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Project name:
MSD Odor Control Master Plan

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Final

Final Memo

Subject: Technical Memorandum #8A – Morris Forman Water Quality Treatment Center New Odor Control Technologies Recommendation

1. Introduction

1.1 Odor Control Master Plan Background

In response to receiving a Notice of Violation (NOV) in November 2019 for failure to control odors from the Morris Forman Water Quality Treatment Center (WQTC, Plant) and its collection system, MSD entered into an agreed order with the Louisville Metro Air Pollution Control District (APCD) to develop and implement a phased District-wide Odor Control Master Plan. MSD has contracted AECOM to provide MSD with professional engineering services for the development of Phase I of the Odor Control Master Plan (Odor Control Master Plan), which is focused on the Morris Forman Service Area. MSD also contracted with a public relations firm to increase public engagement and communications during development and implementation of the phased Odor Control Master Plan.

The Morris Forman WQTC, constructed and commissioned in 1958, is currently the largest wastewater treatment plant in the state of Kentucky. Located in the western region of Louisville along the Ohio River, the plant is responsible for treating 120 MGD of dry weather flow and a peak capacity of 350 MGD during wet weather flow conditions.

Despite recent efforts by MSD to reduce odor emissions generated from the Morris Forman WQTC through development and phased implementation of the 2001 Morris Forman Odor Control Master Plan and 2009 follow-up report, the neighboring community has experienced odors leading to a significant amount of complaints, specifically during the summer of 2019. Primary affected residents were in the Chickasaw, California, and Park DuValle neighborhoods.

1.2 Purpose

This technical memorandum is intended to identify new odor technologies that may be potential options to implement into the Morris Forman WQTC.

1.3 Previous Documentation and Implementation Schedule

In accordance with the agreed order, MSD has submitted several documents to APCD to demonstrate ongoing odor control efforts. Table 1 shows MSD's completed and ongoing efforts towards the APCD agreed order.

Table 1 – Phase I Master Plan Implementation Schedule

Title		Due Date	Status
TM#1	Morris Forman WQTC Background Document Review	Q1 2021	Completed
TM#2	Collection System Background Document Review	Q2 2021	Completed
TM#3	Pump Stations Background Document Review	Q2 2021	Completed
TM#4	WQTC, Pump Stations and Combined Sewer System Planned Process Modifications	Q1 2021	Completed
TM#5	Current WQTC, Pumping Stations and Combined Sewer System Odor Impact Evaluation	Q2 2021	Completed
TM#6A, TM#6B, TM #6C	Morris Forman WQTC (TM#6A), Collection System (TM #6B), and Pump Stations (TM #6C) Sampling Phase Results Analysis	Q4 2022	Completed
TM#7A, TM#7B, TM#7C	Morris Forman WQTC Current Odor Technologies Performance Evaluation Collection System Current Odor Technologies Performance Evaluation Pump Stations Current Odor Technologies Performance Evaluation	Q4 2022	Completed
TM#8	**New Odor Control Technologies Recommendation**	**Q4 2022**	**Ongoing**
TM#9	**Odor Control Conceptual Design**	**Q4 2022**	**Ongoing**
Odor Control Master Plan Phase I Final Report		**Q4 2022**	**Ongoing***

**- The Final Odor Control Master Plan Phase I Final Report will be a comprehensive document which includes information about the Morris Forman Collection System, WQTC, and selected pump stations.*

2. Summary of Sampling Results

Liquid and Vapor sampling was performed in 2020, 2021, and 2022 at multiple locations within the Morris Forman WQTC. The sampling program and full summary of results can be found in TM #6A under separate cover. The results were analyzed, and locations were assigned an odor control priority as shown in Table 2.

Table 2 – Morris Forman WQTC and Bells Lane WWTF Sampling Results Summary

Sampling Location	Target Limit Exceedance(s)**	Odor Control Priority
U7: Sed. Basin #4 Weir	Odor	High
U1: Aerated Influent Channel	Odor, H_2S	High
U2: Sed. Basin #1 Inlet	Odor, Dimethyl Disulfide	High
U8: Sed. Basin Eff. Channel	Odor	High
U3: Sed. Basin #1 Outlet	Odor	High
U5: Sed. Basin #4 Inlet	Odor	High
U4: Sed. Basin #1 Weir	Odor	High
17B: Fugitive Dust Scrubber # 2 Outlet	Odor, Methyl Mercaptan, Dimethyl Sulfide	High
U6: Sed. Basin #4 Outlet	Odor	High
17A: Fugitive Dust Scrubber # 1 Outlet	Odor, Ammonia, Methyl Mercaptan, Dimethyl Sulfide	High
4B: West Headworks Grit Channel	Odor	High
B1: Bells Lane WWTF Splitter Structure #2	Odor, Butyraldehyde	High
1: DAFT Exhaust	Odor	High
4A: East Headworks Grit Channel	Odor	High
14A: RTO # 1 Outlet	Odor, Ammonia, Methyl Mercaptan, Dimethyl Sulfide	High
14B: RTO # 2 Outlet	Odor, Methyl Mercaptan, Dimethyl Sulfide	High-Low
10: Dewatering Building Exhaust	Odor	High-Low
3: West Headworks	Odor	High-Low
9: Digester	Odor	High-Low
12: Silo Dust Scrubber Outlet	Odor, Methyl Mercaptan	High-Low
2A: East Headworks 1st Floor	Odor	Low
5: Dumpster Room	Odor	Low
2B: East Headworks 2nd Floor	Odor	Low
18: MEB Exhaust	Odor	Low
B3: Bells Lane WWTF Grit Dumpster	Odor, Butyraldehyde	Low

