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Odour Pollution Assessment and Study in Hong Kong

香港恶臭污染评估及研究

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Odour Characteristics and Emission Source

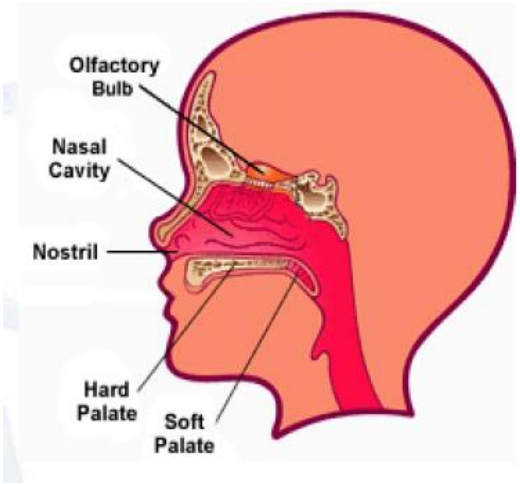
臭味的特征及其来源

Odour Pollution Concerns

- Odours have been ranked as the major generators of public complaints. More than 50% of air pollution complaints were related to odours. (恶臭属于主要的环境投诉案来源)
- The growing awareness of residents to odorous emissions from various industries and municipal facilities has led governments set limits of odour exposures of the neighbouring residents. (政府开始制定恶臭污染相关的规定)
- Odours may cause a variety of undesirable reactions in people, including nausea, vomitting, loss of appetite, upset stomach, or throat irritation, etc. (恶臭可引起众多健康相关问题，包括恶心，呕吐，无食欲，胃痛，喉咙痛等等)

Subjective and Difficult to Measure (臭味测量的主观性及难度)

- Complex (> 300 odorous compounds have been identified)
- Mixture of gaseous compounds (多种组分混合)
- Gas concentrations do not correlate with odour levels (臭味强度与组分浓度并无直接相关的关系)
- The best instrument for measuring odour is still the human nose
- Some individuals have far more sensitive noses. What is objectionable to one person may not be to another (e.g., roasting coffee, baking bread) (人鼻依然是最好的测量工具，但同时具有很多局限性)
- If difficult to measure also difficult to enforce (难以定量测量及规管)



Odourous Substances (恶臭物质)

Compounds	Odour Description	Compounds	Odour Description
Volatile Fatty Acids (挥发性有机酸)		**Nitrogen Compounds (含氮物质)**	
Formic Acid	Biting, Pungent	**Ammonia**	Pungent, Sharp
Caproic Acid	Pungent	Ethylamine	Ammonia-like
Butyric Acid	Rancid butter, Body odour, Garbage	Indole	Fecal
Iso-valeric Acid	Rancid cheese	Skatole	Fecal
Propionic Acid	Rancid, Pungent	Triethylamine	Fishy, Pungent
Capric Acid	Rancid, Soil	Dimethylamine	Rotten Fish
Valeric Acid	Sweat	Cadaverine	Putrid, Decaying flesh
Acetic Acid	Vinegar, Pungent	Methylamine	Putrid, Fshy
Sulfide Compounds (含硫物质)		Putrescine	Putrid
Carbon Disulfide	Sweet, Rotten pumpkin	**Ketones and Aldehydes (酮类及醛类)**	
Methyl-mercaptan	Pungent, Rotten cabbage, Skunk, Garlic	Formaldehyde	Acrid, Medicinal
Dimethyl Disulfide	Putrid, Sulfurous	Acetaldehyde	Sweet, Fruity
Ethyl-mercaptan	Rotten cabbage, Leek-like	Phenol	Medicinal
Hydrogen Sulfide	Rotten egg	Acetone	Pungent, solvent
Dimethyl Sulfide	Sulfurous, Rotten cabbage	Methyl ethyl ketone	Sweet, Solvent

Ranking of Substance by Odour Intensity (臭味物质强度比较)

Sulfur Compounds > Fatty Acids > Amines/Ammonia > Phenol/Acetone/Toluene

含硫物质> 脂肪酸> 胺类物质/氨 > 苯酚/丙酮/甲苯

- Hong Kong's sewage has more significant odour problems than the sewage in other cities, as seawater, with high natural concentration of sulphate, is generally used for toilet flushing, the high sulphate content in sewage is conducive to the emission of sulphur-containing compounds such as hydrogen sulphide. (由于采用海水冲厕的缘故，香港生活污水含硫量高，造成严重的恶臭问题)

Emission Sources of Odour in Hong Kong (香港恶臭排放源)

- Since most industries in Hong Kong have been shifted to the Mainland of China, odour emissions mainly result from municipal sources such as sewage treatment works, refuse transfer stations, landfill sites, stormwater nullars and many others. (香港主要恶臭污染来源包括污水处理厂，垃圾填埋场，以及部分雨水渠)

Sewage Treatment Works
(污水处理厂)

Landfill Sites
(垃圾填埋场)

