC if risk of offsite pollution is high. Conversely, if it can be demonstrated that the risk of impact of a given odour source is low, a lower level of control may be justified.

Odour dispersion modelling is a key tool to establish the risk of impact and inform this decision making process, as referenced in Appendix 3 of H4. The general concept behind modelling is to establish what combination of measures provides an equivalent level of protection to no offsite odour pollution, by reference to odour exposure benchmarks which are published in H4 and in other informative guidance by third parties e.g. the institute of Air Quality Management (IAQM).

1.3 Scope

The scope of the assessment was as follows:

1. Review of the operations undertaken within the permitted area and identify the activities within the area which are likely to generate odour emissions.
2. Estimate the odour emissions generated from each of the identified sources under normal operating conditions.
3. Assess the exposure levels that are likely to occur offsite and at nearby sensitive receptors using a dispersion model and evaluate the risk of impact using the most appropriate odour exposure benchmark defined in H4.
4. Identify the measures that are likely to be required to minimise odour impact and comply with the requirements of BATC.

Full details of each stage and the assumptions applied are presented in the remainder of this report.

1.4 Odour survey and assessment approach

1.4.1 Overview

The first stage of the study involved a review of the site operations to identify activities and processes that have the potential to generate odour emissions. This was followed by an odour survey using 'at-source' sampling and analysis techniques to measure the odour emissions from each element of the sewage treatment process and evaluate the performance of the existing Odour Control systems. Where relevant, smoke testing was also used on selected sources to assess the containment effectiveness of buildings containing odorous plant.

The data collected during the survey was used in combination with reference data from Olfasense's odour emission database to estimate the odour emissions generated from each odour source and define a site odour emission inventory. In defining the emission estimates, consideration was given to the following influencing factors where relevant:

- Liquid turbulence.
- The frequency and duration of release of intermittent activities.

The emission inventory was input into an odour dispersion model and used to assess the odour exposure levels which may occur around the site under current operational conditions. The model used for the study was the US EPA BREEZE AERMOD dispersion model which was established in accordance with relevant guidance issued by the US Environmental Protection Agency (EPA) and other relevant authorities.

The results of the modelling were presented in the forms of maps identifying the areas around the site that are exposed to odour levels that correspond to relevant odour impact criteria.

1.4.2 Sampling techniques

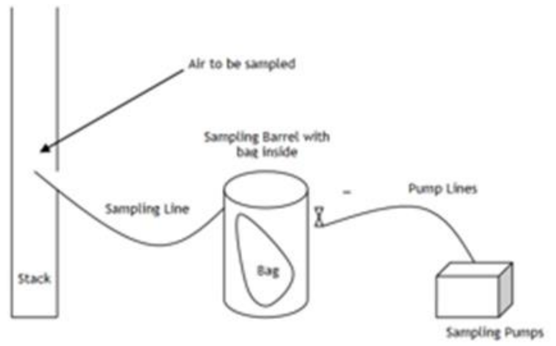
Air samples from each source were collected using standardised techniques based on the European Standard for Olfactometry EN13725[6]. For liquid and solid sources, a ventilated sampling hood was used to isolate the source from the atmosphere as indicated in Figure 1. For duct sources, samples were collected using the 'lung principal' as illustrated in

Figure 2 below.

Figure 1: Sampling hoods for liquid and solid sampling

[6] EN13725: Air Quality: Determination of odour concentration by olfactometry analysis

Figure 2: Sampling from ductwork and enclosed tanks/buildings

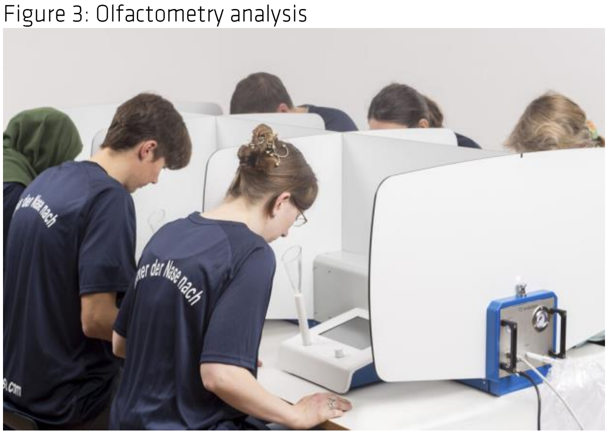


Air flow measurements were also conducted for duct or stack type sources using anemometers/pitot tubes in accordance with the standard ISO 10780[7].

1.4.3 Odour analysis techniques

Odour analysis was conducted by olfactometry using a state of the art TO-Evolution™ olfactometer in full accordance with the procedures defined in EN 13725, using 4 to 6 no. qualified and trained odour panellists. In addition, hydrogen sulphide and ammonia were measured using colorimetric detector tubes and an assessment of the character and relative offensiveness of the odour was conducted using in house sensory assessment techniques.

Figure 3: Olfactometry analysis



1.4.4 Quality Control and Assurance

The study was conducted by experienced odour assessment specialists and in accordance with quality management procedures that are certified to ISO 9001 (Certificate No. A13725). Odour sampling and olfactometry analysis was undertaken using UKAS accredited procedures (UKAS

[7] Stationary Source Emissions: Measurement of velocity and volume flow rate of gas streams in ducts.

Testing Laboratory No. 2430) which comply fully with the requirements of the international quality standard ISO 17025:2017[8] and the European standard for olfactometry BS EN 13725:2003[9]. Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.