B2: Bells Lane WWTF HRTB Influent	Odor	Low
13A: RTO #1 Inlet	Odor, Methyl Mercaptan	N/A*
13B: RTO #2 Inlet	Odor, Methyl Mercaptan, Dimethyl Sulfide	N/A*
B4: Bells Lane WWTF Grit Tank Influent	-	N/A*

* The inlet odor parameters are less important than the odor outlet parameters.
** MSD is only required to meet the liquid discharge regulations and the APCD standard for gaseous H_2S concentrations at the source

The Biotower Odor Control (BOC) was sampled in 2008 and was shown to have an average outlet H_2S removal efficiency of 99% and an average outlet odor concentration removal efficiency of 47%. This odor concentration was taken at the source, not at the fence line. The odor removal efficiency was generally low, but the unit is not designed to have a specific target for odor removal. The BOC will be evaluated as part of the odor control master plan for future odor control measures.

The Solids Handling Odor Control (SHOC) was sampled for H_2S and other reduced sulfur compounds (RSCs) in 2012 and 2013. It was shown to have an H_2S removal efficiency of 99% and a total reduced sulfur (TRS) removal efficiency of 88.9%-95.9% which exceeded the manufacturer's target performance levels. However, further evaluation of the SHOC using an air dispersion model showed the SHOC had a large impact on the overall odor contribution in the surrounding area. The unit was not designed to have a specific target for odor removal, but since the odor contribution to the surrounding area is so high, potential odor control measures to reduce the odor emissions will be considered.

Based on these results, odor control will be considered at the following locations:

- Sedimentation Basins/BOC
- East and West Headworks
- DAFT/ Main Equipment Building Exhaust
- SHOC
- RTOs
- Fugitive Dust Wet Scrubbers

The Digesters were evaluated as part of the air dispersion modeling effort and have a limited impact beyond the fence line. Therefore, the Digesters will not be evaluated for future odor control modifications.

3. Odor Control Technology Review

Feasible odor control technologies were identified and evaluated for odor removal efficiency, applicability, advantages, and disadvantages. Factors such as land footprint and cost considerations were also outlined for each technology. Table 3 identifies the various odor control measures which were considered for inclusion in the Odor Control Master Plan. Multi-stage treatment configurations will also be considered which involve staging of two or more technologies described herein.

Table 3 - Odor Treatment Technology Summary

Odor Control Technology		Description	Configuration(s)
1	Adsorption	Attachment of odorous compounds to surfaces	Dry media scrubbers, fixed bed reactors, or adsorber wheel; Can be combined with thermal gas treatment or biofiltration
2	Absorption	Oxidation and dissolution of odorous compounds	Jet and venturi scrubbers, plate columns, and spray scrubbers
3	Biological Waste Gas Treatment	Degradation of odorous compounds via microorganisms	Biofilters, bioscrubbers, and biotrickling filters
4	Photoionization (UV)	Use of ultraviolet (UV) light and catalyst to oxidize odorous compounds and a carbon unit for polishing	Ionization chambers
5	Hydroxyl Generator	Use of UV or water and electricity to oxidize odorous compounds via hydroxyl molecules	Positive pressure systems involving process fans

3.1 Adsorption

Adsorption involves the attachment of odorous compounds to a solid surface and is typically performed in conjunction with biological treatment. Common adsorbents include activated carbon, activated alumina, and silica gels. Carbon has a high surface-to-volume ratio, providing a large amount of surface area for odors to be adsorbed. The media adsorbs a wide variety of odorous compounds including H_2S and odor causing organic compounds. In an activated carbon odor treatment system, pollutants are removed from the air by physical adsorption onto the surface of the activated carbon particles. Media specific to odor control applications can be modified with alumina, or other chemical binders, which also absorb and oxidize adsorbed odor contaminants. The odorous gases are collected and held within the media pores where the contaminants are oxidized and converted to a harmless solid substance which remains in the media. Other dry media types can be combined with activated carbon media within an odor control system to enhance the odor removal performance of the unit. Media impregnated with potassium or sodium permanganate increase the range of odor causing compounds which can be removed from an odorous inlet airflow. Organic compounds, along with reduced sulfur compounds, aldehydes, and H_2S, can be removed by these types of dry media. An example photo of a carbon adsorption system is shown in Figure 1.

Operation of dry media odor control units is straightforward. The media bed can be arranged for either vertical or horizontal airflow through the treatment vessel. Vertical airflow systems are usually contained within cylindrical vessels where odorous air enters the bottom of the unit and flows upwards through the media to be discharged from the top of the unit. Horizontal airflow units arrange the media in a “V” shape from the bottom to top of the unit vessel. Air passes through the “V” media beds from the open end of the “V” to the point at the exhaust side. Horizontal airflow vessels are not as tall as cylindrical units and are supplied with access hatches on the top of the unit for easy media replacement. Due to the short retention time required in a dry media system, the footprint of an adsorption vessel is less than that of a biofilter while being able to control the same wide range of odor causing compounds.

