

Odour survey to evaluate the benefits of the Mogden STW Odour Control Project.

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Executive Summary

This report presents the findings of an odour assessment study relating to the wastewater treatment operations conducted at Mogden Sewage Treatment Works (STW), Isleworth, London. The odour survey was undertaken by Odournet UK Ltd under instruction from Thames Water Utilities Limited (TWUL).

The study was commissioned to assess the effectiveness of the odour control measures which have been applied at the works under the OFWAT funded Odour Control Project and evaluate whether the reduction target 66% of site emissions set by OFWAT (as compared to 2003 data) has been achieved. The following specific objectives were addressed during the course of the survey:

- To measure the rate of odour release of each aspect of the sewage treatment and sludge handling processes and evaluate the effectiveness of the odour treatment units serving these areas.
- To quantify the overall odorous emissions currently generated from the works.
- To compare the current site emissions to previous datasets obtained prior to the commencement of the Odour Control Project.

The findings of the assessment were as follows:

1. The results of the 2008 odour survey indicate that the total site emissions generated from the site are currently in the order of 58,000 ou_E/s. This compares to approx. 606,000 ou_E/s as calculated in 2003 and approx. 327,000 ou_E/s measured immediately prior to commencement of the Odour Control Project in 2005.
2. The reduction in site emissions compared to the previous survey data are directly associated with the following odour treatment measures that were implemented as part of the Odour Control Project:
 - Enclosure and treatment of emissions from the West Side Inlet Works, East Side Inlet Works, East Side Primary Settlement Tanks and first fill Storm Tanks.
 - Improved cleaning and odour management procedures within the remaining open storm tanks.

A proportion of the reduction may also be due to variations in the odour emission potential of incoming sewage and improvements in sludge handling within the West Side Primary Settlement tanks.

3. The calculated reduction in site odour emissions determined by direct comparison of the survey results is 90% compared to the 2003 dataset and 82% compared to the 2005 dataset.
4. If the influence of variations in emission rates from the primary settlement tanks and activated sludge plant are removed (which assumes the worst case for comparison purposes), the calculated reduction in odour emissions from the site is 72.9% compared to the 2003 dataset and 66.2% compared to the 2005 dataset.
5. It is therefore concluded that the 66% reduction in site emissions defined within the OFWAT funding application has been achieved by the Odour Control Project.

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1 Introduction and scope

1.1 Introduction

This report presents the findings of an odour assessment study relating to the wastewater treatment operations conducted at Mogden Sewage Treatment Works (STW), Isleworth, London. The odour survey was undertaken by Odournet UK Ltd under instruction from Thames Water Utilities Limited (TWUL).

The study was commissioned to assess the effectiveness of the odour control measures which have been applied at the works under the OFWAT funded Odour Control Project and evaluate whether the reduction target 66% of site emissions as set by OFWAT (as compared to 2003 data) has been achieved.

1.2 Scope

The following specific objectives were addressed during the course of the survey:

- To measure the rate of odour release of each aspect of the sewage treatment and sludge handling processes and evaluate the effectiveness of the odour treatment units serving these areas.
- To quantify the overall odorous emissions currently generated from the works.
- To compare the current site emissions to previous datasets obtained prior to the commencement of the Odour Control Project.

1.3 Structure of report.

The report is structured as follows:

- Section 2 of the report describes the approach undertaken during the study.
- Section 3 presents the results of the odour measurement programme.
- Section 4 presents an analysis of the current site emissions to previous datasets.
- Section 5 summarises the findings of the study.

Supporting information is presented in the Appendices.

2 Description of methodology

2.1 Odour measurement programme.

The 2008 survey involved a comprehensive odour measurement exercise which was conducted between the 8th September 2008 and the 30th September 2008, followed by dispersion modelling. The survey was conducted in accordance with a 'Survey Protocol' which was defined for the 2005 odour survey, which was required by Clause 15 of the site abatement notice issued by the London Borough of Hounslow.