Stormwater Nullars
(雨水渠)

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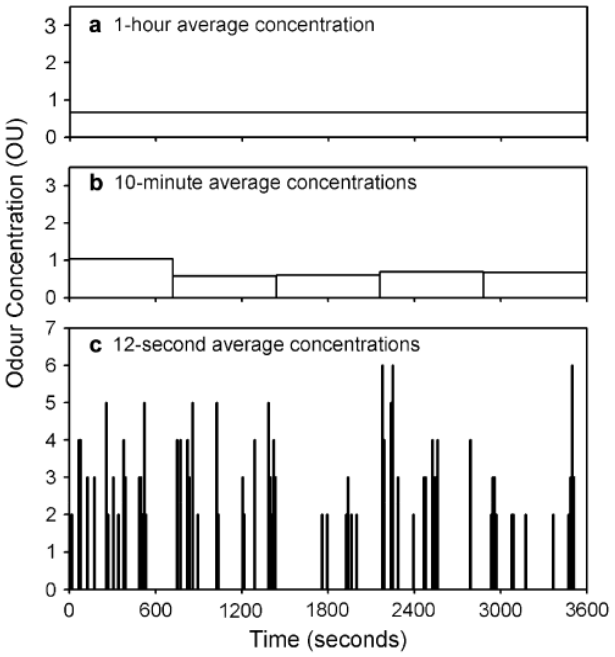
Standards for Odour and Odour Measurement

恶臭环境标准及臭味检测标准方法

International Odour Standards (不同地区的恶臭环境标准)

- Mostly the odour restrictions are based on time scales, which could significantly affect the sensitivity of monitoring data. (多数标准都是基于平均时间的气味强度)

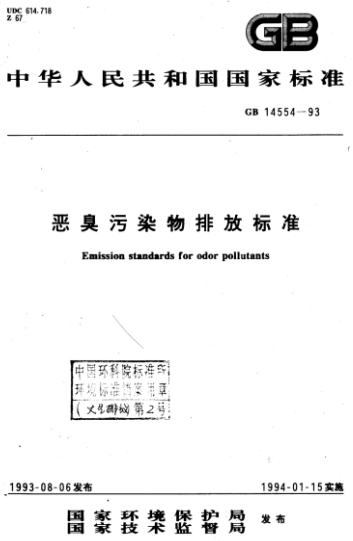


Location	Odour limit (OU or equivalent)	Averaging time @ compliance frequency[a]
Bay Area Air Quality District (San Francisco, USA)	5 (fence line)	Applied after at least 10 complaints within a 90 day period
Colorado (USA)	7 (residential or commercial	Scentometer[b]
Connecticut (USA)	7	Scentometer[b]
Denmark	0.6–1.2 5–10	1 h @ 99% 1 min @ 99%
Hong Kong	5	5 s
Massachusetts (USA)	5	1 h
Netherlands	0.5 (sensitive receptors)	1 h @ 99.5%—for new facilities 1 h @ 98.0%—for existing facilities
Newbiggin-by-the-Sea and Derby WWTP (UK)	5	Not specified @ 98% compliance
New Jersey (USA)	5	5 min or less
New South Wales (AU)	2 (urban) 7 (rural) 15 (area source)	1 s @ 99.5% 1 s @ 99.5% 1 s @ 99.5%
New Zealand	2	1 h @ 99.5%
North Dakota (USA)	2	Scentometer[b]
Oregon (USA)	1–2	15 min
Philadelphia (USA)	20 (residential)	<100 h/yr non-compliance)—wastewater treatment plant
Queensland (Australia)	10	1 h @ 99.5%
San Diego WWTP (USA)	5	5 min @ 99.5%
Seattle WWTP (USA)	5	5 min
South Australia (AU)	2 (2000 persons) 4 (350–1999) 6 (60–349) 8 (12–59) 10 (residence)	3 min @ 99.9%
Taiwan	50 (petrochemical park)	Not specified
Tasmania	1	3 min @ 99.9%
Western Australia (AU)	2 4	3 min @ 99.5% 3 min @ 99.9%

Odour Standard in China (国内恶臭环境标准)

- The odour emission standards are mostly based on the odourous compounds, and standards are different between different facilities.