Figure 1 – Example Carbon Adsorption System

Dry media selected for odor control applications must be capable of performing within an airstream that has a high relative humidity when removing odors from a wastewater source. Humidity in wastewater applications can reach over 98%. Condensation can wet the dry media and fill void spaces that are the sites of odor removal. Media with hydrophobic properties can resist high humidity environments, but further protection from condensation and water droplets may be required. A mist eliminator should be installed on the inlet side of the vessel to trap any fines, greases, or water droplets entrained within the airstream. Inlet dehumidification may be required in very wet inlet airflows where ambient and process temperature differences will lead to significant condensation formation. Dehumidifiers warm the air to reduce the relative humidity of the air and help to warm the media and process vessel. While effective, dehumidification is an energy intensive process that is high in operating and maintenance costs. Keeping the inlet odorous air, dry media, and vessel close in temperature range minimizes condensation formation without the need for dehumidification. This can be achieved by insulating the dry media unit to minimize the temperature difference between the media, vessel walls, and process air.

Dry media units are sized based on the mass inlet loading of odorous compounds and the inlet air velocity. To ensure a reasonable media life, the volume of dry media within a vessel can be sized to hold a specific mass of odor compounds. Dry media removes 99.5% of all inlet odor compounds until the media capacity to do so has been reached. The media in a unit is spent when all the void space within the media is full with adsorbed and oxidized odor contaminants. When this occurs any additional odor compounds will pass through the vessel until the existing media is replaced with a new batch. The life of the media will be longer with lower inlet odor concentrations. When odor loading is high, the void space in the media is more rapidly filled which reduces the system life and increases the frequency of media replacement.

3.2 Absorption

Absorption involves the dissolution of vapor compounds in a scrubbing liquid. Mass transfer is commonly controlled by the solubility of the substances and the gas–liquid interface. The solubility is affected by the selection of the solvent. Densely packed columns are used frequently, as these provide a large interfacial surface. Other devices which are used include jet and venturi scrubbers, plate columns, and spray scrubbers. Accumulation of the waste vapor components in the scrubbing liquid would result in a finite amount of mass transfer, therefore, the scrubbing liquid must be replaced, updated, or regenerated.

Regeneration of the scrubbing liquid can be performed by stripping with air or steam. Similar to adsorption, the objective is to maintain a desorbate flow with a higher concentration than the original incoming airflow. Aqueous scrubbing liquids can also be biologically regenerated using Bioscrubbers. Chemicals can be added to the scrubbing liquid which will react with the dissolved waste gas compounds and improve the scrubbing liquid regeneration (e.g., chemical scrubbers). In these cases, removal of reaction products should be verified.

The use of oxidants is the most common application in chemical scrubbing. Besides ozone (O3) and hydrogen peroxide (H2O2), sodium hypochlorite (NaOCl) is used due to its low-cost and ease of use. A drawback of hypochlorite is the tendency to not only oxidize but also chlorinate the compounds. NaOCl will most easily chlorinate amines and similar basic compounds. To limit compound chlorination, a sulfuric acid scrubber prior to the hypochlorite scrubber can be used to remove amines and other compounds. The small amounts of produced chlorine can then be absorbed in a third scrubber. This three-stage system is a common and effective approach for mitigating odors in wastewater treatment plants.

A disadvantage of adsorption technologies involves the considerable amounts of chemicals required, and the requirement to remove, treat, and dispose of the reaction products. Acidic substances, like hydrogen sulfide (H2S) can be treated with caustic scrubbers using diluted sodium or potassium hydroxide for the removal of organic sulfur compounds.

3.3 Biological Treatment

Biological systems rely on the activity of microorganisms to degrade organic contaminants from the vapor stream. The microorganisms feed on odorous substances and oxidize them. The oxidation is a conversion from the odorous compounds to CO_2, H_2O, or another other odorless compound(s). Therefore, biological systems sustainably reduce odorous emissions and do not leave residues (such as scrubbing liquids or adsorbents). In addition, biological treatments inherently do not require the addition of chemical agents and do not have large associated energy costs as they are operated at atmospheric pressure and ambient temperatures. The materials, installation, and operational costs for biological systems are often the lowest among odor control technologies.

3.3.1 Biofilters

Biofiltration is an odor control technology involving physical adsorption, aqueous absorption, and bacterial oxidation of odorous compounds. Fundamentally, a biofilter is a box filled with a media such as soil, compost, or an engineered inorganic substrate, to support the growth of bacteria which metabolize odorous compounds present in a foul air stream. Biofilters have been used to treat odors in several different applications ranging from various wastewater treatment plant processes, pumping stations, collection systems, and food waste recycling plants among others.

