Implementation of Odour Control Systems for Nuisance-free and Public Friendly Environment in Qatar

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Abstract

The Public Works Authority (Ashghal) is contributing to the development of Qatar with the construction of first class, sustainable infrastructure with a high degree of public acceptance by utilizing best international practices. Pumping stations and sewage treatment works are traditionally constructed at the outskirts of cities, as they are generally associated with odour nuisance; however, as the cities are expanded, the facilities become part of the urban fabric and their operation becomes an issue of concern for nearby residents. To address this public concern, Ashghal has for its sewer infrastructure adopted odour emission limits as stringent as 0.5ppbV of hydrogen sulphide (H_2S) and 0.5ouE/m^3 of odour concentration, which are lower than recognisable levels by humans. Moreover, on the way to FIFA World Cup Qatar 2022™, Ashghal decided to install environmentally friendly and sustainable biological treatment units followed by activated carbon filters to ensure a nuisance-free environment at the existing Doha South Sewage Treatment Works (DS-STW) and the new Doha South Terminal Pump Station (DS-TPS). This paper presents methodologies for determining odour levels in existing and new units, available odour treatment technologies, and the selected treatment schemes for the above projects.

Keywords: Odour control; Odour treatment; Biological treatment; Sustainability; Pumping stations; Sewage Treatment Works

1 Introduction

Sewerage infrastructure is usually associated with public nuisance and health concerns due to odour emissions, the use of hazardous chemicals, increased heavy traffic load and no consideration to aesthetic appearance. This may also drastically devalue the cost of land in the adjacent areas (Arora, 2020). Consequently, sewage treatment works (STW) are typically located at the outskirts of cities.

As the development of cities progresses, STWs and pumping stations become an integral part of the urban fabric; therefore, measures must be taken to apply sustainable and economical solutions to eliminate the causes of nuisance. This paper presents overall air management and odour treatment solutions, and explains how odour can be contained, ventilated, and treated using regional Odour Control Facilities (OCF) with preference to environmentally sustainable biological treatment technologies. This has been adopted by Ashghal on two crucially important projects. The first project entails the recently completed rehabilitation of Doha South Sewage Treatment Works (STW) once considered to be in an outskirt location, to a cumulative odour treatment capacity of approx. 270,000m^3/h. The second project entails active odour extraction from the tunnels of the recently commissioned Doha South Sewer Infrastructure Project (DSSIP) and the new Doha South Terminal Pump Station (DS-TPS).

2 Odourous Compounds and Their Generation

Odours emanating from Sewage infrastructure relating to wastewater collection and treatment

facilities are composed of a mixture of various chemical compounds including hydrogen sulphide (H2S), ammonia (NH4), mercaptans, various volatile organic compounds (VOCs), etc (Baiming et. al., 2019), Odour Emission occurs at locations where the flow is turbulent, e.g., due to high velocities and where it is discharged or dissipated and cause nuisance once they are released into the atmosphere. H_2S is the most important component as it creates significant odour nuisance, is toxic and corrosive. H_2S once biochemically oxidized in the presence of moisture, it forms sulphuric acid, which is even more corrosive and detrimental to concrete.

Under laboratory conditions humans can perceive H_2S at a concentration starting at 0.5 parts per billion (ppb), which is why it is defined as the threshold odour concentration; however, nuisance concentrations are typically 5-10 times the threshold odour concentration (QSDDM, 2005).

Based on the above, Ashghal specified the following odour limits at the property line and beyond of the TPS and DS-STW which are in the close vicinity of the Al Thumama Stadium that hosted events during FIFA World Cup Qatar 2022™ (PWA, 2018 and CH2M, 2017b).

- H_2S less than or equal to 5 ppbv as a 98^{th} percentile of the one (1) hour average concentration at all weather conditions; and
- Odour less than or equal to 5 odour units (OU) per m^3 as a 98^{th} percentile of the one (1) hour average concentration at all weather conditions.

3 Design Stages for Odour Control Systems

According to QSDDM (2005), the preferred option should be to eliminate or at least minimize the development of uncontrolled emissions prior to select appropriate systems to treat the emissions during the design of a dour treatment system. The following design stages were therefore adopted to ascertain Odour Control system needs for DS-STW and DS-TPS:

- **Assessment of the baseline emissions.** For DS-TPS, the emission levels generated in the upstream tunnel system were estimated with the use of septicity modelling and air sampling inside sewer manholes, while the emission levels of the different facilities at the DS-STW were assessed after air sampling at different locations.
- **Assessment of the required performance of the Odour Control Units.** Air dispersion modelling was carried out to determine the maximum allowable emissions as well as the

location, the sizes, and heights of the stacks to ensure that the odour limits would not be exceeded at the property lines and beyond.

