DRAINAGE SERVICES DEPARTMENT

Maunsell

# Agreement No. CE 34/2000
# Environmental Monitoring and Audit for Construction and Operation Phases of Shatin Sewage Treatment Works, Stage III Extension

## Odour Baseline Monitoring Report (Final)

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# 1. INTRODUCTION

1.1 The Shatin Sewage Treatment Works Stage III Extension (the Project) is designed to increase the treatment capacity of the existing Shatin Sewage Treatment Works (STW) to handle increasing wastewater flows and loads as a result of residential developments in the Shatin and Ma On Shan catchment areas. The objective of this Project is to ensure compliance with the new effluent discharge standard set by the Environmental Protection Department (EPD).

1.2 Under the *Environmental Impact Assessment Ordinance*, the Project is classified as a "Designated Project". The Environmental Impact Assessment (EIA) Study for the Project was completed in 1999 and the associated Environmental Permit (EP) has been obtained from the EPD in 2000. The EP stipulates that an Environmental Monitoring and Audit (EM&A) programme is required to ensure that the proposed mitigation measures, recommended in the *EIA Study Report* and the *Environmental Monitoring and Auditing (EM&A) Manual*, are implemented during the construction and operation of the Project.

1.3 The EIA Study identified that odour emission from the proposed STW extension is an area of concern. Addition of chemicals had been proposed at Shatin and Ma On Shan Sewage Pumping Stations to reduce odour emission from the Project. Moreover, odour monitoring is required in the EM&A Manual prior to and during the initial operation of the Stage III Extension. The purpose of the monitoring exercise is to ensure that the recommended mitigation measures are effective and that no residual impacts occure after commissioning of the Project.

1.4 In January 2001, the Drainage Services Department (DSD) of the Hong Kong SAR Government commissioned Maunsell Environmental Management Consultants Ltd (MEMCL) to undertake the Independent Environmental Checker (IEC) services during the construction phase and the Odour Monitoring and Complaint Registration Programme during the operation phase, under the Agreement No: CE 34/2000 *Shatin Sewage Treatment Works, Stage III Extension - Environmental Monitoring and Auditing for Construction and Operation Phases*.

1.5 Gaseous hydrogen sulphide ($H_2S$) concentration was proposed as the principal monitoring parameter throughout the monitoring period. The indicator gas will be employed as the basis to assess the degree of odour reduction for different chemical dosing rates applied, and also used for determination of the impact monitoring odour criteria (Action/Limit levels).

1.6 The olfactometry analysis, specified in the EM&A Manual, as the first set of odour baseline monitoring, was scheduled to be carried out one year prior to the commissioning of the Stage III Extension, i.e. in year 2003. However, it was agreed with and approved by both EPD and DSD in July 2001, that the olfactometry analysis could be advanced to July / August 2001 for the establishment of the correlation between odour and $H_2S$ concentration before the measurement of $H_2S$ in the chemical trials. The revised final *Olfactometry Analysis Report* (OAR) was produced in January 2003, and relationships between odour and gaseous $H_2S$ for different facilities have been discussed with relevant parties. Findings from the OAR is incorporated in this Odour Baseline Report.

1.7 With the completion of the first set of odour baseline monitoring and the correlation between odour and $H_2S$ concentration established, the final Methodology and Implementation for Odour Baseline Monitoring was issued in February 2004, which detailed the approach to the subsequent sets of odour baseline monitoring (i.e. second, third and forth sets). The 2nd, 3rd and 4th sets of baseline monitoring were carried out during the periods 20-23 October 2003, 11-12 February 2004 and 26-27-April 2004 respectively.

1.8 In order to confirm the correlation findings of odour/$H_2S$ at the four ASR locations, it was agreed with DSD and EPD to conduct additional olfactometry analysis only at the ASRs (in addition to $H_2S$ measurements) during the 2nd set of odour baseline monitoring. The results indicated that there was no direct correlation between $H_2S$ and odour at all four ASR locations. These results are detailed in this baseline report.

1.9 Upon completion of the odour baseline monitoring, the monitoring results shall form the basis for determining the odour criteria for the impact monitoring. The results of impact monitoring will be compared with the established Action/Limit Levels. Relevant action in accordance with the Event/Action Plan specified in the EM&A Manual will be taken by DSD for any non-compliance of odour criteria.

1.10 This Odour Baseline Monitoring Report presents the methodology, monitoring results and relevant findings from the four sets of odour baseline monitoring including the olfactometry analysis. Action and Limit Level establishment and the Odour Complaint Register are also presented.

# 2. EM&A REQUIREMENT AND PROGRAM

## EM&A Manual Requirements

2.1 An EM&A programme has been established to protect air sensitive receivers (ASRs) against odour nuisance from operation of the Sha Tin STW and its Stage III Extension.

