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Wessex Water Services Ltd.

Sampling and Enumeration of Bioaerosols from:

Avonmouth Sewage Treatment Works
Avonmouth
Bristol
BS11 0YP

Report Reference: CE-AM-2159-RP01-Final

Report Date: 9 November 2022

Produced by Crestwood Environmental Ltd.

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1 INTRODUCTION

1.1 BACKGROUND

1.1.1 Crestwood Environmental Ltd., a firm of environmental consultants based in Wolverhampton, has been commissioned by Wessex Water Services Ltd. ('the Client') to undertake an examination of the bioaerosol concentrations at locations around the boundary of the permitted area of their Avonmouth Sewage Treatment Works (STW) ('the Site') in Avonmouth, BS11 0YP.

1.1.2 The purpose of the investigation is to obtain measurements of bioaerosols present at a number of locations around the boundary of the permitted area to support an Environmental Permit application for the Site. Within the Site, there are two boundaries for two separate activities, namely anaerobic digestion and food waste processing. Since both activities are so closely aligned with each other, a single assessment has been completed to support each activity. The monitoring was undertaken by Kat Okon of Crestwood Environmental Ltd on 24th of August 2022 whilst the Site was operational.

1.2 THE SITE

1.2.1 The Site is located 2 km northeast of Avonmouth in Bristol within the industrial and commercial area of Avonmouth to the west and north. The eastern and southern sides of the Site are surrounded by undeveloped areas. The motorways M49 and M5 are located to the south and southeast of the Site.

1.2.2 The nearest sensitive receptor is the nearest location to the permitted activities where people are likely to be for a prolonged period of time but not less than 6 hours and falls within 250m of the Site. As agreed with Site representatives, the nearest identified sensitive receptor from the Site is Avonmouth Household Reuse and Recycling Centre located circa 200 m to the north boundary of the Site (360 m from the from the determined centre of the Site). On the day of monitoring the nearest sensitive receptor was situated downwind of the Site (see Appendix 1, Figure 1).

1.2.3 The Site includes Avonmouth Bioresources Centre (BC) and Avonmouth Renewable Energy Site (RES).

1.2.4 Avonmouth BC treats indigenous sewage sludges arising from processes at the Avonmouth Waste Water Treatment Works (WwTWs), as well as materials generated by smaller Wessex Water 'satellite' works. Operations include reception and screening of sludges following by processing within an AD plant in order to generate biogas for combustion within a CHP unit and upgrade prior to injection into the national grid.

1.2.5 Avonmouth RES receives food wastes which are delivered to the Site in Heavy Goods Vehicles (HGVs) and road tankers. The materials are then processed within an Anaerobic Digestion (AD) plant to produce biogas which is combusted using a Combined Heat and Power (CHP) unit in order to generate electricity and heat for use on site. A proportion of the biogas is also upgraded for injection into the national grid.

1.3 AVONMOUTH BIORESOURCES CENTRE

1.3.1 Sludge from the primary sedimentation tanks located at the wider WwTWs flows from an internal pumping station into the raw strain press feed sump. It is then processed through the primary sludge strain presses which remove any residual rags.

1.3.2 The strained sludge is delivered to two pumping stations. At present both sumps are communed together by a penstock between them.

1.3.3 Imported sludges from satellite sites across the Wessex Water portfolio are transported by road tanker and discharged into a reception tank. The sludge is then transferred to strain presses and subsequently to a pumping station. This includes 2 sets of pumps that are used to send the

strained sludge for further treatment within the installation.

1.3.4 Should the raw strain press feed sump go into high level, there is a bypass arrangement that allows sludge from the primary tanks to flow into the strained sump. The purpose of this is to prevent build-up of solids in the primary tanks.

1.3.5 The strained sludge pumping station delivers material at approximately 1.5% dry solids content to the Acid Phase Digestion (APD) Gravity Belt Thickeners (GBTs) 1, 2 and 3. The sludge is then thickened to around 5-6% dry solids and pumped to the APD feed tank where it is mixed with thickened Surplus Activated Sludge (SAS) from the Sequencing Batch Reactor (SBR) process.

1.3.6 The strained sludge pumping station can also deliver material with a dry solids content of approximately 1.5% to the Avonmouth consolidation tanks. These are used to thicken the sludge to around 2.5% dry solids prior to transfer to the Bellmer feed tank. The material is then pumped to the Bellmer GBTs which further thicken the sludge to around 5-6% before transfer to the APD feed tank.

1.3.7 Sludge from the feed tank is heated to 33.5°C using a hot water/sludge heat exchanger and then batch fed through a series of 6 insulated stainless steel covered tanks which form the APD process. The sludge is mixed and sequentially transferred between the tanks using compressors.

1.3.8 The APD sludge is sent to 8 concrete Mesophilic Anaerobic Digestion (MAD) tanks which include dedicated mixing pumps. All digesters feature fixed roofs, a sludge fill & spill withdrawal system, a heating/recirculation system, biogas mixing compressors, pressure/vacuum relief valves, gas flow meters and biogas pipework.