- **Selection of the Odour Treatment Scheme and determination of the capacity of the Odour Control Units.** This was based on the assessment of the emissions at the source and the desired emissions at the stack.
- **Commissioning plan of the DS-STW.** This considered minimizing the potential for septic development due to excessive storage of sludge or sewage during commissioning.
- **Operation and Maintenance Manuals of the system.** This includes description and procedures to carry out seamless and trouble-free operation by performing preventative and corrective maintenance tasks of the installed Odour Control System.

4 Assessment of Baseline Emissions

4.1 Septicity modelling for DS-TPS

A septicity model for the new sewerage conveyance system DSSIP was used to ascertain the baseline emissions for the design of DS-TPS where the three main trunks of the Main Trunk Sewer (MTS) converge before entering the coarse screen shaft at DS-TPS. Septicity model results revealed that vapour-phase H_2S levels in the tunnel could reach as high as 900ppmV while short-term spikes of up to 1700ppmV can also be expected (CH2M, 2017a). Approximately 80% of the airflow from DSSIP would be drawn off for treatment (Figure 1) while the remaining 20% would enter the coarse screen shaft and be extracted for odour control treatment (CH2M, 2017b).

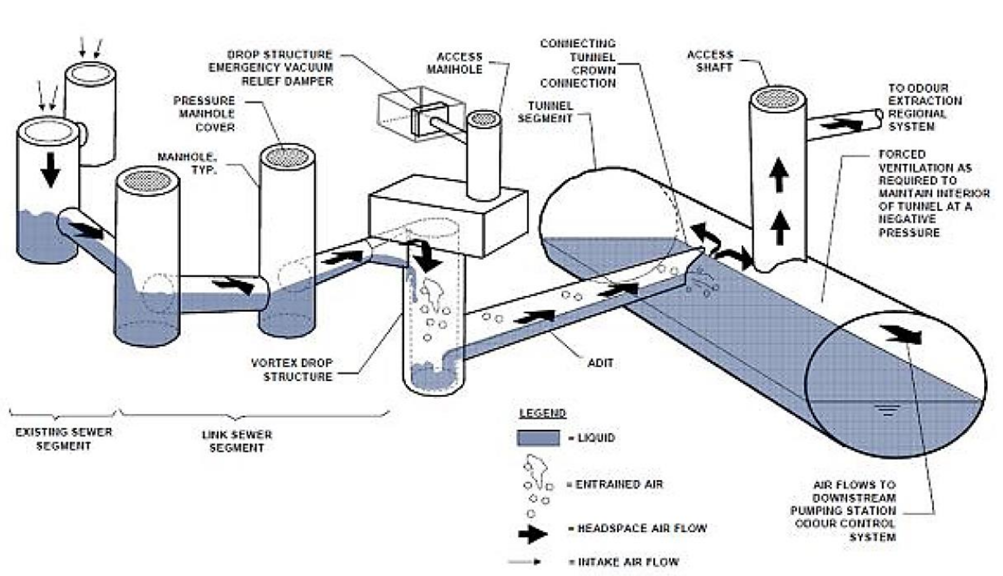

Fig. 1: Interceptor Lateral, Drop Structures and MTS Ventilation Schematic

4.2 Air Sampling at DS-STW

At DS-STW, air sampling was carried out during early morning hours, mid-day and at dusk time to capture the emissions and their concentration in different locations with the works in operation. The locations were selected after studying the STW layout and the operation conditions in order to identify the potential locations of odour development, identify the locations of major odour sources, understand, and assess the odour levels within and surrounding area, and to generate odour data sheets that would be essential for the odour modelling.

Field olfactometers, handheld H_2S detectors and a mobile meteorological station to record temperature, relative humidity, wind speed and direction (with GPS co-ordinate integration) were used to identify the odour emission sources. Air samples were collected from 19 different locations within as well as outside DS-STW, as presented in Figure 2 and Figure 3.

The highest average concentration levels of odour found at DS-STW in the morning and evening time during the study period were as follows (Wabag, 2020):

- 14,000 to 47000ouE/m^3 (100 to 500ppmV H_2S) at the Raw Sewage Handling Units.
- 500ouE/m^3 (0.5 to 2ppmV H_2S) at the existing digester area; and
- 350ouE/m^3 (50ppmV) at Sewage holding tanks area.