物质	单位	一级	二级		三级	
			新扩改建	现有	新扩改建	现有
氨	mg/m^3	1	1.5	2	4	5
三甲胺	mg/m^3	0.05	0.08	0.15	0.45	0.8
硫化氢	mg/m^3	0.03	0.06	0.1	0.32	0.6
甲硫醇	mg/m^3	0.004	0.007	0.01	0.02	0.035
甲硫醚	mg/m^3	0.03	0.07	0.15	0.55	1.1
二甲二硫	mg/m^3	0.03	0.06	0.13	0.42	0.71
二硫化碳	mg/m^3	2.0	3.0	5.0	8.0	10
苯乙烯	mg/m^3	3.0	5.0	7.0	14	19
臭气强度	无量纲	10	20	30	60	70


GB

中华人民共和国国家标准

GB 14554—93

恶臭污染物排放标准

Emission standards for odor pollutants

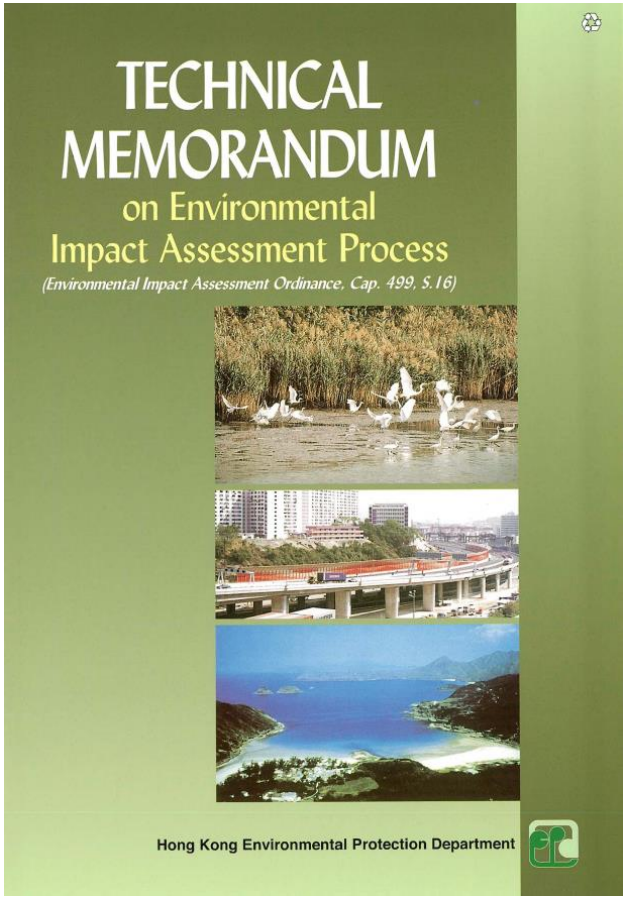
1993-08-06发布 1994-01-15实施

国家环境保护局
国家技术监督局 发布

Source: 《恶臭污染物排放标准》(GB14554-93) 恶臭污染物厂界标准

Odour Standard in Hong Kong (香港恶臭环境标准)

- In accordance with the EIAO-TM in Hong Kong, odour level at Air Sensitive Receivers (ASRs) should not exceed 5 Odour Units (OU) based on an average time of 5 seconds for odour prediction assessment. (香港相关标准为在敏感受体于平均时间5秒以内气味强度不得超过5ou)
- Compared with the related criteria in other countries or regions, which are ranged from 0.5 ou to 50 ou based on different average time, the standard of 5 ou / 5 seconds in Hong Kong is relatively a moderate value. (与其他国家或地区的相关标准比较，香港标准属于一个较为适当的水平)



Standardized Methods of Measuring Odour (气味检测标准)

1) 美国 2004: American Society of Testing and Materials (ASTM) Standard of Practice E679-04: Standard Practice for Determination of Odor and Taste Threshold by a Forced-Choice Ascending Concentration Series Method of Limits (ASTM 2004).

2) 欧盟 2003: European Committee for Standardization (CEN) Standard CEN 13725:2003: Air Quality – Determination of Odour Concentration by Dynamic Olfactometry (CEN 2003).

3) 澳洲/新西兰 2003: Australian/New Zealand Standard. AS/NZS4323.3:2001: Stationary source emissions. Part 3: Determination of odour concentration by dynamic olfactometry. Standard Australia, Sydney, Australia (AS/NZS 2003).

4) 荷兰 2001: Dutch Standard NVN 2820: Air Quality, Sensory Odour Measurement Using an Olfactometer (Netherlands 1995). AS/NZS4323.3:2001

5) 日本 2003: Japanese Triangle Odor Bag Method (Iwasaki 2003, Nagata 2003).

6) 学界 2008: An 8-station vapor delivery device (VDD8), ascending concentration approach. (Cain et al. 2007; Cometto-Muñiz and Abraham 2008).

7) 行业协会 2002: Air and Waste Management Association (AWMA) EE-6 Subcommittee on the Standardization of Odor Measurement. Guidelines for odor sampling and measurement by dynamic dilution olfactometry (AWMA 2002).

8) 相关行业 2005: Others such as those reported by McGinley (2001), St. Croix Sensory (2005).

——Interim Guidelines for Setting Odor-Based Effects Screening Levels，Toxicology Division Chief Engineer's Office May 28, 2010

Current Application of EN13725 (欧盟标准方法的应用)

- 澳大利亚及新西兰: The new European standard has been adopted by Standards Australia and Standards New Zealand as AS/NZS 4323.3:2001 (AS, 2001).
- 新加坡，泰国等东南亚国家: The standard has also been referenced by national organizations in Singapore, Thailand, and several other S.E. Asian countries.
- 北美: Government agencies and universities throughout North America are following or are working towards adoption of the EN13725 standard.
- 美国: In 2004, ASTM revised the E679 odour testing standard to include two additional testing examples. One of these examples includes references to the details of the EN13725 European testing method.

