Appendix 3.6 Calculation of Odour Emission Rate

Design of Deodorization System

DO 1 (Inlet Works + PST)

Building	Location	Nos.	Air Phase Height (m)	Total Odour Emission Area (m2)	Air Phase Volume (m3)	Aeration Rate (m3/hr) (if any)	Air Exchange Rate (Air Changes / hr)	SOER (ou/m2/s)	Unmitigated Odour Emission Rate (ou/s)	Flow Rate (m3/hr)	Total Flow Rate (m3/s)	Velocity (m/s)	Number of Exhaust Point (nos.)	Height of the Deodorizer Exhaust Point (mAG)	Diameter of the Deodorizer Exhaust Point (m)	Removal Efficiency (%)	Mitigated Odour Emission Rate (ou/s)	Temperature at exhaust point (C)
Inlet Works	Inlet Chamber 1	1	5.10	49	251		3	3.26	160	753	15.60	7.5	2	17.9	1.15	95.0%	652	Ambient
Inlet Works	Before Coarse Screen	1	5.20	52	272		3	3.26	171	816								
Inlet Works	Coarse Screen Channel	4	5.38	101	542		3	3.51	354	1,627								
Inlet Works	Before Wet Well	1	5.38	120	646		3	3.26	391	1,937								
Inlet Works	Wet Well	2	5.48	144	789		3	3.26	469	2,367								
Inlet Works	Discharge Sump	1	1.00	86	86		3	3.26	282	259								
Inlet Works	Before Fine Screen	1	1.10	48	53		3	3.26	156	158								
Inlet Works	Fine Screen Channel	4	1.30	101	131		3	3.51	354	393								
Inlet Works	After Fine Screen	1	1.30	126	164		3	3.26	411	491								
Inlet Works	Before Grit Trap	3	1.50	65	97		3	3.26	211	292								
Inlet Works	Grit Trap	3	1.75	104	183		3	3.26	340	548								
Inlet Works	After Grit Trap	3	1.75	115	202		3	3.26	376	605								
Inlet Works	Effluent	1	1.75	53	92		3	3.26	172	277								
Inlet Works	Conveyor	2	0.50	72	36		3	3.51	253	108								
Inlet Works	Skip (enclosure room)	1	6.40	174	1,114		12	3.51	611	13,363								
PST	Influent Distribution Channel	1	3.50	267	935		3	3.26	870	2,804								
PST	Skimmer Tank Area	4	0.50	274	137		3	4.03	1,103	410								
PST	Scum "Y" Channel	3	0.80	19	15		3	1.54	29	45								
PST	Primary Sedimentation Tank Area	4	3.50	1,152	4,032		3	4.03	4,643	12,096								
PST	Primary Sedimentation Tank Inspection Area	1	3.50	356	1,247		12	4.03	1,436	14,969								
PST	PST Effluent Channel	1	4.00	144	576		3	1.54	222	1,728								
PST	Scum Tank	2	4.00	8	34		3	4.03	34	101								
								sub-total	**13,047**	**56,147**								

PST = Primary Sedimentation Tank

DO 2 (Biological Treatment + Secondary Treatment + Sludge Thickening)