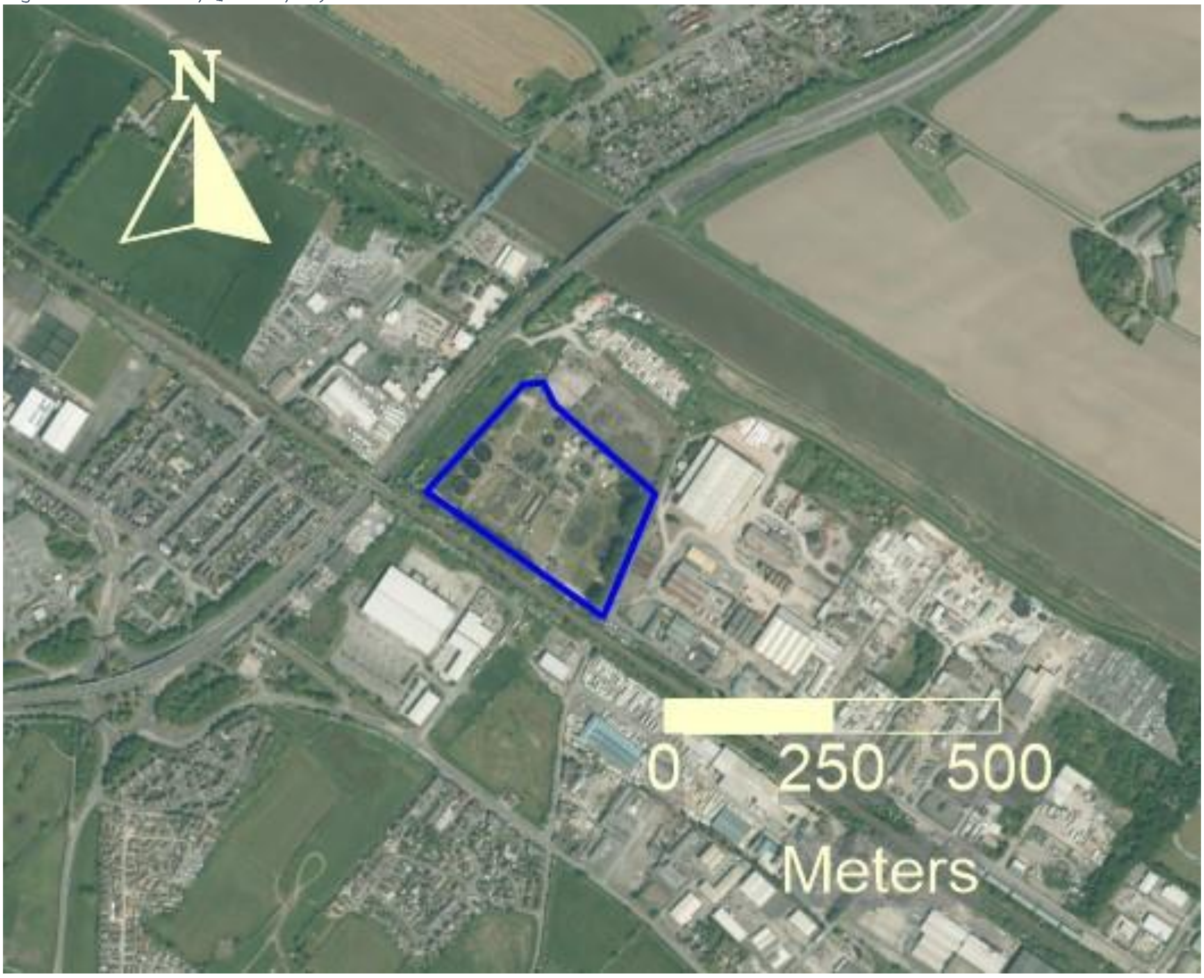
[8] ISO 17025:2017 – General requirements for the competence of testing and calibration laboratories.
[9] BS EN 13725:2003 – Air quality. Determination of odour concentration by dynamic olfactometry.

2 Site details

2.1 Location

Queensferry WwTW is located in Queensferry, Flintshire (Landranger grid SJ322682) close to the junction of the A494 and B5129. The site is bordered by commercial and industrial premises to the east, south and west and waste land and a travellers park to the north. The closest residential developments are located and to the north (Travellers Park), to the west across the A494, to the north along the A494 on the other side of the River Dee, and to the south across the B5129,

Figure 4: Location of Queensferry WwTW



2.2 Overview of site operations

The works receives pumped sewage flows from five separate rising mains including the Deeside Industrial Park to the west, with a maximum onward flow to treatment of 277.6 l/s.

The incoming flows are conveyed to a preliminary treatment works for screening and degritting, before settlement in 2 no. primary settlement tanks. The settled sewage is then treated in two parallel treatment flows which comprise 3 no. high rate filters located near the western boundary (60 to 70% of the flow), and 6 no. stone media biological filters located along the eastern boundary

(30% pf the flow). Following treatment the effluent is settled and then discharged to the River Dee.

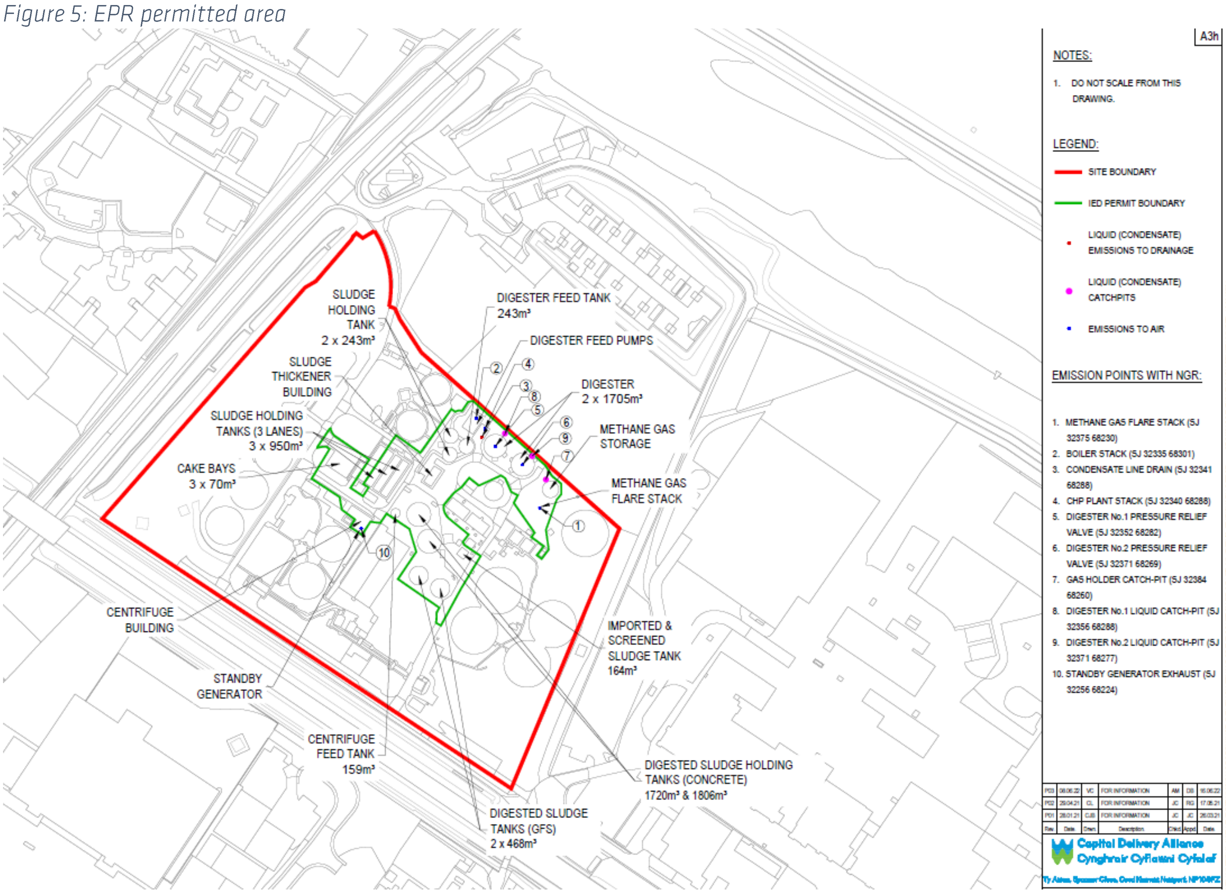
Sludge from the process is mixed with imported sludge received by road tanker, and then digested in a wet anaerobic digestion process. The resultant digested sludge is then dewatered into cake and exported offsite for disposal.

