Morris Forman WQTC Odor Control Master Plan Interim Final Report

Louisville and Jefferson County Metropolitan Sewer District

December 2021

Revision History

Revision	Revision date	Details
0	12-13-2021	Interim Final Report

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****Sections 6 through 10 will be developed following the completion of the ongoing Emergency Dryer Replacement project and subsequent liquid and air phase sampling for inclusion into Final Report***

Figures

Tables

Acronyms and Abbreviations

Acronym/ Abbreviation	Description
APCD	Louisville Metro Air Pollution Control District
ASTM	American Society for Testing and Materials
BOC	Biological Odor Control
BOD5	Biological Oxygen Demand
CFR	Code of Federal Regulations
DO	Dissolved oxygen
D/T	Dilution-to-Threshold
DAFT	Dissolved Air Flotation Thickening
EPA	Environmental Protection Agency
H_2S	Hydrogen sulfide
m	Meter
MFWQTC	Morris Forman Water Quality Treatment Center
m^3/s	Cubic meters per second
MEB	Main Equipment Building
MGD	Million gallons per day
MSD	Louisville and Jefferson County Metropolitan Sewer District
NOV	Notice of Violation
OCMP	Odor Control Master Plan
OSHA	Occupational Safety and Health Administration
ou	Odor unit
PM	Particulate matter
ppb	Parts per billion
ppm	Parts per million
PRV	Pressure Relief Valve
RSC	Reduced Sulfide Compound
RTO	Regenerative Thermal Oxidizers
SHOC	Solids Handling Odor Control
TM	Technical Memorandum
TRS	Total Reduced Sulfur
TUC	Truck Unloading Station
VOC	Volatile Organic Compound
WQTC	Water Quality Treatment Center

1. Executive Summary

1.1 Background

In response to receiving a Notice of Violation (NOV) in November 2019 for failure to control foul odors from the Morris Forman Water Quality 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 a consulting engineering firm (Consultant) 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 WQTC. 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.

This Interim Final Report was developed to document the initial phases of the phased Odor Control Master Plan with primary focus on the Morris Forman WQTC. An updated version of this report (Final Report) will be submitted to APCD tentative no later than December 31, 2022 following the completion of ongoing odor control improvements at the Morris Forman WQTC and the second phase of the Morris Forman WQTC Sampling Program.

1.2 Odor Control Master Plan Development

In accordance with the agreed order, MSD has submitted several technical memoranda to demonstrate ongoing odor control efforts. This Interim Final Report was developed to summarize relevant information included in Technical Memoranda Nos. 1 through 7 (**Table 1-1**) in preparation of the development of a preferred odor control design concept for the Morris Forman WQTC. The main objectives of this Interim Report are to:

1. Identify specific odor sources at the Morris Forman WQTC that may contribute to nuisance conditions;
2. Conduct liquid and vapor sampling at critical process areas;
3. Characterize and evaluate the performance for existing odor control systems and odor control technologies;
4. Investigate potential odor control solutions and treatment technologies required to meet the overall design criteria established by MSD; and
5. Develop an updated implementation schedule for the completion of Phase I of the Odor Control Master Plan in accordance with the Agreed Order.

Development of the Odor Control Master Plan included vapor sampling throughout the Plant to assess existing odor conditions at critical process areas. Phase 1 of the Morris Forman WQTC Sampling Program was performed in June 2021 which involved sampling at the Digesters and Headworks facilities. Phase 2 will be implemented following the completion of ongoing odor control improvements in 2022 at the Main Equipment Building and Solids Handling Odor Control (SHOC) system. The final compilation of sampling results will be used to identify and evaluate potential Plant-wide odor control improvements.

Existing odor control technologies at the Plant were characterized and evaluated for current performance and will be further evaluated in the next version of this report following ongoing improvement projects. A detailed review of potential odor control technologies was also performed in preparation of the development of plant-wide odor control alternatives.

1.3 Implementation Schedule

The Phase I Odor Control Master Plan Implementation Schedule has been developed to document MSD's completed and ongoing efforts towards the APCD agreed order.

Table 1-1 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#6	WQTC Sampling Program Phase Results Analysis	Q4 2021	Completed*
TM#7	Current Odor Technologies Performance Evaluation	Q3 2021	Completed
TM#8	**New Odor Control Technologies Recommendation**	**Q3 2022**	**Ongoing****
TM#9	**Odor Control Conceptual Design**	**Q3 2022**	**Ongoing****
Odor Control Master Plan Phase I Final Report		**Q4 2022**	**Ongoing**

**- Phase 1 of the Morris Forman WQTC Sampling Program was completed in Autumn 2021 and sampling results were summarized in an interim TM. A final version of TM#6 will be published following the completion of Phase 2 air sampling.*

***- TM#8 and TM#9 will be submitted following completion of ongoing Emergency Dryer Replacement project and subsequent liquid and air phase sampling.*

****- TM#5, TM#6, and TM#7 were developed using available data and information and will be updated following the completion of ongoing improvements at the WQTC and subsequent liquid and air sampling.*

The Final Report will include the following sections in addition to the contents included in this Interim Report:

- Morris Forman WQTC Phase 2 Sampling Results

- Collection System Phase 2 Sampling Results
- Current Odor Technologies Evaluation for newly commissioned RTOs, MEB Acid Scrubbers, MEB Fugitive Dust Wet Scrubbers, and MEB Silo Dust Wet Scrubber
- Dispersion Modelling
- Odor Control Design Alternatives
- Feasibility Assessment
- Selected Odor Control Design Alternative
- Proposed Implementation Schedule

The development of the Final Report will include an evaluation of several plant-wide alternatives to meet or exceed the goal of reducing the odor concentration at selected receptors to 20 D/T in accordance with MSD's design criteria threshold. Odor control improvements will be selected based on a planning level feasibility analysis and estimated costs of implementation. Refer to the Table of Contents included in this report for a complete list of sections to be included in the Final Report.

2. Introduction

2.1 Background

The Morris Forman Water Quality Treatment Center (WQTC, Plant), 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 the Louisville and Jefferson County Metropolitan Sewer District (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 foul odors leading to a significant amount of nuisance complaints, specifically during the summer of 2019. Primary affected residents were in the Chickasaw, California, and Park DuValle neighborhoods.

On November 4, 2019, MSD received a Notice of Violation (NOV) from the Louisville Metro Air Pollution Control District (APCD) which indicated that MSD had failed to control objectionable odors from the Morris Forman WQTC and its combined sewer collection system during July and August 2019. To address the violations alleged in Case No. ENF-19-00025, MSD entered into an agreed order which requires the development and implementation of a District-wide Odor Control Master Plan which will be completed in multiple phases over the course of several years. MSD contracted an engineering consulting firm (Consultant) to provide technical assistance in the development of Phase I of the Odor Control Master Plan with priority on the Morris Forman Service Area.

2.2 Purpose and Implementation Schedule

The purpose of this Interim Final Report is to summarize the findings and recommendations to date under Phase I of MSD's Odor Control Master Plan with primary focus on odor mitigation at the Morris Forman WQTC. This document will be updated following ongoing and future odor control improvements and corresponding sampling efforts and a final version will be submitted to APCD no later than Q4 2022 in accordance with the agreed order.

In accordance with the agreed order, MSD shall also submit nine (9) technical memoranda throughout Phase I of the Odor Control Master Plan to demonstrate MSD's continued odor control efforts. **Table 2-1** summarizes the implementation schedule developed to meet the agreed order including each deliverable title, due date, and submittal date, if applicable. These technical memoranda were released periodically to APCD and posted to the MSD website for public use.

Table 2-1 Phase I Master Plan Implementation Schedule

Title		Due Date	Date Submitted
TM#1	Morris Forman WQTC Background Document Review	Q1 2021	2/16/2021
TM#2	Collection System Background Document Review	Q2 2021	4/7/2021
TM#3	Pump Stations Background Document Review	Q2 2021	5/4/2021
TM#4	WQTC, Pump Stations and Combined Sewer System Planned Process Modifications	Q1 2021	3/23/2021
TM#5	Current WQTC, Pumping Stations and Combined Sewer System Odor Impact Evaluation	Q2 2021	6/21/2021
TM#6	WQTC Sampling Program Phase Results Analysis	Q4 2021	12/30/2021
TM#7	Current Odor Technologies Performance Evaluation	Q3 2021	9/24/2021
TM#8	**New Odor Control Technologies Recommendation**	**Q3 2022**	**Ongoing****
TM#9	**Odor Control Conceptual Design**	**Q3 2022**	**Ongoing****
Odor Control Master Plan Phase I Final Report		**Q4 2022**	**Ongoing**

**- Phase 1 of the Morris Forman WQTC Sampling Program was completed in Autumn 2021 and sampling results were summarized in an interim TM. A final version of TM#6 will be published following the completion of Phase 2 air sampling.*

***- TM#8 and TM#9 will be submitted following completion of ongoing Emergency Dryer Replacement project and subsequent liquid and air phase sampling.*

****- TM#5, TM#6, and TM#7 were developed using available data and information and will be updated following the completion of ongoing improvements at the WQTC and subsequent liquid and air sampling.*

This Interim Report summarizes the information included in Technical Memoranda Nos. 1 through 7 and presents the findings to date under Phase I of the Odor Control Master Plan. Future sampling efforts, development and selection of a recommended odor control design concept for the Morris Forman WQTCs will be further detailed in the Odor Control Master Plan Phase I Final Report (Final Report).The Final Report will also include the additional sections listed in the Table of Contents.

2.3 Background Documentation

Prior to the development of this report, a detailed review and analysis of existing documentation was performed in relation to odor control at the Morris Forman WQTC. Background documentation included previous studies, reports, field sampling and performance testing data to gain an understanding of MSD’s odor control efforts to date and to investigate current odor conditions in specific process areas. Key findings of the background documentation review process for the Morris Forman WQTC can be found in **TM#1**.

In 2001, MSD contracted a consulting engineering firm to perform an odor control evaluation of the Morris Forman WQTC. The report, which is referred to as the 2001 OCMP, provided a phased approach to odor mitigation at the WQTC, including recommended operational adjustments, improvements to the Biotower odor control system and installation of a dedicated odor control system at the Headworks and Aerated Influent Channel. The estimated capital cost for a Headworks odor control system was $1.67 Million, in 2001 dollars, with the assumption that biofiltration was the selected odor control technology.

In 2009, a follow-up report was developed which documented the completion of the control improvements listed above and re-evaluated the initial OCMP implementation strategy based on updated sampling and dispersion modeling results. MSD is currently in the process of implementing odor control projects identified as part of the 2009 planning study, including replacement of the Sludge Dryer system at the Main Equipment Building (MEB), rehabilitation of the Sedimentation Basins and Aerated Influent Channel, and digester improvements. **Table 2-2** shows the completion status of major odor control projects identified in previous planning reports.

Table 2-2 Summary of Completed and Ongoing Odor Control Projects

Description		Year(s) Completed
1	Replacement of fume incinerators with Solids Handling Odor Control (SHOC)	2006; Rebuilt in 2011
2	Screw Conveyer improvements at the Main Equipment Building	2006
3	Digester valving improvements	2006
4	Replacement of existing chemical scrubbers with Biological Odor Control (BOC)	2007
5	Upgrades to the existing grit channel covers	2008
6	Control of Primary Clarifier and Aerated Influent Channel Emissions	Ongoing
7	Upgrades to MEB odor control systems including replacement of sludge dryer system, Regenerative Thermal Oxidizers (RTOs), main process wet scrubber, and fugitive dust wet scrubber	Ongoing

As part of the document review process, available field sampling and testing data related to WQTC odor conditions and odor control system performance were compiled and evaluated at the WQTC. Completion dates spanned from 2001 and 2020. Available sampling data included gas and liquid phase sampling for odor concentration, reduced sulfide compound (RSC) concentrations and hydrogen sulfide (H_2S) monitoring at specific locations throughout the WQTC. **Table 2-3** summarizes the available background data provided by MSD for initial evaluation purposes.