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Odour Assessment and Practices

恶臭污染评价措施

Odour Assessment Methods (恶臭评价措施)

- **Odour Patrol** for identifying odour sources, odour strengths and also odour characteristics. (现场气味调查)
- **Odour Sampling and Olfactometry Analysis** for quantitatively determining the odour strengths and emission rates at sampling site. (气味样品采集及实验室分析)
- **Electronic Nose Analysis** for identifying odour patterns. (电子鼻分析)
- **Instrument Chemicals Analysis** for determining individual compound concentration. (相关物质分析)

Odour Panelist Screening (嗅觉员筛选)

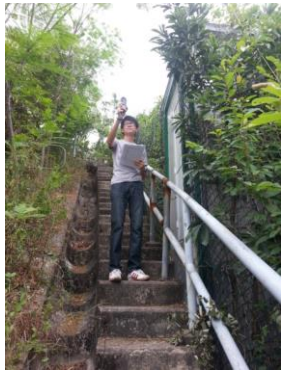
- Odour panelist who will take part in the olfactometry analysis or the odour patrol need to pass a screening test in advance, for ensuring the panelist has moderate olfactory sense. (嗅觉员需先经过筛选)
- n-Butanol is selected as the standard compound for evaluating panelists' olfactory sense. (正丁醇)
- Panelist that could detect n-butanol within the concentration range of 20 -80 ppb/v would be certificated as a qualified odour panelist (European Standard Mehtod EN13725). (嗅觉员需要有适当的对正丁醇的嗅觉阈值，20 – 80 ppb 之间为宜)

Description of Sensitivity	Response to n-Butanol
Slightly to moderately sensitive	< 20 ppb
Average	20 – 80 ppb
Slightly to moderately insensitive	80 – 160 ppb
Moderately to highly insensitive	> 160 ppb

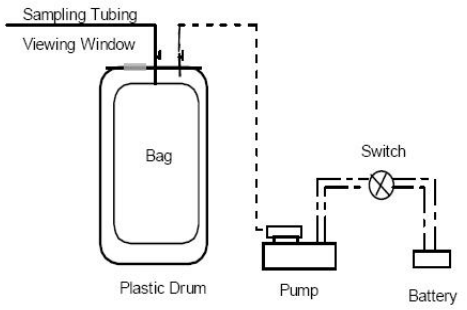
Odour Patrol (现场气味调查)

- Odour patrol means a simple judgment by odour panelists that are qualified by screening test patrolling and sniffing around the survey area to detect any odour at different hours. (简单现场气味评估)
- The odour panel members should be free from any respiratory diseases and should not be normally working at or living in area in the vicinity of the odour sources. (嗅觉员需满足一定要求)
- Each patrol day should cover different time periods (e.g. daytime and night time) in order to detect odour under various conditions. (需覆盖不同时间段)
- The response of an individual to an odour is directly related to the intensity at which it is experienced, where the intensity refers to an individual's perception of its strength or concentration. (现场确认气味强度)

Rank	Description	Intensity
0	Not Detected	No odour perceived or an odour so weak that it can not be easily characterized or described
1	Slight	Identifiable odour, slight
2	Moderate	Identifiable odour, moderate
3	Strong	Identifiable, strong
4	Extreme	Severe odour



Odour Sampling (气味样品采集)



- For the consideration of minimizing contamination of the samples, vacuuming sample system should be applied for odour sampling. By drawing the air out from the vessel, odourous sample gas would be drawn into the sample bag because of the negative pressure inside the vessel. Therefore the sample gas will not pass through the sampling pump that could contaminate the sample. (采用负压采样系统最大程度降低样品被污染的可能性)
- Sample bag would be made of Tedlar (聚氟乙烯) or Nalophane ™ (聚酯), and PTFE (聚四氟乙烯, polytetrafluoroethylene) or Teflon tubing would be used for connecting the equipment.
- Normally the samples will be analyzed by olfactometry, usually large volume samples would be required (~ 60 L). (通常样品需通过实验室嗅觉测定仪进行测定，因此需要较大量的样品)

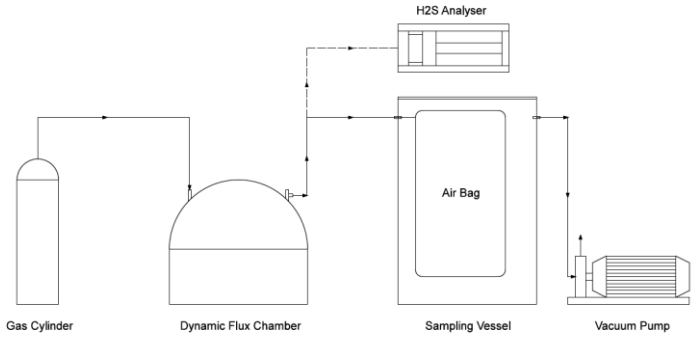
Dynamic Flux Chamber/Wind Tunnel (面源采样方法)