Biofilters are versatile in their design and can be constructed as in-ground basins, stand-alone containers, or above-ground units. Units can be provided as packaged systems with their own Stainless Steel or Fiber Reinforced Plastic vessels (see Figure 2 for example), or they can be constructed on-site with the pouring of a concrete vessel. Modular units include a fan and exhaust stack and can treat flow rates up to 10,000 cfm. Biofilters can be either covered by a roof or removable panels or left uncovered for air to disperse directly out from the media. Covered designs allow treated air to be routed to an external stack for discharge and produce an elevated dispersion profile of exhausted air. The design of large units is more expensive in capital cost, but it provides better performance in terms of off-site odor impingement to the sensitive receptors.

A disadvantage of biofilters is that sulfurous and nitrogenous organic or inorganic compounds that transit through the filter bed media can cause acidification due to their oxidization products (e.g., sulfuric, and nitric acid). In these situations, a combination with other treatment processes should be considered.

Due to the relatively long retention time through the media bed, the technology is best suited for moderate airflow volumes. Large airflow rates will require a larger footprint and may only be practical if the space for a unit is available.

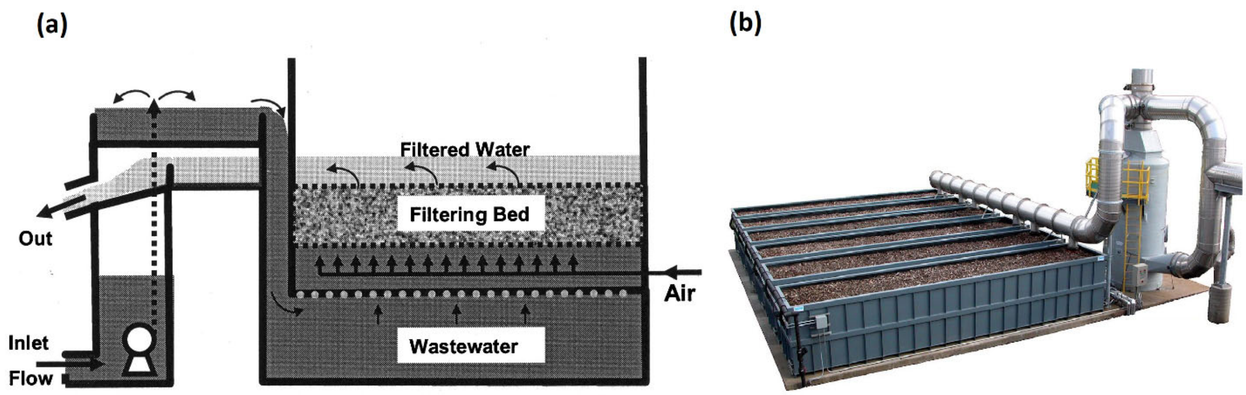

Figure 2 - Example of Biofilter Configurations at Wastewater Treatment Plants

(a) adapted from Verma et al. 2006; (b) adapted from RJM Company

Different types of media can be utilized in a biofilter system. Practical experience has shown that yard compost, sludge compost, and wood and bark chips are used in removing H_2S and other odor causing contaminants. Engineered inorganic media has been developed using inert substrates on which various buffers and nutrients have been impregnated to support an optimal environment for microbial oxidation of odorous compounds. The engineered media is resilient to compaction and settling which lead to an increased pressure drop across the media and reduced removal efficiencies. Compared to organic media, engineered inorganic media generally has higher and more consistent removal efficiency along with a longer media life. Media replacement is between 2 to 4 years for organic media and 10+ years for engineered inorganic media.

Biofilters are very effective at treating a wide range of odor causing compounds including H_2S, organic reduced sulfur compounds (such as methyl mercaptan (MM), dimethyl sulfide (DMS), and ethyl mercaptan (EtSH)), and selected volatile organic compounds (VOCs) when the contaminants loadings are within the limits of the biofilter media performance removal. When the average H_2S inlet loading is above 30 ppm, the pH of the bed is prone to be lowered due to the higher incidence of sulfuric acid as a by-product of microbial H_2S metabolization. This can reduce the removal of organic reduced sulfur compounds and VOCs, as these compounds are more readily oxidized at a neutral bed pH. At high H_2S inlet concentrations (>30 ppm), the biofilter also starts to oxidize H_2S to elemental sulfur which deposits inside the media and can result in a higher pressure drop across the media. Greater pressure drop requires more power to be consumed by the biofilter process fan to move the odorous air through the media bed for treatment. If H_2S inlet concentrations are lower, i.e., average of nearly 0 ppm for an extended period (3 to 4 months), there will be a drop in microbe population, as the H_2S "food" is in lower supply. The system will continue to remove H_2S, but if the biofilter is turned off for an extended period, the population of microbes metabolizing the odor contaminants will die off. This does not impact the life expectancy of the media, and the system can be returned to operation. Over a few weeks of operation, the microbe population will grow back to consume and treat the inlet H_2S. Removal efficiency will increase, as the microbe population is reinstated during the acclimation period. This also occurs during system start-up and commissioning. Vendors recommend performance testing of a new system to be completed following a three (3) to four (4) week acclimation period.