Table 2-3 Background Data Summary

	Field Sampling	Date(s) Completed
1	Gas and liquid phase sampling and H_2S monitoring at (14) process area locations	2001
2	Gas sampling and H_2S monitoring at the Main Equipment Building (MEB), Dissolved Air Floatation Thickening (DAFT), Truck Unloading Station (TUS) and Digester Pressure Relief Valves (PRVs)	2007
3	Gas and liquid phase sampling and H_2S monitoring at (26) process area locations	July-August 2008
4	Gas and liquid phase sampling and H_2S monitoring at Sedimentation Basins and Aerated Influent Channel	September 2020
	Performance Testing	**Date(s) Completed**
1	Solids Handling Odor Control (SHOC) Performance testing	August 2008; April 2013
2	Biological Odor Control (BOC) Performance Testing	September 2008

For further details regarding WQTC background documentation, please refer to **TM#1**. Ongoing and planned improvements are detailed in **Section 4.3** of this report.

2.4 Design Basis and Objectives

The overall purpose of this Odor Control Master Plan is to provide site-specific, cost-effective odor controls which will meet reduce odor emissions from major odor sources at the Morris Forman WQTC and meet the desired odor detection threshold of 20 D/T at critical receptors within the surrounding community.

The Odor Control Master Plan will evaluate a reasonable range of operational and chemical treatment alternatives required to meet the design criteria. Affordability, odor performance and implementation requirements will be considered to help guide selection of the preferred alternatives. In addition, public and regulatory agency input will be considered during development of alternatives.

The following key tasks will be performed as part of this Master Plan:

1. Identification of specific odor sources that may contribute to nuisance conditions;
2. Evaluation of current performance for existing odor control systems and technologies;
3. Preparation and implementation of a vapor and liquid sampling program to evaluate current odor impacts at specific process areas;
4. Investigation of potential odor control solutions and treatment technologies required to meet the overall design criteria established by MSD;

5. Determination of recommended design parameters for existing and future odor treatment technologies;
6. Construction and utilization of an updated air dispersion model to assess odor impacts based on predicted emissions and meteorological data;
7. Performance of a feasibility assessment for each of the three (3) odor treatment design concepts; and
8. Development of an implementation schedule for the selected odor control alternative.

2.5 Community Issues

The Morris Forman WQTC is located in a mixed industrial/residential area of Metro Louisville. Several industrial properties are located adjacent to the Plant including Valero, Buckeye Terminals, Whayne Trucks and the Firearms Training Center. The Park DuValle residential neighborhood is located about 0.7 miles to the east and the Chickasaw neighborhood is located about 0.5 miles to the north.

An overview map of the Morris Forman WQTC is provided in **Figure 2-1** and identifies customer odor complaint locations, MSD-owned property boundaries and adjacent properties which may potentially be impacted by Plant odor emissions.

The performance of this Odor Control Master Plan will be evaluated based on air dispersion modelling and response from adjacent private properties and residents in the Chickasaw, Park DuValle neighborhoods.

Morris Forman WQTC
Community Overview Map
Figure 2-1

2.6 Public Engagement and Communications

MSD contracted a public relations firm to increase public engagement and communications during development and implementation of the phased Odor Control Master Plan. In 2021, MSD launched the “clAIRity” Program which is a proactive odor control initiative designed to reduce sewer and wastewater treatment odors across the system. A webpage for the clAIRity Program is published onto MSD’s website and includes the following:

- Informational brochures and procedures related to odor emissions and proactive control measures;
- Access to the monthly odor complaint log, Odor Control Communication Plan, and technical memoranda developed under this Odor Control Master Plan;
- Updates on MSD’s odor control efforts through community meetings.

2.7 Existing System Configuration

The Morris Forman WQTC began operations in 1958 and is classified as a conventional extended aeration activated sludge process plant. The Plant is currently equipped to treat 120 MGD of dry weather flow and 350 MGD of wet weather flow in addition to solids handling processing abilities. Each major process area is further discussed within this Section.

2.7.1 *Primary Treatment Facilities*

Raw wastewater is conveyed to the Plant Influent Junction structure through the 132-inch Ohio River Interceptor before entering the Headworks. The WQTC is currently equipped with two (2) Headworks facilities. The East Headworks is the primary headworks facility and the West Headworks is used for wet weather flows. The West Headworks is original to the 1958 Plant and is equipped with a dedicated screening facility, grit removal via the West Grit Channel, aeration system and drainage pumping.

In 1998, MSD installed the East Headworks as the primary facility. The East Headworks takes in raw wastewater via Parshall Flumes prior to the screening and grit removal process. After passing through the East Headworks Grit Channel, screened wastewater enters the Aerated Influent Channel.

The screenings and grit removed from the raw wastewater are transferred via belt conveyors to containers for hauling to a commercial landfill. The partially treated wastewater flows through the Aerated Influent Channel into four (4) rectangular Sedimentation Basins, also referred to as Primary Clarifiers. The settled solids are removed from the bottom of the Sedimentation Tanks by scrapers supported from carriages moving on rails. The monorake mechanism also skims floating material (scum) from the surface of the wastewater in the sedimentation tanks. The raw primary sludge is pumped from hoppers in the ends of the sedimentation tank floors to four (4) anaerobic digesters. Collected scum is also pumped to the digesters.

2.7.2 *Secondary Treatment Facilities*

Secondary treatment facilities include five (5) oxygenation trains operated in parallel and twenty (20) final settling tanks, or Secondary Clarifiers. The WQTC is rated for a secondary treatment capacity of 120 MGD and an increasingly reduced performance up to a flow of 140 MGD. All discharge flow from the primary system in excess of 140 MGD and up to 350 MGD bypass the secondary system is conveyed directly into the Chlorine Contact Chambers.

In the 1970s, the oxygenation trains were added to the secondary treatment system to provide extended aeration to primary effluent from the Sedimentation Basins. Each oxygenation train consists of four (4) successive aeration chambers. Oxygen gas and return sludge are added to the wastewater in the first chamber of each train. Each aeration chamber is also equipped with a mixer to provide suspension of solids. A new oxygen plant replaced the original system in 2018.

Mixed liquor effluent from the oxygenation trains flow into the Secondary Clarifiers where flows are distributed equally between each clarifier. Settled sludge from the clarifiers are recycled to the oxygenation trains or wasted to the sludge thickeners.

The Chlorine Contact Chambers consist of two (2) flow chambers and may be operated using either the single or dual chambers. The dual chambers provide a minimum contact period of 11 minutes at the peak flow rate of 350 MGD. Disinfection of the flow is accomplished by injecting a solution of sodium hypochlorite (bleach) into the secondary effluent. Dechlorination is performed by the addition of sodium bisulfite prior to discharging the effluent to the Ohio River.

2.7.3 *Solids Handling Facilities*

Primary sludge undergoes biological treatment via four (4) anaerobic digesters. Waste activated sludge is thickened by eight (8) Dissolved Air Flotation Thickening (DAFT) units housed in the Main Equipment Building. Five (5) high-speed solid bowl centrifuges are used to dewater the thickened waste activated sludge and digested primary sludge. The treated and dewatered sludge is used for land application.

Additional solids handling equipment is housed in the MEB including a sludge dryer and pelletization system, sludge dewatering equipment, and fugitive dust processing units.

2.7.4 *Laboratory Facilities*

The Plant maintains a fully staffed on-site laboratory for the daily analysis of process control and compliance samples. The laboratory is also responsible for analysis of industrial and commercial effluents sampled by MSD's Industrial Compliance and Monitoring Department.

2.7.5 *Existing Odor Control Systems*

To mitigate odor emissions from the process areas listed above, MSD currently operates several odor control systems at the WQTC which are summarized below**.**

- <u>Solids Handling Odor Control (SHOC)</u> – Installed in 2006 and rebuilt in 2011, the SHOC system was designed to replace the fume incinerators for treatment of foul air from the Main Equipment Building and Sludge Holding Tanks. One of the existing fume incinerators remained as a backup to the SHOC system until 2007 when it was decommissioned.
- <u>Biotower Odor Control (BOC)</u> – The Plant’s BOC system was upgraded in 2007 to replace the original chemical scrubbers serving the Bioroughing

towers. The existing BOC system treats foul air from the Aerated Influent Channel. The Bioroughing Towers are not currently in service.

- Regenerative Thermal Oxidizers (RTOs) – Housed in the Main Equipment Building, the RTOs currently treat foul air from solids handling processes primarily the sludge dewatering and sludge drying systems.
- MEB Main Process Wet Scrubbers – The MEB is currently equipped with two (2) venturi scrubbers designed to treat foul air and dust streams produced during the sludge dewatering and drying process.

Detailed evaluations of the odor control systems listed above, and ongoing odor control improvements are included in **Section 3.2.1** of this report.

3. Existing Odor Impact Evaluation

Findings from the background documentation review process were consolidated to establish a comprehensive list of potential odor sources and associated priority ratings. **TM#5** discusses the results of the priority rating process based on previous sampling data, proximity to identified odor hot spots, and current operation status. Using the findings of the odor impact evaluation, high priority odor sources were selected for inclusion into Phase I of the Morris Forman WQTC Sampling Program. A consulting engineering firm was contracted to perform the field sampling and coordinate the laboratory results.

This Section discusses the existing odor impact assessment based on previous sampling reports and the development and partial implementation of the Morris Forman WQTC Sampling Program. An updated compilation of sampling results will be included in the Final Report.

3.1 Existing Odor Assessment

The findings of the background documentation process were consolidated to identify major odor sources at the WQTC. Available odor-related data was compiled from previous sampling and planning studies to determine the following parameters for each potential odor source:

- Average odor concentration (D/T)
- Average hydrogen sulfide (H_2S) concentration
- Average reduced sulfur compound (RSC) concentrations – Carbonyl Sulfide (COS), Methyl Mercaptan (MM), Dimethyl Sulfide (DMS) concentrations

The key parameters listed above were evaluated along with MSD staff field observations to determine a generalized “priority ranking” for each potential odor source, which represents the current odor impact to the surrounding community. **Table 3-1** summarizes the results of the existing odor source identification and ranking process.