Building	Location	No. of Units (Duty)	Air Phase Height (m)	Total Odour Emission Area (m2)	Air Phase Volume (m3)	Aeration Rate (m3/hr) (if any)	Air Exchange Rate (Air Changes / hr)	SOER (ou/m2/s)	Unmitigated Odour Emission Rate (ou/s)	Flow Rate (m3/hr)	Total Flow Rate (m3/s)	Velocity (m/s)	Number of Exhaust Point (nos.)	Height of the Deodorizer Exhaust Point (mAG)	Diameter of the Deodorizer Exhaust Point (m)	Removal Efficiency (%)	Mitigated Odour Emission Rate (ou/s)	Temperature at exhaust point (C)
MBBR	Influent	1	1	320	320		3	1.65	529	961	28.7	7.5	2	20.08	1.56	95.0%	596	Ambient
MBBR	Pre-denitrification	6	1.25	1,814	2,268		3	1.65	2,994	6,804								
MBBR	Aeration 1	6	1.5	958	1,436	26,936	3	1.65	1,580	26,936								
MBBR	Aeration 2	6	1.75	994	1,739	27,948	3	1.65	1,639	27,948								
MBBR	Swing	6	2	403	806		3	1.65	665	2,419								
MBBR	MLR	6	2.25	230	518		3	1.65	380	1,555								
MBBR	Post-denitrification	6	2.25	403	907		3	1.65	665	2,722								
MBBR	Re-aeration	6	2.5	331	828	9,316	3	1.65	546	9,316								
MBBR	Effluent	1	2.5	324	810		3	0.02	6	2,430								
DAF	Influent 1	1	1.4	152	213		3	0.02	3	640								
DAF	Influent 2	1	1.4	169	237		3	0.02	3	711								
DAF	Flocculation	8	1.8	826	1,486		3	0.02	17	4,458								
DAF	Flotation	8	1.8	1,056	1,901		3	0.02	21	5,702								
DAF	Diffuser Effluent	2	2.1	444	932		3	0.02	9	2,797								
DAF	Before Wet Well	1	2.1	224	471		3	0.02	4	1,414								
DAF	Wet Well	2	2.3	54	124		3	0.02	1	373								
DAF	Secondary Sludge Collection Channel	2	3.85	156	601		3	3.98	621	1,802								
DAF	Secondary Sludge Collection Tank	4	3.35	38	129		3	3.98	153	386								
STH	Sludge Blend Tank	2	1.5	108	162		3	3.98	430	486								
STH	Thickening Centrifuge	3	1	14	14		3	3.98	57	43								
STH	Thickened Sludge Holding Tank	3	3.5	270	945		3	3.98	1,075	2,835								
STH	Centrate Tank	2	1.05	38	40		3	3.98	153	121								
DIG	Sludge Buffer Tank (at Digester)	2	2.5	28	70		3	3.98	112	211								
DIG	Sludge Buffer Tank (at Sludge Pumping Station)	2	1.3	64	83		3	3.98	253	248								
								sub-total	**11,917**	**103,318**								

MBBR = Membrane Bioreactor, DAF = Dissolved Air Floatation, STH = Sludge Thickening, DIG = Digesters

Appendix 3.6 Calculation of Odour Emission Rate

DO 3 (Sludge Dewatering, FW Reception + Side Stream)

Building	Location	No. of Units (Duty)	Air Phase Height (m)	Total Odour Emission Area (m2)	Air Phase Volume (m3)	Aeration Rate (m3/hr) (if any)	Air Exchange Rate (Air Changes / hr)	SOER (ou/m2/s)	Unmitigated Odour Emission Rate (ou/s)	Flow Rate (m3/hr)	Total Flow Rate (m3/s)	Velocity (m/s)	Number of Exhaust Point (nos.)	Height of the Deodorizer Exhaust Point (mAG)	Diameter of the Deodorizer Exhaust Point (m)	Removal Efficiency (%)	Mitigated Odour Emission Rate (ou/s)	Temperature at exhaust point (C)
FW	FW Bunker	2	10	202	2,016		3	3.98	802	6,048	8.19	7.5	2	27.65	0.83	95.0%	393	Ambient
FW	FW Diluted Tank	2	1	76	76		3	3.98	301	227								
SDH	Digested Sludge Holding Tank	2	4	694	2,774		3	3.98	2,761	8,323								
SDH	Dewatering Centrifuge	3	1	14	14		3	3.98	57	43								
SDH	Dryer Centrifuge	3	1	14	14		3	3.98	57	43								
SDH	Dryer	3	1	72	72		3	3.98	287	216								
SDH	Wet Sludge Silo	4	1	42	42		3	0.43	18	126								
SDH	Dry Sludge Silo	2	1	21	21		3	0.43	9	63								
SDH	Centrate Tank	2	3.5	72	252		3	3.98	287	756								
SDH	Skip (Enclosure room)	4	4	192	768		12	3.51	674	9,216								
SDH	Conveyor	2	0.3	186	56		3	3.51	655	168								
SS	Anammox Process Tanks	1	2.0	631	1,285		3	2.68	1,692	3,854								
SS	Thickened Sludge Tank Wet Well	1	2	16	31		3	3.98	62	94								
SS	Sludge Mixing Tank Wet Well	1	2	16	31		3	3.98	62	94								
SS	Anammox Sludge Storage Tank	1	2	34	67		3	3.98	134	202								
								sub-total	**7,857**	**29,472**								

FW = Foodwaste, SDH = Sludge Dewatering House, SS = Side Stream

Remarks:

[1] SOER Reference: Shek Wu Hui effluent polishing plant https://www.epd.gov.hk/eia/register/report/eiareport/eia_2132013/eia/pdf/appendix/appendix_3-8.pdf. The SOER from SWHEPP was adopted because SWHEPP receives similar nature of sewage without seawater flushing, adopts the same sewage treatment process of HSKEPP. Among Hong Kong's sewage treatment works with the above similar nature of sewage and treatment process, SWHEPP is of the nearest order of capacity compared to HSKEPP.