The odour measurement programme involved the following:

- Measurement of emission rates from the key processing activities in terms of odour units, ammonia and hydrogen sulphide.
- Measurement of the odour abatement efficiency of the existing odour control units.
- Assessment of the Hedonic tone (relative offensiveness) of odorous emissions from the various aspects of the process.

The techniques applied for each of these approaches are described below:

2.1.1 Measurement of odour, hydrogen sulphide and ammonia emissions.

The odour emission measurement exercise was conducted between 8th September 2008 and the 30th September 2008. The specific aspects of the treatment process from which samples were collected, and the number of samples collected at each location, are summarised in Annex B.

At each location, samples of air were collected using the sampling techniques described in Annex A. The collected samples were then transported back to the Odournet UK Ltd UKAS accredited olfactometry laboratory* where the following analyses were conducted, within 30 hours from the time of collection:

- Determination of the odour concentration in terms of European odour units in accordance with the British Standard for Olfactometry BSEN13725: 2003¹. The analysis was conducted using Odournet's internal quality management procedure which is accredited by the UK accreditation services (UKAS) under certificate No. 2430.
- Measurement of the hydrogen sulphide concentration using either Gastec tubes (for concentrations >50ppm), or a calibrated Jerome gold film analyser (for concentrations less than 50 ppm).

In order to ensure that the odour emission data were representative of conditions that pose the greatest risk of odour impact to nearby sensitive receptors, the qualifying criteria outlined in the survey protocol were as follows:

- 3 days with less than 5 mm of rain were recorded at Heathrow Airport (for all open liquid odour sources or odour sources which are likely to be affected by changes in the quality of the influent over the short-term).
- Sludge levels within the primary settlement tanks were at typical operating levels.

* United Kingdom Accreditation Services (UKAS) laboratory number 2430.

¹ BSEN 13725:2003, *Air quality - Determination of odour concentration by dynamic olfactometry*.

The following critical operating parameters which may influence odour generation from the treatment process were also recorded at the time samples were collected:

Table 1 Critical operational parameters which will be required during the survey.

Stage of treatment	Parameter which were recorded.
Preliminary treatment (liquid samples)	Incoming flow rate of sewage. Sewage temperature. Daily average rainfall (as measured at Heathrow Airport).
Primary settlement	Sludge dip level. Sewage temperature. No. of drum thickeners in operation (for east side samples) No. of SAS centrifuges operational (for east side samples)
Secondary treatment	Mixed Liquors Suspended Solids (MLSS). Sewage temperature.
Sludge odour control systems.	No. of operational drum thickeners Status of the biotherm plant

2.1.2 Analysis of the relative offensiveness of odours.

Analysis of the relative offensiveness (hedonic tone) of the odours generated from each stage of the treatment process was conducted using an in-house analysis method based on VDI 3882:1997, Part 2; Determination of Hedonic Tone, Düsseldorf, Germany. The objective of this analysis was to identify any differences between the offensiveness of odours generated from each stage of the treatment process, by identifying the concentration at which each odour is considered to be 'mildly' and 'moderately' offensive by a panel of observers with a defined acuity to odour. Presentation of the odour samples and determination of the hedonic tone were conducted under controlled conditions using the Odournet UK Ltd olfactometry laboratory.

The sample programme for hedonic tone measurements is presented in Annex B.

2.1.3 Assessment of the efficiency of odour control plant.

The efficiency of the odour control plant currently in place at Mogden STW was calculated from the emission measurement results from the untreated (crude) and treated (clean) air streams for each odour control unit, using the equation below in accordance with Annex H of British Standard for Olfactometry BS13725:2003.

$$\eta_{od} = \frac{q_{od, crude} - q_{od, clean}}{q_{od, crude}}$$

Where: $q_{od, crude}$ = odour emission of the gas stream presented to the abatement plant.

$q_{od, clean}$ = odour emission of the gas stream after treatment by the abatement plant.

2.2 Quantification of site emissions.

The odour emissions from each stage of the processing operations were derived from the emission measurements collected during the sampling programme, in combination with relevant operational data and site plans provided by TWUL. Consideration was also given to the influence of the following factors to derive representative and comparable emission values:

- Turbulence of aspects of the process handling odorous liquid and solid material.