Biofilters require less maintenance than other odor treatment technologies, as there are limited moving parts aside from the process fan(s) and pump(s) for recycling pre-treatment humidification water. Inorganic media is designed to last 10 years or more and therefore will rarely require removal and replacement. Water is needed to humidify the inlet air to 99% relative humidity to aid in the biofiltration process or for irrigation of the media as specified by the vendor. The humidification chamber can be integrated into a packaged or on-site constructed concrete biofilter vessel.

To operate a biofilter, inlet air travels through a packing material which is continuously sprayed with water. The packing and spraying create water droplets through turbulence which increases the water surface area and aids in humidifying the inlet air stream. The humidity in the air aids in the adsorption of odorous contaminants onto the moist biofilm which surrounds the media treatment particles and supports the odor metabolizing microbes. Water also needs to be applied to the media bed at vendor defined intervals to keep the biofilter media bed moist and to remove biomass or elemental sulfur buildup. This process is called irrigation and typically occurs for an hour or two every few days. The water used in the humidification chamber can be collected in a sump and recirculated back through the spray headers and packing, while the water for irrigation cannot be recycled since it contains the removed biomass and elemental sulfur. If a bioscrubber unit is paired upstream with a biofilter system, a humidification system is no longer required.

Typical removal efficiency of H_2S through a biofilter is 99%. This is accompanied with removal of other odor causing compounds such as those present in the STS air; MM, DMS, and EtSH. Odor is removed by greater than 90% as well.

3.3.2 Bioscrubbers

Bioscrubbers are similar to biofilters, as they are both based on aqueous adsorption, absorption, and bacterial oxidation of the odorous contaminants. Similar to a biofilter, odorous air in a bioscrubber is moved through a bed of high surface area media in which microorganisms grow and biodegrade the odorous contaminants of the inlet air. The media used in bioscrubbers is inorganic and engineered by specialist vendors to withstand a low pH (1-3) environment which develops through oxidation of H_2S in the system. The media is designed to last for 10 years or more and is typically guaranteed for 10 years of service before requiring a media bed change out. In contrast to biofilters where irrigation is periodic, water is continuously sprayed and distributed over the top of the media counter-currently to the flow of air. This humidifies the air in the same was as a dedicated humidification chamber. Airflow travels from underneath the media, up through the bed, and then out of the unit to further treatment stages or directly exhausted to the atmosphere. Horizontal airflow through a bioscrubber system is therefore not common. Due to the bottom-up airflow configuration, bioscrubbers are commonly designed in a tower configuration. To lower the height of a bioscrubber treatment tower, some vendors offer units which come with several individual bioscrubber cells which each treat a fraction of the overall system airflow. However, this requires a larger quantity of process piping and media to maintain. Concrete vessels can be used to house bioscrubbers. However due to the low pH of recycled process water in the system, vessels need to be lined for corrosion protection. The benefits of a concrete vessel include a reduced system height, as the system footprint can be poured on-site and enlarged over a pre-constructed fiber-reinforced plastic tower unit.

The water spray headers are located at the top of the vessel and deliver water down onto the top of the media counter-current to the airflow direction. Water percolates through the media and is collected at the bottom of the vessel in a sump. Water is returned to the spray headers at the top of the unit through recirculation pumps located adjacent to the units. The microbes which oxidize H_2S prefer an acidic environment and create sulfuric acid as a by-product of H_2S treatment. The pH of the recirculated water in the system is at an optimal condition when ranging from 1 to 3. To maintain the quality of the recirculated water, a small percentage is drained and replaced with clean water in the bioscrubber sump. An example picture and schematic of a bioscrubber is shown in Figure 3.

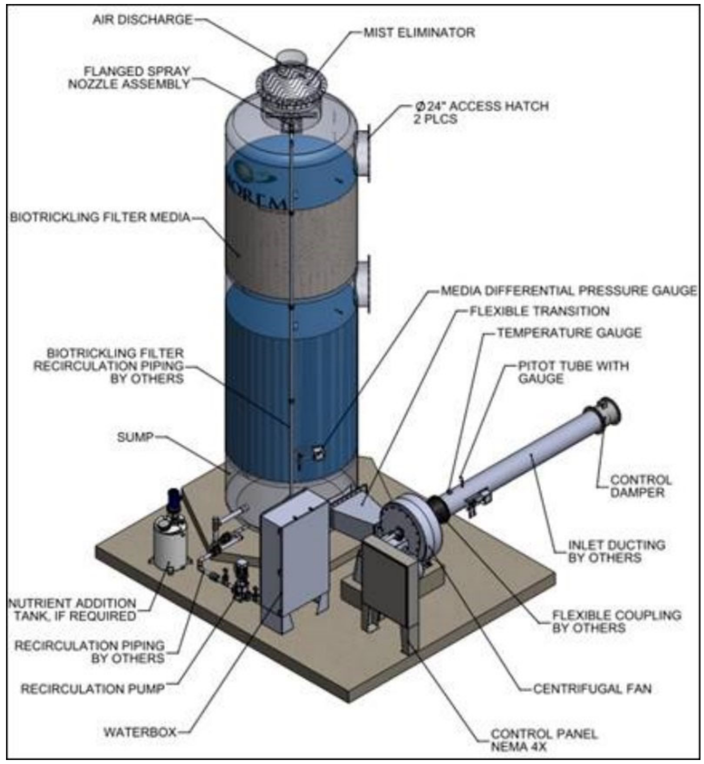

Figure 3 – Example Bioscrubber Filter System

Since the pH of the recirculated water is low (1-3), the water that is drained to maintain water quality in the scrubber unit may need to have its pH neutralized. Most clients dictate the minimum or maximum pH of a solution that can be drained into sewer systems. A caustic addition system can be used to dose the drained water with a basic solution to neutralize the pH to meet these requirements. However, the use of caustic can create handling and safety issues for maintenance. Therefore, the addition of a caustic system should be avoided, if possible, to minimize maintenance and chemical handling by operations staff.