1.3.9 Biogas from the digesters can either be used as fuel for the CHP units or upgraded for injection into the national grid depending on site requirements. The primary source of biogas consumption is the gas to grid process.

1.3.10 Digested sludge is transferred to the Secondary Sludge Storage Tanks (SSSTs). These provide 1-day retention of material prior to dewatering. Compliant digested sludge from the SSSTs is transferred to the centrifuge feed sludge tank where it is dewatered producing a sludge cake at 25% dry solids content. The cake is discharged by conveyor into trailers and transported to skips.

1.3.11 Due to the loss of embedded dewatering equipment at the Site, three temporary dewatering rigs have been hired on site to allow processing at the required capacity. Sludge cake generated by the plant is transported to the skips. The liquors are discharged into the foul drainage system and transferred to the internal pumping station prior to return to the head of the WwTWs for treatment.

1.3.12 All other liquors from the various thickening/dewatering processes are returned to the internal pumping station via the site foul water drainage network and transferred back to the head of the works.

1.4 AVONMOUTH RENEWABLE ENERGY SITE

1.4.1 A summary of operations at Avonmouth RES is provided in the following Sections:

WASTE RECEPTION AND SEPARATION

1.4.2 Waste is delivered to facility using a variety of vehicles. On arrival these are weighed, logged and then directed to the biowaste reception hall. Access is to the building is provided by fast acting doors which are activated by the hall operator in response to signals from delivery drivers.

1.4.3 Delivery vehicles reverse into the building. The fast-acting doors then close to contain the reception area. Once contained, the drivers tip the loads onto the reception hall floor, wash the vehicle wheels and surrounding areas, and then exit via the fast-acting doors.

1.4.4 Delivered waste is pushed by the reception area operator using a dedicated front-end loader into

a pile using 'push walls'. The waste is then loaded into a fixed shredder within the reception area where it is macerated.

1.4.5 Liquid generated by wet materials within the reception area and shredder drains via enclosed conduits into a sump and is then pumped to the buffer tank feed sump via the rotary drum screen, which is located within the separation area and provides contaminant removal. The liquid is then pumped to the hydrolysis tank. Wash down water generated by clean down operations within the reception hall is collected in the same manner.

1.4.6 Plastics/ contaminants removed by the screen are transferred back to the reception area where they drop directly into a hopper which feeds to a hammer mill to provide further organics recovery. The organics are contained in a thick slurry which is conveyed by gravity to the sump to join the other liquid stream prior to transfer to the hydrolysis buffer tank.

1.4.7 The plastics and other contaminants separated by the hammer mill are squeezed in a press to recover more liquid which is captured. The residual contaminants are then loaded into a skip for removal from the Site and subsequent energy recovery at other facilities.

1.4.8 Air is extracted from the reception building using mechanical ventilation and transferred to an Odour Control Unit (OCU) for treatment prior to discharge to atmosphere. The reception area is partitioned from the separation area by a dividing wall. This allows general extraction from the reception area at a rate equivalent to 2 air changes per hour (ac/hr) for improved emission control.

WASTE MIXING

1.4.9 The waste mixing area contains process equipment designed to mix organic material prior to AD and to dilute it to level suitable for discharge to the screening step. Packaging, contaminants and oversize materials are screened out and discharged to the hammer mill in the waste reception area, as described above. The liquors are discharged into the foul drainage system and then transferred to the internal pumping station prior to return to the head of the WwTWs for treatment.

1.4.10 Material from the reception area is fed into a fixed shredder where it is reduced in size to <50mm. Shredded material is then transferred to a surge hopper with sufficient storage capacity for a turbo-dissolver mix batch. The discharge from the hopper feeds to a double shaft-less screw conveyor and from this point on, all processing equipment is enclosed with only manual inspection hatches within the separation area.

1.4.11 Shredded material is conveyed to 2 number turbo-dissolver mixers which operate on a batch system. The dissolvers liquefy the organic material reducing partial size, whilst leaving packaging, hard inorganic particles and root vegetables unaffected. Each dissolver has a working capacity of 8m^3 and a nominal hydraulic retention time of 20-minutes.

1.4.12 Material delivered to the waste reception hall has a typical dry matter content of 20% - 40% by weight, whilst the anaerobic digesters operate with a feed solids concentration of 12%. To achieve this, liquid food waste, potable water and centrate (limited to a maximum of 50% of volume required) is added to the dissolvers and mixed with the raw material. Addition of feed dry solids and liquids is controlled by a Programmable Logic Controller (PLC) via a configurable menu.

1.4.13 The mixture of solid/liquid biowaste and final effluent is blended for 10 to 20-minutes and then discharged via actuated valves to a rotary drum screen. This removes contamination larger than 10mm which is then de-watered using a screw compactor.

1.4.14 The remaining contaminants are discharged back to the hammer mill within the reception area which reprocesses the material to recover further organic material through a screen. Following hammer mill treatment, the remaining contaminants are compacted and then loaded into skips for removal from the Site and disposal at an energy recovery facility.