- For measuring the odour emission rate, sampling from emission surface is required, and the methods of Dynamic Flux Chamber or Wind Tunnel would be applied.
- Odour-free sweeping gas with certain flow rate will be injected into the flux chamber, which is covering a certain area of the emission surface. Odourous compounds will be brought out by the sweeping gas and be drawn into the sample bag by a typical odour sample system. By obtaining the odour strength, a Specific Odour Emission Rate (SOER) could be determined. (通过覆盖面积及载气流量可计算得出污染物排放率)

$$\text{SOER } (ou/m^2/s) = \frac{\text{Odour concentration } (ou/m^3) \text{ x Air flow rate inside hood } (m^3/s)}{\text{Covered water surface area } (m^2)}$$

Dynamic Flux Chamber

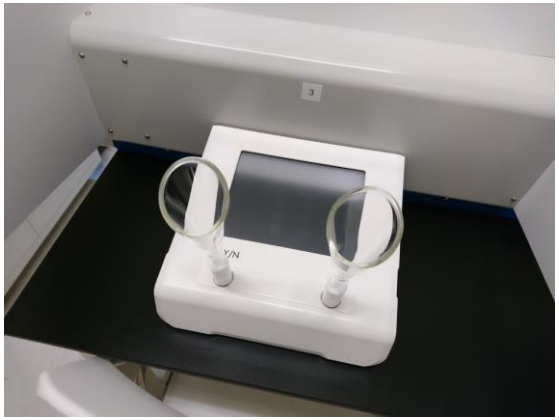
Wind Tunnel



Olfactometry Analysis (嗅觉测定仪分析)

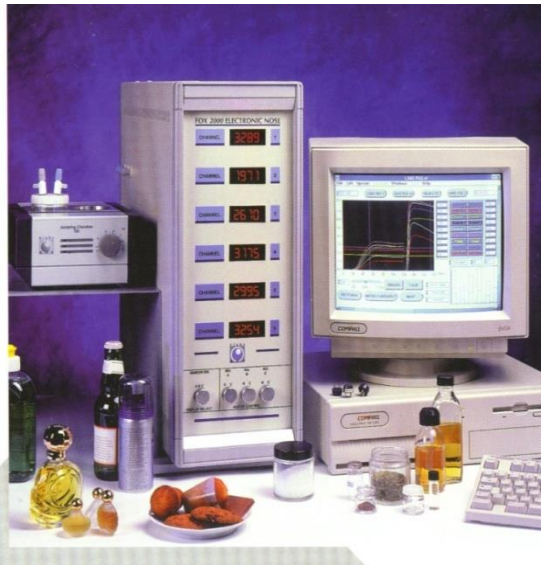
- Olfactometry is the science of odour measurement using sensory methods.
- It measures odour strength in terms of the degree of dilution with clean air required to reduce a given odour sample to the level where it is barely detectable. (基于稀释倍数)
- The Odournet TO Evolution (olfactometer) is a dilution apparatus designed to perform one-out-of-two forced choice odour threshold measurements, one measurement, using a panel of 4 persons, can be completed within half an hour.

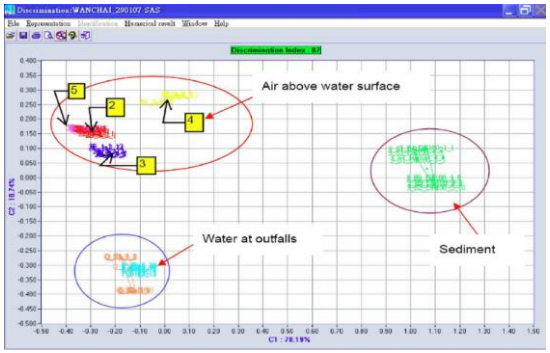
Odournet TO Evolution olfactometer



Electronic Nose Analysis (电子鼻分析)

- The electronic nose is an instrument to detect volatile chemicals or categories of chemicals then uses the information to predict sensory-like properties. (分析相似性特征)
- Electronic noses contain an array of sensors (sintered metal oxides, catalytic metals, conducting polymers, lipid layers, phtholocyanins, organic semi-conductors, surface acoustic wave or combinations) which respond to a wide variety of chemicals.
- All of these sensors (and their combinations) vary in the magnitude of response to any one compound giving them the discriminatory ability required to analyze odors.
- Response data are exported to a computer which has been trained to use chemometric and "artificial neural network" computer software as a way to recognize the pattern of a mixture of compounds as a specific odor and to discriminate slight differences. (人工神经网络)





Instrument Chemicals Analysis (仪器物质分析)