Bioscrubbers have a lower media bed retention time than biofilters. The reduced retention time results in a lower volume of media required to treat the inlet odorous air. The footprint of bioscrubbers is therefore smaller than that of biofilter systems. Bioscrubbers are excellent at removing high levels of H_2S, over a range of 50 to 400 ppm, but they have limited capacity in removing other compounds such as MM, DMS, EtSH and VOCs. For this reason, bioscrubbers are most effective for applications where inlet H_2S levels are high. However, they do still remove low level H_2S concentrations effectively. For example, AECOM has installed bioscrubber systems in applications where the average H_2S concentration is 2 ppm. The systems run effectively at the low H_2S level, while providing capacity for higher levels of H_2S is present in the future. Like biofilters, the microbe population which metabolizes the odor compounds grows to equilibrium with the available "food" (H_2S). Odor removal for a bioscrubber only system is low at a minimum of 75%. This is due to the low removal rates of the reduced sulfur compounds aside from H_2S.

The presence of other odor causing compounds requires a second stage treatment technology to maximize removal efficiencies. When paired with a second stage such as dry media or photoionization technology, the system can be highly effective at cleaning air with multiple odor compounds and a high H_2S loading. The upstream bioscrubber would act as pre-treatment stage to remove inlet H_2S, and the dry media unit would capture the remaining low concentration odor contaminants and any remaining H_2S. Because the media bed life of a dry media system is determined by the concentration of inlet odor contaminants, removing H_2S with a bioscrubber upstream of a dry media unit extends the life expectancy of the dry media.

Bioscrubber maintenance is similar to that of an inorganic media based biofilter, aside from requiring a nutrient solution to be added to the recirculated water in the system to support the health of the microbes. Water is continuously sprayed over the media bed to assist in phase transfer of the contaminants, to supply nutrients, and to promote favorable microbial environmental conditions. The nutrient solution can be continually added to the recirculated water using small metering pumps. The nutrient solution can be pumped out of a dedicated storage tank, but the solution will need to be mixed and prepared by maintenance staff at least once a month. If exposed to the elements, the water in the bioscrubber sump can freeze during winter months. Consequently, the water will need to be heated to maintain the temperature of the inlet air at, or above, 50°F. Below 50°F, the microbes begin to slow the rate at which they oxidize H_2S. This will reduce the removal efficiency performance of the system. To warm the water and air, an immersion heater can be installed within the sump and programmed to turn on below a certain water temperature. To ensure the heater element is not exposed to the inlet air, the level of the sump water must be monitored by an ultrasonic device, or float switch. If the water level drops too low, the heater will shut-off and will not turn-on until the water level is restored. By enclosing the bioscrubber system and sump within a dedicated heated building, heating requirements for the sump water will be reduced, as the unit would be better protected from the elements and ambient temperature.

3.3.3 Biotrickling Filters

These systems work similarly in that they use microorganisms, media, and water. Odorous or polluted air is collected and forced up through the structured media within the vessel. But in biotrickling filters, the microorganisms grow within the media.

The key differentiator of biotrickling filters is that they do not recirculate water. The water used in these systems passes through only once to rinse the metabolized compounds away and to provide nutrients for the optimal growth of microbes. And while at first glance this might seem inefficient, biotrickling filters and bioscrubbers actually use identical amounts of water to treat identical airflows. An example schematic biotrickling filter is shown in Figure 4.

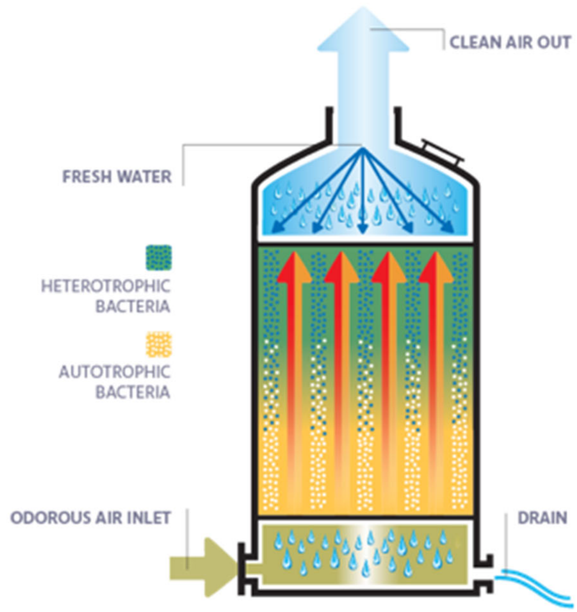

Figure 4 – Example Biotrickling Schematic

Research has shown that biotrickling filters support a greater diversity of bacteria. As impacted air is forced upward through the vessel, it encounters different types of microorganisms. That diversity has been shown to eliminate a larger quantity and variety of the compounds produced in industrial processes. This is why biotrickling filters can remove a host of compounds —such as H2S, NH3, volatile fatty acids, organic odors and select VOCs— with great efficiency.

