ODOR CONTROL COMPENDIUM

Compiled for

Riverbend Landfill
McMinnville, OR

Solid Waste Operations

January 2014

Contents

RIVERBEND ODOR CONTROL COMPENDIUM

1 Introduction

Waste Management (WM) subsidiaries own and operate solid waste management facilities throughout the U.S. and Canada. These facilities serve community needs and significantly contribute to public health and well-being. WM is aware of the need to manage facility operations in compliance with environmental regulations and standards and to minimize adverse community impacts. One potential impact is odor.

This compendium is intended to demonstrate compliance with Condition 9.22 of the Title V Air Permit. Condition 9.22 states;

> *"Within 30 days of permit issuance, the permittee shall develop and submit to DEQ a comprehensive report delineating what odor control/gas collection efforts or measures are being undertaken at other Waste Management landfills similar in nature to Riverbend Landfill and whether those measures can be instituted (if not already being used) at Riverbend Landfill. The report shall propose a timetable, for DEQ approval, for implementing any measures not already employed at the landfill."*

This document also reviews all current Riverbend Landfill odor control/gas collection activities. The document also provides a summary of current industry odor control strategies at landfills and other odor control technologies, and is an update to a WM Odor Control document originally produced in 2003. As part of the development of this document Riverbend Landfill has made a review of substantially all current odor control strategies via the use of the internet.

The WM Odor Control guidance document was developed by a team of solid waste professionals. In general the team identified the following progressively implemented strategies to prevent odors at MSW landfills;

- Working face odorous waste management procedures
- Immediate burial of odorous wastes
- Use of odor control chemistries on odorous wastes
- Rerouting odorous wastes
- Use of odor misting systems near property boundary
- Curtailed acceptance, where practicable, of H2S generating wastes
- Landfill Gas Control and Collection System management
- Optimizing gas collection in well field
- Dewatering of gas collection and control system (GCCS) Wells
- Installation of Temporary Pin Wells in recently placed wastes
- Effective cover management strategies
- Timely application of daily and intermediate covers
- Regular surface emissions monitoring (SEM) and cover integrity observations
- Timely repair of damaged cover areas
- Application of intermediate bio-covers
- Effective leachate management strategies
- Removal of operational roads and interim decks

- Carbon absorption vent controls on leachate storage tanks
- Removal of daily and intermediate covers when filling begins in an area
- Limiting stormwater intrusion
- Review of all odor complaints and reports
- Meteorological and operational review of site conditions for all odor complaints

As a part of the development of this compendium Riverbend Landfill has completed a review of current state of the practice for solid waste industry best management practices with respect to odor control. The results of this review indicate that, in general, no new odor management technologies or best management practices have been developed outside of Waste Management since WM's study. Since the development of the study, the only non-WM developments have been to odor control chemistries for use in misting systems. These practices are currently prohibited at Riverbend Landfill except for application directly on the waste. Alternatively Waste Management has made a substantial new development in the use of temporary non-NSPS wells identified as "Pin Wells" specifically designed for the control of odors in newly placed waste areas.

1.1 Riverbend Specific Odor Control Strategies

In recent years Riverbend Landfill has implemented substantially all of above identified Waste Management and the industry's standard odor control/gas collection strategies. In addition to the above identified odor control/gas collection strategies, in recent years Riverbend Landfill has made the following landfill gas collection system and odor control modifications:

- More than 120 vertical gas collection wells
- Addition of horizontal landfill gas collectors to collection strategy
- Installation of a new 100hp gas collection system blower in…?
- Installed 19 landfill gas well dewatering pumps in..?
- Upgraded gas collection header piping from 12 to 18 inches to allow for increased gas collection capacity in…?
- Installed new enclosed flare and six landfill gas-to-energy engines in 2010
- Odor survey around landfill was conducted daily using Nasal Ranger (discontinued)
- Quarterly landfill gas samples taken and analyzed for H_2S
- Semiannual public meetings required to inform public of odor abatement measures
- Monthly operational reports required on landfill systems operations
- Quarterly surface emissions monitoring for methane and corrective actions required (new permit requires monthly)
- Cover integrity inspections being completed monthly
- Monthly gas well static pressures, oxygen levels, and temperature measurements required
- Diversion of over 60,000 tons per year of odorous, and demolition wastes in 2012
- Diversion of 65% of paper mill ash from landfill and other sulfur bearing wastes
- Florida State H2S bio-cover study in 2013, (ongoing).