1.4.15 The organic slurry from the dissolvers flows from the fine rotary drum screen via gravity to the buffer tank feed sump within the separation hall and is joined by the recovered slurry from the

hammer mill. From here it is pumped to the hydrolysis buffer tank.

FOOD WASTE LIQUID TANK

1.4.16 Liquid wastes are delivered by tanker into an above ground storage tank. The tank is made from epoxy coated steel with a Glass Reinforced Plastic (GRP) roof and is vented to atmosphere. Material within the tank is mixed using a chopper-pump system to maintain solids in suspension.

1.4.17 Slurry is pumped from the reception tank to the turbo dissolvers using a positive displacement system. Addition of slurry to the system is controlled by the PLC via a configurable menu.

HYDROLYSIS BUFFER TANK

1.4.18 Slurry from the separation building is transferred to the hydrolysis buffer tank via duty/standby pumps. The tank has a working volume of 800m^3 and acts as a buffer between the intermittently working reception and separation halls and the continuously operating AD plant. Material within the vessel is mixed continuously using an external pump recirculation system in order to reduce settlement of solids. Air is extracted from the hydrolysis tank and transferred to the OCU for treatment prior to discharge to atmosphere.

1.4.19 Condensate from the biogas pipework (connected to the pasteurisers) is collected in a vessel at the lowest point by gravity and then returned to the hydrolysis buffer tank using a positive displacement pump.

PASTEURISATION SYSTEM

1.4.20 Slurry is transferred from the hydrolysis buffer tank to the pasteurisation plant at a rate of approximately 10m^3/hr. The material is initially pumped via a heat exchanger which raises the temperature from 30°C to 50°C through recovery from the hot pasteurised sludge. Pasteurisation then takes place in 3 parallel tanks each with a maximum working volume of 15m^3. At any one time, one tank is filling and being heated to 70°C, one tank is holding at 70°C to ensure pathogen kill and one tank is emptying. This approach allows a continuous feed in and a continuous feed out whilst providing the 1-hour batch hold time required by the Animal By-Products Regulations for Category 3 material.

1.4.21 Hot pasteurised sludge is pumped from the plant via a heat recovery exchanger where the temperature is reduced from 70°C to 50°C and then transferred to the AD plant. Heat exchange is via a sludge/water/sludge unit with detachable bends on the slurry side for ease of cleaning.

1.4.22 The pasteurisation tanks are externally mixed and incorporate at least 3 temperature transmitters and a level transducer per vessel. Each batch treated is logged for time and temperature to monitor Hazard Analysis Critical Control Point (HACCP) compliance.

1.4.23 The biogas pipework connected to the pasteurisers is fitted with a relief valve to protect the vessels and biogas train against excessively high or low pressures, which could occur under abnormal fault conditions. This is a safety device and should not operate under normal working scenarios. However, under abnormal conditions the valve is designed to release biogas to atmosphere.

ANAEROBIC DIGESTION

1.4.24 Pasteurised slurry is pumped in turn to one of two anaerobic digesters via the heat recovery exchanger and discharged through a limpet-box weir arrangement.

1.4.25 The anaerobic digesters convert organic material to biogas, which comprises methane (CH_4) and carbon dioxide (CO_2), through the fermentation of organic material in the absence of oxygen. The minimum retention time of the digesters is over 18-days and biogas is collected within the roof spaces of the vessels which are connected to the gas line.

1.4.26 Digested slurry is displaced by gravity overflow from the digesters via the existing weir on the limpet-box which acts as a siphon break in the event of a down-stream pipe fracture. The slurry is then transferred via duty/standby pumps to the post digestion storage tank.

DEWATERING

1.4.27 Digested slurry is pumped from the post digestion tank to the dewatering centrifuge where polymer is added and solids are reduced to a dry concentration of approximately 25%. The centrifuges are located indoors within the processing building and digested solid material falls by gravity into the cake storage bay where it is captured in open skips. The storage area is designed to hold 1-days' worth of digested cake and is connected to the odour control system to allow direct extraction and treatment of air prior to discharge to atmosphere.

1.4.28 Liquor from the dewatering process gravitates from the centrate tank overflow to the head of the WwTWs for further treatment.

GAS HOLDER

1.4.29 There are two double membrane gas holders at the Site and these act as storage for the biogas produced by the RES and BC.

1.4.30 Firstly, the gas holders are a safety device acting as a volume buffer to the digester and pasteuriser tanks. When liquid is pumped out of one of the tanks, the gas holders supply biogas to replace the lost volume hence maintaining system pressure. Similarly, when biogas is produced within the digesters the gas holders act as a storage volume preventing an increase in pressure.

1.4.31 Secondly the gas holders act as a buffer for biogas production and use. The CHP plant uses biogas at a fixed rate of approximately 500m^3/hr per engine. However, production within the digesters can vary widely. The gas holders act as a buffer to allow the CHP plant to operate at a constant rate with varying gas production.