[2] The odour removal efficiency for deodourization units is referenced from Scottish Executive Environment Group Code of Practice on Assessment and Control of Odour Nuisance from Waste Water Treatment Works

[3] The adopted SOER for Food Waste Reception Building is referenced from SOER from sludge in Shek Wu Hui EPP. Compared to the SOER adopted for food waste (3.68 OU/m2/s) for North Lantau RTS Building Area in the approved Organic Waste Treatment Facilities Phase 1 (OWTF-P1) EIA Report (AEIAR-149/2010), and its subsequent Environmental Review Report for Variation of Environmental Permit (VEP-488/2015), SWHEPP's sludge SOER of 3.98 OU/m2/s is higher and more conservative. It is therefore adopted in this assessment.

[4] Iowa State University Extension (May 2004). "The Science of Smell Part 1: Odor perception and physiological response" (PDF). PM 1963a)

Appendix 3.6 Calculation of Odour Emission Rate

HSKEPP Detail Calculation of Source Odour Emission Rate

Exhaust Design

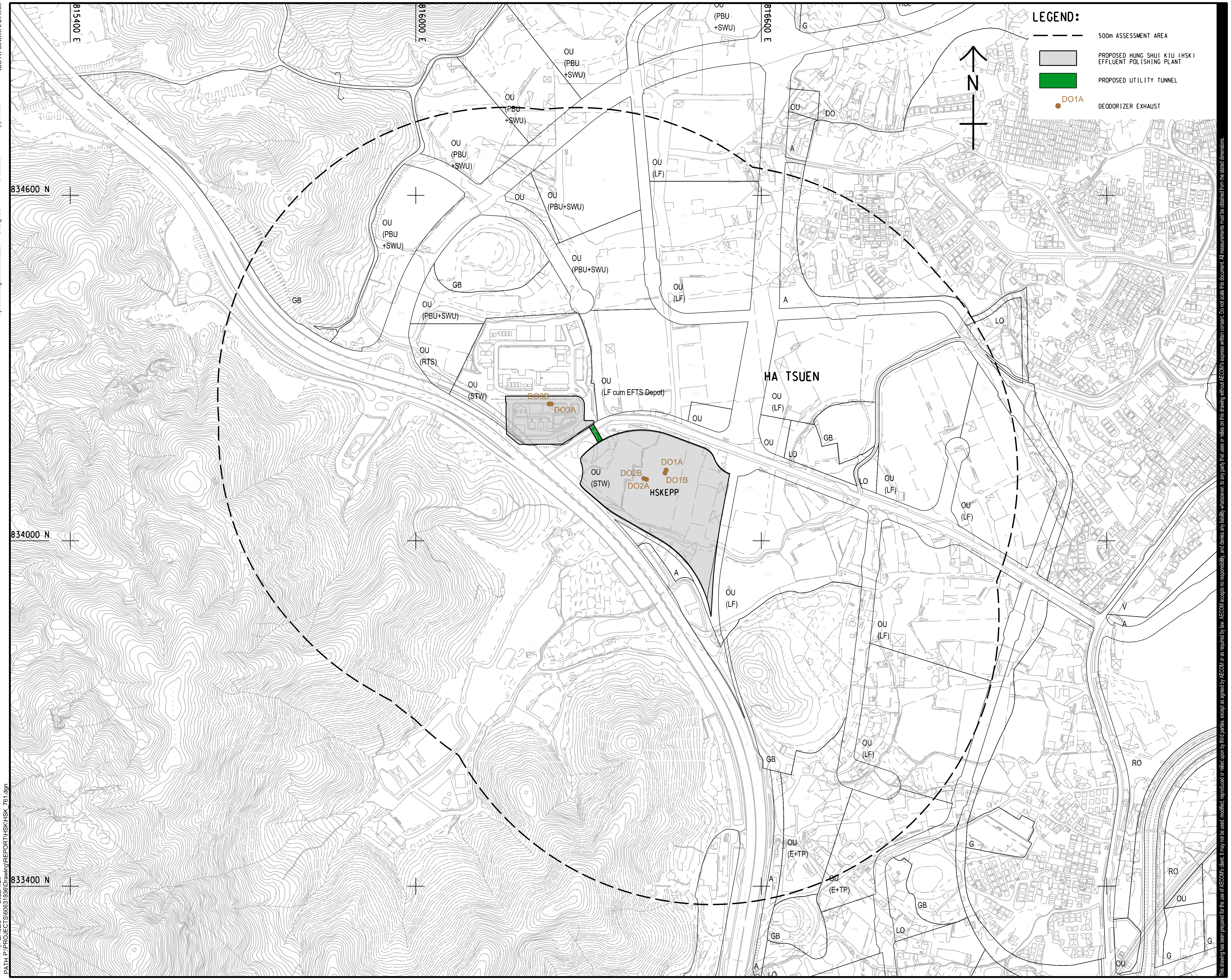
Deodouriser	Description	Source Type	Exhaust Location		Exhaust Diameter (m)	Height (mAG)	Exit Temperature (K)	Exit Velocity (m/s)
			X	Y				
DO1A	Exhaust point (Inlet Works + PST)	POINTHOR	816434.71	834122.85	1.15	17.90	Ambient	7.5
DO1B	Exhaust point (Inlet Works + PST)	POINTHOR	816432.85	834117.81	1.15	17.90	Ambient	7.5
DO2A	Exhaust point (Biological Treatment + Secondary Treatment + Sludge Thickening)	POINTHOR	816400.77	834106.60	1.56	20.08	Ambient	7.5
DO2B	Exhaust point (Biological Treatment + Secondary Treatment + Sludge Thickening)	POINTHOR	816396.08	834108.34	1.56	20.08	Ambient	7.5
DO3A	Exhaust point (Sludge Dewatering, FW Reception + Side Steram)	POINTHOR	816235.50	834237.70	0.83	27.65	Ambient	7.5
DO3B	Exhaust point (Sludge Dewatering, FW Reception + Side Steram)	POINTHOR	816231.50	834237.70	0.83	27.65	Ambient	7.5