2.2 The EM&A Manual required that one year prior to the operation of the Stage III Extension, the following tasks should be undertaken:

- Establish a programme to monitor concentrations of odour/ gaseous $H_2S$ at the identified ASRs and potential odour sources within the Sha Tin STW;
- Establish an odour complaint register.

2.3 The incidence rate for odour complaints from the odour complaint register, as well as the measured results of $H_2S$ and odour concentration would serve as the baseline data set prior to commissioning of the STW Stage III Extension. The baseline data set would be compared with the results obtained during the impact monitoring stage.

2.4 According to the EM&A Manual, an *Olfactometry Analysis Study* is required during the 1st set of baseline monitoring to establish the correlation of odour and gaseous $H_2S$ at the Shatin STW. As mentioned in Section 1, the olfactometry analysis has already been conducted in advance of the programme, during July and August 2001, to facilitate chemical dosing evaluation in the Chemical Mitigation Trial Tests. The OAR was issued in January 2003. The findings and the established odour/$H_2S$ correlations have been discussed with DSD and EPD.

2.5 It should be pointed out that although the 1st set of odour baseline monitoring, that is the odour/$H_2S$ correlation study, was carried out in accordance with the requirements specified in the EM&A Manual, only clear correlation was established at W1 (inlet works) and W2 (primary sedimentation tanks). As discussed in the OAR, weak odour/$H_2S$ correlation was identified at W3 to W5 (sludge processing facilities), which was due to the close proximity of these locations to the sludge handling facilities of the Shatin STW where the odour is not dominated by $H_2S$. It was agreed with EPD and DSD that further establishment of odour/$H_2S$ correlation at W3 to W5 in subsequent odour baseline monitoring was considered not necessary, since the measured $H_2S$ concentrations at these source locations had no direct correlation to the measured odour levels. Based on the above justification, only $H_2S$ was measured at the five monitoring locations inside Shatin STW (i.e. W1 to W5) during the 2nd, 3rd and 4th sets of baseline odour monitoring.

2.6 Regarding the ASRs, since there were other odorous sources deemed to be affecting the odour level at these locations, in order to confirm the findings of the odour/$H_2S$ correlation, it was agreed with DSD and EPD that olfactometry analysis would be conducted during the 2nd set of baseline monitoring at the four ASR locations only. The results confirmed that there was no correlation at the ASRs, and hence only $H_2S$ would be measured in the subsequent odour monitoring. The findings are presented in Section 4 of this report.

**Odour Baseline Monitoring Programme**

2.7 In accordance with the EM&A Manual, a total of four baseline $H_2S$ monitoring events were conducted for the Sha Tin STW, prior to the commissioning of Stage III works. The baseline monitoring events were carried out every three months at the identified monitoring stations prior to the commissioning. Phase I of the Stage III extension works was scheduled for commissioning in the end of May 2004, and the baseline measurements were arranged in the sequence as shown in Table 2.1.

**Table 2.1 Baseline Monitoring Schedule**

| Monitoring Events | Month/Year |
|---|---|
| 1st set of baseline monitoring | July/August 2001 |
| 2nd set of baseline monitoring | September/October 2003 |
| 3rd set of baseline monitoring | December 2003/January 2004 |
| 4th set of baseline monitoring | March/April 2004 |

2.8 The detailed odour baseline monitoring schedule is shown in Table 2.2 listing out the actual dates of odour/$H_2S$ measurement and monitoring locations.

**Table 2.2 Actual Odour Baseline Monitoring Programme**

| Baseline Monitoring Events | Date | Location | | | |
|---|---|---|---|---|---|
| | | Source | | ASR | |
| | | $H_2S$ | Odour | $H_2S$ | Odour |
| 1st set | 23, 26-27, 30-31/July 2001, 1-3/August 2001 | ✓ | ✓ | ✓ | ✓ |
| 2nd set | 20-23/October 2003 | ✓ | | ✓ | ✓ |
| 3rd set | 11-12/February 2004 | ✓ | | ✓ | |
| 4th set | 26-27/April 2004 | ✓ | | ✓ | |

"✓": Measurements were carried out for the particular parameter.

# 3. SURVEY METHODOLOGY

## Survey Parameters and Instrumentation

$H_2S$ Measurement for All Locations

3.1 Concentrations of gaseous $H_2S$ were monitored with a portable $H_2S$ analyzer, type Jerome 631-X $H_2S$.

3.2 The $H_2S$ analyzer, type Jerome 631-X $H_2S$, was used for the baseline monitoring. The analyzer is capable of measuring $H_2S$ concentration in the range of 1 ppb to 50 ppm, with a resolution of 1 ppb. The analyzer operates within a temperature range of 0 to 40$^oC$, at an air flowrate of 0.15 L/min. Grab air samples drawn by built-in suction pump of the analyzer and passed through a gold film sensor. The electrical resistance of the gold film changes according to the change in mass of hydrogen sulphide in the gas sample.