1.4.32 The gas holders also act as the pressure regulating device in the system. Air is blown into an outside bag which surrounds the inner membrane. The outlet is restricted by a valve to create a constant air pressure in the outer bag, typically 20 – 25mbarg, and this in turn regulates the gas to the same pressure. By maintaining the gas at a positive pressure at all times, the risk of oxygen being drawn into the gas system from a leak or relief valve is eliminated and hence the potential for an explosive mixture of methane and air forming within the plant is reduced.

1.4.33 The gas holders are fitted with pressure and vacuum relief valves that protect the units against excessively high or low pressures which could occur under abnormal fault conditions. These are safety devices and do not operate under normal working conditions. However, under abnormal operating scenarios, the valves are designed to release biogas to atmosphere.

COMBINED HEAT AND POWER PLANT

1.4.34 The CHP units are generators which convert biogas into heat and power. Electricity is generated from the combustion of biogas with air and heat is recovered from the cooling jacket, oil lubrication system and flue gas into a common hot and cold header. This supplies heat to 8 number AD tanks and the acid phase digestion system which feeds into 8 of the 10 digesters. Hot water for the pasteurisation system is taken from the circuit in such a way that the existing plant on site is not disrupted or starved of heat.

1.4.35 Flue gasses from the CHP units are used to generate steam which in turn provides energy for a drier at the Site.

GAS TO GRID

1.4.36 The Gas to Grid plant is connected to the system at the digesters which allows gas to flow to the holders or to the Malmberg upgrading plant. The volume of biogas that enters the plant is controlled by one of two blowers that operate as duty/assist. These units increase the pressure to 0.78bar. Moisture is then removed, and the gas cooled.

1.4.37 The biogas is compressed using one of four dedicated units causing the temperature to rise to 78°C. The gas is then cooled to 8.4°C and fed into the absorption column which is held at 6.10bar pressure and filled with plastic media in order to allow water to flow from the top to the bottom at a rate of 0.16m^3/m^3bio-gas/hr. The gas is introduced at the bottom, so it has an opposing flow to the water. The water 'scrubs' the gas of all undesirable compounds such as hydrogen sulphide (H_2S) and CO_2, leaving a high concentration bio-methane

1.4.38 The bio-methane is vented at the top of the column for further treatment. The contaminated water passes through a column where the pressure is reduced to 1.14bar which causes any trapped CH_4 to be 'flashed' out as a gas and retrained to the top for further treatment.

1.4.39 The final process is the desorption column which is maintained at atmospheric pressure and used to remove all remaining undesirable compounds from the contaminated water so it can be recycled. The water flows from the top over plastic media and collects at the bottom ready for reuse. As the water falls, an opposing air flow is forced up from the bottom causing the release of CO_2, H_2S and any other contaminants. The waste gas is vented to atmosphere via an abatement system. Bio-methane vented from the top of the absorption and flash columns is combined and transferred through two carbon filters which can be set to run in series, parallel or as singular modules.

1.4.40 In line with national grid injection regulations, the calorific value (CV) of the gas must be increased from 36.09Mj/m to 39.0Mj/m. This is achieved by injecting propane into the bio-methane stream. Once the gas has reached the correct CV, an odourant is added and it is injected to the grid through a fiscal meter.

1.5 BIOAEROSOLS

1.5.1 Bioaerosols are airborne particles consisting of, or originating from micro-organisms (i.e., bacteria, viruses, and fungi), metabolites, toxins or fragments of micro-organisms. These particles come from organic matter, plants, soil, animals and humans. They may be put into suspension in the air, adhere to organic dust particles and tiny droplets of water with which they come into contact and then may be transported, creating bioaerosols.

1.5.2 Typically, bioaerosols consist of very fine particles measuring less than 20 microns in diameter. These particles can be inhaled and held in the nose and mouth while the smallest, less than 10 microns, are respirable and can penetrate deep into the lungs.

1.5.3 Bioaerosols could potentially cause ill heath in the people exposed to them either by infection, or through an allergic reaction. The main route of exposure to bioaerosols is by inhalation. Mean and median background levels are highly variable and can range from 1 to 100,000 colony-forming units per cubic metre (cfu/m^3) (Pearson. C et al, 2015). Many micro-organisms grow and are released into the air at irregular intervals or depend on some form of air turbulence or material disturbance to make them airborne. Because there is a large variation in size, shape and mass of microbial particles, some remain airborne for extended periods, while others fall back to the ground rapidly. In outdoor situations, temperature, humidity and wind speed are all critical factors in determining the airborne concentration of bacteria and fungi as well as their metabolic products. In indoor situations, micro-organisms are more likely to be aerosolised following jet washing or high levels of turbulence from the unloading of biodegradable waste (Mette Madsen and Matthiesen, 2013).