- Direct measurements of odourous compounds could be significant references for the odour assessment. (可作为参考比较)
  - H_2S measurement (on-site portable detector & laboratory stationary instrument analysis)
  - NH_3 measurement (laboratory stationary instrument analysis)
  - Mercaptans measurement (laboratory stationary instrument analysis)
  - TVOC measurement (on-site portable detector measurement)
  - Separated VOCs species analysis (laboratory GC/MS analysis)

Related Projects Experience

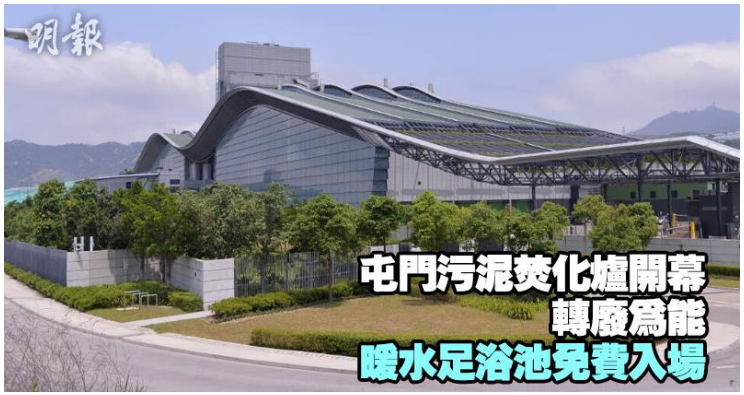
相关项目分享

Recent Consultant or Service Projects (近期相关咨询项目)

- Odour Emission Evaluation at **SENT Landfill**
- **New Yau Ma Tei Typhoon Shelter (NYMTTS)** Odour Source Measurement
- Collaboration Works on EM&A of **Tai Po Sewage Treatment Works**
- Odour Survey on **HATS Stonecutters Sewage Treatment Works**
- Provision of Services for Monitoring of Hydrogen Sulfide (H_2S) Emission of Sewage Sludge And Risk Assessment due to Sludge Delivery and Unloading at the **Sludge Treatment Facility**

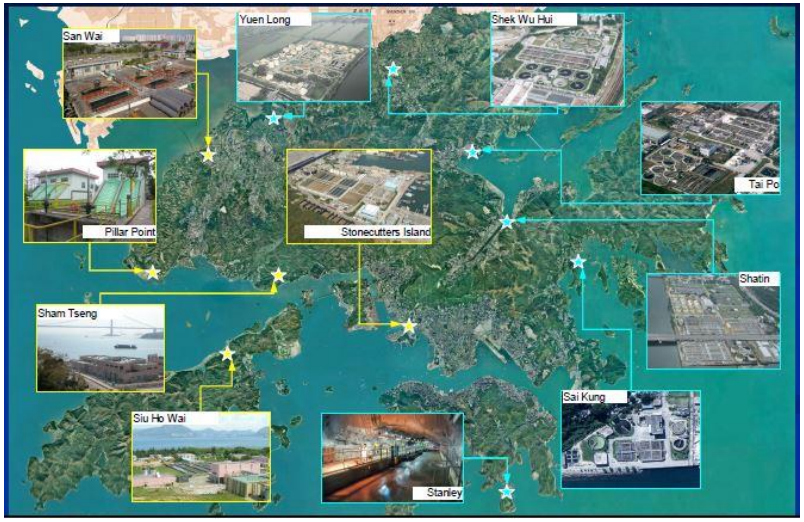
Introduction to Sludge Treatment Facility (STF, 香港污泥处理中心)

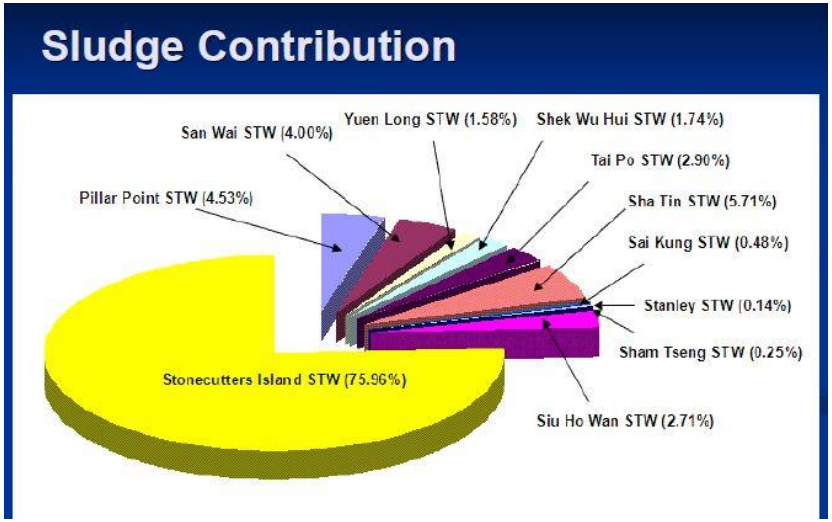
- Located in Nim Wan, Tuen Mun, the **Hong Kong Sludge Treatment Facility (STF)** is an innovative facility for **depressing the related pollution** caused by sewage sludge, as well as **utilizing the energy** generated by sludge **incineration**, which is the major approach selected to **stabilize** the sewage sludge.
- The energy generated could fulfill the electricity requirement for the **STF** itself and the **Environmental Education Center (EEC, also known as T-Park)** located next to the facility, which serves as a public education and entertainment center. There would also be excess electricity that could be provided to the public.