- The effect of seasonal changes in the influent quality and rate of biological generation of odours within the process proper.
- The frequency and duration of release of intermittent activities.
- The relative offensiveness of odours generated from each aspect of the process.

The emission rates derived from the 2008 survey were then compared to the results of the odour surveys conducted immediately prior to commencement of the Odour Control Project (summer of 2005) and the data which was used to justify the OFWAT funding application (collected in the summer of 2003).

3 Review of 2008 survey results

3.1 Summary of odour measurement data

The results of the odour measurement programme are summarised in the tables below:

Table 2 Odour measurements collected using hood sampling.

Stage of treatment	Source	Mean area emission rate	
		Odour [ou _E /m ² /s]	H ₂ S [mg/m ² /s]
Preliminary	West side grit channel	3.1 & 20.8	0.0008 & n/d
	Pre-aeration lane - WS Rect PST	4.2 & 27.8	0.0003
Storm water	Storm water inlet channel	1.9 & 4.8	0.0009 & 0.0011
	Storm tank hopper	1.6	0.0003
	Storm tank (full)	2.5	0.0004
Primary	Rectangular PST (west)	2.2 & 0.5	0.0001 & n/d
	Circular PST (west)	0.9 & 0.4	0.0001 & n/d
Secondary	Activated sludge plant (east)	0.7 & 0.4	<0.0001
	Activated sludge plant (west)	0.4 & 0.6	<0.0001

Table 3 Odour measurements from buildings, odour control plant and enclosed odour sources.

Stage of treatment	Odour source	Mean concentration	
		Odour (ou _E /m ³)	H ₂ S (mg/m ³)
Preliminary	Main Inlet Pumping station OCU (in)	7451	n/m
	Main Inlet pumping station OCU (out)	<64	n/m
	East side OCU (Inlet)	2503 to 3578	0.32 to 0.89
	East side OCU (intermediate)	197 to 295	0.028 to 0.036
	East side OCU (combined outlet)	116	0.0005
	West side OCU (inlet)	6957	0.34
	West side OCU (intermediate)	81	0.015
	West side OCU (outlet)	114	n/d
Sludge	Sludge transfer area OCU (inlet)	8107	1.32
	Sludge transfer area OCU (intermediate)	727	0.017
	Sludge transfer area OCU (outlet)	542	0.010
	Sludge imports (normal) OCU (inlet)	29078	2.78
	Sludge imports (normal) OCU (outlet)	1072	0.15
	Sludge imports (loading) OCU (inlet)	133121	12.5
	Sludge imports (loading) OCU (outlet)	943	0.045
	Sludge thickening OCU (inlet)	387143	104
	Sludge thickening OCU (intermediate)	7425	0.92
	Sludge thickening OCU (outlet)	11666	0.64
	Pasteurisation OCU ²	-	-

² OCU was not operational during sampling survey as the pasteurisation plant was not operating. The emissions from this source have been estimated using 2005 data.

	Pasteurisation OCU (out)	-	-
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The results of the hedonic tone measurements are presented in Table 4 below.

Table 4 Results of hedonic tone

Stage of treatment process	Source	Concentration at which odours are perceived as 'mildly offensive' [ou _E /m ³]	Concentration at which odours are perceived as 'moderately offensive' [ou _E /m ³]
Preliminary	East side OCU outlet	1.5	4.3
	West side OCU outlet	1.7	5.2
Storm	Storm tanks during storm conditions	1.8	9.5
Primary	Primary tanks	2.1	7.5
Secondary	ASP plant (West Side)	3.1	14.6

3.2 Discussion of results

3.2.1 Comparison to previous surveys

The odour measurement program was undertaken at similar dates to both the 2003 and 2005 surveys and under similar meteorological conditions. During all visits, the conditions were dry with moderate ambient temperatures.