Table 3-1 Existing Odor Impact Evaluation

	Odor Source	Avg. Odor Conc. (D/T)	Avg. H_2S Conc. (ppm)	Avg. COS Conc (ppm)	Avg. MM Conc. (ppm)	Avg. DMS Conc. (ppm)	Date(s) of Sampling	Priority Ranking (1)	Status
1	BOCs (Bioway) (2)	5,400	0.11	0.12	0.39	0.91	2008	High	Active
2	SHOC (Biorem) (2)	4,900	0.18	0.06	0.43	0.53	2008-2009	High	Active
3	RTOs (2)	335	0.02	-	-	-	H_2S 2001, Odor 2004	Low	Active / Planned Improvements
4	DAFT (2)	665	0.22	0.004	0.04	<0.003	2008	Low	Active / Planned Improvements
5	West “Old” Headworks	4,750	1.41	0.01	0.02	<0.003	2008	High	Active
6	East “New” Headworks	1,035-4,700 (3)	0.35-1.89 (3)	0.01	0.05	<0.001	2008	High	Active
7	Aerated Influent Channel & Junction Chamber	308,000	44.0	ND (5)	0.61	0.80	2020	High	Active / Planned Improvements
8	Aerated Grit Channels (East and West)	5,500	52.10	0.02	0.58	0.01	2008	High	Active
9	Sedimentation Basins (Primary Clarifiers)	18,300-346,667 (4)	0.7-20.1 (4)	ND-0.03 (4)	0.16-0.62 (4)	0.04-0.130 (4)	2020	High	Active / Planned Improvements
10	MEB Solids Exhaust	240	0.13	0.01	0.01	<0.001	2008	Low	Active / Planned Improvements
11	MEB Dryer Area Exhaust Fans	905	0.20	0.01	0.01	<0.003	2008	Moderate	Active / Planned Improvements
12	Sludge Holding Tanks	-	69.66	-	-	-	2008-2009	Moderate	Active / Planned Improvements
13	Sludge Receiving Tanks	-	6.02	-	-	-	2008-2009	Moderate	Out of Service
14	Digesters	127,000	210.50	0.03	<5	0.06	2008	High	Active / Planned Improvements
15	Bioroughing Towers	6,600	6.80	0.01	0.56	0.03	2008	High	Out of Service

Notes:

(1) **Priority Rating** based on subjective analysis of available odor concentration (D/T), H_2S, RSC concentration data, and proximity to customer odor complaints.
(2) Outlet Concentration Data was used to determine odor emissions following odor control system treatment.
(3) Range represents average odor concentrations at upper and lower levels of Headworks.
(4) Range of average H_2S concentration at Sedimentation Basin No. 1 and No. 4 Outlet and Effluent Weirs
(5) ND = Compound was analyzed for, but not detected above the laboratory reported limit

3.2 Sampling Program

Major odor-emitting processes at the Morris Forman WQTC were targeted for a vapor sampling program to determine the existing odor conditions at process area. Sampling procedures were developed and implemented to evaluate the concentration of relevant contaminants from existing infrastructure, recently implemented infrastructure which has not been evaluated in detail, and infrastructure that is currently under development or considered for future development.

The Morris Forman WQTC Sampling Program will consist of (2) phases:

- **Phase 1 – Existing Process Areas**: June 14, June 15, and June 22, 2021
- **Phase 2 – Future Improved Process Areas**: Ongoing

Phase 1 involved sampling of existing odor processes and was performed on June 14, 15 and 22, 2021. Phase 2 will be performed following the completion of ongoing and future odor control improvements including SHOC upgrades, BOC system upgrades, and process improvements under the Emergency Dryer Replacement project.

Table 3-2 summarizes the sampling parameters, description and corresponding standard or guideline used during the Sampling Program. Samples were obtained when odor control systems and related equipment were fully operational. For sampling locations with quiescent surfaces such as the Digesters, a surface emission flux chamber was used and sweep air was added to the chamber at a controlled, fixed rate. A vacuum chamber, pump and Tygon tubing was used at point sources to prevent contamination of air samples.

Specific sampling parameters included in the phased Morris Forman WQTC Sampling Program are listed for each sampling location in **Table 3-3**. Refer to **TM#6** for detailed sampling results from Phase 1 of the Morris Forman WQTC Sampling Program.

Table 3-2 Sampling Program Parameters

	Sampling Parameter	Description	Standard/ Guideline
1	Odor	10-liter Tedlar bag grab samples collected and shipped to St. Croix Sensory to measure odor detectability as Detection-to-Threshold (D/T)	ASTM E679-91/ E544-99
2	Reduced Sulfur Compounds (RSC)	3-liter Tedlar bag grab samples collected and shipped to ALS Environmental for analytical analysis	ASTM 5504-12
3	Volatile Organic Compounds (VOCs)	3-liter Tedlar bag grab samples collected in pre-calibrated canisters and shipped to ALS Environmental for analytical analysis	EPA TO-15
4	Ammonia	Air samples pulled from odor and RSC grab sample bags and tested on-site using GASTEC detector tubes and pump model GV-100S	EPA CTM 027
5	Amines	Sorbent tubes used to collect air samples and shipped to ALS Environmental for analytical analysis	OSHA Method 40
6	Dust (Particulate Matter)*	Particulate matter collected on a glass fiber filter and shipped for analytical analysis	EPA 40 CFR 60 Appendix A Method 5
7	Source Exhaust Air Flow*	Measured using metal pitot tube, flux chamber or vacuum chamber and pump	EPA 40 CFR 60 Appendix A Method 2
8	Instantaneous Hydrogen Sulfide (H_2S)	H_2S analyzers used to measure and instantaneous H_2S concentration using Arizona Instruments Jerome 631X	-

**- Dust / PM and Source Exhaust Air Flow will be measured in Phase 2 of the Morris Forman WQTC Sampling Program*

Table 3-3 Sampling Program Overview

ID	Sampling Location	Sampling Phase	Vapor Sampling Parameter								
			Odor	RSC	Ammonia	Amines	VOC	Aldehydes	Dust (PM)	Airflow	H_2S (2)
1	DAFT Outlet	2	✓	✓	✓	✓	✓				✓
U1	Sedimentation Basins	2	✓	✓							✓
2A	East Headworks 1st Floor Exhaust	1	✓	✓	✓	✓	✓				✓
2B	East Headworks 2nd Floor Exhaust	1	✓	✓	✓	✓	✓				✓
3	West Headworks Exhaust	1	✓	✓	✓	✓	✓				✓
4A	East Headworks Grit Channel	1	✓	✓	✓	✓	✓				✓
4B	West Headworks Grit Channel	1	✓	✓	✓	✓	✓				✓
5	Dumpster Room	1	✓	✓							✓
6	SHOC Inlet	2	✓	✓	✓	✓	✓	✓			✓
7A	SHOC Bioscrubber #1 Outlet	2	✓	✓	✓	✓	✓	✓		✓	✓
7B	SHOC Bioscrubber #2 Outlet	2	✓	✓	✓	✓	✓	✓		✓	✓
8	Solids Holding Tanks (SHT)	2	✓	✓	✓	✓	✓				✓
9	Annular Space Between Digesters	1	✓	✓		✓	✓				✓
10	MEB Dewatering Area Exhaust	2	✓	✓	✓	✓	✓				✓
11	Silo Dust Wet Scrubber Inlet	2	✓	✓	✓	✓					✓
12	Silo Dust Wet Scrubber Outlet	2	✓	✓	✓	✓	✓		✓	✓	✓
13A	RTO #1 Inlet	2	✓	✓	✓	✓	✓				✓
13B	RTO #2 Inlet	2	✓	✓	✓	✓	✓				✓
14A	RTO #1 Outlet	2	✓	✓	✓	✓	✓			✓	✓
14B	RTO #2 Outlet	2	✓	✓	✓	✓	✓			✓	✓
15	Fugitive Dust Wet Scrubber #1 Inlet	2	✓	✓	✓	✓			✓		✓
16	Fugitive Dust Wet Scrubber #2 Inlet	2	✓	✓	✓	✓			✓		✓
17A	Fugitive Dust Wet Scrubber #1 Outlet	2	✓	✓	✓	✓			✓	✓	✓
17B	Fugitive Dust Wet Scrubber #2 Outlet	2	✓	✓	✓	✓			✓	✓	✓
U2	BOC Inlet	2	✓	✓	✓	✓		✓			✓
U3	BOC Outlet	2	✓	✓	✓	✓		✓		✓	✓

(1) Sampling Locations included in Morris Forman WQTC Sampling Phase 2 are considered preliminary and are subject to change in quantity or location based on available performance testing results provided by odor control equipment manufacturer(s).

(2) Instantaneous H_2S concentration

3.2.1 *Phase 1 Sampling Results*

Phase 1 of the Morris Forman WQTC Sampling Program included evaluation of the following vapor properties for the selected process areas listed in **Table 3-2**:

1. Odor concentration (D/T);
2. Instantaneous H_2S concentration;
3. Reduced sulfur compound (RSC) concentrations including H_2S, Carbonyl Sulfide (COS), Methyl Mercaptan (MM), Dimethyl Sulfide (DMS), Carbon Disulfide (CDS), Dimethyl Disulfide (DMDS), and Diethyl Sulfide (DES);
4. Amines including Diethylamine, Dimethylamine, Ethylamine, and Methylamine; and
5. VOC concentrations including propene, Dichlorodifluoromethane (CFC 12), Ethanol, Acetone, Trichlorofluoromethane (CFC 11), 2-Propanol, Methylene Chloride, Carbon Disulfide, 2-Butanone (MEK), cis-1,2-Dichloroethene, Ethyl Acetate, n-Hexane, Chloroform, Benzene, Bromodichloromethane, n-Heptane, Toluene, n-Octane, Tetrachloroethene, Ethylbenzene, m,p-Xylenes, Styrene, o-Xylene, n-Nonane, Cumene, alpha-Pinene, n-Propylbenzene, 4-Ethyltoluene, 1,3,5-Trimethylbenzene, 1,2,4-Trimethylbenzene, 1,4-Dichlorobenzene and d-Limonene.

Table 3-4 summarizes the Phase 1 Sampling Program results for Items 1 through 4 above. Three (3) grab samples were obtained from each sampling location for odor, H_2S and RSC analysis with the exception of the West Grit Channel which consisted of two (2) grab samples. The analytical results were averaged for each sampling parameter to determine an average representative value. If an analyte was detected above the Minimum Reporting Limit (MRL) in one or two of the grab samples while the other samples were non-detectable (ND) for a corresponding location, then the average value was calculated assuming the ND samples were equal to the MRL. This approach is considered conservative for evaluating analytical results. The MRL for H_2S, COS, MM, DMS, and DES is 5 ppmV and the MRL for CDS and Dimethyl Disulfide DMDS is 2.5 ppmV.

A summary of the VOC sampling results is provided in **Table 3-5**. One (1) grab sample was collected and analyzed for each sampling location.

Table 3-4 Sampling Program Phase 1 Results Summary – Odor, H_2S, RSC and Amines

Odor Source		Avg. Odor Conc. (D/T)	Inst. H_2S (ppbV)	Avg. RSC Concentrations (ppm)							Amines
				H_2S	COS	MM	DMS	CDS	DES	DMDS	
2A	**East Headworks 1st Floor Exhaust**	817	67.7	193	ND	6	ND	ND	ND	ND	ND
2B	**East Headworks 2nd Floor Exhaust**	330	33.0	60	ND	ND	ND	ND	ND	ND	ND
3	**West Headworks Exhaust**	E	E	345	ND	12	ND	ND	ND	ND	ND
4A	**East Headworks Grit Channel**	3733	330.0	297	ND	9	ND	ND	ND	ND	ND
4B	**West Headworks Grit Channel**	E	E	27,667	ND	447	71	9	5	-	ND
5	**Dumpster Room**	1300	30.7	11	58	58	4	9	5	-	ND
9	**Annular Space Between Digesters**	1117	186.7	863	ND	6	ND	ND	ND	ND	ND

H_2S= Hydrogen Sulfide
COS=Carbonyl Sulfide
MM=Methyl Mercaptan
DMS=Dimethyl Sulfide
CDS= Carbon Disulfide
DES=Diethyl Sulfide

DMDS= Dimethyl Disulfide

Notes:
(1) ND = Compound was analyzed for, but not detected above the laboratory reported limit
(2) E= Instrument Error