3.3 A 15-minute gaseous $H_2S$ sample was collected every 3 hours for a period of 24 hours at each of the 9 monitoring locations. Maximum, average and minimum $H_2S$ levels for each monitoring location were recorded.

3.4 During the sampling period**,** meteorological data including wind speed, wind direction and temperature were obtained from the Hong Kong Observatory's Sha Tin Racecourse Weather Station.

Olfactometry Analysis

3.5 Grab samples of odorous gas were collected with Tedlar bags with the use of an airtight plastic container. Each sample was collected over a period of 15 minutes. The plastic container was flushed with odour-free gas and then evacuated before sampling. The odorous gas was then drawn into the Tedlar bag by means of pressure difference. The use of sampling pumps was avoided to eliminate adsorption loss of the odorous gas. The Tedlar bag is made of an inert material, which does not react with the odorous gas.

3.6 The collected air samples were delivered to the Odour Research Laboratory of Hong Kong Polytechnic University for olfactometry analysis within 24 hours. The temperature was kept above dew point of the samples to avoid condensation. Exposure of samples to direct sunlight was avoided to minimize photochemical reactions. The odour laboratory was ventilated to maintain an odour-free environment and to provide fresh air to the panel members.

3.7 A total of seven qualified panelists participated in each odour testing session. All of them were screened beforehand by using a 50-ppm solution/mixture of certified n-butanol standard gas. The most sensitive and least sensitive individuals were eliminated.

3.8 Smoking, eating and drinking (apart from water) was not allowed 30 minutes before and during olfactometry measurement. The use of odorous cosmetics, perfumes etc was prohibited. Communication between panel members was not allowed.

3.9 The samples were analysed by a force-choice dynamic olfactometer in accordance with the *Dutch National Standard Method* (NVN2820). The olfactometer is an apparatus that presents an air sample containing the odorous component to an individual at varying dilutions with odour-free air. The dilution levels required for 50% of the panelists to detect the odour were determined.

**Monitoring Locations**

3.10 The EM&A Manual has identified nine monitoring stations, five odour sources within Sha Tin STW and four ASRs, for odour baseline monitoring. They are listed in Table 3.1 below and shown in *Figure 3.1 and Figure 3.2.*

**Table 3.1 Odour Monitoring Locations**

| ID | Description | Remarks |
|---|---|---|
| W1 | Inlet Works | Source |
| W2 | Primary Sedimentation Tank No. 10 | Source |
| W3 | Sludge Holding Tank | Source |
| W4 | Sludge Storage Tank | Source |
| W5 | Sludge Dewatering House | Source |
| ASR1 | Kamon Gardens | ASR |
| ASR2 | Marine Police North Division Base | ASR |
| ASR3 | Kam Tai Court (1) | ASR |
| ASR4 | Shatin New Fisherman's Village | ASR |

Note: (1) Previously identified as Home Ownership Scheme Housing Area in the EIA Study and EM&A Manual.

3.11 For location W2 (Primary Sedimentation Tank – PST), the monitoring point was indicated in the EM&A Manual as PST No.15. Since PST No.15 would only be existent after commissioning of the Stage III Extension, the monitoring point was shifted to PST No. 10 for the baseline monitoring. It was agreed with DSD and EPD in July 2001 that the monitoring point for W2 would be located back to PST No.15 during the impact monitoring.

3.12 For location W3, the EM&A Manual indicated two monitoring points, the Sludge Holding Tank and the Final Settling Tank. It was clarified with EPD in July 2001, that the monitoring point for W3 should be at the Sludge Holding Tank, which had a higher contribution of the odour emission to the overall emission rate. It was agreed with EPD and DSD in August 2001 that location W3 was the Sludge Holding Tank.

**Quality Assurance and Control**

$H_2S$ Measurement

3.13 In order to ensure that the analyzer was functioning properly, manual sensor regeneration and zero adjustment was performed before each set of the baseline monitoring.

3.14 Verification of the $H_2S$ analyzer was conducted prior to each set of baseline monitoring, with a known concentration of gaseous $H_2S$ of 0.25 ppm, generated by the functional test module. The analyzer would not be used in the baseline monitoring if the verified data exhibits error of more than 20% (i.e. fall outside the calibration range between 0.2 and 0.3 ppm $H_2S$).