Conversion of 1-hour Average to 5-second Average Concentration

Deodouriser	Emission Rate (OU/s)	Stability Class	Conversion Multiplier	Emission Rate with 5-second Peak Factor (OU/s)	Reference
DO1A	326	A, B, C, D, E, F	2.3	750.21	- Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales. - Katestone Scientific 1995, The Evaluation of Peak-to-Mean Ratios for Odour Assessments, volumes I and II, Katestone Scientific Pty Ltd, Brisbane. - Katestone Scientific 1998, Peak-to-Mean Concentration Ratios for Odour Assessments, Katestone Scientific Pty Ltd, Brisbane.
DO1B	326	A, B, C, D, E, F	2.3	750.21	
DO2A	298	A, B, C, D, E, F	2.3	685.23	
DO2B	298	A, B, C, D, E, F	2.3	685.23	
DO3A	194	A, B, C, D, E, F	2.3	447.06	
DO3B	194	A, B, C, D, E, F	2.3	447.06	

Emission Source Listing in AERMOD

Source ID	Type	X	Y	Exhaust Diameter (m)	Height (mAG)	Exit Temperature (K)	Exit Velocity(m/s)	Emission Rate with 5-second Peak Factor (OU/s)
DO1A	POINTHOR	816434.71	834122.85	1.15	17.90	Ambient	7.5	750.21
DO1B	POINTHOR	816432.85	834117.81	1.15	17.90	Ambient	7.5	750.21
DO2A	POINTHOR	816400.77	834106.60	1.56	20.08	Ambient	7.5	685.23
DO2B	POINTHOR	816396.08	834108.34	1.56	20.08	Ambient	7.5	685.23
DO3A	POINTHOR	816235.50	834237.70	0.83	27.65	Ambient	7.5	447.06
DO3B	POINTHOR	816231.50	834237.70	0.83	27.65	Ambient	7.5	447.06



AECOM

PROJECT

HUNG SHUI KIU EFFLUENT POLISHING PLANT AND YUEN LONG SOUTH EFFLUENT POLISHING PLANT - INVESTIGATION

CLIENT

渠務署 Drainage Services Department

CONSULTANT

AECOM Asia Company Ltd.
www.aecom.com

SUB-CONSULTANTS

ISSUE/REVISION

I/R	DATE	DESCRIPTION	CHK.