Table 3-5 Sampling Program Phase 1 Results Summary – VOCs

Compound	Sampling Location					
	East HW 1st Floor	East HW 2nd Floor	Dumpster Room	East HW Grit Channel	West HW Grit Channel	Digesters
Propene	0.57	0.98	1.5	7.4	ND	ND
Dichlorodifluoromethane (CFC 12)	0.42	0.41	ND	0.44	0.36	0.37
Ethanol	1,700	600	5,500	110	7.20	4.60
Acetonitrile	ND	ND	ND	1.9	ND	ND
Acrolein	ND	0.70	ND	ND	ND	ND
Acetone	9.7	8.5	25	15	ND	ND
Trichlorofluoromethane (CFC 11)	0.20	0.21	ND	ND	0.16	0.16
2-Propanol (Isopropyl Alcohol)	ND	1.9	ND	2.6	ND	ND
Methylene Chloride	0.24	0.22	ND	ND	ND	ND
Carbon Disulfide	0.58	1.0	2.4	3.9	ND	ND
2-Butanone (MEK)	1.1	1.1	2.4	1.9	ND	ND
cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND
Ethyl Acetate	6.5	89	16	2.0	1.40	ND
n-Hexane	1.3	1.4	1.1	2.9	ND	ND
Chloroform	1.4	0.71	1.9	ND	ND	ND
Benzene	0.27	0.79	2.0	3.7	ND	ND
Bromodichloromethane	0.11	ND	ND	ND	ND	ND
n-Heptane	0.49	0.56	ND	3.0	ND	ND
Toluene	5.2	6.2	2.2	11	ND	ND
n-Octane	0.19	0.26	ND	4.1	ND	ND
Tetrachloroethene	ND	0.15	0.59	0.75	ND	ND
Ethylbenzene	0.24	0.26	ND	ND	ND	ND
m,p-Xylenes	0.79	0.87	ND	ND	ND	ND
Styrene	1.3	0.71	ND	0.47	ND	ND
o-Xylene	0.28	0.34	ND	ND	ND	ND
n-Nonane	ND	0.18	ND	3.8	ND	ND
Cumene	ND	ND	0.83	0.36	ND	ND
alpha-Pinene	0.14	0.97	1.7	4.6	ND	ND
n-Propylbenzene	ND	ND	ND	ND	ND	ND
4-Ethyltoluene	ND	ND	ND	ND	ND	ND
1,3,5-Trimethylbenzene	ND	ND	ND	ND	ND	ND
1,2,4-Trimethylbenzene	0.20	0.28	ND	ND	ND	ND
1,4-Dichlorobenzene	0.19	ND	ND	ND	ND	ND
d-Limonene	5.1	18	83	92	ND	ND

4. Current Odor Control Technologies Evaluation

4.1 Current Odor Technologies Characterization

The Plant is currently equipped with several odor control technologies for the treatment of foul air generated from various process areas. A summary of the existing and planned future odor control systems at the WQTC provided in **Table 4-1.** An evaluation was performed to assess the existing conditions of each odor control system and discussed in this Section.

Table 4-1 Existing Odor Control Technologies Summary

	Odor Control System	Manufacturer/ Model	# of Units	Year Installed	Associated Odor Source(s)
1	BOC	Bioway Purspring 1000	(2)	2007	Aerated Influent Channel
2	SHOC	Biorem Biofiltair	(2)	2006; Rebuilt in 2011	MEB Dewatering Area (1), Sludge Holding Tanks
3	RTOs (2)	Gulf Coast Environmental Systems 100-95-RTO	(2)	Ongoing	MEB Dewatering Area, MEB Sludge Drying Area (1)
4	MEB Acid Scrubbers (2)	Andritz TOP-85 DT-CB/SUMP-VT520'2 OT-DB-SS	(2)	Ongoing	MEB Dewatering Area, MEB Sludge Drying Area (1)
5	MEB Fugitive Dust Wet Scrubbers (2)	Monroe Environmental DT-3000-SS	(2)	Ongoing	MEB Sludge Drying Area Fugitive Dust
6	MEB Silo Dust Wet Scrubber (2)	Monroe Environmental DT-1000	(1)	Ongoing	MEB Storage Silos Fugitive Dust

(1) – MEB Dewatering Area and MEB Sludge Drying Area process sludge from the Digesters as well as hauled sludge.

(2) – MSD is currently in construction phases of the Emergency Dryer Replacement Project which involves installation of new RTOs, MEB Acid Scrubbers, MEB Fugitive Dust Wet Scrubbers, and MEB Silo Dust Wet Scrubber.

The RTOs, MEB Acid Scrubbers, MEB Fugitive Dust Wet Scrubbers, and MEB Silo Dust Wet Scrubber are currently being installed under the Emergency Dryer Replacement Project which is expected to be commissioned in early 2022.

Updated process flow diagrams depicting the existing and planned future odor control systems at Morris Forman WQTC are included in **Figure 4-1** and **Figure 4-2**. These diagrams also show each of the two (2) potential odor control alternatives currently being considered at the existing BOC system under the Rehabilitation and Replacement of Primary Sedimentation Basins Project.

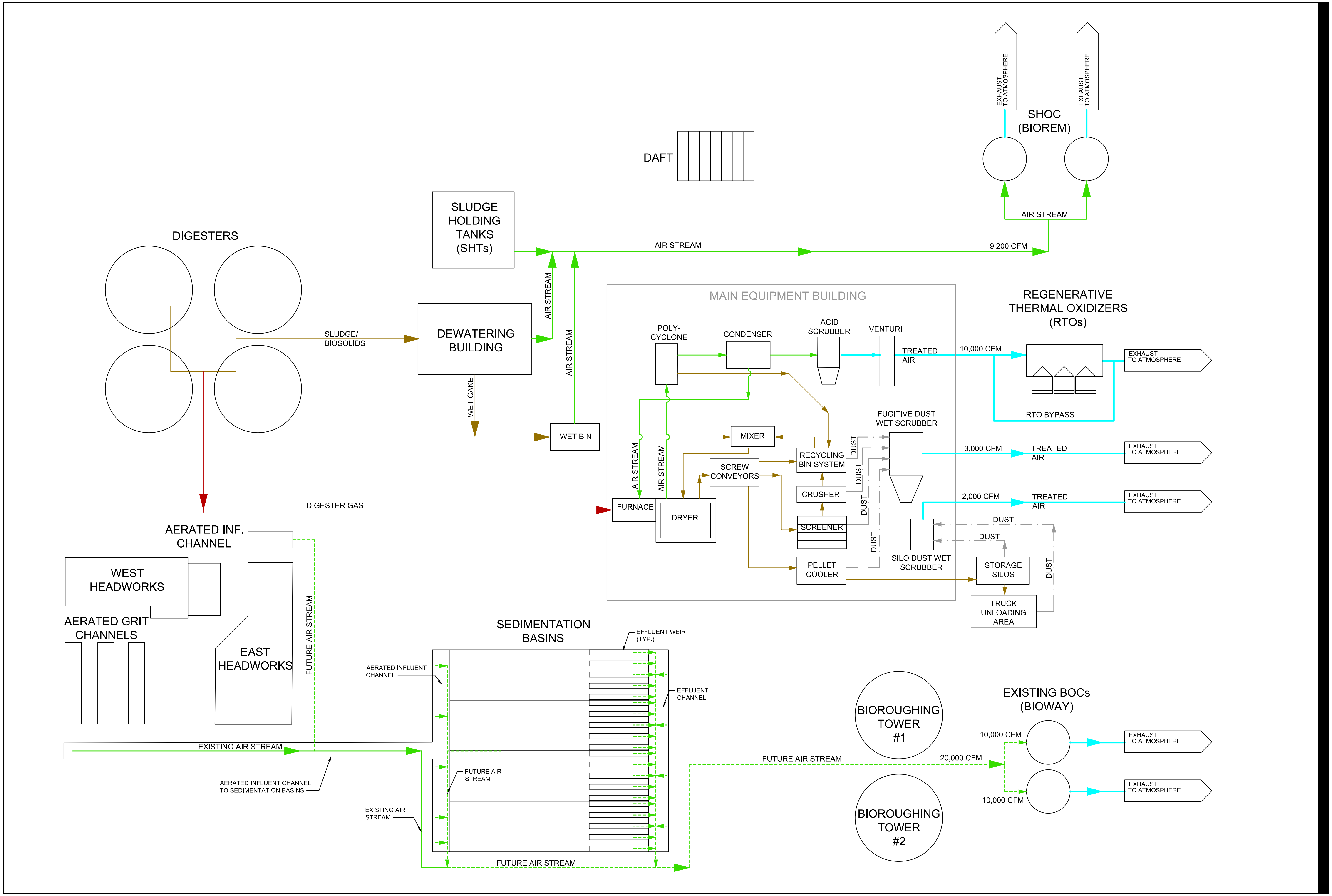

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Figure 4-1
Existing and Future Odor Control Systems
Alternative 1

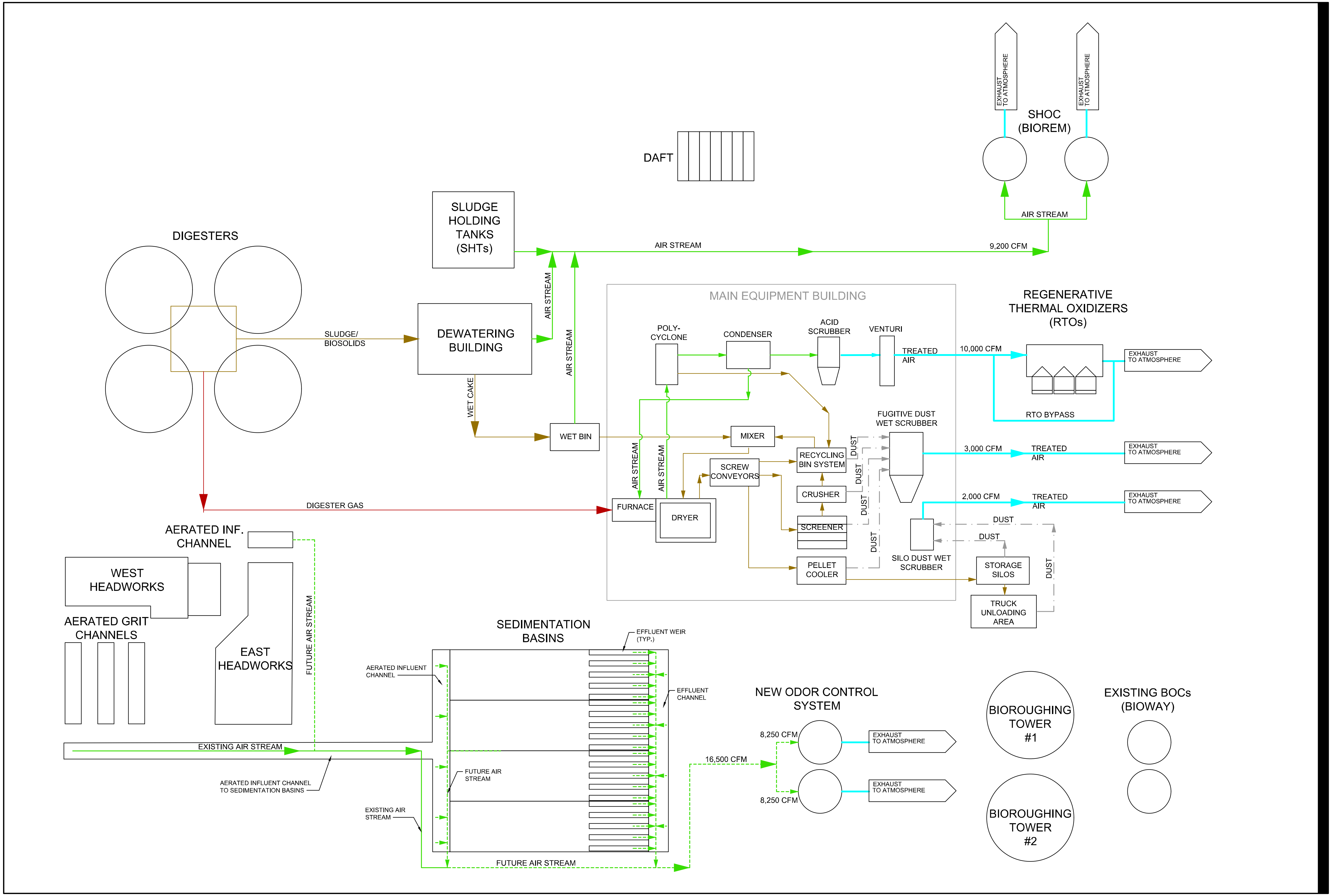


Figure 4-2
Existing and Future Odor Control Systems
Alternative 2

4.1.1 *Biotower Odor Control (BOC)*

The Plant's existing BOC system was installed in 2007 to replace the original chemical scrubbers serving the Bioroughing towers. These units were originally designed to receive and treat air from the existing Bioroughing towers and the Aerated Influent Channel. The Bioroughing Towers have recently been taken out of service; therefore, the BOC system currently treats foul air from the Aerated Influent Channel.