In general terms, the odour emission data obtained during the 2008 survey present a picture which is broadly comparable with previous surveys. The highest surface odour emission rates were measured from the incoming influent and were comparable between all three odour surveys, in terms of both emission magnitude and degree of temporal variation. The emission rates then demonstrated a decrease as the sewage travelled through the process to the activated sludge plant, as did the offensiveness of the odours released.

The main differences in terms of surface emission rates measured between the 2008 and previous datasets were the reduced emissions from the west side primary settlement tanks and activated sludge plant. There is some evidence to suggest that these reductions in emissions may be due to variations in the odour potential of incoming sewage. It is plausible that improvements to sludge handling within the tanks have also had a beneficial effect. However, on the basis of the data available, it is not possible to confirm that these specific emission reductions have been achieved as a direct result of operational intervention through the Odour Control Project.

In terms of the storm tanks, the 2008 data indicate that improvements have been achieved since 2005 which are likely to be accounted for by the further improvements to cleaning procedures implemented as part of the Odour Control Project.

The performance of the odour control systems installed on the East side and West side works is discussed below.

3.2.2 Review of odour control unit performance

The results of the assessment for the odour control units currently in place on site are presented in Table 5 below:

Table 5 Results of odour removal efficiency assessment

OCU unit	Odour in (ou _E /s)	Odour out [ou _E /s]	% removal	H ₂ S in [mg/s]	H ₂ S out [mg/s]	% removal
Inlet Pumping station	6110	53	99.1	n/m	n/m	-
East side OCU	124705	4837	97.3	25.23	0.01	99.6
West side OCU	16558	271	98.4	0.81	n/m	>99.9
Digested sludge transfer	3648	244	93.3	0.59	0.005	99.1
Sludge imports (normal)	54580	377	99.3	2.78	0.15	94.6
Sludge imports (peak)	11922	429	96.4	12.5	0.05	99.6
Sludge thickening OCU	662015	19945	97.0	177	1.09	99.4
Pasteurisation OCU ³	-	-	-	-	-	-

The results of the efficiency assessments indicate that the new odour control units serving the East and West side works are both exceeding their performance specifications, with measured odour concentrations well below the target 1000 ou_E/m³ at the outlet for all treatment streams (the measured outlet odour concentrations were 116 ou_E/m³ and 114 ou_E/m³ for the Eastside and West side OCU's respectively).

In terms of the other existing odour control systems, all were found to be operating above 90% odour and hydrogen sulphide removal efficiency, and are generally considered to be performing within the optimal range for all units. The only exception was the sludge thickening biofilter, whose outlet odour emissions were higher than expected. This fact was highlighted to management for review and remediation. The Tideway Thames Quality Improvements for Mogden STW proposes a new sludge OCU for this area.

3.3 Quantification of site emissions

The odour emission data collected during the survey was used to quantify the emissions from each aspect of the works operations. A breakdown of the time-weighted odour emissions generated from each aspect of the sewage treatment for each operational condition are presented in Table 6 below:

³ OCU was not operational during sampling survey. The emissions from this source have been estimated using 2005 data.

Table 6 Summary of time-weighted odour emissions for each aspect of the sewage treatment process

Stage of treatment	Source	Post odour control project (2008 data)	
		Time weighted emission (ou _E /s)	% of site emissions
Preliminary treatment	East side inlet works	324	0.5%
	West side inlet works	3938	6.8%
	Inlet odour control unit	53	0.1%
Storm	Storm tanks	9274	16.0%
Primary settlement	Primary settlement (East)	-	-
	Primary settlement (West)	7509	13.0%
Secondary treatment	Activated sludge plant (East)	6027	10.4%
	Activated sludge plant (West)	3608	6.2%
Sludge handling	Surplus activated sludge handling	-	-
	Digested sludge handling	244	0.4%
	Imported sludge handling	386	0.7%
	Raw sludge handling	19945	34.4%
	Pasteurisation chemical scrubber OCU	1562	1.0%
New OCUs	West side OCU	271	0.5%
	East side OCU	4837	8.3%
	TOTAL	57978	100%

The breakdown of emissions show that total site emissions were calculated at approximately 58,000 ou_E/s during the sampling exercise in 2008. The main contributors to site emissions are from the raw sludge handling operations (34.4%), storm water handling (16%), west side PSTs (13.0%) and the east side ASP lanes.