2.3 Permitted activities

2.3.1 Permit boundary

The area of the site that is included within the IED permit is outlined in green in Figure 2 below and includes sludge storage and processing plant associated with the wet anaerobic digestion process, including biogas storage and utilisation.

Figure 5: EPR permitted area



2.3.2 Process description

Imported sludge is tankered onto site and discharged into a covered sludge import tank before being screened and transferred to the adjacent screened imported sludge tank. The screened sludge is then pumped to 2 No. covered concrete sludge holding tanks and mixed with indigenous sludge before being pumped to a drum thickener, which thickens the sludge to approximately 6% dry solids with the aid of a polymer.

The sludge is then stored in a third covered concrete sludge storage tank, which is called the digester feed tank. From here the sludge is transferred to two 1600 m^3 concrete digester tanks on a timed basis to undergo mesophilic anaerobic digestion. After digestion the digested sludge is directed to a number of digested sludge storage tanks arranged in five zones as follows:

- Zone 1 comprises 2 no. open topped circular tanks.
- Zone 2 is an open topped concrete tank.
- Zone 3 is a covered concrete former digestor.
- Zone 4 is an open rectangular concrete tank.
- Zone 5 is an open 2 no. lane rectangular concrete tank next to zone 4.

The treated sludge is pumped to a 142 m^3 open glass fused steel centrifuge feed tank and then dewatered via a single centrifuge with the aid of polymer to increase the percentage dry solids to between 20 and 25%. The dewatered sludge is then transferred and to an open concrete cake pad ready for export to Five Fords for further treatment.

The biogas generated during digestion is stored in a a double membrane gas holder and is then used in a combined heat and power unit for electricity generation, which supplies the digestion plant and for recovering heat, to maintain digester temperature. The site has one biogas, one dual fuel and one oil boiler which provides hot water for the digestion process. Any excess biogas is flared off via the on-site waste bio-gas burner (flare stack).

The IED permit includes the following assets:

- Import sludge area.
- Screened sludge tanks.
- Sludge screen.
- Sludge thickener building.
- Thickened sludge tank.
- Digesters.
- CHP unit.
- Boilers.
- Standby Generator.
- Digested sludge holding tanks.
- Gas Holder.
- Waste Gas Flare.
- Centrifuge feed tank.
- Centrifuge building.

- Cake bays.

The CHP engine is powered by biogas and has a thermal rated input of 0.545 MWth. The CHP total annual operating hours is 8,500, allowing for routine maintenance. There are three dual fuel boilers (gas oil/biogas) all running continuously. Each boiler has a thermal rated input of 0.39 MWth. There is one standby 0.7 MWth generator which is only used when there is a mains power outage on the site.

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3 Review of odour sources and estimation of emissions

3.1 Odour sources

The following potential odour sources were identified during the site review and survey.

Figure 6: Odour sources

Potential Odour source	Odorous material	Control measures	Emission type	Frequency and duration
Imported sludge tank	Imported sludge	Covered tank	Fugitive	Continuous
Screened sludge tank		Covered tank	Fugitive	Continuous
Screenings skip	Screenings	Enclosed	Fugitive	Continuous
Sludge holding tank 1	Indigenous sludge	Covered tank	Fugitive	Continuous
Sludge holding tank 2	Imported sludge	Covered tank	Fugitive	Continuous
Sludge thickeners	Indigenous/imported sludge	Enclosed in building	Fugitive	Continuous
Digestor feed tank		Enclosed and located in building	Fugitive	Continuous
Digested sludge tanks (Zone 1)	Digested sludge	2 No. open tanks	Diffuse	Continuous
Digested sludge tank (Zone 2)	Digested sludge	Open tank	Diffuse	Continuous
Digested sludge tank (Zone 3)	Digested sludge	Covered tank	Diffuse	Continuous
Digested sludge tank (Zone 4)	Digested sludge	Open tank	Diffuse	Continuous
Digested sludge tanks (Zone 5)	Digested sludge	2 No. Open tanks	Diffuse	Continuous
Centrifuge feed tank	Digested sludge	-	Diffuse	Continuous
Sludge cake pad	Digested sludge cake	-	Diffuse	Continuous
Sludge handling	Digested sludge cake	-	Diffuse	Intermittent

The odours generated from the elements of the process prior to the wet digestion process are likely to be considered highly offensive based H4. After digestion, the offensive reduces to moderately offensive.

It is possible that incidental emissions may also occur from time to time in the event of process failure or plant breakdown. However, such emissions will be minimised through adoption of the measures described in the site Odour Management Plan (OMP) and hence have not been included in the impact assessment.

3.2 Odour composition and offensiveness

The odours generated from raw sewage and sewage sludge comprises a wide range of odorous organic and inorganic volatile compounds. The precise composition can vary depending upon the type of sludge, age and level of decomposition, but include aldehydes, ketones, fatty acids, esters, alcohols, amines, and reduced sulphur compounds, as well as hydrogen sulphide and ammonia.

Raw sludge odours are generally considered to be highly offensive and have a sulphidic and faecal character. Aerobic activated sludge and digested sludges tend to be considered moderately offensive with a more earthy and ammonia like character.

3.3 Estimation of odour emissions

Estimates of the odour emissions which may occur from the site were defined on the basis of survey data collected in 2018 and 2020 (See Annex A) and library data collected at other sewage and sludge treatment works by Olfasense in the UK. Where necessary, modifications have been applied to reflect site specific conditions or other factors that may influence odour release, based on Olfasense's experience.