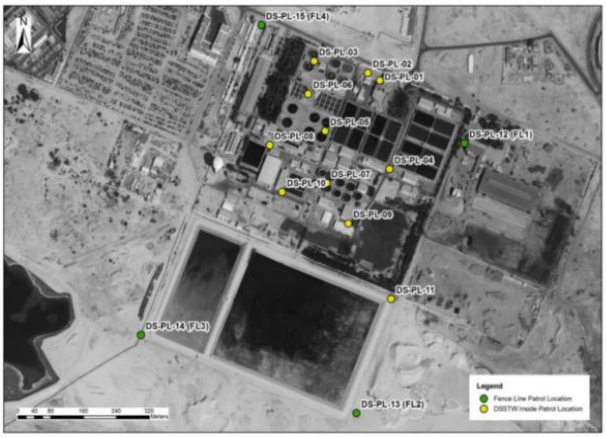

Fig. 2: Odour Sampling Locations within DS-STW

Fig. 3: Odour Sampling Locations outside DS-STW

5 Odour Impact Assessment Through Dispersion Modelling

For DS-TPS, it was assumed that a dilution ratio of 250:1 can be achieved after stack discharges. Therefore, an expected discharge concentration of 50ppbV H_2S at the stack was considered for the OCF design to meet a value of 0.20ppbV H_2S offsite (CH2M, 2017b).

For the emissions of the DS-STW, air dispersion modelling using US Environmental Protection Agency's (EPA) AERMOD algorithm (version 18081) was carried out to identify which existing and proposed sources on the DS-STW site needed to be connected to the odour control system to achieve the target levels.

Air sampling results, meteorological data for the most recent five years; and terrain and Building/Structure data of the vicinity were used as inputs to the model. The following scenarios were considered:

- ***Scenario 1***: Existing works without the implementation of Odour Control

  The dispersion model demonstrated that emissions from several existing sources such as sewage holding tanks, existing OCU stack, Thickening Building, SBR Anoxic zone, Inlet Works Building, and Septic Tank off-loading area are required to be controlled.

- ***Scenario 2***: Existing and new works without the implementation of Odour Control

  The dispersion model showed that (i) emissions from new aerobic digesters that are close to the plot limits must be controlled and (ii) H_2S emissions are exceeded at the site boundary due to the sewage holding tanks and the existing OCU stack as seen in Figure 4 and Figure 5 (Wabag, 2020).

- ***Scenario 3***: Existing and new works with Future Odour Control System

  An additional modelling scenario was run with the controlled residual emissions from the stacks of the proposed units as input to verify that with the selected scheme and when the emissions from the different sources are adequately treated, the residual odours and H_2S concentration would be less than 5ouE/m^3 and 5ppbV H_2S respectively at or beyond the site boundary as seen in Figure 6 and Figure 7 (Wabag, 2020).

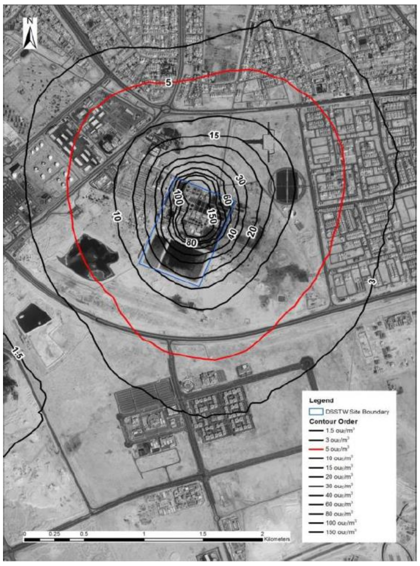

Fig. 4: Contour Plot of Scenario 2 Maximum 98th Percentile Odour Impacts (ouE/m^3)

Fig. 5: Contour Plot of Scenario 2 Maximum 98th Percentile H_2S Impacts (ppbv)

Fig. 6: Contour Plot of Scenario 3 Maximum 98th Percentile Odour Impacts (ouE/m^3)

Fig. 7: Contour Plot of Scenario 3 Maximum 98th Percentile H_2S Impacts (ppbv)

6 Selection of Odour Control Treatment Technologies

6.1 Odour Treatment Technologies

In choosing an odour control technology, several aspects need to be evaluated, such as: collection efficiency, ease of reuse or disposal of recovered material, ability of system to handle variations in gas flow and loads at required collection efficiencies, equipment reliability and freedom from operational and maintenance attention, and initial investment and operating cost (Stanley & Muller, 2002).

There are several odour treatment technologies available on the market (WEF, 2020), which are presented and compared against each other in Table 1.