STATUS

SCALE: A1 1 : 3000

DIMENSION UNIT: METRES

KEY PLAN

PROJECT NO.: 60631936

CONTRACT NO.: CE 6/2019 (DS)

SHEET TITLE

LOCATION OF DEODORIZER EXHAUST POINT

SHEET NUMBER

60631936/APPENDIX 3.6.1

ISO A1 594mm x 841mm Approved: Checked: Designer: Project Management Initials:

Plot File by: ZHUZC 2022/4/26
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Scottish Executive Environment Group

Code of Practice on Assessment and Control of Odour Nuisance from Waste Water Treatment Works

April 2005
Paper 2005/9

- The design of tanks and covers should minimise the need for regular access for maintenance and inspection as confined space entry systems will be required
- The vent volumes need to be adequate to ensure no odour escape and also to account for air quality inside the cover (occupational exposure, corrosion and explosion hazard).
- Ventilation rates will depend upon the exact process operations but for tanks the design flows are typically 0.5 – 12 air changes per hour based upon the empty tank volume or 120% of the maximum filling rate. In the case of thickener tanks, the volume may increase to 200% of the maximum fill rate
- The design will take account of the fill and empty rate, maximum rate of change in headspace, likely gaps and leakage, evolution rate of flammables to maintain <25% LEL for methane (10% is good design)
- Allowance should be made for emergency ventilation of the tanks
- One problem with tank covers is that they cannot be easily inspected therefore tend to be poorly maintained.

Additionally, guidance on the design of waste water treatment plants in BS EN 12255 advises designers to :-

- Locate sources requiring abatement close together to optimise abatement options and minimise costs
- Consider explosion risk, corrosion, access and health and safety.

14.2 Odour Abatement Equipment

The air which is exhausted from enclosures usually requires abatement to avoid odour nuisance. It is possible to establish performance criteria to reflect what constitutes best practicable means (bpm) in relation to abatement equipment. This can be specified as follows:-

> *Any odour abatement equipment installed on contained emissions (ventilation air from the process building) should have an odour removal efficiency of not less than 95%[2]. Determination of the destruction efficiency should be by dynamic olfactometry based upon manual extractive sampling undertaken simultaneously at the inlet and outlet of the odour control equipment. At least three samples should be taken from both the inlet and outlet.*

There is a wide range of odour abatement equipment that can be used to treat emissions of contained air from WWTW. There are many factors which will affect the choice of equipment including required odour removal efficiency, flow rate and inlet odour concentration, type of chemical species in the odour, variability in flow and load, space requirements and infrastructure (power, drainage etc.). The range of technologies available is detailed in the Environment Agency H4 Guidance Note on odour.

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[2] *Where the inlet odour concentrations are very low and the 95% destruction efficiency is difficult to demonstrate due to measurement reproducibility and equipment efficiency at low concentrations, the final discharge to air should contain less than 500 odour units/m^3.*

It is important when evaluating the most appropriate control technology to consider both total cost (capital and operating) and environmental impact (such as energy use, chemical use and secondary pollutant generation). Often operating costs are closely linked with environmental impact (that is costs for energy, raw materials etc.) and wherever possible the most environmentally sustainable technique should be selected.

As odour abatement plant capacity is usually tightly specified (little spare capacity), the assumption is that all other measures are being correctly used – covers, doors, chemicals replenished etc. This therefore becomes a key management issue that should be included in the Odour Management Plan.

The site layout may permit a centralised plant or due to locational constraints it may be necessary to use more than one system for example on the inlet works and the sludge process. It may be economical to provide a number of smaller biofilters for individual sources but if the selected technology is wet scrubbing it may be more cost effective to provide a single system. In some cases it may be appropriate to divide the odour streams and use different technology based upon the load and characteristics of each system.

Table 2 below summarises the main types of abatement equipment and the odour abatement efficacy that may be achieved.