3.3.1 Imported and screened imported sludge tanks

The two imported sludge tanks are located side by side at ground level and have a similar design i.e. Concrete tanks fitted with GRP covers.

Smoke testing of the tanks identified a number of leakage points as summarised in the table below.

Table 1: Leakage areas identified in the imported sludge tanks

Source	Leakage points	Estimated leakage rate (ACPH)
Sludge import tank	▪ Two hatches with loose fitting covers ▪ Holes from redundant pipework ▪ Gaps between the concrete and covers along one side of the tank ▪ Air vent	2 ACPH
Screened imported sludge tank	▪ Loose fitting hatch seal ▪ Gaps between the concrete and covers along one side of the tank ▪ Air vent	1 ACPH

The odour emission rates estimated from each tank due to fugitive leakage are outlined in the table below.

Table 2: Odour estimates for imported sludge tanks

Source	Odour concentration [ou_E/m^3]	Average leakage rate [m^3/s] assuming 2 m headspace	Estimated odour emission rate [ou_E/s]
Imported sludge tank	13,682	0.07	963
Screened imported sludge tank	13,682	0.04	482

3.3.2 Imported sludge screenings skips

The imported sludge screen is located in its own enclosure which is fitted with plastic curtains across the entrance. The containment of the enclosure is however likely to be low since it is not actively extracted to an odour control system.

The odour emissions from the sludge screenings skip have been estimated using a precautionary emission rate derived from library data of 50 $ou_E/m^2/s$ multiplied by the surface area of the skip, with no reduction for enclosure. The measured value in the 2020 survey was 37 $ou_E/m^2/s$.

3.3.3 Raw sludge holding tanks and digester feed tanks

The sludge consolidation and digester feed tanks are all of a similar design and are fitted with GRP covers. The condition of the covers is variable and smoke testing identified a range of leakage routes. The estimated average leakage rate of air used to define emissions is summarised in the table below.

Table 3: Leakage areas identified in the sludge holding tanks

Source	Leakage route	Estimated leakage rate [ACPH]
Raw Sludge tank 1 (indigenous sludge)	▪ 1 no. hatch with missing cover and 1 no. hatch with loose fitting temporary cover ▪ Various gaps between the cover and concrete tank ▪ Holes left by redundant pipes	3 ACPH
Raw sludge tank 2 (imported sludge)	▪ 1 no. hatch with missing cover and 1 no. hatch with loose fitting temporary cover ▪ Various gaps between the cover and concrete tank ▪ Holes left by redundant pipes	3 ACPH
Digester feed tank	▪ Gaps between the cover and concrete tank ▪ Loose fitting hatch ▪ Holes left by redundant pipes	2 ACPH

The odour emission rates estimated from each tank due to fugitive leakage are outlined in the table below.

Table 4: Emission estimates for raw sludge holding tanks

Source	Odour concentration [ou_E/m^3]	Average leakage rate [m^3/s] assuming 2 m headspace	Estimated odour emission rate [ou_E/s]
Raw Sludge tank 1 (indigenous sludge)	90,869	0.16	14,393
Taw sludge tank 2 (imported sludge)	90,869	0.16	14,393
Digester feed tank	37,092	0.11	3,477

3.3.4 Sludge thickening building

The sludge thickener building is of single skin construction and fitted with a roller door. The building is not extracted and hence air exchange is likely to occur.

Odour emissions from this area have been estimated assuming an average air exchange rate of 3 No. building volumes per hour and an estimated odour concentration of 5,000 ou_E/m^3. This is higher than was measured during the survey and is designed to reflect operator reports that elevated odour levels are commonly encountered in this building when the drum thickener is in operation.

The estimated emission rate is 1,463 ou_E/s.

3.3.5 Digested sludge holding tank and centrifuge feed tanks

The digested sludge tanks and centrifuge feed tank are all open, and hence odours will be released directly to the atmosphere. The measured emission rate of odour from the sludge was 1.7 to 4.3 $ou_E/m^2/s$ which is within the expected range for digested sludge.

The odour emissions from the digested sludge have been estimated using the geometric mean of these figures (i.e. 2.7 $ou_E/m^2/s$) assuming all tanks are full. The estimated emission rates are therefore as presented in the table below.

Table 5: Emission estimates for raw sludge holding tanks

Source	Odour emission rate[ou_E/m^3]	Surface area	Estimated odour emission rate [ou_E/s]
Zone 1 digested sludge holding tanks	2.7	125	338
Zone 2 digested sludge holding tanks	2.7	201	261
Zone 3 digested sludge holding tanks	2.7	201	543
Zone 4 and 5 digested sludge holding tanks	2.7	420	1134
Digested sludge dewatering well	16.2	1.7	28
Centrifuge feed tank	2.7	38	104

3.3.6 Digested sludge cake

The odour emissions from the digested sludge cake have been estimated using the geometric mean of the survey data of 3.9 $ou_E/m^2/s$ and assuming that the cake pad is full, reflecting worst case conditions. The total area of the three lanes of the cake bay is 150 m^3 giving a total odour emission rate of 585 ou_E/s.

3.3.7 Sludge cake loading operations

Transfer and loading operations of sludge cake on the pad have been estimated assuming that the active handling of sludge cake during discharge of the sludge conveyor and trailer loading is around 10 x the surface emission rate from the static sludge pile[10].

Table 6:Emission estimates for sludge cake handling

Source	Duration/day (hours)	Surface area for agitation [m^2]	Area emission rate [$ou_E/m^2/s$]	Odour emission rate (ou_E/s)
Fresh sludge drop from conveyer	12	2.25	39	88
Sludge cake export	1 hour per day	6	39	234

[10] Based on a comparison of data collected by Olfasense in the wastewater and waste sector.

3.4 Site odour emission hierarchy

A breakdown of the estimated 'time weighted' odour emissions from the permitted area is presented in the table below.

Table 11: Breakdown of time weighted emissions

Odour source	Emission rate [ou_E/s]	% of site emissions
Sludge imports tanks	1,445	4%
Sludge skip	195	1%
Sludge thickening building	1463	4%
Raw sludge holding tank 1 : Indigenous	14,393	37%
Raw sludge holding tank 2: Imported	14,393	37%
Digestor feed tank	3,477	9%
Digested sludge storage tanks	2,276	6%
Centrifuge feed tank	104	<1%
Centrifuge building	28	<1%
Sludge cake handling and storage	643	2%
Digested sludge dewatering well	28	<1%
Total	38,442	100%

Review of the table above indicates that the total estimated time-weighted odour emission rate from sludge processing operations is estimated at ~38,000 ou_E/s.