3.15 Calibration of the analyzer and functional test module were checked against with a sophisticated NIST traceable calibration system every year at the laboratory of the manufacturer.

Olfactometry Analysis

3.16 Exposure to direct sunlight was avoided for the sample. If any condensate is observed on the inner surface of the air bag, the sample was discarded.

3.17 To ensure that the chemical properties of odour samples remain intact during transportation or storage, concentrations of gaseous $H_2S$ in the odour sample were recorded on site and at the odour laboratory. Any odour sample with difference in monitored value more than 5% of the range setting was discarded.

3.18 The odour samples delivered to the odour laboratory were analysed within two hours.

# 4. MONITORING RESULTS

## Odour Complaint Register

4.1 During the odour baseline monitoring period, all the odour complaint records received one year prior to the commissioning of the Stage III Extension (end of May 2004) related to Shatin STW were obtained and registered in Table 4.1.

**Table 4.1 Odour Complaint Register for Odour Baseline Monitoring Period**

| Date (Day-Month-Year) | Name of Complainant | Location | Nature of Complaint |
|---|---|---|---|
| 6-6-2003 | Ms. Kilion Lui of EPD | Tolo Highway | Malodour |
| 17-6-2003 | Ms. Kilion Lui of EPD | Tolo Highway & Tate's Cairn Highway | Foul smell |
| 1-7-2003 | Mr. Kwok | Mountain Shore | Malodour |
| 4-7-2003 | Ms. Kilion Lui of EPD | Kam Tai Court Ma On Shan | Malodour |
| 19-7-2003 | Ms. Cheung | Seaview Nursing Home | Malodour |
| 22-7-2003 | Ms. Cheung | Seaview Nursing Home | Malodour |
| 12-8-2003 | Ms. Cheung | Seaview Nursing Home | Malodour |
| 2-1-2004 | Mr. Cheung | Sam Mum Tsai #2 P/S | Malodour |
| 5-1-2004 | Mr. Fong | Sam Mum Tsai #3 P/S | Malodour |
| 11-2-2004 | Ms. Cheung | Seaview Villa | Malodour |
| 12-2-2004 | Mr. Wan | Forest Hill Management Office | Malodour |
| 24-2-2004 | Mr. Leung | Tai Po Industry Estate | Malodour |
| | | **Total No. of Odour Complaints:** | **12** |

Note: The complaint register will be further updated to take into account the latest odour complaints received prior to the actual commissioning date

4.2 In order to take into account the latest odour complaints received prior to the STW commissioning, the register will be further received and updated in the final Odour Baseline Monitoring Report. A total of twelve odour complaints associated with Shatin STW were recorded during the period from June 2003 to February 2004. Seven of these complaints were received in the summer of 2003, while five were received in the spring of 2004.

**Olfactometry Analysis during 1st Set of Odour Baseline Monitoring**

4.3 Results of the odour and $H_2S$ measurements at each of the 9 sampling points (sampled during the 1st set of odour baseline monitoring between 23 July 2001 and 3 August 2001) are shown in *Appendix A* and are summarized in *Table 4.2* below.

**Table 4.2 Range of Measurement Results for Odour and $H_2S$ levels**

| Location | Odour level (ou/$m^3$) | | $H_2S$ level (ppb) | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| **Source** | | | | |
| W1 | 159 | 3019 | 19 | 690 |
| W2 | 60 | 2310 | 10 | 430 |
| W3 | 42 | 1380 | 2 | 160 |
| W4 | 128 | 2354 | 3 | 54 |
| W5 | 43 | 627 | 2 | 22 |
| **ASR** | | | | |
| ASR1 | < 10 | 62 | 0 | 5 |
| ASR2 | 16 | 73 | 2 | 9 |
| ASR3 | <10 | 85 | 0 | 6 |
| ASR4 | 11 | 48 | 0 | 5 |

4.4 Measurement results indicated that W1 (inlet works) was the main source of both odour and $H_2S$. Highest odour and $H_2S$ level of 3019 ou/$m^3$ and 690 ppb respectively were obtained at W1 during the measurement.

4.5 Odour levels up to 85 ou/$m^3$, and $H_2S$ level up to 9 ppb were measured at the ASRs.

*Pairwise Measurement*

4.6 Measurements of odour and $H_2S$ were conducted in parallel (within a 3-hour period) at the sources and receivers. A total of eight sets of data were obtained from samples collected over different periods of a 24-hour cycle day. During the measurement periods, either northeasterly or southwesterly winds pre-dominated with average wind speed of about 3 m/s. Levels of odour and $H_2S$ at the sources and the receivers for both upwind and downwind conditions have been identified and are summarized in *Table 4.3.* Separations between receivers and odorous sources have also been presented in the tables.