1.5.4 Signs such as respiratory symptoms, nausea and headaches have been reported at concentrations of 10^5 or 10^6 cfu/m^3 for total bacteria. Fungi are known to cause the same

symptoms at concentrations >10^4 cfu/m^3. Review of Health Risks for Workers in the Waste and Recycling Industry, Institute of Occupational Medicine, 2012 states:

"Bacterial exposures have not been widely measured in epidemiological studies of the waste industry. Adverse effects on respiratory and more general health (excessive tiredness) have been reported in waste workers exposed to concentrations exceeding 10^6 total bacteria/m^3 or 10^5 cfu/m^3. There are few data from studies in other sectors relevant to the waste industry. "

"The exposure-response information available for airborne fungi is highly inconsistent and the use of a variety of measurement metrics limits inter-study comparison, as does the variation of the species present in different environments. Adverse effects on respiratory health have been generally reported in workers in the waste and other industries at concentrations exceeding 10^4 cfu/m^3 with limited data suggesting that gastrointestinal effects may arise at concentrations of less than 10^5 cfu/m^3. More severe respiratory symptoms including hypersensitivity pneumonitis have been reported at concentrations of 10^6-10^9 cfu/m^3."

2 METHODOLOGY AND METHODS

2.1 BIOAEROSOLS MONITORING METHODOLOGY

2.1.1 British Standard 13098:2001 Workplace Guidelines for Measurement of Airborne Micro-Organisms and Endotoxins provides guidelines for the assessment of workplace exposure to airborne micro-organisms including the determination of total number and culturable number of micro-organisms in the workplace atmosphere (BSI, 2001).

2.1.2 In line with these guidelines Crestwood Environmental follows Technical Guidance Note (Monitoring); M9: Environmental monitoring of bioaerosols at regulated facilities (Environment Agency, Version 2, July 2018).

2.2 METHODS AND PROCEDURES

2.2.1 The Technical Guidance Note M9 was applied to determine the sampling locations and methodology.

2.2.2 For the monitoring of bioaerosols, sterile filters and sterile filter holders are used for the measurements. The sterile filter holders and sterile filters were carefully mounted on the sampling apparatus using sterile gloves to avoid any risk of cross-contamination. Sampling air was drawn into the sampling apparatus by a vacuum pump with a calibrated flow rate of 2 litres/min.

2.2.3 Downwind concentrations are determined to assess the level of emission directly from the Site.

2.2.4 Sampling is carried out downwind of the Site, using a fan like shape arrangement to detect the position of the plume. The orientation of the measurement area is determined by the prevailing mean wind direction and the accessibility. The distance of the downwind locations from the centre of the active operational area should be the same as the distance of the nearest sensitive receptor from the source.

2.2.5 Upwind data provides information on the concentration of specified bioaerosols that are present in the air blowing onto the Site. The sample location of the upwind concentration measurement should be measured at a distance of 50m from the centre of the active operational area.

2.2.6 Comparison of the concentrations in air unaffected by the activities of the Site (background air sampled upwind of the Site) with the concentration of bioaerosols in air downwind of the plant enables an assessment of the plant related contribution over a specified area to be made. The difference between the upwind and downwind concentration caused by bioaerosol emissions from the Site is known as the process contribution.

3 MONITORING AND RESULTS

3.1 SITE INFORMATION (DAY OF MONITORING)

3.1.1 Bioaerosol monitoring was carried out on 24th August 2022.

3.1.2 On the day of monitoring, the upwind and downwind locations were based on conditions observed at the time of actual set up, which indicated that the predominant wind direction was variable but mainly from the south. The sampling locations were based on the prevailing wind direction and on the distance from the operational area. The physical restrictions at the Site, accessibility and the structural setup of the Site were also taken into consideration.

3.1.3 The odour of sewage was detected during samples collection at locations DW1 and DW3.

3.1.4 The meteorological conditions on the day of monitoring were mostly cloudy (8/8 cover) and warm (~20°C), with an average wind speed of 14 km/h, which is classed as 'Gentle breeze' on the Beaufort scale descriptions (see Appendix 3 for meteorological data).

3.2 BIOAEROSOL MONITORING LOCATIONS

3.2.1 A total of 12 boundary bioaerosol samples were taken from locations around the Site. Monitoring included two additional "blank" samples.

3.2.2 Boundary bioaerosol monitoring was undertaken at four separate locations around the Site and three samples were taken at each location. The locations were chosen according to the Technical Guidance Note (Monitoring) M9 (i.e., based on the wind direction in the area at the time of monitoring, the location of the nearest sensitive receptor and accessibility).

3.2.3 Samples were referenced 'UW', DW1', 'DW2' and 'DW3'. The first part of the reference indicates the location of the samplers, i.e., 'UW' for 'Upwind' and 'DW' for 'Downwind'. Three samples were each taken at `UW`, `DW1`, `DW2 and`DW3`.

3.2.4 The nearest sensitive receptor, i.e., the Avonmouth Household Reuse and Recycling Centre is situated circa 200 m north of the Site boundary and circa 360 m from the determined centre of the Site. As recommended in Technical Guidance Note M9, the distance of the downwind locations from the centre of the of the active operational area should be the same as the distance of the nearest sensitive receptor.

3.2.5 The downwind locations were conducted as close as possible to the nearest sensitive receptor while maintaining the fan shape arrangement to detect the position of the plume. The downwind DW1 monitoring location was situated approximately 260m north of the centre of the permitted area, DW2 - 320m and DW3 - 310m.

