Appendix 3.7 - Calculation of Odour Emission Rate

Design of Deodorization System

Location	No. of Units (Duty)	Air Phase Height (m)	Total Odour Emission Area (m2)	Air Phase Volume (m3)	Aeration Rate (Unit) (m3/h)	Air Exchange Rate (Air Changes / hr)	SOER (ou/m2/s)[1]	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[2]	Mitigated Odour Emission Rate (ou/s)	Temperature at exhaust point (C)
DO 1 (Inlet Works + Primary Sedimentation Tank)																	
Inlet Works																	
Inlet Well	1	4	63.0	252.0		3	3.26	205	756								
Coarse Screen Channel	4	4	86.4	345.6		3	3.51	303	1,037								
Distribution Channel (screen - wet well)	1	4.5	48.0	216.0		3	3.26	156	648								
Wet Well	2	4.5	96.0	432.0		3	3.26	313	1,296								
Distribution Channel (wet well - fine screen)	1	2	81.6	163.2		3	3.26	266	490								
Fine Screen Channel	4	2.5	96.0	240.0		3	3.51	337	720								
Distribution Channels (fine screen - grit trap) A	1	2.5	51.0	127.5		3	3.26	166	383								
Distribution Channels (fine screen - grit trap) B	1	2.5	45.0	112.5		3	3.26	147	338								
Distribution Channels (fine screen - grit trap) C	1	2.5	88.5	221.3		3	3.26	289	664								
Grit Trap Influent Channels	3	2.5	36.7	91.8		3	3.26	120	275								
Grit Trap	3	2.5	126.2	315.5		3	3.26	411	946								
Grit Trap effluent Channels	3	2.5	51.8	129.6		3	3.26	169	389								
Distribution Channel (grit trap to Distribution chamber) wide	1	2.5	42.0	105.0		3	3.26	137	315	13.12	7.5	1	15.5	1.49	95%	579	Ambient
Distribution Channel (grit trap to Distribution chamber) narrow	1	2.5	16.8	42		3	3.26	55	126								
Coarse Screening Skip Area	1	3	48.6	145.8		12	3.51	171	1,750								
Screening and Grit Skip Area	1	3	168.0	504		12	3.51	590	6,048								
Conveyors	6	0.3	21.6	6.48		3	3.51	76	19								
Equalization Tank	1	3.5	642.6	2249.1		3	3.26	2,095	6,747								
Distribution Chamber	1	1.5	70.5	105.8		3	3.26	230	317								
Primary Treatment																	
Inlet Channel	1	4	57.0	228		3	3.26	186	684								
Scum Tank	2	1	9.0	9		3	4.03	36	27								
Influent Distribution Channel	1	4	105.0	420		3	3.26	342	1,260								
Scum "Y" Channel	2	1.5	19.2	28.8		3	1.54	30	86								
Skimmer Tank Area	2	2	153.6	307.2		3	4.03	619	922								
Primary Sedimentation Tank Area	2	3	604.8	1814.4		3	4.03	2,437	5,443								
Primary Sedimentation Tank Inspection Area	1	3	379.2	1137.6		12	4.03	1,528	13,651								
PST Effluent Channel	1	6	105.0	630.0		3	1.54	162	1,890								
							Total	**11,575**	**47,227**								

Location	No. of Units (Duty)	Air Phase Height (m)	Total Odour Emission Area (m2)	Air Phase Volume (m3)	Aeration Rate (Unit) (m3/h)	Air Exchange Rate (Air Changes / hr)	SOER (ou/m2/s)[1]	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[2]	Mitigated Odour Emission Rate (ou/s)	Temperature at exhaust point (C)
DO 2 (Sludge + Sidestream)																	
Thickening & Dewatering House																	
Sludge Blend Tanks	2	1.5	36.0	54.0		3	3.98	143	162								
Thickening Centrifuges	2	1	9.6	9.6		3	3.98	38	29								
Thickened Sludge Holding Tanks	2	1	159.6	159.6		3	3.98	635	479								
Centrate Buffer Tanks	2	1	33.6	33.6		3	3.98	134	101								
Digested sludge holding tank	2	1.5	174.2	261.4		6	3.98	693	1,568								
Dewatering Centrifuges	2	1	9.6	9.6		3	3.98	38	29								
Dryer Centrifuges	1	1	4.8	4.8		3	3.98	19	14								
Dryer	1	1	24.0	24.0		3	3.98	96	72	3.09	7.5	1	15.5	0.72	95%	189	Ambient
Sludge Silo (Dewatering)	3	1	31.5	31.5		3	0.43	14	95								
Dried Sludge Silo (Drying)	4	1	36.0	36.0		3	0.43	15	108								
Sludge Skip Room	1	3	165.3	495.9		12	3.51	580	5,951								
Conveyors	6	0.3	47.5	14.256		3	3.51	167	43								
Side Stream																	
Anammox Process Tanks	1	1.81	411	745		3	2.55	1,049	2,235								
Thickened Sludge Tank Wet Well	1	2	9.3	19		3	3.98	37	56								
Sludge Mixing Tank Wet Well	1	2	9.3	19		3	3.98	37	56								
Ammamox Sludge Storage Tank	1	2	20.2	40		3	3.98	81	121								
							Total	**3,776**	**11,117**								