Sources of Sewage Sludge in Hong Kong (污泥来源)

- Sewage sludge are mainly come from HATS Stonecutters Island Sewage Treatment Works and other 10 regional sewage treatment works. (主要来自昂船洲污水厂及其余10座污水处理厂)
- Daily intake of sewage sludge keeps rising. It is estimated that after the commencement of operation of HATS stage II, the sludge daily intake could reach a level over **2,200 tonnes**. (污泥产量仍在不断上升)

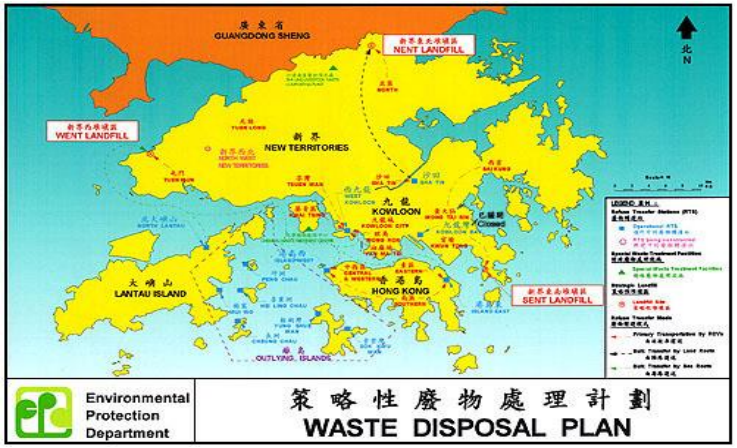




Source: Environmental Protection Department, The Government of Hong Kong Special Administrative Region.

Concerns on Sewage Sludge (污泥处置问题)

- Previously, landfill disposal is the only mean for treating with the sewage sludge. But since there were limited space for landfill in Hong Kong, urgent need for alternative sludge treatment measures was presented. (填埋场渐趋饱和，需要寻找新的污泥处置方式)
- It is also difficult to depress the gaseous pollutants and odour emission while the operation at landfill. Stabilizing the sludge shall be another major concern for alternative treatment method. (填埋操作中不能很好地控制气体污染物及恶臭的扩散)



Source: Environmental Protection Department, The Government of Hong Kong Special Administrative Region.

International Experiences (其他地区的污泥处置状况)

- Japan – The majority is treated by incineration (over 80%), and fluid bed incineration predominated. (日本: 污泥焚化占主导)
- United States – Most of the sludge is reused for land application, while incineration takes up approximately 20%. (美国: 主要通过回收用于土地及土壤用途)
- Europe – Landfill is decreasing while incineration is increasing, also reuse for land application is another stable alternative. (欧洲: 直接填埋处理逐渐减少，被污泥焚化逐渐取代)

Source: Environmental Protection Department, The Government of Hong Kong Special Administrative Region.

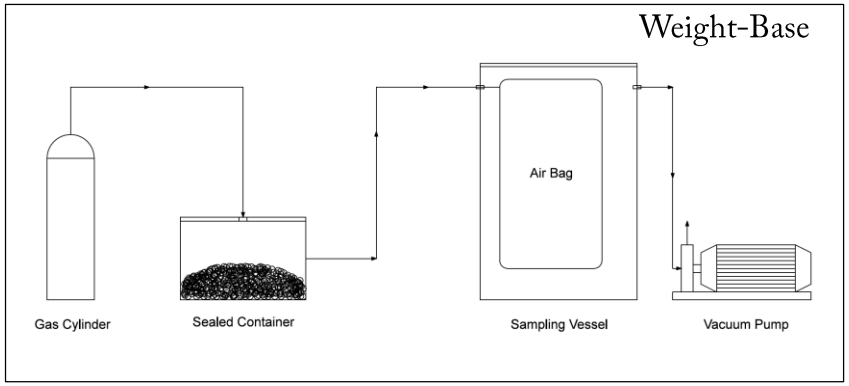
Odour Control Approaches at STF (污泥处置中心的气味控制措施)