In addition to being more effective than bioscrubbers, biotrickling filters also are less expensive, have lower operating costs, and are easier to maintain because they do not include the extra pumps and piping necessary for water recirculation.

3.4 Photoionization (UV)

Photoionization utilizes ultraviolet (UV) light and a catalyst to oxidize odor compounds such as H_2S. The system is composed of ionization chambers where UV bulbs produce hydroxyl and oxygen radicals. The radicals react with and oxidize the odor compounds within the inlet airflow in the presence of the UV chamber and catalyst. The catalyst is typically a carbon based medium and captures compounds not broken down within the UV chamber. The technology is very effective at oxidizing and removing wastewater odors. Its performance is also not negatively impacted by high inlet air humidity and can be turned off for extended periods of time without reducing the systems performance once returned to operation. No water or additives are needed for system operation. Only electricity to power the UV bulbs is needed.

UV systems have the ability to achieve 99.5% removal of influent H_2S. As the concentration increases the removal efficiency also increases. This is due to the treatment limits of RSCs compared to the moderate average concentration loadings. Odor concentrations are reduced by at least 99%. However, while used in Europe for more than a decade, using photoionization to treat odors in North America is relatively new when compared to other treatment methods. As a result, the reliability and effectiveness of this treatment method is not as well established as bio-treatment or carbon media.

If the reaction within the ionization chamber is not fully complete, oxygen radicals can pass through the system and be discharged into the environment. The catalyst captures any remaining radicals, as they are highly oxidative and hazardous if they come into contact with oxidants or people. Ozone monitors will be equipped on the exhaust to ensure that the treatment system is shutdown if ozone is detected in the treated air, but regular maintenance of the UV bulbs and catalyst are the best practice to avoid any breakthrough. Yearly replacement of the catalyst and UV bulbs is required to maintain a properly functioning system.

Access to the bulbs and catalyst is through a maintenance door on each treatment chamber. The system runs under negative pressure with the process fans on the clean-air side of the photoionization unit pulling air through the treatment equipment. This arrangement is needed, as air can leak through the chamber doors. If air is being pushed through the unit, rather than pulled, untreated air or ions can escape through leaks in the doors. By running under negative pressure, any air leaks will bring ambient air into the system instead.

Photoionization systems are composed of individual treatment chambers which have a set airflow capacity, shown in Figure 5. To create a system sized to treat the required airflow, the chambers are added together into units until the cumulative airflow capacity of all the photoionization chambers equal that of the inlet airflow volume. Depending on the system vendor, between 14 to 20 UV bulbs will be installed in each chamber. These UV bulbs are responsible for the high energy demand of photoionization systems (38 kW), which is the highest of all the single-stage technologies evaluated.

Figure 5 - Photoionization Example Photo

Source: Neutralox Umwelttechnik GmbH represented by Ambio

3.5 Hydroxyl Generator

Hydroxyl generators create hydroxyl radicals (OH) using ozone, water, and air which are blown via a process fan into the headspace to remove contaminants. These units use positive pressure to move the radicals into the area where odors are to be treated which differs from photoionization where the treatment occurs under negative pressure within the UV chamber and catalyst. Some manufacturers utilize UV bulbs and optics to create radicals for odor containment oxidation. Figure 6 shows a unit with UV.

The pH in wet well areas can reach low levels depending on the chemistry of the wastewater, which causes corrosion. A hydroxyl generator can raise the pH closer to neutral, thereby reducing corrosion on the infrastructure. In addition, hydroxyl radicals can break down the double carbon bonds that form fatty acid chains which reduces odor compounds and fats, oils, and grease (FOG) within the system.

Hydroxyl generators can be installed indoors or outdoors and can be integrated into an existing HVAC system. The units are relatively small and can treat a large area.. The hydroxyl generator is recommended to be installed outside of the area treated for the odorous compounds. The unit is using ambient air and since it is resulting in an additional volume of air, a vent or goose neck is recommended to discharge the treated air outdoors.

Figure 6 – Hydroxyl Generator Example Photo – Unit with UV (Pyure Dynamic Protection)

3.6 Technologies Comparison Summary

Table 4 outlines the advantages and disadvantages of each potential odor control technology considered as part of this memorandum.