**Table 4.3 Results of Pairwise Measurements**

| ASR | ASR at Downwind | | | ASR at Upwind | | | Location of Odorous Sources |
|---|---|---|---|---|---|---|---|
| | Odour/ $H_2S$ Concentration | | Wind Speed/ Wind Direction ($ms^{-1}$/degree) | Odour/ $H_2S$ Concentration | | Wind Speed/ Wind Direction ($ms^{-1}$/degree) | |
| | Receiver Downwind (ou $m^{-3}$/ ppb) | Source Strength Upwind (ou $m^{-3}$/ ppb) (1) | | Receiver Upwind (ou $m^{-3}$/ ppb) | Source Strength Downwind (ou $m^{-3}$/ ppb) (1) | | |
| ASR 1 | 19/2 | 691/114 | 3.5/326 | 46/2 | 140/21 | 3.5/ 140 | • STSTW at 150m<br>• Stables at 270m<br>• Raw sewage from village at 1100m<br>• Shing Mun River at 650 m |
| ASR 2 | -/-(2) | -/-(2) | -/-(2) | 37/3 | 591/110 | 3.1/ 207 | • STSTW at 80m<br>• Stables at 700m<br>• Raw sewage from village at 1000 m<br>• Shing Mun River at 500 m |
| ASR 3 | -/-(2) | -/-(2) | -/- (2) | 28/3 | 691/114 | 3.2/ 224 | • STSTW at 400m<br>• Stables at 1100m<br>• Raw sewage from village at 700 m<br>• Shing Mun River at 200m |
| ASR 4 | 22/0 | 341/99 | 2.8/ 160 | -/- (2) | -/-(2) | -/-(2) | • STSTW at 400m<br>• Stables at 550m<br>• Raw sewage from village at 20m<br>• Shing Mun River at 250m |

(1) Average sources strength of STW (i.e. $\Sigma W_i A_i / \Sigma A_i$)

(2) Upwind/ downwind relationship between source and receiver not identified during the monitoring periods.

4.7 A receiver located downwind of an odour source would experience higher impact than a receiver located upwind. However, the measurement results did not indicate such trend. At the receiver location (e.g. ASR1), the odour and $H_2S$ levels under downwind condition were no higher than those measured under upwind conditions. In addition, higher emission from the sources did not necessarily result in higher pollutant levels at the receivers. It is indicated that the pollutant levels at the receivers were not proportional to the source strength.

4.8 The measured results suggest that the STW was not the only source affecting the odour levels at the ASR. The EIA Report identified that the Shing Mun River Main Channel, raw sewage from villages and stables of Sha Tin Racecourse are also odorous sources of the area. It is indicated in Table 4.3 above that these odorous sources are located near the ASRs and the monitored odour/$H_2S$ concentrations would likely be affected by these odorous sources (e.g. ASR 1 by stables, ASR 3 by Shing Mun River and ASR 4 by raw sewage from village).

4.9 Pairwise relation between odour/$H_2S$ levels at the receivers and the STSTW could not be established, as the strength of other odorous sources in the region is not available for this Study.

*Correlation between Odour and $H_2S$*

4.10 Based on the results obtained from the odour and $H_2S$ measurements for the olfactometry analysis, the correlation between odour and $H_2S$ is discussed in the following sections. Note that all equations presented are measured in ou/$m^3$ and ppb for odour level and gaseous $H_2S$ concentration respectively.

*Air Sensitive Receivers*

4.11 *Figures 4.1a and 4.1b* show the odour concentrations plotted against $H_2S$ level at the ASRs for both upwind and downwind conditions respectively. *Figure 4.1a* indicates that the correlation for upwind condition was weak with correlation coefficient, $R^2$, of 0.1255 obtained. *Figure 4.1b* indicates that the there was no correlation and odour levels were not sensitive to changes in the $H_2S$ concentrations at the ASRs under downwind conditions. There was no direct relationship between the odour and $H_2S$ at the ASRs.

4.12 $H_2S$ levels were generally low at the ASRs and it is likely that $H_2S$ was not the major contributor to odour, since the $H_2S$ level did not change with the odour level. It is likely that other odorous gas components such as ammonia and mercaptans from other odorous sources (e.g. Shing Mun River channel and stables of Shatin Racecourse) are affecting the odour level at these areas.

*All Sources*

4.13 Odour concentration and $H_2S$ level for all the sources at the STW have been plotted on a log–log graph and are shown in *Figure 4.2*. A straight line with correlation coefficient of R = 0.69 was obtained. It is indicated that the odour level of the STW is proportional to the $H_2S$ concentration, and satisfies the Power Law Model.

$$\log [Odour] = 1.73 + 0.53 \log [H_2S] \qquad (1)$$

*Or* $[Odour] = 52.8\ [H_2S]^{0.53}$ *(2)*

4.14 A good correlation coefficient was obtained between odour and $H_2S$ concentrations for the sources at the STW. Statistically, there is a strong relationship between the two parameters. Hence, it is concluded that odour from the STW is related to the $H_2S$ emission.