Appendix 3.7 - Calculation of Odour Emission Rate

Location	No. of Units (Duty)	Air Phase Height (m)	Total Odour Emission Area (m2)	Air Phase Volume (m3)	Aeration Rate (Unit) (m3/h)	Air Exchange Rate (Air Changes / hr)	SOER (ou/m2/s)[1]	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[2]	Mitigated Odour Emission Rate (ou/s)	Temperature at exhaust point (C)
DO 3 (Bioreactor)										15.35	7.5	1	15.5	1.61	95%	188	Ambient
Bioreactor																	
Outlet Channel (PST to Fine Screen)	1	1.00	25.2	25.2		3	1.65	42	76								
Fine Screen Chamber	4	2.00	144.0	288.0		3	3.51	505	864								
Fine Screen Effluent Channel A	2	1.50	45.6	68.4		3	1.65	75	205								
Fine Screen Effluent Channel B	1	1.50	60.0	90.0		3	1.65	99	270								
Fine Screen Effluent Channel C	1	1.50	87.8	131.8		3	1.65	145	395								
Pre- Anoxic Tank	3	2.00	491.4	982.8		3	1.65	811	2,948								
Aerobic Tank	3	2.00	619.9	1239.84	46,656	3	1.65	1,023	46,656								
Post- Anoxic Tank	3	2.00	143.6	287		3	1.65	237	862								
Bioreactor Effluent Channel A	2	2.00	261.1	522.2		3	1.65	431	1,567								
Bioreactor Effluent Channel B	1	2.00	237.6	475.2		3	1.65	392	1,426								
							Total	**3,760**	**55,269**								

Location	No. of Units (Duty)	Air Phase Height (m)	Total Odour Emission Area (m2)	Air Phase Volume (m3)	Aeration Rate (Unit) (m3/h)	Air Exchange Rate (Air Changes / hr)	SOER (ou/m2/s)[1]	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[2]	Mitigated Odour Emission Rate (ou/s)	Temperature at exhaust point (C)
DO 4 (Membrane Bioreactor Building)										14.19	7.5	1	16	1.55	95%	107	Ambient
MBR Building																	
Inlet Channel	1	1.00	151.2	151.2		3	1.65	249	454								
Membrane Tank	10	1.00	892.8	892.8	49,872	3	1.65	1473	49872								
Deoxygenation zone	1	1.00	252.0	252.0		3	1.65	416	756								
							Total	**2,138**	**51,082**								

Location	No. of Units (Duty)	Air Phase Height (m)	Total Odour Emission Area (m2)	Air Phase Volume (m3)	Aeration Rate (Unit) (m3/h)	Air Exchange Rate (Air Changes / hr)	SOER (ou/m2/s)[3]	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[2]	Mitigated Odour Emission Rate (ou/s)	Temperature at exhaust point (C)
DO 5 (Food Waste)										0.54	7.5	1	11.5	0.30	95%	31	Ambient
Food Waste Reception [3]																	
Food Waste Bunker	2	5.00	123.984	619.9		3	3.98	493	1860								
Food Waste Dilution Tank	1	1.00	14.4	14.4		3	3.98	57	43.2								
Digester																	
Sludge Buffer Tank	1	1.00	19.2	19.2		3	3.98	76	58								
							Total	**627**	**1,961**								

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 YLSEPP. 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 YLSEPP.
[2] The odour removal effiency 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.