SYSTEM	CAPITAL	CONSUMABLES	EFFECTIVENESS
Biofilters	Moderate	Need space, fan energy, media replacement 3 – 5 years	High >95% - not able to rapidly adjust to changes in flow or load
Bioscrubbers	Moderate	Fan energy, effluent needs oxygenation	High >95% - can handle higher H_2S loads than biofilters
Activated sludge plant	Low additional	Needs fully aerobic sludge	90 – 95% for H_2S and NH_3 ; may be ideal as a polishing stage
Wet scrubbers	High	Fan energy, pump energy, dosing chemicals and effluent disposal – high energy user	Single stage <80% but multiple stage - >98%
Dry scrubbing (carbon or impregnated media)	High	Media replacement is a high cost with strong odours, suffer with moisture loading	> 95% ; Widely used for passive sources. Need several seconds residence for treatment
Catalytic iron oxidation	Moderate	Low operating cost	Specific for H_2S – good for low flow high load
Thermal oxidation	High	Fan energy and support fuel	>98% ; good for dryer vents and VOC loads
Ozone	Moderate	Replacement of source and energy for fan and ozone generator	>90% on low concentrations – good for building vents
Counteractants and masking	Low	Replenishment of chemicals	Not an abatement method – may be suitable for short-term use

TABLE 2– ODOUR ABATEMENT

Experience in operation of peat and heather type biofilters has shown that they do not perform well when the flow or odour load from the process is variable although other media (shell-type material) appears to perform better for these applications. There has been a considerable amount

of biofilter and bioscrubber equipment installed at WWTW. The units range in size from 75 – 435,000m^3/hr but are typically 1600 – 3000m^3/hr. The suppliers tend to offer 95-98% odour removal, 95-99.9% H_2S removal and 300 ou_E/m^3 in exhaust gases.

The industry approach is that emission sources which exhibit strong odour peaks are best treated in wet scrubbers or carbon systems as some bio systems have been overloaded previously. It is increasingly common to have scrubbers on the sludge processing operations (often 3 or 4-stage scrubbers are used).

Quantification of NH_3 Emission From Sidestream Anammox Process

The NH_3 emission from the sidestream anammox process is calculated as 13.4 ppm in total according to *Appendix A of Dynamic of nitric oxide and nitrous oxide emission during full-scale reject water treatment (Kampschreur, et. al, 2008)* (12 ppm from the nitritation reactor and 1.4 ppm from the anammox reactor, therefore a total of 13.4 ppm emission).

In anammox process, there are two main reactors, the nitritation reactor and the anammox reactor. Air is blown from the bottom of the nitritation reactor, which is referred to as aeration. In the literature, the average aeration rate is 2.2×10^4 Nm^3/day over the measurement period, which is equivalent to 2.2 x 10^4/24 = 916.7 m^3/hr, assuming the aeration rate is constant.

The ammonia and Total Kjeldahl Nitrogen (TKN) loading of the quoted process is also similar to HSKEPP design. Therefore, the NH_3 gaseous emission from the quoted paper is considered representative of the HSKEPP NH_3 gaseous emission and adopted in this calculation of NH_3 emission for HSKEPP's anammox process.

Converting 13.4 ppm gas phase NH_3 to OU, by using 0.037 ppm NH_3 = 1 OU/m^3 (Odour threshold of NH3 is 0.037 ppm, reference from *Iowa State University Extension (May 2004). "The Science of Smell Part 1: Odor perception and physiological response" (PDF). PM 1963a)*

The OU concentration of gas phase NH_3 = 13.4 ppm NH_3 / (0.037 ppm NH_3/(OU/m^3)) = 362 OU/m^3. This is corresponding to the WWTP studied by the reference paper which treated 773 m^3 of influent per day.

The dewatering centrate flow for HSKEPP is estimated to be 1300 m^3 per day so the OU concentration can be prorated as 362 / 773 × 1300 = 609 OU/m^3.

The odour extraction air flow rate of the anammox process in HSKEPP's design is 3,854 m^3/hr = (3,854 m^3/hr / (3600s/hr) = 1.07 m^3/s while the total surface area of the sidestream treatment facility is 631 m^2.

Hence, the Specific Odour Emission Rate (SOER) of sidestream treatment in the proposed HSKEPP due to NH_3 emission = 609 OU/m^3 x 1.07 m^3/s /631 m^2 = 1.03 OU/m^2/s.

The total SOER adopted for sidestream treatment = 1.65 (SOER value referenced from bioreactor of Shek Wu Hui STW) +1.03 (due to NH_3 gas emission) = 2.68 OU/m^2/s.

Reference:

Kampschreur, M. J.; van der Star, W.R.L.; Wielders, H.A.; Mulder, J.W.; Jetten, M.S.M.; van Loosdrecht, M.C.M. 2008. Dynamic of nitric oxide and nitrous oxide emission during full-scale reject water treatment. Water Research 42 (2008), p812 – 826

Iowa State University Extension (May 2004). "The Science of Smell Part 1: Odor perception and physiological response" (PDF). PM 1963a

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