4.15 However, it was observed that at some source locations, very low $H_2S$ levels (e.g. less than 10 ppb $H_2S$) were recorded while the odour levels were high. The most likely reason is that odorous gases other than $H_2S$ (such as ammonia, amines, mercaptans, skatoles and indoles) may also be emitted from the STW, and when the $H_2S$ level is low, other odorous gases would dominate. But when the concentration of $H_2S$ increases, its effect would in turn dominate the odour environment of the STW.

*Inlet Works (W1) and Primary Sedimentation Tank (W2)*

4.16 *Equation 2* describes the relationship between $H_2S$ concentration and odour concentration, based on all the data measured at the 5 locations within the STW. However, there may be reasons to suppose that odour and $H_2S$ emissions are better related at a few of the monitoring locations. For instance, since aqueous $H_2S$ concentration may be formed within the pipeline during transfer of raw sewage from the pumping stations to the STW, it could be expected that when the sewage is exposed to the atmosphere, gaseous $H_2S$ would be released. In this case, high $H_2S$ concentration would be expected at the inlet works (W1) and the primary sedimentation tank (W2). Thus, odour samples collected at W1 and W2 may contain a high percentage of gaseous $H_2S$, and a better correlation curve for $H_2S$ and odour could be obtained.

4.17 *Figure 4.3* and *4.4* shows the correlation curve of odour and $H_2S$ concentrations, monitored at W1 and W2 respectively. It is indicated that correlation coefficients, $R^2$, of 0.91 was obtained for W1 and 0.82 for W2 respectively, suggesting that the equations give more significant correlation than that of all the sources combined (i.e. *Figure 4.2*). Statistically, there is a very strong indication that $H_2S$ is the major odour source at the monitored stations. It also agrees with the postulation that $H_2S$ is the key odorous gas at W1 and W2.

4.18 Relationship between odour and $H_2S$ concentrations at W1 and W2 respectively can therefore be described by the following equations:

*Inlet Works (W1)*

$$\log [Odour_{W1}] = 0.96 + 0.85 \log [H_2S_{W1}] \quad (3)$$

*Or* $$[Odour_{W1}] = 9.19\ [H_2S_{W1}]^{0.85} \quad (4)$$

*Primary Sedimentation Tank (W2)*

$$\log [Odour_{W2}] = 0.95 + 0.89 \log [H_2S_{W2}] \quad (5)$$

*Or* $$[Odour_{W2}] = 8.89\ [H_2S_{W2}]^{0.89} \quad (6)$$

4.19 *Equation (4)* and *(6)* describe the relationship between odour and $H_2S$ concentrations at the inlet works and at primary sedimentation tank respectively when the odorous effect of $H_2S$ dominates the environment.

*Sludge Facilities (W3, W4 & W5)*

4.20 The characteristics of odour from sludge facilities, i.e. W3, W4 and W5, are expected to be similar in nature, with similar gaseous composition. Odour concentration and $H_2S$ level for sludge facilities were plotted on a log–log graph and presented in *Figure 4.5, Equation (8)* shows the relation of the two pollutants, with correlation coefficient of $R^2 = 0.22$. The low value in correlation coefficient suggested that other odorous gases, other than gaseous $H_2S$, are also affecting the odorous environment at these locations.

*Sludge Facilities (W3, W4, W5)*

$$\log [Odour_{W345}] = 1.90 + 0.42 \log [H_2S_{W345}] \quad (7)$$

Or $$[Odour_{W345}] = 79.4 [H_2S_{W345}]^{0.42} \quad (8)$$

*Chemical Dosage for Odour Mitigation Trial*

4.21 Dosage of chemical will be applied on the Shatin and Ma On Shan Sewage Pumping Station to reduce odour emission from the STW. The Inlet Works (W1) is located at downstream of the chemical dosage point. Effectiveness of the chemical dosage on odour reduction is represented by measuring the $H_2S$ reduction at the Inlet Works (W1), where $H_2S$ is the dominating odour source. *Equation (4)* is therefore recommended for the odour mitigation trials.

4.22 Monitoring at other sources (W2 to W5) are not recommended to check the effectiveness of chemical dosing. Odour emissions from the sedimentation tank (W2) are affected by other factors (e.g. maintenance of tank and septic condition of sludge) and is located further downstream from the dosing point. $H_2S$ monitoring at W2 is, therefore, not recommended at this location.