Emission Source Listing in AERMOD

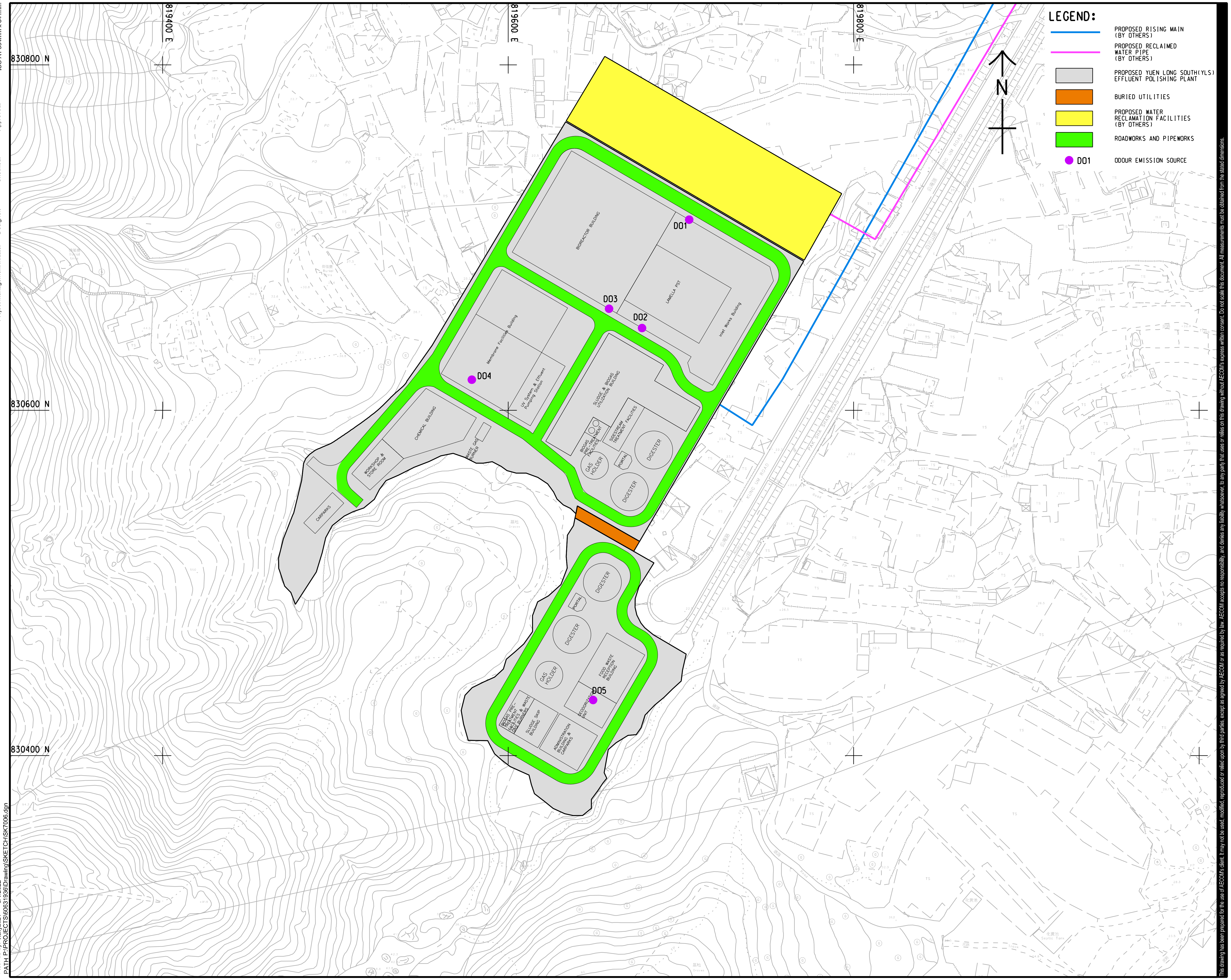
Source ID	Type	X	Y	1-hour Average Emission Rate, OU/s	Conversion Multiplier	5-second Average Emission Rate, OU/s	Release Height (mAG)	Exhaust Diameter, m	Exit Velocity, m/s	Exit Temperature
DO1	POINTHOR	819704	830710	579	2.3	1331	15.5	1.49	7.5	Ambient
DO2	POINTHOR	819677	830648	189	2.3	434	15.5	0.72	7.5	Ambient
DO3	POINTHOR	819658	830659	188	2.3	432	15.5	1.61	7.5	Ambient
DO4	POINTCAP	819578	830617	107	2.3	246	16	1.55	7.5	Ambient
DO5	POINTCAP	819650	830432	31	2.3	72	11.5	0.30	7.5	Ambient