The two newly commissioned OCUs serving the east side and west side inlet works are working to a high odour abatement efficiency (97% and 98% respectively) and together contribute to less than 9% of the total site emissions.

4 Review of the benefits of the Odour Control Project

4.1 Background

In order to determine the effect of the Odour Control Project on site emissions, the results of the 2008 survey have been compared to two sets of the emission data obtained from the works under two historic operational conditions, as defined below:

- The situation immediately prior to commencement of the Odour Control Project (2005 data).
- The situation upon which the original application for OFWAT funding was based (2003 data).

These two conditions have been analysed to ensure that a realistic assessment of the effect of the Odour Control Project is achieved, in acknowledgement that a number of modifications were applied to the site operations that may have influenced odour emissions between 2003 and 2005 and which were unrelated to the OFWAT funded project.

In addition, each of these comparisons also considers the influence that changes in the odour potential of the influent received at the site may have had on emissions from the open west side primary settlement tanks and the activated sludge plant. This sensitivity analysis has been conducted by 'normalising' the emission rates used to calculate emissions from these areas between each dataset. This approach very much reflects a worst case comparison since odour emissions from these areas may also be influenced by sludge levels in the primary settlement tanks and the way in which the activated sludge plant are managed.

4.2 Comparison of site emissions to pre-OFWAT funding application conditions (2003 data)

Breakdowns of the emissions from each key aspect of the site operations for the 2008 and 2003 datasets are presented in Table 7 below:

Table 7 Breakdown of odour emissions for the 2003 survey, 2008 survey and normalised 2008 survey data.

Stage of treatment	Source	Pre odour control project (2003 data)		Post odour control project (2008 data)		Post odour control project (normalised)	
		Time weighted emission (OU _E /s)	Time weighted emission (OU _E /s)	Time weighted emission (OU _E /s)	Time weighted emission (OU _E /s)	Time weighted emission (OU _E /s)	% of site emissions
Preliminary treatment	East side inlet works	41800	6.9%	324	0.5%	324	0.2%
	West side inlet works	68800	11.3%	3938	6.8%	16300	9.9%
	Inlet odour control unit	-	-	53	0.1%	53	0.0%
Storm	Storm tanks	110200	18.2%	9274	16.0%	9274	5.6%
Primary settlement	Primary settlement (East)	233000	38.4%	-	-	-	-
	Primary settlement (West)	29100	4.8%	7509	13.0%	29100	17.7%
Secondary treatment	Activated sludge plant (East)	57400	9.5%	6027	10.4%	57400	34.9%
	Activated sludge plant (West)	24600	4.1%	3608	6.2%	24600	15.0%
Sludge	Surplus activated sludge handling	1200	0.2%	-	-	-	-
	Digested sludge handling	-	-	244	0.4%	244	0.1%

	Imported sludge handling	4300	0.7%	386	0.7%	386	0.2%
	Raw sludge handling	35800	5.9%	19945	34.4%	35800	12.1%
	Pasteurisation OCU	-	-	1562	2.7%	1562	1.0%
New OCUs	West Side inlet works OCU	-	-	271	0.5%	271	0.2%
	East side OCU	-	-	4837	8.3%	4837	2.9%
	TOTAL	606200	100%	57978	100%	164296	100.0%

Comparison of the 2008 data to the 2003 data indicates a drop in overall site emissions of approximately 90%. This reduction is attributable to:

- The enclosure and treatment of emissions from the west side & east side preliminary treatment operations, first fill storm tanks and the east side primary settlement tanks;
- The incorporation of automated cleaning systems in the remaining open storm tanks in the form of Amajet cleaning jets, and refinements of the Odour Management Plan to minimise odour generation from storm tank hoppers and channels;
- Improvements to the sludge handling operations and performance of sludge odour control systems;
- Reductions in the average odour emission rates measured from the sewage in the open aspects of the treatment process (i.e. west side primary tanks; east and west side activated sludge plant).