Table 4 – Odor Control Technologies Evaluation

Technology	Advantages	Disadvantages
Adsorption	• Excellent removal efficiency for odor, H2S, and RSC removal • Equipment is technologically simple and adaptable to many treatment formats • Wide range of commercial products available • Wide variety of target contaminants	• Activated carbon adsorption can be costly on the media replacement frequency • Non-selective method • May have additional requirements based on the type of adsorbent applied • Requires regeneration or replacement of adsorbent material • Often results in rapid saturation and clogging of reactors without a dehumidification system
Absorption	• High efficiency for RSC and odor removal • Rapid treatment • Potential for water recycling • Disinfectant (bacteria and viruses) • Increases biodegradability of product	• Chemical inputs required • Production, transportation, and management of oxidants required • Efficiency is dependent by type of oxidant • Potential formation of intermediates including chlorine and amines • Potential sludge production
Biofiltration	• Low capital costs • Efficiently eliminates biodegradable organic matter • High removal of BOD and suspended solids	• Requires maintenance of optimal conditions for organisms • Slow process • Potential sludge production and uncontrolled degradation products • High H2S peak loadings may cause biofilter to acidify
Bioscrubber	• High reliability and efficiency for H2S removal	• Performance is dependent on operation of recirculation system • Lower removal efficiencies for RSCs • Water demand requirements for recirculation system
Biotrickling	• High reliability and efficiency for H_2S removal	• Performance is dependent on operation of recirculation system • Lower removal efficiencies for RSCs • Water demand requirements for recirculation system
Photoionization (UV)	• High efficiency for odor, H2S, and RSC removal • Minimal impacts from high inlet air humidity • Minimal space requirements	• Relatively new technology for odor control application • Safety and environmental concerns due to possibility of unreacted radicals remaining in air stream • High energy demand requirements • High maintenance requirements
Hydroxyl Generator	• High efficiency for odor, H2S, and RSC removal • Minimal space requirements • Green technology due to low noise, small footprint, chemical and waste free technology	• Safety and environmental concerns due to possibility of unreacted radicals remaining in air stream • May not be suitable for occupied buildings/facilities

4. New Odor Technologies Recommendation

As described in Section 2, odor control was considered at five (5) locations within the Morris Forman WQTC based on the sampling results and air dispersion modeling. A description of the results at each plant location, along with the recommended technology is described in the following sub-sections.

4.1 Sedimentation Basins/BOC System

The sampling results for the sedimentation basins, fully described in TM #6A, indicate that odor and H_2S levels are high at this location. MSD is currently working with a design engineer to incorporate odor control on the sedimentation basins. The proposed system involves rehabilitation of the biotrickling filters and replacement of the media. This new odor control system should remove 99.9% of H_2S but is not designed to reduce odor. A second treatment stage may be considered to handle odor once the main system is installed. Once the new odor control system is installed and commissioned, performance testing is recommended to confirm removal efficiency. A multi-media carbon unit is recommended to be installed as a polishing unit on the BOC to reduce the odor emission concentration.

4.2 East and West Headworks

The East and West Headworks buildings and grit channels were all sampled as part of the recent sampling campaign (see TM #6A). The results indicate high odor and H_2S levels are present within the East and West Headworks. In order to mitigate these odor issues, it is recommended that covers are installed on the open channel portions of the flow train, and either a biofilter with synthetic media or a biotrickling filter is installed for the Headworks. The Biofilter and Biotrickling media would be designed to reduce both the odor and H_2S levels within the East and West Headworks including the Dumpster Building, but the Biofilter would require a larger footprint that may not be available at the Headworks area. A biotrickliing filter is a tower installation, so it typically requires less of a footprint. The biotrickling filter may also need carbon polishing incorporated as well to further reduce odor emissions.

4.3 DAFT/Main Equipment Building Exhaust

The DAFT system and Main Equipment Building exhaust at the Morris Forman WQTC had high odor levels when sampled during the recent sampling campaign. In order to reduce the odor, a biofilter with synthetic media or a biotrickling filter is recommended at this location. The proposed unit would manage the high odor levels present in the DAFT unit and Main Equipment Building exhaust.

4.4 SHOC

The SHOC had high H_2S and TRS removal efficiency, in addition, the air dispersion modeling showed the SHOC had a large impact on the overall odor contribution in the surrounding area. Therefore, it is recommended that additional odor control units be considered here. A multi-media carbon unit is recommended to handle the odorous air after it goes through the SHOC to reduce odor emissions.

4.5 RTOs

Testing performed as part of commissioning of the RTOs indicated that the percent odor reduction was high, and the methyl mercaptan and dimethyl disulfide concentrations were also elevated. However, the preliminary air dispersion model results do not indicate the RTOs as contributing a large amount of odor to the surrounding area. As a result, no additional odor control is recommended currently for the RTOs. These units can be re-evaluated in future phases of the odor control master plan if deemed necessary.

4.6 Fugitive Dust Wet Scrubber

Testing performed as part of commissioning of the Fugitive Dust Wet Scrubber indicated that the units had high odor concentrations, and elevated methyl mercaptan, dimethyl disulfide, and ammonia. The Fugitive Dust Wet Scrubber was also shown in the air dispersion model to have a moderate impact on the surrounding community. However, no additional odor control is currently recommended for the Fugitive Dust Wet Scrubbers. This system can be re-evaluated in future phases of the odor control master plan if deemed necessary.

5. Conclusions

As previously described, an odor control system is proposed to be installed on the Sedimentation Basins/BOC System, East and West Headworks, DAFT Exhaust/Main Equipment Building Exhaust, and SHOC. Conceptual design information on the selected technologies discussed above will be developed next and provided as part of TM #9, and the Odor Control Master Plan will include final recommendations.