The BOC system consists of two (2) identical Purpring 1000 biotrickling scrubbers manufactured by Bioway. Each scrubber is equipped with a 30-ft diameter tower which contains synthetic media with biomass used for air treatment. The existing BOC units are pictured in **Figure 4-3**.

Figure 4-3 Existing BOC System Photo, 2009

4.1.2 *Solids Handling Odor Control (SHOC)*

The SHOC system was installed in 2007 to replace the fume incinerators for treatment of foul air from the MEB and Sludge Receiving Tanks. One of the existing fume incinerators remained as a backup to the SHOC system until 2007 when it was decommissioned. Existing foul air sources include foul air from the Sludge Holding Tanks and MEB sludge drying area including the centrifuge conveyors, wet material bins and dewatering wet well. The Sludge Receiving Tanks are currently out of service and therefore no longer convey air streams to the SHOC.

The SHOC system consists of two (2) 14-ft diameter multi-stage biological odor control units. Each bioreactor consists of three (3) stages:

1. Stage 1 (Preliminary Treatment via Biotrickling) – Foul air is humidified and degradation of H_2S occurs in acidic conditions.
2. Stage 2 (Biological Oxidation) – Air passes through two biofilter media beds where H_2S is solubilized and bio-oxidized by microbes. MSD currently operates Stage 2 in Alpha mode (low pH) to remove primarily H_2S.
3. Stage 3 (RSC Removal) – Biofilter media is used to remove residual H_2S and other RSCs, resulting in

Figure 4-4 Existing SHOC System Photo, 2009

additional TRS removal. An irrigation was installed to clean biotrickling filters and biofilters.

The SHOC system was rebuilt in 2011. After running Beta mode per previous odor control recommendations, the support columns of the scrubbers collapsed. After the re-build, MSD changed the media type in Stage 3 to improve reduced sulfur RSC removal. The existing SHOC system is pictured in **Figure 4-4**.

4.1.3 *Regenerative Thermal Oxidizers (RTOs)*

The existing RTO units are used to treat foul air from the MEB dryer system and are being currently replaced under the ongoing Emergency Dryer Replacement project. The MEB drying system will be configured to operate under negative pressure, allowing the collection and treatment of foul air through the RTOs. The RTO system will consist of two (2) identical RTOs manufactured by Gulf Coast Environmental Systems Each RTO will be installed with a dedicated exhaust fan, dryer train and air duct.

4.1.4 *MEB Main Process Wet Scrubbers*

The MEB is currently equipped with two (2) venturi scrubbers designed to treat foul air and dust streams produced during the sludge dewatering and drying process. These scrubbers are housed on the 6th floor of the MEB.

4.2 Design Parameters and Operation Performance Review

Equipment specifications and reports were evaluated to identify key design parameters for each of the existing or planned future odor control systems and is summarized **Table 4-2**. The project team also compiled previous performance testing results and expected performance parameters to assess current operational performance.

As of Q4 2021, performance testing data was available for the Bioway BOC system and the Biorem SHOC system. Performance tests will be conducted following ongoing media replacement of the SHOC systems and commissioning of the new RTOs, MEB Acid Scrubbers, MEB Fugitive Dust Wet Scrubbers, and MEB Silo Dust Wet Scrubber which will be evaluated in the Final Report.

Table 4-2 Existing Odor Control System Design Summary

	Inlet Conditions			Expected Performance	
Odor Control System	Total Peak Capacity (cfm)	Average/ Peak H_2S (ppmv)	Average/ Peak Odor Conc. (ou)	H_2S % Reduction	TRS % Reduction
1 BOC	20,000	60 (average) /150 (peak)	N/A	N/A	60 (average) /150 (peak)
2 SHOC	9,200	150 / 200	<6,000 / 15,000	99% H_2S Reduction; 90% TRS Reduction	150 / 200
3 RTOs	10,000	N/A	N/A	99% or less than 10 ppmv Removal Efficiency	N/A
4 MEB Acid Scrubbers	3,000	N/A	N/A	N/A	N/A
5 MEB Fugitive Dust Wet Scrubbers	6,000	N/A	N/A	95% Removal Efficiency	N/A
6 MEB Silo Dust Wet Scrubber	1,000	N/A	N/A	99.9% Removal of dust 2.0 microns or larger	N/A

4.2.1 *BOC Performance Data Evaluation*

MSD conducted performance testing at the BOC system in 2008. The study focused on H_2S removal efficiency and odor reduction efficiency. Performance data results are summarized in **Table 4-3** including inlet and outlet H_2S levels and odor concentrations during the 2008 monitoring period. H_2S measuring instrumentation did not have the ability to record H_2S values exceeding 2 ppm, therefore the peak H_2S values during the monitoring period are unknown and average values may be skewed.

Table 4-3 BOC Performance Data Summary, 2008

	H_2S Concentration (ppb)			Odor Concentration (D/T)		
Location	Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction
BOC Unit #1	29,347	182	99.4%	13,000	4,600	65%
BOC Unit #2	31,112	155	99.5%	8,700	6,200	28%
Average:	**63,337**	**169**	**99.4%**	**10,850**	**5,400**	**47%**

**- Sampling Day #2 was utilized for evaluation due to high peak loading conditions on Day #1*

The 2008 performance testing results showed that average H_2S removal efficiency was approximately 99.4% between the two BOC units. However, odor reduction was generally poor with an average odor concentration of 5,400 D/T and an average odor reduction of 47%. Outlet odor emissions were likely impacted by alternate reduced sulfur compounds, amines, aldehydes, or VOCs which were not sampled during the 2008 performance tests.

MSD is currently considering the replacement of the existing BOCs under the Rehabilitation and Replacement of Primary Sedimentation Basins Project. The proposed process airflow for the new system is 16,500 cfm.

4.2.2 *SHOC Performance Data Evaluation*

MSD has conducted several performance tests at the SHOC since the system was commissioned in 2006. The following sampling data was evaluated:

1. RSC and H_2S Sampling, September 2008
2. RSC and H_2S Sampling, November 2012
3. RSC Sampling, April 2013

Table 4-4 summarizes the results of the SHOC sampling data listed above, including observed outlet RSC concentrations and associated percent (%) reduction at the SHOC units. The TRS concentration represents the sum of MM, DMS, and DMDS.

Table 4-4 SHOC Performance Data Summary

	Outlet Conc. (ppb)					% Reduction				
Location	**H_2S**	**MM**	**DMS**	**DMDS**	**TRS**	**H_2S**	**MM**	**DMS**	**DMDS**	**TRS**
September 2008										
SHOC Unit #1	116	266	1932	37	**2235**	99.9%	99.0%	52.8%	96.1%	**93.1%**
SHOC Unit #2	116	376	1742	144	**2262**	99.9%	98.6%	57.4%	84.7%	**93.0%**
November 2012										
SHOC Unit #1,	<5	262	35	13	**310**	99.9%	92.3%	39.7%	63.9%	**65.3%**
SHOC Unit #2	<5	106	34	4.4	**144**	99.9%	96.9%	41.4%	87.8%	**75.3%**
April 2013										
SHOC Unit #1	-	483	262	146	**100**	-	88.4%	86.3%	95.0%	**89.9%**
SHOC Unit #2	-	<3	29	4.4	**40**	-	99.4%	88.9%	97.0%	**95.1%**

MM= Methanethiol
DMS= Dimethyl Sulfide
DMDS= Dimethyl Disulfide
TRS=Total Reduced Sulfur; Sum of MM, DMDS, and DMS.

Available sampling data shows that both SHOC units met expected performance targets for H_2S percent reduction with 99.9% at both units, exceeding the expected performance level of 99%. SHOC Unit #1 did not meet the 90% TRS reduction threshold during any of the sampling tests, with observed values ranging from 65.3% to 89.9% TRS removal. SHOC Unit #2 met the 90% TRS reduction performance level during the September 2020 and April 2013 sampling periods but fell significantly below expected levels during the November 2012 performance test with 65.3% TRS removal.

Table 4-5 shows the observed H_2S percent reduction versus the expected performance levels provided by the equipment manufacturer.

Table 4-5 SHOC Observed vs. Target H_2S and TRS % Removal

	H_2S % Reduction		TRS % Reduction	
Location	**Observed**	**Target***	**Observed**	**Target***
SHOC Unit #1	99.9%	99%	65.3%-93.1%	90%
SHOC Unit #2	99.9%	99%	75.3%-95.1%	90%

**-Percent removal targets are based on manufacturer performance data for expected performance.*

Based on the findings of previous performance data evaluation, the following conclusions were made regarding the existing SHOC system:

- SHOC Unit #2 has shown better operating performance than SHOC Unit #1 in terms of RSC removal
- While the 99% H2S reduction target was met during previous performance tests, the 90% reduction target was not met during the November 2012 performance test for both BOC units and during the April 2013 performance test for Unit #1.

The media is currently being replaced at the SHOC units. Performance testing will be conducted after re-commissioning the units and will be considered in the final version of this report.

4.3 Planned Process Modifications

As mentioned previously, MSD is in the process of performing several process modifications at the WQTC which will have significant impacts on existing odor emissions. The planned process modifications were previously documented in **TM#4** and are discussed in this Section.

4.3.1 *Emergency Dryer Replacement*

MSD is currently performing the Emergency Dryer Replacement project (Contract No. 16453) which involves design and construction of two (2) new Andritz Rotary Drum Dryer Systems to replace the original units installed in 2001. These systems are very similar to the original system, with some modifications and improvements to the equipment. Each dryer train will process 70 dry tons per hour (dtph) which is considered sufficient based on solids loading requirements. These Dryer trains are currently in construction with commissioning expected in Spring 2022.

The Emergency Dryer Replacement project includes replacement of dryers at the Main Equipment Building, elimination of (4) existing regenerative thermal oxidizers (RTO) trains and installation of (2) new RTO units. Major improvements will be performed at the Main Equipment Building including replacement of screw conveyors, removal of existing venturi scrubbers and installation of new acid/wet scrubber system and fans. The following equipment will be installed during these improvements.

- Two (2) Condensers

- Two (2) Venturi Acid Scrubbers
- Two (2) Fugitive Dust Wet Scrubbers
- Two (2) RTOs
- One (1) Silo Wet Dust Scrubber

4.3.2 *Sedimentation Basin Rehabilitation*

MSD is in the process of performing the Rehabilitation and Replacement of Primary Sedimentation Basins project (Contract No. 16460). This project involves modifications to the existing Aerated Influent Channel, Primary Sedimentation Basins, North and South Pump Stations, installation of a Chemically Enhanced Primary Treatment (CEPT) system, and the addition of an odor control system at the Primary Sedimentation Basins and related equipment.