If the influence of variations in emission rates from the open primary settlement tanks and activated sludge plant are removed, the reduction in emissions that can be directly attributed to the Odour Control Project in comparison to 2003 data is 72.9%.

4.3 Comparison of emissions to the pre Odour Control Project conditions (2005 survey data).

Breakdown of site emissions for the 2005 and 2008 surveys are presented in Table 8 below.

Table 8: Breakdown of odour emissions for the 2005 survey, 2008 survey and normalised 2008 survey data.

Stage of treatment	Source	Pre-odour control project (2005 data)		Post odour control project (2008 data)		Post odour control project (normalised)	
		Time weighted emission (ou _E /s)	% of site emissions	Time weighted emission (ou _E /s)	% of site emissions	Time weighted emission (ou _E /s)	% of site emissions
Preliminary treatment	East side inlet works	10101	3.1%	324	0.5%	324	0.3%
	West side inlet works	33433	10.2%	3938	6.8%	4558	4.1%
	Inlet odour control unit	846	0.3%	53	0.1%	53	0.0%
Storm	Storm tanks	16022	4.9%	9274	16.0%	9274	8.4%
Primary settlement	Primary settlement (East)	85416	26.1%	-	-	-	-
	Primary settlement (West)	29021	8.9%	7509	13.0%	29021	26.2%
Secondary treatment	Activated sludge plant (East)	25597	7.8%	6027	10.4%	25597	23.1%
	Activated sludge plant (West)	14648	4.5%	3608	6.2%	14648	13.2%

Sludge	Surplus activated sludge handling	6047	1.8%	-	-	-	-
	Digested sludge handling	199	0.1%	244	0.4%	244	0.2%
	Imported sludge handling	100539	30.7%	386	0.7%	386	0.3%
	Raw sludge handling	3907	1.2%	19945	34.4%	19945	18.0%
	Pasteurisation OCU	1562	0.5%	1562	2.7%	1562	1.4%
New OCUs	West Side inlet works OCU	-	-	271	0.5%	271	0.2%
	East side OCU	-	-	4837	8.3%	4837	4.4%
TOTAL		327338	100%	57978	100%	110720	100%

Comparison of the 2008 data to the 2005 data indicates a drop in overall site emissions of approximately 82%. This reduction is attributable to:

- The enclosure and treatment of emissions from the west side & east side preliminary treatment operations, first fill storm tanks and east side primary settlement tanks;
- The incorporation of automated cleaning systems in the remaining open storm tanks in the form of Amajet cleaning jets and refinements of the Odour Management Plan to minimise odour generation from storm tank hoppers and channels;
- Improvements to the performance of sludge odour control systems;
- Reductions in the average odour emission rates measured from the sewage in the open aspects of the treatment process (i.e. west side primary tanks; east and west side activated sludge plant).

If the influence of variations in emission rates from the open primary settlement tanks and activated sludge plant are removed, the reduction in emissions that can be directly attributed to the Odour Control Project by comparison to the 2005 data is 66.2%

5 Conclusions

The findings of the survey are as follows:

1. The results of the 2008 odour survey indicate that the total site emissions generated from the site are currently in the order of 58,000 ou_E/s. This compares to approx. 606,000 ou_E/s as calculated in 2003 and approx. 327,000 ou_E/s measured immediately prior to commencement of the Odour Control Project in 2005.
2. The reduction in site emissions compared to the previous survey data are directly associated with the following odour treatment measures that were implemented as part of the Odour Control Project:
 - Enclosure and treatment of emissions from the west side inlet works, east side inlet works, east side primary settlement tanks and first fill Storm Tanks.
 - Improved cleaning and odour management procedures within the remaining open storm tanks.

A proportion of the reduction may also be due to variations in the odour emission potential of incoming sewage and improvements in sludge handling within the West Side Primary Settlement tanks.