The main contributors are the raw sludge holding tanks, digested sludge feed tank and imported sludge tanks, which contribute 79% of the site emissions. The sludge thickening building is also a potentially significant odour source accounting for 6% of emissions. The odour emissions from these tanks are characterised by high concentration / highly offensive odours associated with raw sludge.

The remainder of site emissions are related to storage and handling of digested sludge, the odours from which are significantly less concentrated and have a less offensive character.

4 Dispersion modelling

4.1 Model assumptions and input data

4.1.1 Land use and sensitive receptors

The land use immediately surrounding the site is industrial/commercial to the west, south and east and wasteland and with a travellers park to the north leading up to the River Dee.

The nearest residential receptors to the site are located 0.13 km to west across the A494, 0.13 km to the north of site, and 0.34 km to the north across the River Dee.

Each of these areas are marked on the figure below and have been defined as discrete receptors in the dispersion model as referenced in the figure and described in the table below.

Figure 7: Location of sensitive receptors

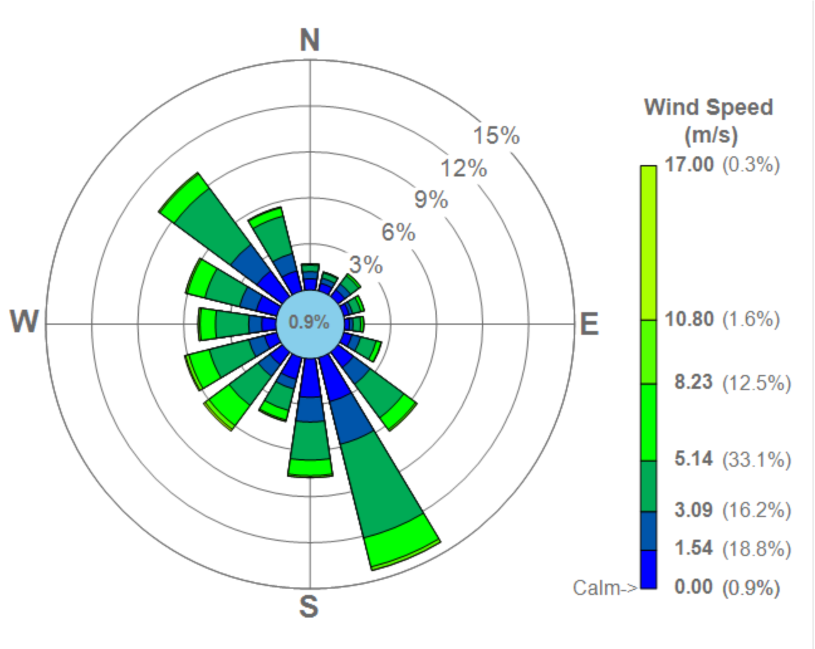
Table 6: Discrete receptors considered within dispersion model.

#	Nature of receptor	Land-use	Distance to site [km]	Sensitivity to odour
1	Toyota Queensferry	Commercial	0.18	Medium
2	Deeside delivery office	Commercial	0.10	Medium
3	Number One Gym	Commercial	0.10	Medium
4	Spinney Caravan Dealer	Commercial	0.13	Medium
5	Dundas Street Residential	Residential	0.14	High
6	Makro Queensferry	Commercial	0.12	Medium
7	Whizz Kids	Commercial	0.11	Medium
8	Knauf insulation	Industrial	0.11	Low
9	Warehouse	Industrial	0.07	Low
10	Scottish Power	Industrial	0.09	Low
11	Caravan Park	Residential	0.13	High
12	Claremont Avenue Residential	Residential	0.32	High

4.1.2 Meteorological data

Meteorological data utilised within the study was derived from 5 years of recent sequential hourly average data obtained from Hawarden meteorological station for the years 2016, 2018, 2019, 2020, 2021. 2017 was not used as it is missing significant amounts of data. This meteorological recording station is located approximately 4 km to the southwest of the works. The meteorological data was adjusted to reflect the surface characteristics of the meteorological site in accordance with the guidelines issued in the AERMOD Implementation Guide[11] issued by the US EPA. The wind rose for the meteorological data utilised in the study is presented below.

Figure 8: Wind rose for Lakenheath meteorological data 2016, 2018-2021



[11] AERMOD Implementation Guide, Published by the US EPA, Last Revised: March 19, 2009

Table 7: Pre-processing values applied to meteorological processing.

Sector[degrees]	Surface roughness [m]	Albedo / Bowen Ratio
8-71	0.055	0.25115/1.085
71-188	0.187	
188-243	0.057	
234-274	0.205	
274-8	0.549	

4.1.3 Receptor grid

A cartesian grid, 1.3 km by 1.15 km was defined for the study area with a 50 m spacing (southwest coordinates 333000, 367900). All receptors were assigned a 1.5 m flagpole height

4.1.4 Model settings

The model was run without considering any urban heat effects. A review of land use in the vicinity of Queensferry WwTW, in line with procedures detailed in the AERMOD Implementation Guide, indicated that the site is in a predominantly rural setting.

Data describing the topography of the area surrounding the works was obtained from Ordnance Survey in Landform Panorama™ format and processed through the AERMAP terrain processing module of AERMOD to define elevations and hill height data for all receptors, buildings, and emission sources within the model. Flagpole receptor heights of 1.5 m were applied.

4.1.5 Buildings

The following buildings were included in the model. The AERMOD Building Profile Input Parameters (BPIPRPIME) subprogram was run to calculate the potential for building downwash on each emission source in each of the 36 wind direction sectors (10° width/sector). This data is then used in AERMOD to calculate plume downwash (i.e. adjusted plume centreline due to building wake affects). The effect of building downwash is considered for point sources.

Table 8: Buildings

Building	Height [m]
Centrifuge feed tank	5
Sludge thickening building	4
Drum thickener building	4
Zone 1 digested sludge tanks	3
Zone 2 digested sludge tank	5
Zone 3 digested sludge tank	5
Zone 4 & 5 digested sludge tank building	2
Sludge holding tanks	1.5

4.2 Odour impact criteria

The Environment Agency publication entitled H4 Odour Management defines three indicative odour impact benchmarks that can be used to assess odour impact risk under EPR[12]. The criteria are expressed in terms of a modelled odour exposure at the 98th percentile of hourly average concentrations over a typical year (notation: $C_{98,\ 1\text{-hour}}$).