Two (2) conceptual odor control design alternatives were presented in a Basis of Design Report (BODR) to improve odor conditions at the Primary Sedimentation Basins and related areas:

1. Alternative 1: Re-purpose the existing BOC system
2. Alternative 2: Install a new odor control system involving new biotrickling scrubbers

Regardless of the selected alternative, MSD plans to perform the following improvements:

- Coverings at the Aerated Influent Channel
- Coverings at the Sedimentation basin Effluent Weirs
- Coverings at the Sedimentation Basin Effluent Channels
- Conveyance ductwork from capture locations to Odor Control System

Table 4-6 summarizes the preliminary basis of design parameters for the proposed odor control systems included in the BODR.

Table 4-6 Sedimentation Basin Odor Control System Basis of Design Summary

Parameter	Alternative 1	Alternative 2
Manufacturer:	Bioair or Evoqua	Bioway
Process Conditions:	Continuous	Continuous
Process Airflow:	16,500 cfm	20,000 cfm
Inlet H_2S Conditions:	30 ppmv (avg)/ 200 ppmv (peak)	60 ppmv (avg)/ 150 ppmv (peak)

Alternative 1 was the selected odor control strategy based on MSD’s experience with the BOCs, anticipated odor compounds and concentrations, lower O&M requirements compared to other methods, and proven efficacy.

5. 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 5-1** identifies the various odor control measures which will considered for inclusion into this Odor Control Master Plan. Multi-stage treatment configurations will also be considered which involve staging of two or more technologies described herein.

Table 5-1 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	**Waste Gas Incineration**	Combustion of odorous gases in exhaust air	Regenerative thermal oxidizers (RTOs), catalytic oxidizers
5	**Photoionization (UV)**	Use of ultraviolet (UV) light and catalyst to oxidize odorous compounds	Ionization chambers
6	**Hydroxyl Generator**	Use of UV and optics to oxidize odorous compounds via hydroxyl molecules	Positive pressure systems involving process fans
7	**Ozonation**	Generation of ozone (O_3) for oxidation of odorous compounds	Single source or multiple source ozone generators
8	**Plasma**	Production of free radicals to oxidize odorous compounds	Modular reaction chambers

5.1 Adsorption

Adsorption involves the attachment of odorous compounds to a solid surface and is typically performed prior to thermal gas treatment or in conjunction with biofiltration. Common adsorbents include activated carbon, activated alumina, and silica gels. These are adsorbents with a non-uniform internal structure and without a clearly defined shape.

Typical design configurations involve fixed bed reactors where the waste vapor passes through a stationary bed. To allow continuous operation, simultaneous adsorption and desorption is required so the bed does not become saturated. For heavy waste vapor loads, this may be achieved by utilizing parallel operations of several adsorbers or by using an adsorber wheel where only a portion of the adsorber surface area is exposed to the waste gas at a time. Regeneration of the adsorbent media is usually conducted by means of hot gas including steam.

Adsorption is commonly used as an enrichment step prior to thermal gas treatment. It can also be combined with other technologies such as biofiltration. This combination is especially suitable for processes with varying exhaust air concentrations, such as facilities with varying operational capacities (daily, monthly, or annually). Under transient exhaust air conditions, the adsorbent amount can be adjusted. A limitation of adsorption technologies is the reduced efficiency with increasing moisture content.

5.2 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 add to 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 (O_3) and hydrogen peroxide (H_2O_2), 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, which therefore have to be removed from the gas by a sulfuric acid scrubber prior to the hypochlorite scrubber. The small amounts of produced chlorine can then also 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 involve the considerable amounts of chemicals required, and the requirement to remove, treat, and dispose of the reaction products. Acidic substances, like hydrogen sulfide (H_2S) can be treated with caustic scrubbers using diluted sodium or potassium hydroxide for the removal of organic sulfur compounds.

5.3 Biological Waste Vapor Treatment

Biological waste gas treatment 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 waste gas systems are often the lowest among odor control technologies.

Biofilters and Bioscrubbers/biotrickling filters are the two most common biological system used for odor control at wastewater treatment plants and are discussed in the following subsections.

5.3.1 *Biofilters*

Biofilters consist of fixed bed reactors where the waste vapor is treated by passing through a biofilter bed. Microorganisms settle on the biofilter-bed surface and form a biofilm layer in which the airborne substances are absorbed. An important consideration for biofilter media is the requirement to provide optimum environments for the microorganisms; therefore, an essential property is the ability to store water. Additional criteria are a low pressure drop which serves to assure a relatively unform air distribution and a large specific surface for the mass transfer and the microorganisms to settle on. Frequently used biofilter media are compost, peat, bark and wood chips. A combination of biofilter medias may be utilized. In most cases, the biofilter material already provides mixed cultures of microorganisms, which mostly adapt to the condition and composition of the waste vapor.

One of the key parameters of biofiltration is the moisture content of the biofilter material. To avoid drying of the filter media, the waste gas should be saturated with water vapor. This is commonly achieved by humidifying the vapor using wet scrubbers or bioscrubbers in an earlier stage. Biofilter beds can be designed up to 2-meters in depth and with an open, or enclosed heading.

In open biofilters, the air passes through the bed in an upward-flow direction. A known issue with open biofilters is the direct exposure of the media to climatic conditions which may influence its functionality. For example, a hot and dry climate or prolonged weather occurrence may result in a drying of the filter media. The opposite holds true as well. Enclosed biofilters are less affected by weather conditions, and also offer an increased moisture distribution, as they can be operated under down-flow conditions.

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.

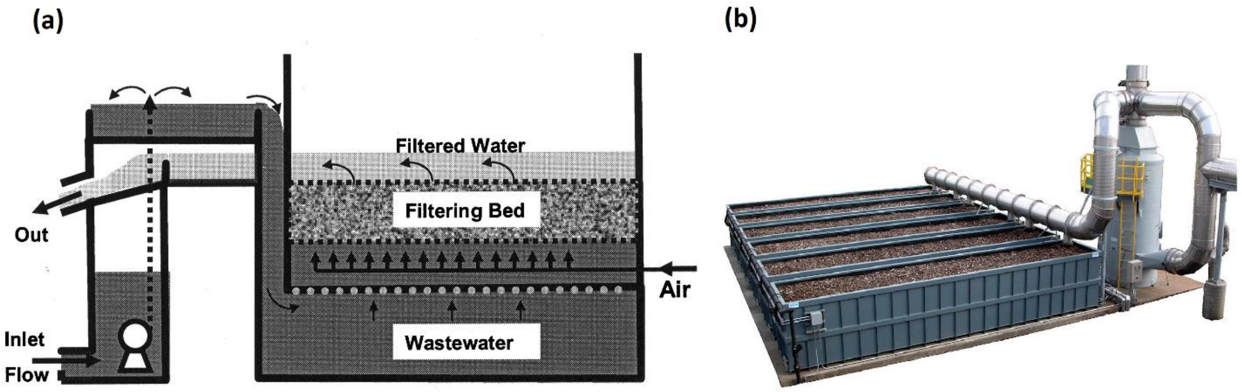


Figure 5-1 Example of Biofilter Configurations at Wastewater Treatment Plants
(a) adapted from Verma et al. 2006); (b) adapted from RJM Company

5.3.2 *Bioscrubbers/Biotrickling Filters*

In bioscrubbers/biotrickling filters, the microorganisms are suspended in a scrubbing liquid but may additionally be immobilized on the packing material. The critical component of these systems is the absorption column where the mass transfer between the gaseous and aqueous phase takes place, allowing the airborne substances to be made available to the microorganisms. Packing materials are installed to enhance the contact surface of both phases. In most applications the gaseous and the aqueous phases are distributed in counter flow to each other, if no packing materials are installed, cross-flow systems are utilized.

Once the odorous substances are dissolved in the scrubbing liquid, if degradable they are removed by the microorganisms. The degradation process takes place in the liquid or in the biofilm that grows on the packing materials. These internals enhance the surface for the mass transfer and also provide an additional surface for the microorganisms to settle. During the adaptation phase, the microorganisms start to grow and form a biofilm which has a prominent effect on the degradation efficiency of the scrubber. As such, a disadvantage of bioscrubbers is that clogging may occur and may impact the system performance. To avoid clogging, the packed bed should have sufficiently large pores and be cleaned frequently.

The scrubbing liquid is continuously cycled; therefore, an activation tank may be incorporated into the cycle to increase the regeneration time. The degree of regeneration can be influenced by the size of the activation tank and consequently the retention time of the scrubbing liquid. It may be necessary to install an additional aeration system to provide a sufficient amount of oxygen. Nutrients may be added to the scrubbing liquid in order to provide elements such as phosphorous, nitrogen, potassium, etc., for the microorganisms.

5.3.3 *Bioscrubber-Biofilter Combination*

A bioscrubber-biofilter combination system involves adding moisture to reduce the odor load into the biofilter. A unique advantage of this system is that it inherently includes a buffering effect to prevent high concentrations of odors from entering the biofilter and leading to an increased temperature of the biofilter media due to excessive degradation processes. As noted in ***Section 5.3**,* the biofilter moisture content is a key parameter corresponding to the odor removal efficiency of the biofilter.

5.4 Waste Vapor Incineration

Thermal treatments are an effective technology for minimizing the release of contaminants and odors. These systems can be applied to any exhaust air stream. Since VOC concentrations in exhaust streams are often low, the addition of natural gas or a pre-concentration such as adsorption may be required.

Incineration technologies operate using a catalytic or non-catalytic approach. Catalytic processes are operated at lower temperatures when the exhaust flow rate is relatively low. This approach results in a considerably lower energy demand, however, costs for the catalyst must be considered. For non-catalytic processes, energy costs can be significantly reduced by using systems with a high percentage of heat recovery, such as a regenerative thermal oxidizer (RTO).

An RTO operates by having waste gas pushed or pulled into the inlet manifold of the oxidizer via a system fan. Flow control or poppet valves then direct this gas into energy recover chambers where it is preheated. The process gas and contaminants are progressively heated in the media beds as they move towards the combustion chamber. Once oxidized in the combustion chamber, the hot purified air releases thermal energy as it passes through the ceramic media bed in the outlet flow direction. This causes the outlet bed to become heated, and the gas to become cooled so that the outlet gas temperature is only slightly higher than the process inlet temperature. Poppet valves alternate the airflow direction into the media beds to maximize energy recover within the oxidizer. The high energy recovery within the oxidizers reduces the auxiliary fuel requirement and leads to a relatively low operating cost. The RTO has potential to achieve high destruction efficiency (up to 99%) while self-sustaining its operation without auxiliary fuel.

Catalytic and non-catalytic systems operate similarly; the removal of odors and other pollutants are dependent on temperature, internal turbulence, and residence time. Proper operating conditions will result in the conversion of pollutants to odorless compounds such as CO_2 and H_2O.

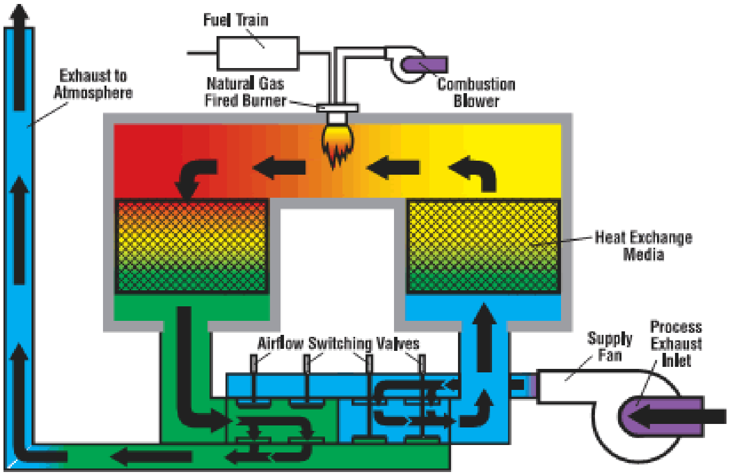


Figure 5-2 Regenerative Thermal Oxidizer Airflow Process ***(CMM Group)***

5.5 Chemical Addition

A chemical addition approach can be utilized to minimize the concentration of dissolved sulfides in influent wastewater streams. By minimizing the concentration of hydrogen sulfide in the wastewater process/sewer headspace, the structural integrity of the concrete is extended and the odor concentration is considerably lowered.