3. The calculated reduction in site odour emissions determined by direct comparison of the survey results is 90% compared to the 2003 dataset and 82% compared to the 2005 dataset.
4. If the influence of variations in emission rates from the primary settlement tanks and activated sludge plant are removed (which assumes the worst case for comparison purposes), the calculated reduction in odour emissions from the site is 72.9% compared to the 2003 dataset and 66.2% compared to the 2005 dataset.
5. It is therefore concluded that the 66% reduction in site emissions defined within the OFWAT funding application has been achieved by the Odour Control Project.

Annex A Odour Sampling techniques

A.1 Collection of odour samples from odour control plant.

Collection of samples from ducts or vents as conducted using the 'Lung' principle. A 60l Nalophane sample bag was placed in a rigid container and connected to the duct containing odorous gas using a PTFE sample line. Air was withdrawn from this container using a pump which caused a sample of the odorous air to be drawn through the line into the bag.

If necessary, samples were pre-diluted with nitrogen at the point of collection to prevent condensation from forming in the sampling lines and odour bag, which may influence the odour concentration prior to analysis. Pre-dilution was conducted using OdourNet's patented Sample Master stack sampling system.

The temperature and velocity of the airflow at each point was also determined using suitable monitoring techniques.

The emission rate of odour was then calculated by multiplying the measured odour concentration by the volume flow rate (m³/s) as measured in the duct.

A.2 Collection of odour samples from sources with no measurable flow.

Collection of samples from area sources where there is no measurable flow were conducted using a ventilated canopy known as a 'Lindvall hood'. The canopy was placed on the odorous material and ventilated at a known rate with clean odourless air. A sample of odour was collected from the outlet port of the hood using the Lung principle.

The rate of air injected into the hood was monitored for each sample and used to calculate a specific odour emission rate per unit area per second (E_{sp}) as follows:

$$E_{sp} = C_{hood} \times L \times V$$

Where,

C_{hood} is the odour concentration measured from the sample bag.

L is the hood factor, which is equal to the path length (m²) of the hood divided by the covered area (m²).

V is the velocity (m/s) of air presented to the hood.

Annex B Odour sampling program

Table 9 Sampling locations for collection of odour samples

Stage of treatment process	Process/odour source	Sample location	Number of sample sets (based on triplicate samples per set)
Preliminary treatment	Inlet works	West side grit channels (control)	2
		Surface of pre aeration lane (serving the west side rectangular PSTs)	2
	Main pumping station biofilter (east side)	Inlet (untreated) air stream	1
		Outlet (treated) air stream	1
	New West-side preliminary works biofiltration tower and carbon filter	Inlet (untreated) air stream	1
		Intermediate stage air stream	1
		Outlet (treated) air stream	1
	New East-side preliminary works/PSTs/storm tanks scrubber and carbon filter (2 treatment streams)	Inlet (untreated) air stream	2
		Intermediate stage air stream	2
		Outlet (treated) air stream	2
Storm	Storm tanks	Storm water inlet channel	2
		Storm tank hopper	1
		Storm tank when full	1
Primary treatment	Primary settlement tanks (West side)	Surface of rectangular PST	2
		Surface of circular PST	2
Secondary treatment	Activated sludge plant	Surface of tank (East side)	2
		Surface of tank (West side)	2
Sludge handling treatment	RSHT/Sludge thickening building biofilter and carbon filter	Inlet (untreated) air stream	1
		Intermediate stage air stream	1
		Outlet (treated) air stream	1
	Imported sludge reception carbon filter (ambient conditions)	Inlet (untreated) air stream	1
		Outlet (treated) air stream	1
	Imported sludge reception carbon filter (during sludge import)	Inlet (untreated) air stream	1
		Outlet (treated) air stream	1
	Pasteurisation chemical scrubber (2 stage)	Inlet (untreated) air stream	1
		Intermediate stage air stream	1
		Outlet (treated) air stream	1
	Sludge transfer area biofilter and carbon filter	Inlet (untreated) air stream	1
		Intermediate stage air stream	1
Outlet (treated) air stream		1	