3.2.6 The access to the exact required sample locations is not always possible. Under these circumstances it is acceptable to sample a few degrees off-axis from the required locations. At the Site, the arrangement of various structures made it impossible to get to the desired locations DW2 and DW3; see Appendix 1 – Figure 1.

3.2.7 Because of the size of the Site, the upwind monitoring point (UW) could not be positioned at the 50 m distance recommended in Technical Guidance Note M9 as it would be within the operational Site boundary. Instead, UW was sampled 120 m from the centre of the Site in a safe location avoiding on-site hazards, such as site traffic; see Appendix 1 – Figure 1.

3.2.8 Table 1 below gives a full description of the monitoring locations.

Table 1 Description of Monitoring Locations

Location Number	Ref.	Location Description
Location 1 (Upwind)	UW	Approximately 120 m from the centre of the operational area.
Location 2 (Downwind 1)	DW1	Approximately 260 m from the centre of the operational area.
Location 3 (Downwind 2)	DW2	Approximately 320 m from the centre of the operational area and 55° from central downwind location.
Location 4 (Downwind 3)	DW3	Approximately 310 m from the centre of the operational area and 65° from central downwind location.

3.3 LABORATORY PROCEDURES

3.3.1 All samples were stored and transported to the Crestwood Environmental laboratory at 3-5°C where processing was carried out within 24-hours of the sampling.

3.3.2 Crestwood Environmental laboratory follows the guidelines of Technical Guidance Note (Monitoring); M9: Environmental monitoring of bioaerosols at regulated facilities (Environment Agency, Version 2, July 2018).

3.3.3 In the Crestwood Environmental laboratory, quantitative determination of the concentrations of Aspergillus fumigatus and mesophilic bacteria is performed by counting visually recognisable colonies following cultivation.

3.3.4 The filters were washed and starting with the highest dilution step, the resulting fluid was spread onto 3 plates (parallels) of the appropriate media and incubated in the laboratory. Inoculation of at least 3 parallel plates for each dilution step is required for quality assurance.

3.3.5 Half strength nutrient agar medium was used to culture total mesophilic bacteria. The agar plates were incubated for 7 days in 37°C. Colonies of Aspergillus fumigatus was growing on malt extract agar for 2 days at 45°C.

3.3.6 After incubation, colonies were enumerated, in accordance with the Protocol and BS IS0 7218:2007 and presented as raw data, before CFU/m^3 calculations were undertaken.

3.3.7 The “Blank” samples were included in the incubation and enumeration process in an identical manner to exposed samples. Due to the fact that there is no measurable flow rate, the colonies were enumerated but are not displayed as CFU/m^3.

3.3.8 Three control plates of each medium were also plated out and incubated as controls.

3.4 BOUNDARY BIOAEROSOL MONITORING RESULTS

3.4.1 Results for all samples were converted to 60 minutes time to provide standardised results for all samples.

3.4.2 The full results for the estimated concentration of bioaerosols are included in Appendix 2 ‘Estimated Concentration of Bioaerosols’. Detailed information is summarised in Table 2 below.

Table 2 Sampling information and raw laboratory results

Location	Flowrate (m^3/min)	Mean flowrate	Duration [mins]	Dilution	Number of Aspergillus fumigatus (cfu/m^3)	Number of mesophilic bacteria (cfu/m^3)
UW1	0.002	0.12	60	NEAT	Not detected	Not detected
UW2	0.002	0.12	60	NEAT	Not detected	Not detected
UW3	0.002	0.12	60	NEAT	Not detected	Not detected
DW1A	0.002	0.12	60	NEAT	Not detected	139
DW1B	0.002	0.12	60	NEAT	Not detected	Not detected
DW1C	0.002	0.12	60	NEAT	Not detected	139
DW2A	0.002	0.12	60	NEAT	Not detected	Not detected
DW2B	0.002	0.12	60	NEAT	Not detected	417
DW2C	0.002	0.12	60	NEAT	Not detected	Not detected
DW3A	0.002	0.12	60	NEAT	Not detected	Not detected
DW3B	0.002	0.12	60	NEAT	Not detected	Not detected
DW3C	0.002	0.12	60	NEAT	Not detected	Not detected

3.4.3 The results in Table 2 represent bioaerosol concentrations for the locations sampled on the day that monitoring took place. Concentrations of bioaerosols fluctuate significantly depending on the prevailing weather conditions and activities taking place in the area. Sampling air was drawn into the sampling apparatus by a vacuum pump with a flow rate of 2 litres/min for 60 minutes.

3.4.4 The additional “blank” samples are required as per the sampling guidance for quality control purposes in relation to the loading and unloading process of the samples and the presence of bioaerosols in the surrounding atmosphere. The blank is a filter treated in an identical manner as the real sample, but without drawing air through the sampling pump. The resulting blank represents the bioaerosols entering the sample simply by handling the filter during sampling.