Potential odor-reducing chemical agents include hydrogen peroxide, potassium permanganate, sodium hypochlorite, ferrous chloride and magnesium hydroxide. Each of these technologies provide odor control and corrosion protection by removing dissolved H_2S and sulfide from wastewater through oxidation reactions with the exception of magnesium hydroxide. Magnesium hydroxide acts as a pH buffer, raising and maintaining the pH in sewer systems at a level which inhibits the formation of H_2S. Chlorine gas has been excluded from further evaluation due to its toxicity. Nitrates were also not considered feasible chemical agents due to the slow reaction time and pressure requirements during injection.

5.5.1 *Hydrogen Peroxide*

Hydrogen peroxide may be used to chemically oxidize H_2S to elemental sulfur or sulfate, depending on the wastewater pH. For collection system applications, peroxide has been successfully applied in both forcemains and gravity mains. The decomposition of excess peroxide in water and oxygen increases the dissolved oxygen concentrations of wastewater and produces no chemical residue. Peroxide can reduce sulfides to near zero, depending on the dosage. Depending on the concentration of peroxide, the storage tank material varies from stainless steel and high-purity aluminum at high concentrations to polyethylene at lower concentrations.

5.5.2 *Potassium Permanganate*

Potassium permanganate is a strong chemical oxidizing agent that reacts with H_2S. Potassium permanganate is available in dry crystal, granule, or pellet form and must be mixed with water to approximately a 3 to 4% solution before use. When kept dry and cool, potassium permanganate is relatively stable. However, when contaminated with organics or acids, it can become unstable and decompose, causing potentially hazardous conditions. Potassium permanganate reactions produce manganese dioxide as a by-product. Manganese dioxide is a fluffy, brown flock that is practically nonreactive and settles as chemical solids in the treatment plant and will slightly increase solids products.

5.5.3 *Sodium Hypochlorite*

Sodium hypochlorite, commonly known as household bleach can be used to treat odorous compounds in wastewater when delivered at high concentrations. Industrial sodium hypochlorite is generally sold in aqueous solutions containing 5 to 15% sodium hypochlorite, with 0.25 to 0.35% free alkali (usually NaOH) and 0.5 to 1.5% NaCl.

5.5.4 *Ferrous Chloride*

Iron based products are widely used in the water and wastewater industry for the removal of suspended solids during the purification processes. Iron and other metals can chemically combine with dissolved sulfide to form relatively insoluble precipitates. Both ferrous and ferric metal salts can react with dissolved sulfide. The following four types of iron salt solutions are commercially available: ferrous sulfate, ferrous chloride, ferric sulfate, and ferric chloride.

5.5.5 *Magnesium Hydroxide*

Milk of Magnesia, ($Mg(OH)_2$), is a viscous, mildly alkaline mixture widely known for its medicinal use. Industrial grade milk of magnesia is developed and adapted for use in municipal wastewater collection and treatment. Chemically magnesium hydroxide ($Mg(OH)_2$) provides a freely moving slow release source of non-carbonate alkalinity. It is easy to handle and adds no sodium or TDS. Alkalinity contributes to the properties of wastewater, many of which positively affect the physical, biological and chemical processes required for better wastewater transport and treatment. Raising the pH of the wastewater will shift the sulfide species from H_2S to HS^-, thereby decreasing the concentration of aqueous phase H_2S.These solutions also provide Mg2+, an important micronutrient necessary for improved flocculation, clarification and biologic treatment.

5.5.6 *Chemical Addition Technology Assessment*

All of the selected chemicals, except hydrogen peroxide and magnesium hydroxide, reach 100% efficiency within 5 to 10 minutes. Hydrogen peroxide is slightly slower – requiring 15 minutes to reach 90% effectiveness and 40 minutes to reach 100% effectiveness. Magnesium hydroxide would require approximately 20-40 minutes to adjust the pH to a level capable of inhibiting H_2S generation.

Hydrogen peroxide and ferrous chloride have a catalytic relationship that causes a faster and more complete reaction with H_2S (<5 min) than either technology as a standalone. Generally, it is preferred to add these chemicals at two independent addition sites; with ferrous chloride injected first and then hydrogen peroxide injected downstream but it is not required, and the chemicals may be injected at a single site.

Reaction Time Duration

The control duration for hydrogen peroxide and sodium hypochlorite ranges from 1 to 2 hours, however control for 3 hours can be achieved by increasing the dosage rate. The reaction time duration for magnesium hydroxide range considerably depending on the initial pH, however, with proper dosing, can last several hours to days in the sewer. Ferrous chloride has a long control duration at approximately 20 hours, while the control duration of potassium permanganate is only 1 hour.

Dosage, Storage Volume and Footprint

Due to the density and lower dosage rate, hydrogen peroxide and potassium permanganate have the smallest storage volume and footprint requirements. Dosage and storage of ferrous chloride will require storage volume of approximately 42,000 L for supply of 30 days. The largest footprint will be required if using sodium hypochlorite. A 30-day supply of sodium hypochlorite will require 280,000 L of storage. Since magnesium hydroxide lowers the pH of the entire wastewater stream, it has the highest total dosage requirements; a 30-day supply of magnesium hydroxide requires 2.5 million liters.

By-products

Hydrogen peroxide does not produce unwanted by-products and increases the dissolved oxygen content in the wastewater if the initial dosage is set higher than the stoichiometric requirement. Potassium permanganate and ferrous chloride will produce high biosolids loading and heavy metals downstream. Additionally, ferrous chloride consumes dissolved oxygen. Addition of sodium hypochlorite can produce chlorinated VOCs, air, and odor emissions. Magnesium hydroxide produces free Mg ions that bind with sulfides and assists with other wastewater treatment processes.

Chemical Handling Requirements

The least restrictive chemical in terms of handling requirements is magnesium hydroxide. The solution is a slurry that is not a fire or spill hazard. The slurry may pose a health hazard and therefore personal protection such as glasses and gloves are required. Tanks for magnesium oxide must not be constructed of aluminum. Tanks must be equipped with agitation devices and plugging of the pipes and equipment is possible if mixing of the slurry is inadequate. Tank must also be heated to ensure the slurry does not freeze. Dried slurry may release nuisance particulate matter and the storage area must be properly ventilation to reduce the buildup of air contaminants.

All of the other chemical addition technologies require health and safety precautions due to the inherent hazardous properties. Potassium permanganate must be handled and stored as a dry powder and mixed into solution prior to injection as a liquid. This may require an equalization tank and/or mixer. Sodium hypochlorite has a short shelf life in storage tanks. Ferrous chloride tanks must be heated or the solution will freeze. Storage tanks for potassium permanganate, sodium hypochlorite and ferrous chloride can be FRP, PVC, polyethylene, or polypropylene. Double wall tanks are not typically required. All chemical systems must be closed looped and be built with containment or dykes. Secondary containment from vehicular traffic, fire and spills is also required. Tanks should have a bottom drainpipe with an emergency relief valve on the end. Leaks or spills must be dealt with using proper personal protection equipment, including safety goggles, chemical resistant gloves, neoprene boots, lab coat and SCBA respirator. The storage area must be properly ventilation to reduce the buildup of air contaminants.

Hydrogen peroxide has more stringent handling requirements and all skin/eye contact, absorption, inhalation and ingestion should be entirely avoided. The product is not flammable; however, it is not stable and readily decomposes to oxygen. It has a long shelf life in storage tanks; however, the preferred material of the tanks and piping is stainless steel. All valves and gasket should be Teflon or vinyl. The tanks must be installed with emergency dilution capabilities, heat sensors and leak detection. Leaks or spills must be dealt with using proper personal protection equipment, including safety goggles, chemical resistant gloves, neoprene boots, impermeable apron and SCBA respirator. The storage area must be properly ventilation to reduce the buildup of air contaminants.

Chemical Delivery Requirement

Since magnesium hydroxide is not considered a hazardous substance, delivery requirements are not restrictive. Delivery of the other chemicals must adhere to strict and specific requirements. Populated areas should be avoided for public safety reasons, but these addition chemicals may be transported through a residential development. Vendors must comply with any municipal by-laws concerning the transportation of dangerous goods and associated truck routes.

Similar to the handling requirements, hydrogen peroxide also has more stringent delivery restrictions than the other chemicals. Delivery of hydrogen peroxide must follow a direct route, avoid populated areas and travel on commercial truck routes only. Drivers must also be provided specific training on handling and off-loading of hydrogen peroxide.

Preferential Control of H_2S

Both hydrogen peroxide and ferrous chloride have preferential control of H_2S and their effectiveness is not reduced by other compounds that may be in the wastewater. In addition, hydrogen peroxide may also react with other corrosive/odorous compounds after neutralizing H_2S. Potassium permanganate and sodium hypochlorite will react with many chemicals simultaneously and do not show preference for H_2S, thereby requiring a higher initial dose to ensure that H_2S is eliminated. Their ability to oxidize other odors (caused by organics and reduced compounds), in addition to H_2S, provides more significant vapor phase odor control than by removing only H_2S. Sodium hypochlorite reacts with ammonia to provide residual odor control. All of the oxidizing chemicals will have some minor effect on oxidizing VOCs before they enter the vapor phase. The main mechanism of magnesium hydroxide does not specifically target H_2S, instead it alters the pH to a level which does not promote the formation of H_2S. Raising the pH in the wastewater will depend on other acidic compounds and sources.

Chemical Addition Technology Evaluation

Due to its short duration of effect and lack of a preferential control of H_2S, potassium permanganate is not recommended to be utilized as a chemical addition agent. Sodium hypochlorite addition is also not recommended due to its lack of a preferential control of H_2S, large footprint requirements, and formation of undesired byproducts. Magnesium hydroxide was eliminated as a chemical agent option due to its excessive dosage requirements. Hydrogen peroxide is not recommended to be utilized as a chemical addition agent due to its highly restrictive delivery, handling, and storage requirements which will require an exceptionally high-level health and safety training for staff as well as an updated emergency response protocol in the event of an emergency. Ferrous chloride had the highest overall score on the Technology overview matrix (**Table 5-2**) and therefore will be considered as a potential odor control technology at Morris Forman Collection System.