Table 10 Location of hedonic tone measurements

Stage of treatment process	Process/odour source	Sample location	Number of sample sets (based on duplicate samples per set)
Preliminary treatment	Inlet	East side OCU outlet	1
		West side OCU outlet	1
Storm storage	Storm tanks (when full)	Surface of tank	1
Primary treatment	Primary tanks	Surface of tank	1
Secondary treatment	ASP plant	Surface of aerobic stage of tank	1

Annex C Overview of the olfactometry and hedonic tone analysis.

C.1 General Principles of odour measurement

The sensory perception of odorants can be characterised by four major attributes or dimensions:

- detectability;
- intensity;
- hedonic tone;
- odour quality;

A fifth attribute has been proposed recently in the Netherlands, to characterise the propensity of an odour to cause odour annoyance. However, no operational method for characterisation and interpretation is available for this fifth attribute:

- Annoyance potential.

In addition to the sensory dimensions used to describe how odorants act when perceived as odours, efforts are ongoing to devise a more technical approach to characterise odorants, using analysis of the chemicals involved. The approach can be to look at simple key substances that can be perceived as an odour, such as H₂S or ammonia. It may involve measuring a tracer component that is non-odorous itself, but occurs with the odorants, e.g. methane as a tracer for landfill gas. Finally, an attempt can be made to actually measure a multitude of odorants in the mixture, using advanced analytical methods such as GC-MS or 'electronic nose' devices.

The practical application of such methods is, so far, limited. The sensitivity of the analytical methods is usually not nearly sufficient to approach that of the human nose, and the capability to predict or model the actual odour perception in humans on the basis of measured parameters is currently poor.

The most common approach in characterising odours is measurement of odour concentration (detectability).

C.2 Measurement of odour concentration using olfactometry

Odour measurement is aimed at characterising environmental odours, relevant to human beings. As no methods exist at present that simulate and predict the responses of our sense of smell satisfactorily, the human nose is the most suitable 'sensor'. Objective methods have been developed to establish odour concentration, using human assessors. A British standard applies to odour concentration measurement:

- BSEN 13725:2003, *Air quality - Determination of odour concentration by dynamic olfactometry*, CEN/TC264/WG2 'Odours'.

The odour concentration of a gaseous sample of odorants is determined by presenting a panel of selected and screened human subjects with that sample, in varying dilutions with neutral gas, in order to determine the dilution factor at the 50% detection threshold (D₅₀). The odour concentration of the examined sample is then expressed as multiples of one European Odour Unit per cubic meter [ou_E/m³] at standard conditions.

C.3 Hedonic tone: the relative offensiveness of odours.

Hedonic Tone is a judgement of the relative like (pleasantness) or dislike (unpleasantness) of the odour. The method which will be applied for determining the hedonic tone is derived from the following standard document:

VDI 3882:1997, part 2; *Determination of Hedonic Tone*, Düsseldorf, Germany

The principle of measurement is presentation of the odour to human assessors with known acuity to odour in an odour panel, at concentrations, and hence at varying perceived hedonic tone.

The members of a panel of assessors are asked to indicate perceived hedonic tone at each presentation (concentration level) as a value from the nine-point hedonic tone scale:

+4	very pleasant
+3	pleasant
+2	moderately pleasant
+1	mildly pleasant
0	neutral odour / no odour
-1	mildly unpleasant
-2	moderately unpleasant
-3	unpleasant
-4	offensive

A minimum of seven presentations are performed for each hedonic tone analysis. The order of presentation is performed in a random manner, in duplicate.

For each presentation (concentration level), the mean of the values for H of all panel members is calculated, and plotted against the odour concentration in ou_E/m^3 . Using a suitable curve fitting procedure, a line can be fitted through the points obtained in the analysis. The concentration at which a given odour generates a mildly or moderately offensive reaction can then be identified which provides a means to compare the relative offensiveness of odours generated from different activities or processes