4.23 Chemical dosing is effective to remove odour from the sewage only. It is not effective in removing odour from other parts of the plant such as sludge holding tank and sludge dewatering house. $H_2S$ monitoring at W3 to W5 cannot determine the effectiveness of chemical dosing and is, therefore, not recommended for the odour mitigation trial.

**Olfactometry Analysis during 2nd set of Odour Baseline Monitoring (ASRs only)**

4.24 In order to confirm the correlation findings of odour/$H_2S$ at the four ASR locations, it was agreed with DSD and EPD to conduct olfactometry analysis only at the ASRs (in addition to $H_2S$ measurements) during the 2nd set of odour baseline monitoring. The results are summarized in Table 4.4 and presented in Appendix A.

**Table 4.4 Range of Measurement Results for Odour and $H_2S$ levels during 2nd set of Odour Baseline Monitoring**

| Location | Odour level (ou/$m^3$) | | $H_2S$ level (ppb) | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| **ASR** | | | | |
| ASR1 | 13 | 93 | 3 | 9 |
| ASR2 | 14 | 81 | 5 | 16 |
| ASR3 | 19 | 51 | 4 | 34 |
| ASR4 | 25 | 58 | 4 | 12 |

4.25 Odour levels up to 93 ou/$m^3$, and $H_2S$ level up to 34 ppb were measured at the ASRs.

4.26 *Figure 4.6* show the odour concentrations plotted against $H_2S$ level at the ASRs and it indicated that the correlation was weak with correlation coefficient, $R^2$, of 0.046 obtained. There was no direct relationship between the odour and $H_2S$ at the ASRs.

4.27 $H_2S$ levels were generally low at the ASRs and it was confirmed that $H_2S$ was not the major contributor to odour, since the $H_2S$ level did not change with the odour level. It was suspected that the Sha Tin STW was not the only source affecting the odour levels at the ASRs. Other sources of odour and $H_2S$, such as the Shing Mun River and associated nullahs etc, also affected the ASRs.

**Odour Baseline $H_2S$ Monitoring Results**

4.28 The four sets of odour baseline $H_2S$ monitoring data are summarized in Table 4.5 and the data is detailed in Appendix B.

**Table 4.5 Summary of Odour Baseline Monitoring $H_2S$ Data**

| Location | | Description | $H_2S$ Concentration (ppm) | | | |
|---|---|---|---|---|---|---|
| | | | Range | Average | Overall Range | Overall Average |
| **Source** | W1 | Inlet Works | 0.019 - 11.700 | 1.590 | 0.002 - 11.700 | 0.378 |
| | W2 | Primary Sedimentation Tank No. 10 | 0.006 - 1.106 | 0.148 | | |
| | W3 | Sludge Holding Tank | 0.002 - 0.356 | 0.095 | | |
| | W4 | Sludge Storage Tank | 0.003 - 0.186 | 0.028 | | |
| | W5 | Sludge Dewatering House | 0.002 - 0.144 | 0.031 | | |
| **ASRs** | ASR 1 | Kamon Gardens | 0.000 - 0.012 | 0.005 | 0.000 - 0.034 | 0.006 |
| | ASR 2 | Marine Police North Division Base | 0.002 - 0.016 | 0.007 | | |
| | ASR 3 | Kam Tai Court | 0.000 - 0.034 | 0.006 | | |
| | ASR 4 | Shatin New Fisherman's Village | 0.000 - 0.018 | 0.005 | | |

4.29 For the Shatin STW source locations, the overall baseline $H_2S$ data ranged from 0.002 ppm to 11.700 ppm, with an average of 0.378 ppm.

4.30 For the ASR locations, the overall baseline $H_2S$ data ranged from 0 ppm to 0.034 ppm, with an average of 0.006 ppm.

4.31 Findings from the baseline $H_2S$ monitoring results indicated that the 1st set of data measured in July and August 2001 was, in general, lower than the subsequent sets measured in 2003-04. The average $H_2S$ concentrations for all locations, source locations and ASR locations are compared separately as follows:

- Overall average $H_2S$ concentration for the 1st set was 0.065 ppm, while those for the 2nd, 3rd and 4th sets were 0.227 ppm, 0.110 ppm and 0.449 ppm respectively
- For source locations, average $H_2S$ concentration for the 1st set was 0.116 ppm, while those for the 2nd, 3rd and 4th sets were 0.401 ppm, 0.192 ppm and 0.805 ppm respectively
- For ASR locations, average $H_2S$ concentration for the 1st set was 0.002 ppm, while those for the 2nd, 3rd and 4th sets were 0.009 ppm, 0.007 ppm and 0.005 ppm respectively.