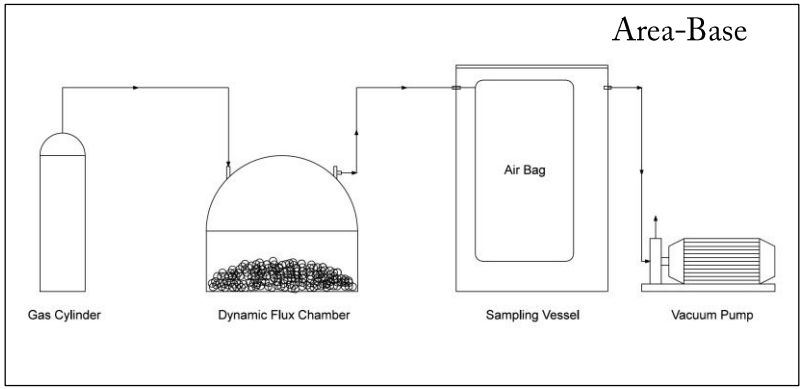
- Odour and health related concerns are mainly raised inside the delivery bay, where the truck drivers will have sludge unloading operations.
- For depress the odour pollution caused by sludge unloading operations, measures for **controlling the dispersion** have been applied, including:
  - **Negative pressure design** inside the unloading bay, preventing the dispersion of high concentration H_2S gas. (负压设计)
  - **Automatic washing system** is applied for each truck that finishing the sludge unloading operation before heading out of the delivery bay. (自动洗车系统)
- Also a trail system for reducing the odour emission from the **source** is now being tested, in which the gas inside each sludge container will be drawn out and treated by an **adsorptive deodorization system**. (吸附除臭系统仍在试验阶段)

Source: Environmental Protection Department, The Government of Hong Kong Special Administrative Region.

Sludge Emission Rate Study (污泥污染物排放率研究)

- For assessing the accidence-based health risks to the occupants at STF, the **H_2S emission rate** from raw sludge that is intensively transported between the pier and the STF is measured for dispersion modelling approach. (测量所得的污染物排放率可用于模拟污染物扩散，继而可进行风险评估)
- Both odourous compound emission rate and odour emission rate could be determined by the following measures. (基于污泥质量或暴露面积的污染物排放率)
- For weight-based emission rate, a **sealed chamber** shall be used for measurement, while for area-based emission rate, the **dynamic flux chamber** shall be used for measurement.
- **Sweeping gas** will be injected with certain **flow rate**. Based on the weight of the sludge or exposed area, and the measured concentration results, the emission rate could be obtained.





Odour Assessment Equipment

- Odour Sampling
  - Equipped with large volume negative pressure **sampling vessel**, which is suitable for obtaining odour samples for olfactometry analysis.
  - **Dynamic flux chamber** and **wind tunnel** are also equipped for obtaining odour emission rates from emission surface.

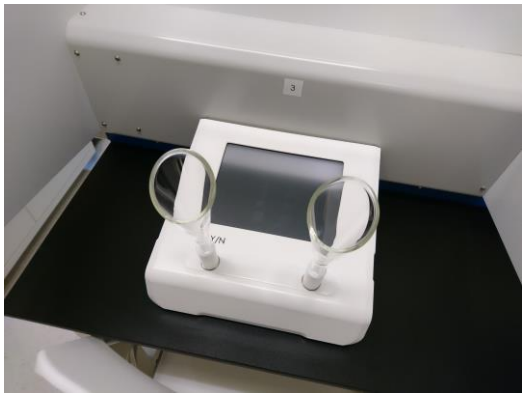
Sampling Vessel

Dynamic Flux Chamber

Wind Tunnel

Odour Assessment Equipment

- Olfactometry
  - Odournet TO Evolution **olfactometer** is equipped in laboratory.
  - Well-established **data base for certified odour panelists**.
  - FOX 3000 **e-nose** is also available for odour assessment.



Odournet TO Evolution Olfactometer

E-nose Sampler

Odour Assessment Equipment

- Odour Related Compounds Analysis
  - **ppb-level and ppm-level** portable hydrogen sulfide analyzers for on-site measurement.
  - Stationary hydrogen sulfide analyzer for accurate measurement.
  - GC/MS for odourous organic compounds in-lab analysis.
  - In the future PTR-MS will also be applied for the odour pollution apportionment studies.

Conclusion and Outlook

总结及展望

Conclusion and Outlook (总结与展望)

- Intensive efforts have been paid on odour sampling and intensity determination.
- There are still difficulties on the source apportionment of the odour pollution, since the information on the contribution of single odourous compound or single emission source to the bulk environment is significantly insufficient. (缺少单一物质及污染排放源与气味强度的关系资料)
- For determining the contribution of odourous compounds, higher resolution detection measures (e.g. PTR-MS or PTR-TOFMS) need to be employed for quantitatively revealing the relationship between the odour intensity and odourous compound (especially the sulfide compounds, fatty acids, amines and ammonia species) concentration. The source profiles from odour emission sources shall also be studied. (关于气味的定性及定量的研究需要达到更低的检测限)
- Odour intensities and odourous compounds concentrations shall also studied for the source apportionment of odour pollution. (臭味源解析还需要在敏感受体的监测数据)

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Thank you for your attention