Table 9: Environment Agency odour impact risk benchmarks

Benchmarks	Modelled exposure level	Example
High or most offensive odours	$C_{98,\ 1\text{-hour}} \geq 1.5\ ou_E/m^3$	Rotten animal, septic sewage
Medium or moderately offensive odours	$C_{98,\ 1\text{-hour}} \geq 3\ ou_E/m^3$	Aerobic green waste composting
Low or least offensive odours	$C_{98,\ 1\text{-hour}} \geq 6\ ou_E/m^3$	Confectionery, bakery

Exceedance of these benchmarks indicates that there may be a risk of unacceptable pollution at odour sensitive receptors. Hence, the objective under EPR is to demonstrate that odour control measures at a given site are sufficient to prevent exceedance under normal operating conditions.

On the basis of Olfasense experience, odours from sludge treatment facilities are generally classified as highly offensive unless the sludge has undergone treatment such digestion, is very fresh and maintained in an aerobic state (e.g. fresh activated sludge), or the odours have been treated in an abatement system prior to release e.g. a biofilter or carbon adsorber.

However, it is also important to note the H4 criteria are designed for application to highly sensitive residential receptors. As a result, the use of the criteria for commercial/industrial receptors is likely to overstate the impact.

The H4 guidance provides provision to adjust criteria to reflect the lower sensitivity. However, no precise framework is defined. Research conducted on behalf of the EA in 2002 indicates that the difference in impact criteria between receptor sensitivity categories (e.g. from high to moderate) is likely to be in the region of a factor 2.

Odour impact criteria published in odour guidance prepared by the Institute of Air Quality Management (iAQM)[13] in July 2018 provides a more refined and explicit approach for determining the odour impact criteria for receptors with different sensitivities. Under this guidance, a stepped approach in impact criteria is applied as follows to reflect odour offensiveness and receptor sensitivity as follows:

- For highly sensitive receptors such as residential properties the odour exposure criteria which are expected to result in a significant adverse impact are $C_{98,\ 1\text{-hour}} \geq 1.5\ ou_E/m^3$ for highly offensive odours and $C_{98,\ 1\text{-hour}} \geq 3\ ou_E/m^3$ for moderately offensive odours.
- For moderately sensitive receptors, such as offices, the odour exposure criteria which are expected to result in a significant adverse impact are $C_{98,\ 1\text{-hour}} \geq 3\ ou_E/m^3$ for highly offensive odours and $C_{98,\ 1\text{-hour}} \geq 5\ ou_E/m^3$ for moderately offensive odours.

[12] Environment permitting: H4 odour management. Published 2014.
https://www.gov.uk/government/publications/environmental-permitting-h4-odour-management
[13] Guidance for the assessment of odour for planning, IAQM, Version 1.1, July 2018.

- For low sensitivity receptors, such as industrial premises, the odour exposure criteria which are expected to result in a significant adverse impact are $C_{98,\ 1\text{-hour}} \geq 5$ ou_E/m^3 for highly offensive odours, and $C_{98,\ 1\text{-hour}} \geq 10$ ou_E/m^3 for moderately odours.

5 Results of dispersion modelling

5.1 Model output

The results of the dispersion modelling are presented in the figure below. The figure presents isopleths encompassing the area where odour exposure levels are predicted to exceed 1.5, 3, 5 ou_E/m^3 for greater than 2% of the hours in the year, for the current operations associated with sludge treatment.

Figure 5: Results of odour dispersion modelling under normal operational conditions