Riverbend Landfill has initiated an innovative academic study with Florida State University to evaluate landfill H2S fugitive emissions at Riverbend Landfill and the effects that various cover types have on the mitigation of fugitive H_2S emissions. This study is the first of its kind in the United States and includes both laboratory and field elements. In August 2013 the Florida State

project team field measured and quantified the worst case fugitive H_2S emissions from the landfill of 0.0077 tons of fugitive H_2S per year. This actual measurement was found to be significantly lower than the estimated 8.01 tons per year.
In October 2013, Riverbend Landfill also received authorization from Oregon Department of Environmental Quality to begin installation of the Waste Management Pin Well technology. Riverbend Landfill will deploy as needed the pin well technology on areas of recently placed waste (< 5yrs) for odor control. Compost covers in lieu of intermediate covers are also being studied in the Florida State study.

1.2 Planned Systems Enhancements

Enhancement	Scheduled Start Date
Addition of carbon vent system on north leachate tanks	First Quarter 2014
Florida State field study cover type H_2S mitigation	Construction Season 2014
2013 Expansion of LFG well field	Fourth Quarter 2013
Use of WM Pin Wells for odor mitigation	First Quarter 2014
Application of compost intermediate cover on first 10 acres	Construction Season 2014
2014 Expansion of LFG well field	Construction Season 2014

2 Odor Control Alternatives

RBLF has reviewed the state of the industry with respect to odor control and,after review of available literature and industry practices, has complied a list of techniques and practices.

In general the review indicates that odor control is generally best accomplished by a phased process of implementing simple housekeeping and operational fixes first and then moving up the ladder in complexity and cost until the problem is solved. Some examples of odor control techniques, are presented below and on the pages following. Note that not every suggestion will apply or be feasible to implement at RBLF.

Landfills

- Housekeeping, operational controls, effective management of odorous waste streams.
- Maintain an odor complaint log
- Install an on-site weather station and record at a minimum wind speed, wind direction, barometric pressure, rainfall and temperature to track odor dispersion.
- Identify odor-generating activities and waste streams.
- Regularly inspect condition of caps of closed portions of the landfill. Repair cracks.
- If viable, consider an alternate working face location for days with unfavorable wind conditions.
- To the extent allowed by landfill phasing, utilize site topography to effectively manage odor and wind transport issues.
- Reduce odor-generating activities during morning, evening, weekends and holidays when neighbors are outside.
- If temperature inversions occur, consider limiting delivery of odorous waste streams until conditions improve.
- For one-time event jobs that involve odorous waste, dispose in a dedicated trench or pit, cover frequently and utilize an odor control agent misted around the perimeter of the disposal area and/or add odor control product directly to the waste.
- Add an odor control agent to the water truck and water perimeter roads with the solution, especially when dealing with odorous wastes and at the end of the day.
- Be proactive in dealing with odor issues.
- Air permit allowing, implement the installation of “Pin Wells” in newer waste areas
- Install, expand or optimize the existing landfill gas extraction system.
- Connect sideslope risers and other landfill penetrations/venting points to the landfill gas extraction system. Make sure these are sealed to avoid unintentional air intrusion.
- Add liquid odor control chemistry directly to leachate or sludge tanker truck.
- When alternate daily cover (e.g. tarps) is used, consider applying odor control material under the tarp-to reduce odor when tarp is removed.
- If more rigorous odor control efforts are required, have an odor control survey done by a qualified consultant or supplier.
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- See Appendix ‘B’ for additional Best Management Practices

Appendixes

Appendix A – Odor and its Control

Appendix B – Best Management Practices

Appendix C – Odor Control Products

Appendix D – Odor Control Systems

Appendix A. Odor and its control

A1. The Basics of Odor Control

It is beneficial to have a basic understanding of the science and chemistry of odor to achieve effective control. This includes odor perception, odor chemistry and characteristics, odor measurement and odor transport.