3.4.5 Table 3 shows the number of individual colonies on the “blank” samples after incubation.

Table 3 Mean number of bioaerosols colonies on the blank samples

Samples no	Aspergillus fumigatus (cfu/plate)	Mesophilic bacteria (cfu/plate)	Gram Negative Bacteria (cfu/plate)
Blank 1	Not detected	Not detected	Not detected
Blank 2	Not detected	Not detected	Not detected

4 DISCUSSION AND CONCLUSIONS

4.1 RESULTS OBTAINED FOR BOUNDARY BIOAEROSOL MONITORING AT UPWIND AND DOWNWIND LOCATIONS

4.1.1 Concentrations of boundary bioaerosols are subject to large variations due to factors such as meteorological conditions, individual site characteristics, neighbouring sites and other local activities. Variation in bioaerosol concentrations is likely to be due to a heterogeneous distribution of bioaerosols in the air.

4.1.2 The Environment Agency Position Statement 031 (Version 1.0), 2010 states that in relation to composting activities, acceptable levels of mesophilic bacteria and Aspergillus fumigatus at the site boundary are 1,000 and 500 cfu/m^3 respectively.

4.1.3 Because of the broad scatter inherent in the measurement of bioaerosol concentrations, the median of replicate samples is used to assess the result for each sample location. Use of the median reduces the effect of extreme values, and any outliers present will have much less influence on the measurement result.

4.1.4 When using the simplified fan approach for routine compliance monitoring, the maximum median result of the 3 downwind sample locations is used to assess the impact of bioaerosols at the nearest sensitive receptor.

4.1.5 The full results for the estimated concentration of bioaerosols are included in Appendix 2 'Estimated concentration of bioaerosols'. The results indicate that:

- **Median of upwind location**:

- Aspergillus fumigatus = 0 cfu/m^3,

- Mesophilic bacteria = 0 cfu/m^3.

- **Median of downwind locations**:

- Aspergillus fumigatus median results for downwind locations were 0 cfu/m^3 at DW1, DW2 and DW3,

- Mesophilic bacteria median results for downwind locations were 0 cfu/m^3 at DW2 and DW3 and 139 cfu/m^3 and DW1.

4.1.6 Median bioaerosol monitoring results showed that levels were below the Environment Agency threshold levels for Aspergillus fumigatus and mesophilic bacteria at upwind monitoring location and at all downwind locations. In summary,

- **For the upwind location:**

- Level of Aspergillus fumigatus was below Environment Agency's threshold limit of 500 cfu/m^3,

- Level of Mesophilic bacteria was below Environment Agency threshold limit of 1,000 cfu/m^3.

- **For downwind locations:**

- Levels of Aspergillus fumigatus were below Environment Agency's threshold limit of 500 cfu/m^3,

- Levels of Mesophilic bacteria were below Environment Agency's threshold limit of 1,000 cfu/m^3.

4.2 CONCLUSIONS

4.2.1 The bioaerosol monitoring results reported represent bioaerosol concentrations for locations upwind and downwind around the boundary the Site.

4.2.2 Aspergillus fumigatus and mesophilic bacteria were not detected at the upwind location, which reflects the background concentration at that time.

4.2.3 The maximum median result of the 3 downwind sample locations is used to assess the impact of bioaerosols at the nearest sensitive receptor. The highest result was detected at location DW1 however all median results for all downwind locations were within Environment Agency threshold limits for mesophilic bacteria and Aspergillus fumigatus of 1,000 and 500 cfu/m^3 respectively.

4.2.4 The difference between the upwind and downwind concentration caused by bioaerosol emissions from the Site is known as the process contribution. Median bioaerosol monitoring results for the downwind locations showed that the process contribution was low or none.

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APPENDICES:

APPENDIX 1 BOUNDARY BIOAEROSOLS MONITORING LOCATIONS

LEGEND:

- Site boundary
- Sludge IED
- Food waste IED
- Activated sludge plants
- Composting pad
- Sequence Batch Reactors (SBR)
- Upwind monitoring location
- Downwind monitoring locations
- Nearest sensitive receptor
- Predominant wind direction

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Client:
Wessex Water Services Ltd.

Avonmouth STW

Drawing Title:
Bioaerosol Monitoring Locations

Date:	Scale	Paper Size:
16 September 2022	1:3,000	A3 (420×297mm)

Drawn By:	Checked By:	Status:	Final Revision:
KO	AA	FINAL	-

Drawing Ref:	Drawing No:
CE-AM-2159-DW01-Final	**Figure 1**

APPENDIX 2 ESTIMATED CONCENTRATION OF BOUNDARY BIOAEROSOLS

Estimated concentration of boundary bioaerosols:

Site: Avonmouth STW

Commissioning laboratory: Crestwood Environmental Ltd.

Site Operator: Wessex Water Services Ltd.