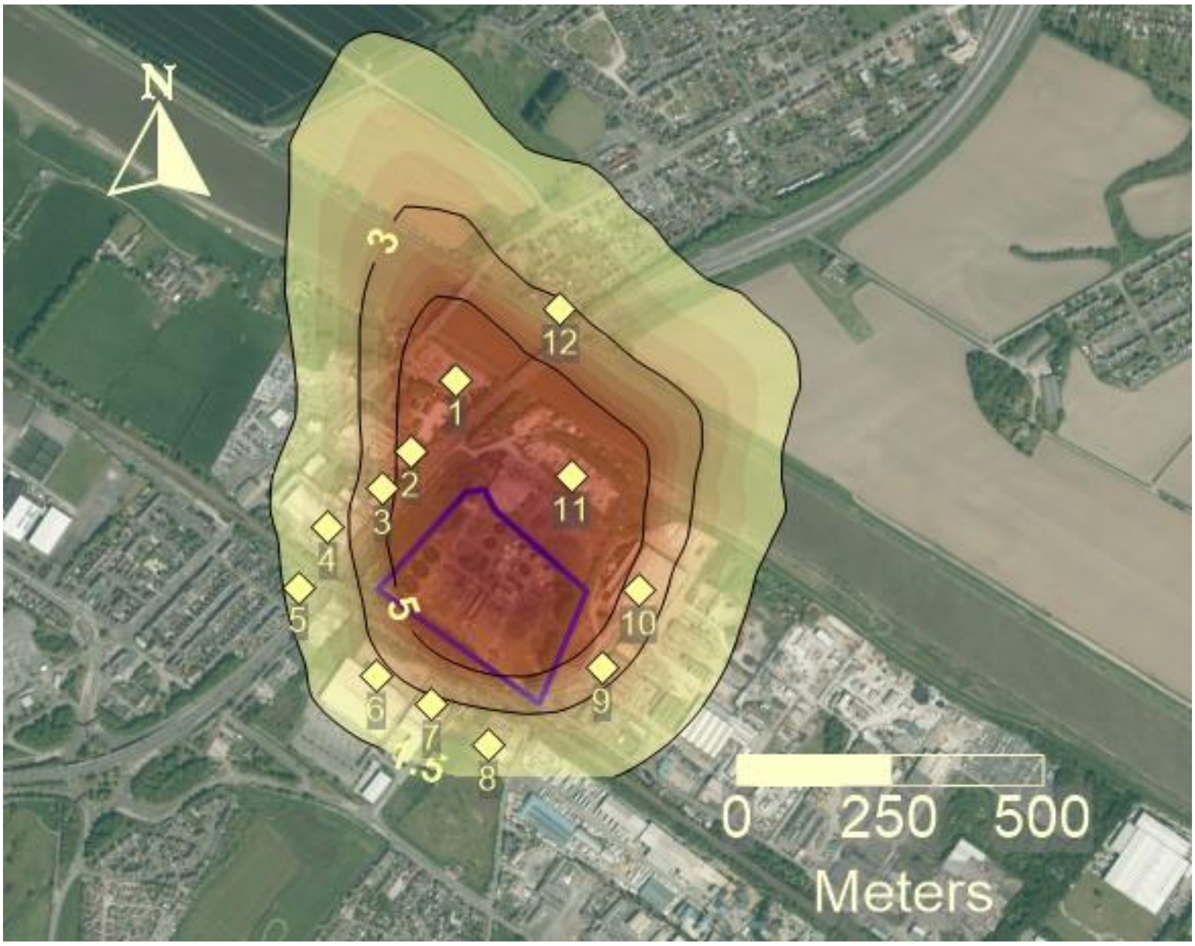


Table 10: Exposure levels predicted at named receptors

#	Land use		Sensitivity to odour	Impact criterion [$C_{98, \text{1-hour}}$, ou_E/m^3]	Predicted odour exposure level [$C_{98, \text{1-hour}}$, ou_E/m^3]
1	Toyota Queensferry	Commercial	Medium	3 ou_E/m^3	9.4
2	Deeside delivery office	Commercial	Medium	3 ou_E/m^3	6.3
3	Number One Gym	Commercial	Medium	3 ou_E/m^3	4.0
4	Spinney Caravan Dealer	Commercial	Medium	3 ou_E/m^3	2.4
5	Dundas Street Residential	Residential	High	1.5 ou_E/m^3	1.7
6	Makro Queensferry	Commercial	Medium	3 ou_E/m^3	2.5
7	Whizz Kids	Commercial	Medium	3 ou_E/m^3	2.6

8	Knauf insulation	Industrial	Low	5 ou_E/m^3	2.0
9	Warehouse	Industrial	Low	5 ou_E/m^3	3.6
10	Scottish Power	Industrial	Low	5 ou_E/m^3	4.0
11	Travellers Park	Residential	High	1.5 ou_E/m^3	12.4
12	Claremont Avenue Residential	Residential	High	1.5 ou_E/m^3	3.2

Review of the results indicates that odours from the site operations pose a potential risk of impact to residential development up to 0.78 km from the site boundary, which includes residential developments to the north, south and east of the site including the travellers park. Furthermore, a number of commercial premises to the west of the site across the A494 are also exposed to odour levels that could cause annoyance and complaints.

5.2 Assessment of uncertainties

The main factors that influence the uncertainty of the odour assessment are as follows:

- Model uncertainty.
- Meteorological data.
- Variation in emission rates.

5.2.1 Model uncertainty

The US EPA Aermod model has been used extensively in the UK for undertaking odour impact assessments from a wide range of industries and source types. Whilst the model cannot be expected to fully reflect reality, its performance in terms of prediction of odour or pollutant exposure is considered to be good and the model is frequently used for regulatory purposes.

Since odour impact benchmarks applied in the UK are model derived, and have been tested extensively using the AERMOD model, the inherent uncertainties in the model predictions in comparison to real world conditions are not generally considered relevant.

5.2.2 Meteorological data

Meteorological data selection has a significant impact on model uncertainty and is arguably the most important factor to consider when assessing the outputs of odour dispersion modelling assessments.

In this case, the site is located a short distance from the nearest meteorological station and considered to be representative of site conditions.

5.2.3 Emission rates

Variations in the average source emission rates have a broadly proportional influence in terms of predicted offsite exposure. The odour emission rates used in the model have been selected using site specific data from two odour surveys, and assuming sludge tanks and cake storage areas are full.

However, variations are possible, particularly in relation to the areas which handle raw indigenous and imported sludges, which generate odours which pose the greatest risk of impact due to their high offensiveness. It is therefore possible that the impact area may change with time and that odours may be detectable and pose an impact beyond the area indicated by the model.

6 Improvement measures

6.1 Recommendation for optimising odour control

It is evident from the dispersion model results that predicted odour exposure levels generated by the site exceed the NRW exposure impact benchmark at a number of sensitive receptors.

The main contributors to the predicted exposure levels are fugitive odours from the raw sludge holding tanks, imported sludge tanks and sludge thickening building, all of which are likely to be highly offensive in nature. It is therefore recommended that mitigation is applied to these sources.

The following improvements are recommended, with corresponding BATc conclusions:

1. Refurbish/replace the covers on the raw sludge holding tanks, digestor feed tank and imported sludge tanks to minimise any leakage routes (BATc14d).
2. Provide active extraction to the following tanks to ensure they are maintained under negative pressure under all normal foreseeable operational conditions including filling and inspection (BATc14d):
    a. Imported sludge tank.
    b. Screened imported sludge tank.
    c. Sludge holding tank 1.
    d. Sludge holding tank 2.
    e. Digestor feed tank.
    f. Sludge thickener building.
3. Install a new odour control system to treat the extracted air from the sources above. (BATC14d).

6.2 Assessment of the likely impact of implementing the recommended improvements

6.2.1 Changes to the model assumptions

The effect of the recommended improvements on offsite odour exposure and impact risk has been assessed using the dispersion described in section 4 with the following modifications:

- It was assumed that fugitive emissions from the sludge holding tanks, imported sludge tank, digestor feed tank and sludge thickener building are eliminated by application of recommendation 1 and 2.
- The odour emissions from the new odour control system have been estimated as follows:
    - An indicative airflow of 0.75 m^3/hr which reflects an extract rate from each tank of 1 air change per hour and an extract rate from the thickener building of 5 air changes per hour. These estimates are subject to detailed design.

o The residual odour concentration is assumed to be 1,000 ou_E/m^3.

o Emissions are released through a 3 m stack.

o The system is located adjacent to the sludge thickener building.

6.2.2 Model outputs

The results of the modelling are presented in Figure 5 and Table 10 below:

Figure 5: Results of odour dispersion modelling following application of mitigation measures