Table 5-2 Chemical Addition Technology Overview Matrix

	Chemical Agent				
	Hydrogen Peroxide	**Potassium Permanganate**	**Sodium Hypochlorite**	**Ferrous Chloride**	**Magnesium Hydroxide**
Reaction Time	Fair	Good	Good	**Good**	Poor
Duration of Effect	Fair	Poor	Fair	**Good**	Good
Dosage/Storage Volume and Footprint	<10,000 L for 30d Small footprint	<10,000 L for 30d Small footprint	~250,000 L for 30d Large footprint	**~40,000 L for 30d** **Medium footprint**	~2.5 million L for 30 d Very large footprint
By-products	No	Yes; inert	Yes	**Yes; inert**	Yes; inert
Chemical Handling Requirements	Most restrictive especially at high concentrations	Restrictive due to powder and oxidizer	Restrictive due to corrosive and reactive	**Restrictive due to corrosive and acidic**	Minor restrictions
Chemical Delivery Requirements	Most restrictive	Restrictive	Restrictive	**Restrictive**	Minor; Not classified as regulated substance by TDG
Preferential Control of H_2S	Yes	No	No	**Yes**	Yes

5.6 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 the odor compounds within the inlet airflow in the presence of the catalyst. The catalyst is typically a carbon based medium. The technology is very effective at oxidizing and removing wastewater odors. Its performance is also not negatively impacted due to high inlet air humidity and can be turned off for extended periods of time without reducing the systems performance once returned to operation again. 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, photoionization to treat odors in North America is relatively new when compared to other treatment methods. Reliability and effectiveness of the treatment method is not as well established as bio-treatment or dry 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 is to capture any remaining radicals as they are highly oxidative and hazardous if they come into contact with oxidants or people.

Access to the bulbs and catalyst is through a maintenance door on each treatment chamber. The system is to be run 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 as shown in **Figure 5-3**. To create a system sized to treat the required airflow the chambers are added together into units. Photoionization systems are supplied in modular chambers which have a set airflow capacity. Chambers are added 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 5-3 Photoionization Example Photo

Source: Neutralox Umwelttechnik GmbH represented by Ambio

5.7 Hydroxyl Generator

Similar to the photoionization technology, UV bulbs and optics are used to create radicals for odor contaminant oxidation. Hydroxyl generators create the radicals which are blown via a process fan to inject the hydroxyl into a headspace or airflow to remove contaminants. The 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 within the UV chamber and catalyst.

A negative pressure differential is not created by a hydroxyl generator system. The addition of air with hydroxyl molecules into a sewer headspace increases a positive pressure environment which will raises the risk of fugitive emissions and radicals through leak points when the system does not operate properly. The hydroxyl radicals present a health risk if leaked into the environment like the ozone created by a photoionization unit.

5.8 Ozonation

Ozone is a highly reactive form of oxygen, with three oxygen atoms (O_3) instead of two (O_2). The third oxygen atom is what makes ozone such a powerful oxidant, as it will react indiscriminately with other compounds to return to its more stable dioxygen form. Historically, this characteristic has resulted in the use of ozone technology as a powerful disinfectant and polishing tool for water treatment. More recently, ozone has also found applications in the wastewater industry for the treatment of odor and corrosion in wastewater collection systems, where it has been shown to be highly effective in oxidizing odorous compounds.

Ozone is generated by introducing sufficient electrical or optical energy to a flow of oxygen. Though this can be accomplished in several ways (e.g., as one of the by-products of photoionization systems), the most common way that large amounts of ozone are generated for the purpose of odor control is the corona discharge method. With this method oxygen molecules are passed through an electrical “corona” discharge field that causes the oxygen atoms to split. Ambient air can be used as a feed source for the oxygen; however, it is more common to use oxygen concentrators, which supply oxygen to the ozone generators at much higher concentrations for increased ozone production. Though some of the oxygen atoms revert back to their dioxygen forms, some of the individual atoms combine with other dioxygen compounds to form ozone. This method is preferable to UV ozone generators for demanding applications because UV generators tend to produce less ozone over time at lower concentrations while generating more harmful by-products.

One advantage of ozone systems is that the system components are much simpler than other treatment technologies (consisting mainly of an ozone generator, oxygen concentrator, air compressor, tubing and electrical equipment). As a result, ozone systems tend to be lower in cost. Though the actual size of the ozone generators are small, it is important to note that ozone systems also require the design of a ventilation contacting/retention system to allow the ozone and odorous air stream enough contact time to mix and oxidize the odorous compounds. This contact time can be achieved by injecting the ozone directly into an expanded section of ductwork or a stand-alone contact chamber.

Safety is another important consideration for ozone systems. Even at low concentrations, the highly reactive and oxidizing nature of ozone makes it a primary irritant that especially affects the eyes and respiratory systems. People most at risk from breathing air containing ozone include people with asthma, children, older adults, and people who are active outdoors. Ozone can also be harmful to sensitive vegetation and ecosystems such as parks. These considerations are especially important given the near proximity of the AMF to two (2) sensitive receptors (a soccer club and daycare). Ozone itself also has an antiseptic odor, chlorine like smell that may be disagreeable to some. To safeguard against possible leaks, ozone monitors and alarms will have to be used. A safety interlock between the ozone generating equipment and ventilation system will also ensure that no ozone is generated unless the ventilation system is in operation. In addition to this, all materials that may come in contact with the ozone must also be chosen carefully, as ozone can cause some materials to deteriorate (e.g., tubing for conveying the ozone must be Teflon-lined).

Ozone systems can either be configured as a single-source system, or as multiple smaller systems combined into a larger system for redundancy. Larger systems can be completely self-contained units with the corona chamber, electrical panel and transformers fully enclosed in a metallic casing. The Odotron unit shown in **Figure 5-4** is one example of these self-contained units and has the added benefit of not requiring an air compressor or oxygen concentrator. It also has the optional feature of adding an H_2S monitor at the outlet of the discharge air duct from the air duct chamber to help modulate the output of oxidized air. Smaller combined systems like the rack mounted Envron ENVDG4 ozone generators shown in **Figure 5-5** have the added benefit of even greater space savings. External air compressors are not required with these units as the supplied oxygen concentrators are self-contained. The larger self-contained ozone system can be housed indoors or outdoors, while the smaller units must be confined to environments suitable for electronics (e.g., the electrical control room). The self-contained units are more expensive, and have higher energy demands than the rack-mounted units.

Figure 5-4 Self-Contained Ozone Odor Control System Photo

Ozone Generators/Oxygen Concentrators (typical configuration)

Figure 5-5 Rack-Mounted Ozone Odor Control System Photo

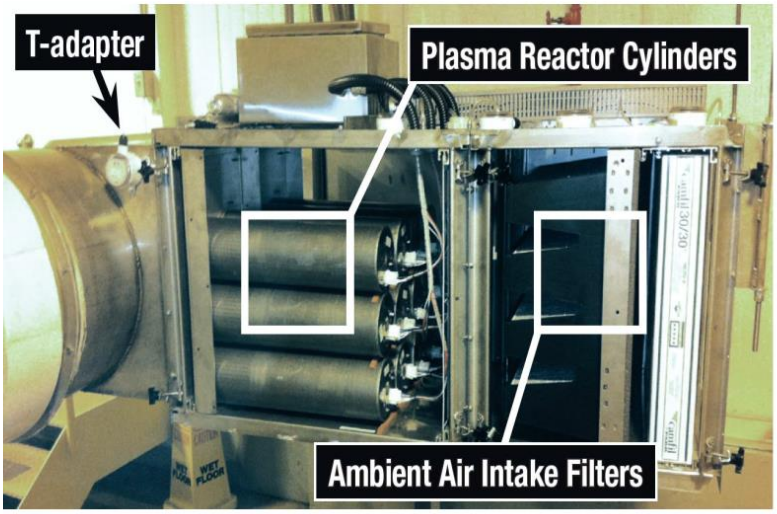
Maintenance requirements for ozone systems are relatively simple and can be completed by anyone with knowledge of basic plumbing skills. Basic maintenance activities include cleaning/flushing the corona cells, replacing compressor filters, checking safety components and checking oxygen output. Note that with the rack-mounted system, the entire system does not need to be maintained at once and individual generators can be rotated for maintenance.

It should also be noted that though the use of ozone has proven successful in water treatment and wastewater applications, its application for large-scale gas-phase odor treatment is relatively new. One reason for this is that ozone is less reactive in the gas phase than in the liquid phase. Another limitation of ozone systems is if there is moisture or particulate matter in the air flow to be treated, the odorous compounds may not have the contact residence time or sufficient exposure to the ozone to completely react. Considering the high humidity characteristics of the sewer air to be treated, this limitation may hinder the system's ability to obtain consistently reliable contaminant removal results. A mist eliminator may be required as a result.

5.9 Plasma

Cold plasma technologies work on the same principles as photoionization and ozone generation technologies. Free radicals are created by exposing the molecules in ambient air to a strong electrical field known as a dielectric-barrier discharge. The free radicals, which consist of highly reactive oxygen and reactive nitrogen species such as ozone and hydroxyl molecules, are then used to oxidize the odorous compounds.

The free radicals are generated in modular reaction chambers within a self-contained steel cabinet (**Figure 5-6**). Once the ambient air has become activated with reactive species within the reaction chamber it is known as plasma.



Example PLASMA-INJECTOR (doors open) with T-adapter and Pre-Filter
High frequency 30kHz cold plasma oxidizer, no supply of water, no waste.

Figure 5-6 Plasma Odor Control System Example Photo

Operation of the system is quite simple as the plasma systems are supplied with a control panel with PLC that requires a simple one-button start/stop control. The system is also interlocked with the process fan for automatic start-up and shut-down based on the operation of the fan.

As with the photoionization and ozone technologies, plasma systems have the advantage of operating without water or waste. Maintenance of the system is also quite simple as there are no moving parts. Vendor estimates for maintenance are 1 hour per 3,000 hours of operation or approximately 3 hours per year. Maintenance activities consist of replacing the plasma reactor cylinders once per year (this can be done by vendor representatives or the AMF operators once trained), replacing one large filter once per year and replacing four (4) small filters on an annual basis.

The application of plasma for odor control is relatively new and information on performance is therefore limited. Compared to other treatment technologies, there are very few plasma installations for odor-control. The majority of current installations are in the food processing, and pet/animal feed manufacturing industries, where the technology has seen some success. The limiting factor for the application of this technology for large-scale odor control for sewer gases is the high H_2S concentrations.

5.10 Technologies Comparison Summary

Table 5-3 outlines the advantages and disadvantages of each potential odor control technology considered as part of this Odor Control Master Plan.

Table 5-3 Odor Control Technologies Evaluation

Technology	Advantages	Disadvantages
Adsorption	- Excellent removal efficiency for odor, H_2S 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 - 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
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 H_2S peak loadings may cause biofilter to acidify
Bioscrubber	- 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
Waste Vapor Incineration	- Viable for concentrated effluents or sludges - High efficiency for pollutant and organics removal - Produces energy which can be recycled	- High initial investment - High operating costs - Potential to create dioxins or other pollutants - Poor public perception
Photoionization (UV)	- High efficiency for odor, H_2S 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, H_2S and RSC removal - Minimal space requirements	- Safety and environmental concerns due to possibility of unreacted radicals remaining in air stream - Requires ability to create negative differential pressure - High maintenance requirements
Ozonation	- High efficiency for H_2S and RSC removal and corrosion prevention - Simplicity of treatment design	- Relative new technology for odor control application - Safety and environmental concerns due to possibility of unreacted ozone remaining in air stream - Performance limited by inlet air humidity - Extensive space requirements for contact chamber

6. Design Parameters Recommendation*

**This Section will be developed following the completion of the ongoing improvements and subsequent liquid and air phase sampling and will be included in the Final Report.*

7. Dispersion Modelling*

**This Section will be developed following the completion of the ongoing improvements and subsequent liquid and air phase sampling and will be included in the Final Report.*

8. Odor Treatment Design Concepts*

***This Section will be developed following the completion of the ongoing improvements and subsequent liquid and air phase sampling and will be included in the Final Report.*

9. Feasibility Assessment*

**This Section will be developed following the completion of the ongoing improvements and subsequent liquid and air phase sampling and will be included in the Final Report.*

10. Selected Odor Control Design Concept*

**This Section will be developed following the completion of the ongoing improvements and subsequent liquid and air phase sampling and will be included in the Final Report.*

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