4.32 The 1st set of baseline measurements was conducted in the summer period, during which the expected worst odour emission should have been detected. However, the results showed that the $H_2S$ concentrations obtained in the 1st set were significantly lower than the last three sets (measured in autumn, winter and spring). As such, the 1st set of baseline $H_2S$ data is obviously not representative of the odour baseline monitoring period. Therefore, it is considered that the 1st set of baseline $H_2S$ data could be omitted from the odour baseline monitoring.

4.33 In order to confirm the aforementioned, a statistical analysis was performed for the 4 sets of baseline $H_2S$ data. The results from the analysis concluded that the 1st set of baseline $H_2S$ data was significantly different from the 2nd, 3rd and 4th sets. Details of the statistical analysis are presented in Appendix D.

4.34 According to the findings discussed above, it is deemed adequate to discard the 1st set of baseline $H_2S$ data from the odour baseline monitoring, while retaining the 2nd, 3rd and 4th sets for the use of establishing the odour criteria.

**Establishment of Action and Limit Levels**

4.35 The baseline monitoring results form the basis for determining the odour criteria for impact monitoring. Impact monitoring results will be compared with the odour criteria, namely Action and Limit Levels as shown in Table 4.6.

**Table 4.6 Action and Limit Levels for Odour Monitoring**

| Parameters | Location | Action Level | Limit Level |
|---|---|---|---|
| $H_2S$ conc. | Shatin STW | Average baseline H2S concentration measured at any sources in the Shatin STW | - |
| | ASRs | - | Average of baseline $H_2S$ concentration, or the 5 $OUm^{-3}$ equivalent whichever is greater, at respective ASR location |
| Incidence of odour complaints | - | Any incidence of odour complaint received through the Odour Complaint Register | Two or more odour complaints received through the Odour Complaint Register within three months. |

4.36 As stated in the pervious Section, since the 1st set of baseline $H_2S$ data is significantly different from the other sets, only the last three sets of baseline $H_2S$ data would be applied to the calculation of the odour criteria. The calculated Action and limit Level for monitoring of $H_2S$ is presented in Table 4.7.

**Table 4.7 Calculated Action and Limit Levels for $H_2S$ Monitoring**

| Parameters | Location | | Action Level (ppm) | Limit Level (ppm) |
|---|---|---|---|---|
| $H_2S$ conc. | Source Locations | W1 | 1.995 | - |
| | | W2 | 0.159 | |
| | | W3 | 0.108 | |
| | | W4 | 0.030 | |
| | | W5 | 0.038 | |
| | ASR Locations | ASR1 | - | 0.006 |
| | | ASR2 | | 0.008 |
| | | ASR3 | | 0.007 |
| | | ASR4 | | 0.006 |

4.37 These Action/Limit Levels will be further reviewed if necessary during the period of odour impact monitoring with DSD and EPD's approval.

# 5. CONCLUSION

5.1 The Odour Complaint Register had been established for the baseline monitoring period, there were a total of 12 odour complaint records obtained related to Shatin STW for the period from June 2003 to February 2004.

5.2 Concentrations of odour ($ou/m^3$) and gaseous $H_2S$ (ppb) were measured at 5 locations within the STW and at 4 ASR locations in the vicinity of the STW for the Olfactometry Analysis. Correlation curves between the two parameters were established.

5.3 At the ASRs, measurement results indicated that there was no direct relation between odour and $H_2S$. The measured results suggested that the STW was not the only source affecting the odour levels at the ASRs. Other sources of odour and $H_2S$, such as the Shing Mun River channel and associated nullahs etc, might be affecting the ASR.

5.4 Correlation curves for odour and $H_2S$ measured at the STW, *Equations (1) – (8),* have been established for this Study. The equations satisfy the Power Law Model, with correlation of between 0.22 and 0.91. Other odorous gases such as ammonia, amines, mercaptans, skatoles and indoles emitted from the STW also probably influenced the correlation for some facilities.

5.5 The correlation curve developed from W1, i.e. *Equation (4*) had the highest correlation coefficients. ($R^2 = 0.91$) Since the effectiveness of chemical dosage on odour reduction from sewage is represented by reduction of $H_2S$ level at the Inlet Works (W1), where $H_2S$ is the dominating odour source. It was agreed in the OAR that *Equation (4)* would be used for the determination of degree of odour reduction due to chemical dosing.

5.6 The Action and Limit Levels for odour impact monitoring were established. The $1^{st}$ set of baseline $H_2S$ data was not representative of the odour baseline monitoring period and significantly different from the $2^{nd}$, $3^{rd}$ and $4^{th}$ sets, therefore, it was omitted from the determination of the odour criteria.