Table 1: Comparison of Odour Treatment Technologies

SN	Treatment Technology	Cost Factors	Advantages / Disadvantages
1	Packed tower wet scrubbers	Moderate capital, high operation, and maintenance (O&M) costs	**Advantages** Can be used on intermittently operated odour sources, which is often the case in bio-solids applications **Disadvantages** High chemical consumption; High O&M cost
2	Activated carbon absorbers	Cost-effectiveness depends on carbon replacement or regeneration frequency	**Advantages** Simple operation, few moving parts; Best for relatively dilute airstreams **Disadvantages** Not economical for highly concentrated streams
3	In-ground bio-filters	Low to moderate capital; low O&M	Advantages Simple operation; few moving parts; Low O&M cost Disadvantages Large footprint: Not well suited to intermittent odour sources, which is sometimes the case in bio-solids applications
4	Pre-engineered bio-filters	Moderate to high capital; low O&M	**Advantages** Low O&M cost can be very effective on bio-solids cake applications that run 24/7 **Disadvantages** Higher capital costs than in-ground bio-filters; Not well suited to intermittent odour sources
5	Bio-scrubbers, bio-trickling filters	Moderate capital; low O&M	**Advantages** High H_2S loading capacity **Disadvantages**. Little long term performance data for non-H_2S applications; Not well suited to intermittent odour sources
6	Thermal oxidizers	Very high capital and O&M (energy)	**Advantages** Effective for wide spectrum of odours and VOCs; Suitable for very complex odorous air streams **Disadvantages** Only economical for high-strength, difficult-to-treat airstreams
7	Ionization Systems	High initial capital costs, lower operational costs	**Advantages** Some systems have proven effective on complex bio-solids odours **Disadvantages** Systems suitable for small applications (51 m/s or less); Limited vendors with proven experience
8	Neutralization	Moderate capital, high operation, and maintenance (O&M) costs	**Advantages** Suitable for extend uncovered odour sources **Disadvantages** Suitable for low odour concentrations only; Limited vendors with proven experience

6.2 Odour Control Methodology at DS-TPS

To select the odour treatment scheme at DS-TPS to comply with the offsite odour limits, a multi-stage approach was selected as it reduces the risk by improving the system reliability, robustness, and overall performance. Technologies in series were evaluated based on specific set of qualitative criteria, where each technology combination was ranked for each criteria category. A combination of BTF followed by ACF was considered the most favourable and was therefore considered as preferred option to treat the odorous air from the DSSIP tunnels and emissions at DS-TPS.

Based on the references and experience from DS-TPS, the odour treatment scheme for the Wakrah-Wukair Drainage Tunnel Project (WWDT) is in the process of being designed and constructed with the same two-stage treatment comprising of BTF followed by ACF, where dispersion modelling is used to determine the treatment efficiency of the units as well as size and height of the stack. This standalone facility to later cater for an ultimate capacity of 75,600m^3/h once it is linked with DSSIP.

6.3 Odour Control Methodology at DS-STW

Based on the Scenario 2 dispersion modelling results, a scheme of three (3) Odour Control Units (OCU) was proposed to collect emissions as indicated in Table 2. The different units were designed to reduce the H_2S levels and consequently the odour levels by >99%.

Table 2: Emission Sources and respective OCU

Odour Control Unit	Emissions Collected
OCU-1	Stack of the existing OCU for the inlet works, Screenings and Grit Skips, Sewage Holding Tanks, currently used as excess flow balancing tanks, Anoxic tanks, Thickening sludge tanks. Centrifuge centrate line for SSF, Centrifuge dewater sludge line (for new SSF)
OCU-2	SBR Anoxic zones, SBR splitting chambers
OCU-3	Existing Aerobic digesters, New covered aerobic digesters; SAS balancing tanks, Sludge tanks in the Sludge Thickening Buildings, Centrifuge centrate lines in the old Sludge Thickening Buildings, Centrifuge centrate line in the existing Dewatering Building, Sludge Thickening Buildings, Tanker unloading station

Initially, emissions from the Inlet works were treated in chemical scrubbers, which was decided to be refurbished and integrated with the new OCU-1 considering its robustness to handle the intermittent spikes. The existing unit using USFilter LO/PRO® consisted of three stage chemical scrubbers with integral sump with a rated capacity of 20,428m^3/h treating an average of 750ppmV H_2S or peak of 1000ppmV H_2S. The new OCU-1 consists of a bio-tricking (BTF) filter followed by Activated Carbon Filters (ACF) with a capacity of 47,500m^3/h. The treated gas is disposed to the atmosphere through a stack of 20m high (Figure 8).