Sampling Date: 24/08/2022

Type of materials on Site: Sewage

Operations ongoing during sampling: Sludge Anaerobic Digestion and Food Waste Processing

Location	Distance from the centre of active area (m)	Sampling start/end times (hh:mm:ss)	Median of upwind samples (CFU/m³)		Median of downwind replicate field samples (CFU/m³)	
			Aspergillus fumigatus	Mesophilic bacteria	Aspergillus fumigatus	Mesophilic bacteria
UW	120	11:30/11:45	0	0	-	-
DW1	260	11:23/12:25	-	-	0	139
DW2	320	11:16/12:16			0	0
DW3	310	11:25/12:30			0	0

APPENDIX 3 METEOROLOGICAL DATA

Meteorological data:

Site: Avonmouth STW

Commissioning laboratory: Crestwood Environmental Ltd.

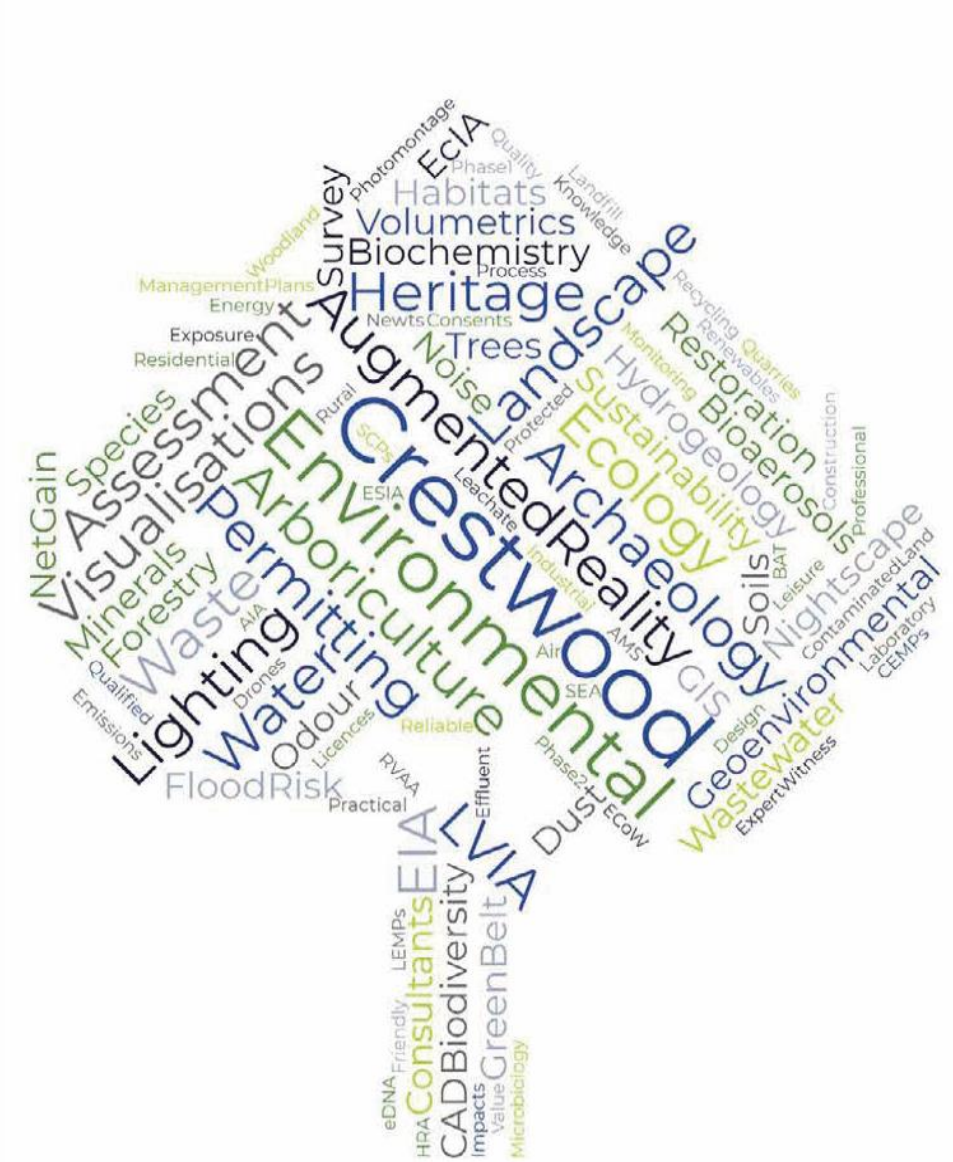
Site Operator: Wessex Water Services Ltd.

Sampling Date: 24/08/2022

Type of materials on Site: Sewage

Operations ongoing during sampling: Sludge Anaerobic Digestion and Food Waste Processing

Location	Bearing of samplers from centre of operational area or turning / screening operation (° from true north)	Mean direction the wind blows to during the sampling period (each individual sample) (° from true north)	Difference in bearing between location of samplers from centre of operational area and mean direction wind blows to (°)	Mean wind speed during sampling (m/s)	Arithmetic mean of air temperature (°C)	Arithmetic mean of relative humidity (%)	Prevailing weather conditions (cloud cover in 8ths)
UW	180	0	180	3.88	20	87	8/8
DW1	355	0	355	3.88	20	87	8/8
DW2	300	0	300	3.88	20	87	8/8
DW3	60	0	60	3.88	20	87	8/8



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