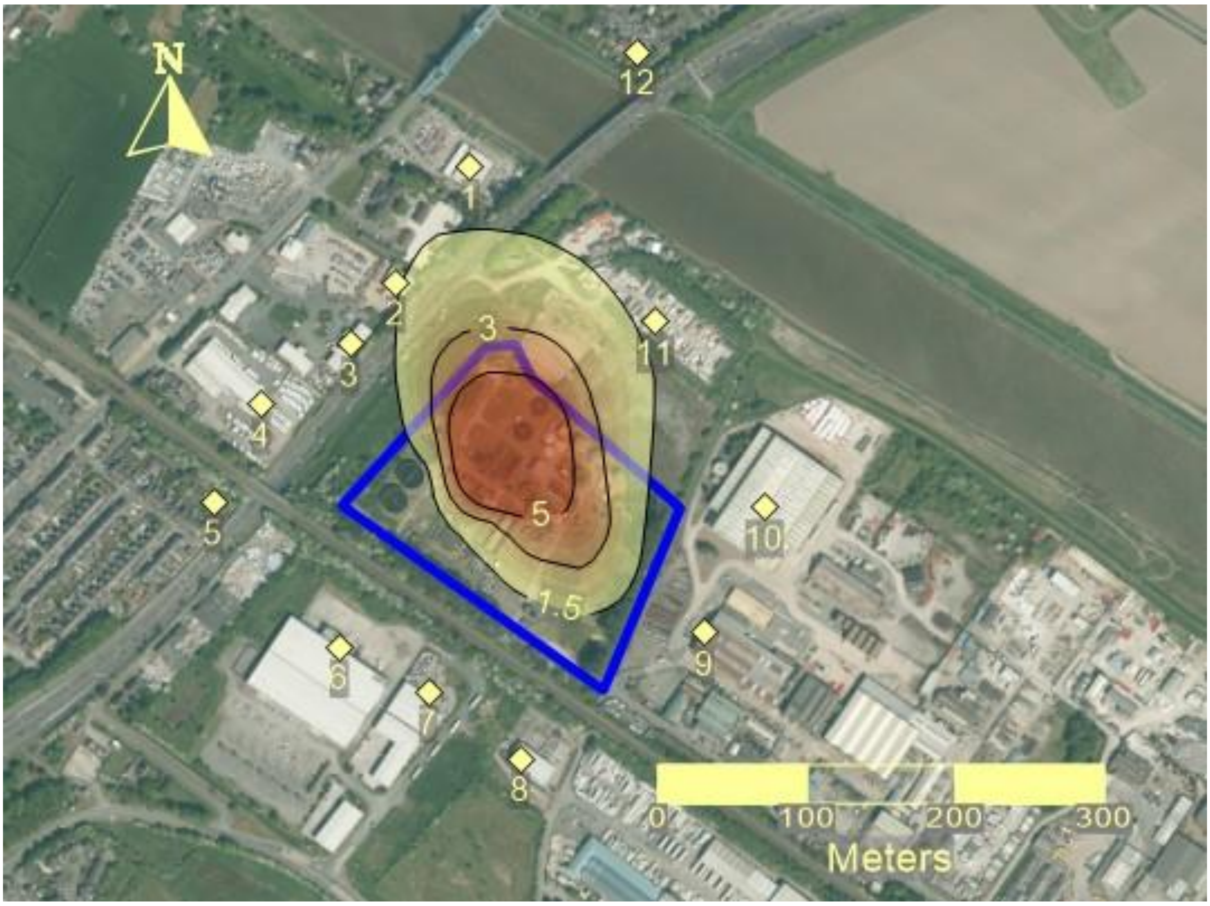


Table 11: Exposure levels predicted at named receptors

#	Land use		Sensitivity to odour	Impact criterion [$C_{98, 1\text{-hour}}$, ou_E/m^3]	Predicted odour exposure level [$C_{98, 1\text{-hour}}$, ou_E/m^3]
1	Toyota Queensferry	Commercial	Medium	3 ou_E/m^3	0.1
2	Deeside delivery office	Commercial	Medium	3 ou_E/m^3	1.4
3	Number One Gym	Commercial	Medium	3 ou_E/m^3	0.7
4	Spinney Caravan Dealer	Commercial	Medium	3 ou_E/m^3	0.2
5	Dundas Street Residential	Residential	High	1.5 ou_E/m^3	<0.1
6	Makro Queensferry	Commercial	Medium	3 ou_E/m^3	0.1
7	Whizz Kids	Commercial	Medium	3 ou_E/m^3	0.1

8	Knauf insulation	Industrial	Low	5 ou_E/m^3	0.1
9	Warehouse	Industrial	Low	5 ou_E/m^3	0.7
10	Scottish Power	Industrial	Low	5 ou_E/m^3	0.4
11	Travellers Park	Residential	High	1.5 ou_E/m^3	1.2
12	Claremont Avenue Residential	Residential	High	1.5 ou_E/m^3	0.5

The modelling indicates that following application of the recommended control measures, the offsite odour exposure levels are predicted to fall below the exposure benchmarks defined, assuming that the odours are highly offensive in nature, at all of the nearest sensitive receptors.

It should be noted that the residual odours from the remaining odour sources, which involve handling of digested sludge and treated air from the odour control system, would typically be considered to be of moderate rather than high offensiveness. Hence, there is likely to be a significant margin of safety in the above impact assessment conclusion.

7 Conclusions and recommendations

The findings of the assessment were as follows:

1. Odour emissions from the permitted site are currently predicted to pose a risk of impact up to 0.8 km from the site boundary, which includes residential properties to the north, south and east of the site, the traveller park to the north of the site, and a number of commercial premises to the west of the site across the A494.
2. The main contributors to the predicted exposure levels are fugitive odours from the raw sludge holding tanks, imported sludge tanks and sludge thickening building all of which are likely to be highly offensive in nature and account for an estimated 85 % of total site emissions.
3. In order to mitigate offsite impact risk and reduce exposure to below the applicable odour impact benchmark, the following mitigation measures are recommended:
    a. Refurbish/replace the covers on the raw sludge holding tanks, digestor feed tank and imported sludge tanks to minimise any leakage routes.
    b. Provide active extraction to the following tanks to ensure they are maintained under negative pressure under all normal foreseeable operational conditions include filling and inspection.
        i. Imported sludge tank.
        ii. Screened imported sludge tank.
        iii. Sludge holding tank 1.
        iv. Sludge holding tank 2.
        v. Digestor feed tank.
        vi. Sludge thickener building.
    c. Install a new odour control system to treat the extracted air from the sources above.

Annex A: Odour survey data

A.2 Survey results

Table 12: Odour survey data from tanks and buildings

Source	Odour concentration [ou_E/m^3]		
	Geometric mean	2020	2018
Imported sludge well	4,566	1,524	13,682
Sludge holding tank 1	37,203	35,226	39,291
Sludge holding tank 2	234,407	234,407	-
Digester feed tank	1,041	37,092	29.225
Sludge thickening building	234	-	234
Centrifuge building	69	-	69
Centrate well	70	70	-

Table 13: Odour survey data from area sources

Source	Odour emission rate [$ou_E/m^2/s$]		
	Geometric mean	2020	2018
Screen skip	35.7	35.7	-
Digested sludge (liquid)	2.6	1.7	4.1
Sludge cake	3.9	5.2	3.0