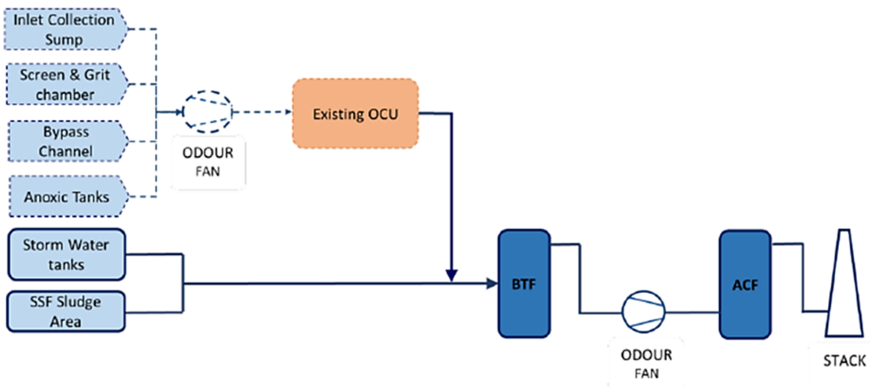

Fig. 8: Schematic Representation of OCU-1

Air from various sources identified for OCU-2 & OCU-3 has a low concentration of H_2S & Odour and pass through ACF prior to be released to the atmosphere through a 20m high stack (Figure 9 and Figure 10). OCU-2 has a treatment capacity for a flowrate of 42,200m^3/h, whereas OCU-3 has been designed for the flowrate of 182,000m^3/h.

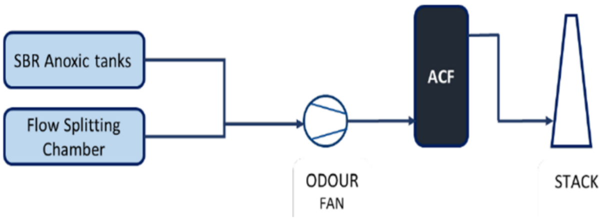

Fig. 9: OCU-2 Schematic Representation

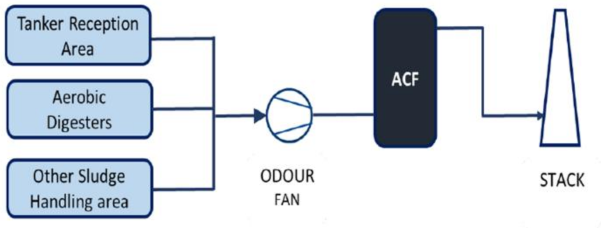

Fig. 10: OCU-3 Schematic Representation

To mitigate any observed odour emissions from large storage tanks and lagoons for sewage and TSE, SBR aeration basins and aerobic lanes which cannot be covered due to their large size, odour masking was proposed using neutralization chemicals. These chemicals consist primarily of essential oil solutions which either mask or react with the offensive odour components in the vapour phase when the solutions are atomized and sprayed as a mist around the odour source. This was the treatment strategy adopted to deal with any odorous conditions identified by the operators during the FIFA World Cup Qatar 2022™.

7 Sustainability Benefits From BTF Technologies as Primary Treament

Combination of technologies with BTF and ACF as principal treatment assures robust and reliable odour removal of a wide range of odour causing components, with limited use of chemicals. This minimizes the operation cost, and the requirements for chemical storage, handling, and the associated risks. BTF are also efficient in handling odour spikes and have relatively small footprint. In contrary, Chemical Scrubbers consume greater amounts of chemical reagents and demand higher quality potable water (preferably softened); while a portion of the solution will be wasted continuously after its reaction with the contaminants.

Finally, in a society that is increasingly committed to sustainable development, the use of biologic treatments where they can replace chemical reagents is a sustainable and environmentally preferable solution (Baiming et. al., 2019).

By selecting these technologies for odour control systems, Ashghal ensures sustainable development and provision of high standard of living for the citizens of Qatar in line with the Qatar National Vision 2030.

8 Conclusion

No odour nuisance is a key factor for public acceptance of sewerage infrastructure in residential development and Ashghal has adopted odour emission limits for its sewer infrastructure, as stringent as 0.5ppbV of hydrogen sulphide (H_2S) and 0.5ouE/m^3 of odour concentration.

From the several odour treatment technologies available, Ashghal promotes the installation of biological treatment units followed by activated carbon filters at the existing Doha South Sewage Treatment Works (DS-STW), new Doha South Terminal Pump Station (DS-TPS) and upcoming Wakrah-Wukair Drainage Tunnel Project (WWDT), as the most environmentally friendly and sustainable scheme.

The Odour Control Systems at DS-STW & DS-TPS ensured no odour nuisance at the venues of FIFA World Cup Qatar 2022™ and will continue to facilitate high living standards for the residents of Doha.

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