Exhaust Design

Deodouriser	Description	Source Type	Exhaust Location		Height, mAG	Exhaust Diameter, m	Exit Velocity, m/s	Exit Temperature
			X	Y				
DO1	Exhaust point (Inlet Works + PST)	POINTHOR	819704	830710	15.5	1.49	7.50	Ambient
DO2	Exhaust point (Sludge + Sidestream)	POINTHOR	819677	830648	15.5	0.72	7.50	Ambient
DO3	Exhaust point (BR)	POINTHOR	819658	830659	15.5	1.61	7.50	Ambient
DO4	Exhaust point (MBR Building)	POINTCAP	819578	830617	16	1.55	7.50	Ambient
DO5	Exhaust point (Food Waste)	POINTCAP	819650	830432	11.5	0.30	7.50	Ambient

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

Deodouriser	1-hour Average Emission Rate, OU/s	Stability Class	Conversion Multiplier	5-second Average Emission Rate, OU/s	Reference
DO1	579	A, B, C, D, E, F	2.3	1331.16	-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.
DO2	189	A, B, C, D, E, F	2.3	434.24	
DO3	188	A, B, C, D, E, F	2.3	432.37	
DO4	107	A, B, C, D, E, F	2.3	245.92	
DO5	31	A, B, C, D, E, F	2.3	72.13	



ISO A1 594mm x 841mm

Approved:

Checked:

Designer:

Project Management Initials:

Plot File by: vicky.xia1 6/1/2022

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AECOM

PROJECT 項目

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

CLIENT 業主

渠務署 Drainage Services Department

CONSULTANT 工程顧問公司

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ISSUE/REVISION 修訂

I/R 修訂	DATE 日期	DESCRIPTION 內容摘要	CHK. 複核

STATUS 階段

SCALE 比例	**DIMENSION UNIT** 尺寸單位
A1 1 : 1000	METRES

KEY PLAN 索引圖

PROJECT NO. 項目編號	**CONTRACT NO.** 合約編號
60631936	CE 6/2019 (DS)

SHEET TITLE 圖紙名稱

LOCATION OF DEODORIZER EXHAUST POINT

SHEET NUMBER 圖紙編號

60631936/SK7006

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 1.3 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 x 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 full scale anammox process quoted in the above literature is of similar size (773 m^3/d in the literature) as YLSEPP anammox reactor of 793 m^3/d. The ammonia and Total Kjeldahl Nitrogen (TKN) loading of the quoted process is also similar to YLSEPP design. Therefore, the NH_3 gaseous emission from the quoted paper is considered representative of the YLSEPP NH_3 gaseous emission and adopted in this calculation of NH_3 emission for YLSEPP's anammox process.

Converting 13.4 ppm gas phase NH_3 to OU, by using 0.037 ppm NH_3 = 1 OU/m3 (Reference from Ammonia Fact Sheet, AERISA)

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

The odour extraction air flow rate of the anammox process in YLSEPP's design is 2,235 m^3/hr = (2,235 m^3/hr / (3600s/hr) = 0.62 m^3/s. The design aeration rate of the anammox process in YLSEPP is lower than this value.

The aeration flow rate of anammox process from the quoted paper is on average 916.7 m3/hr or 0.25 m^3/s, which is also lower than the YLSEPP anammox odour extraction air flow rate of 0.62 m^3/s.

As both the quoted aeration flow rate of 0.25 m^3/s and the applied odorous air extraction rate of 0.62 m^3/s are smaller than 1 m^3/s. For conservative purpose, the air flow rate is taken as 1 m^3/s for subsequent calculation.

The odour emission rate is 362 OU/m3 x 1 m3/s = 362 OU/s.

Odour emission rate is prorated from the quoted anammox reactor water flow rate of 773 m^3/d in the literature to the 793m^3/d of the dewatering centrate flow rate for YLSEPP: 362/773 x 793= 371 OU/s

Sidestream treatment total surface area of YLSEPP = 411 m^2

Therefore, the SOER of sidestream treatment NH_3 emission = 371 OU/s/411 m^2 = 0.90 OU/m^2/s.

The total SOER adopted for sidestream treatment = 1.65 (SOER value referenced from bioreactor of Shek Wu Hui STW) +0.90 (due to NH_3 gas emission) = 2.55 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