A2. Odor Perception

Odor is a human sensation resulting from stimulation of the olfactory organ. Each person has a different level of odor sensitivity. The human nose is a highly sensitive instrument capable of detecting extremely low concentrations of certain chemicals. Even with sophisticated analytical instruments, there is no better measurement of odor than the human nose. Odor complaints are based on the perception of odor.

A3. Odor Chemistry and Characteristics

Odors are mixtures of individual compounds that are generated by the decomposition of organic material containing carbon, hydrogen, nitrogen and sulfur under reducing (anaerobic) conditions. This type of condition occurs in solid waste operations including solid waste storage, trucks, transfer trailers, containers, transfer stations and landfills. Odor compounds are low molecular weight compounds (50-200 m.w.), with relatively low boiling points (45°F to 75°F) and low vapor pressure. There are over 300 common odorous compounds generated by solid waste processing operations. A partial list of the most common odorous substances found in landfills and leachate is shown in Table 1. Note that many of the compounds are detectable at very low concentrations. WM compliance records indicate that landfill gas, food wastes, petroleum-tainted wastes, sewage and hydrogen sulfide (rotten egg odor) are the most common complaints. Some typical sources of these odors are listed below:

- Based on metrics from the WM Southern Group, significant numbers of the odor complaints are related to Landfill Gas issues. Balance of the odor complaints are related to special wastes or sludges.
- Food wastes become odorous quickly, especially in warm weather.
- Volatile fractions from refinery waste such as tank bottoms, fuel spill cleanup residuals, and contaminated soils. These tend to evaporate in the buried garbage. The more volatile fractions are vented with landfill gas.
- Biosolids (sludge) from wastewater treatment (aerobic and anaerobic) can result in odor emissions if not covered quickly.
- If solid waste arrives wet, it ferments rapidly and the gas is generated earlier than would occur otherwise.
- Loading transfer trailers the night before and keeping them at the transfer station or keeping a few loads ready for the next day can aggravate odor issues.
- Composting of yard waste can lead to odor complaints.
- Seasonal events can cause odors. For example, in Gulf Coast states, crawfish, shrimp and

other seafood residuals cause container odors in spring and summer months.

- Wallboard and dry wall, common components of C& D waste, contains calcium sulfate ($CaSO_4$-$2H_2O$). When fermented in a landfill this yields hydrogen sulfide (H_2S) which has a characteristic rotten egg odor.
- The generation of H_2S at landfills in Oregon has been exacerbated with the implementation of C&D material recovery facilities. These facilities generate significant amounts of C&D fines which when disposed in landfills yields hydrogen sulfide (H2S).

Table 1; Partial List of Odorous Substances Found in Landfills and Leachate

Compound	Formula	Characteristic Odor	Odor Threshold (ppm)
Acetaldehyde	CH_3CHO	Pungent fruity	0.004
Allyl Mercaptan	CH_2CHCH_2SH	Strong garlic, coffee	0.00005
Ammonia	NH_3	Sharp pungent	0.037
Amyl Mercaptan	$CH_3(CH_2)$ CH2SH	Unpleasant, putrid	0.0003
Benzyl Mercaptan	$C_6H_5CH_2SH$	Unpleasant, strong	0.00019
Butylamine	$C_2H_5CH_2CH_2NH_2$	Sour, ammonia- like	--
Cadaverine	$H_2N(CH_2)_5NH_2$	Putrid, decaying flesh	--
Chlorophenol	ClC_5H_5O	Medicinal, phenolic	0.00018
Crotyl Mercaptan	$CH_3CHCHCH_2SH$	Skunk-like	0.000029
Dibutylamine	$(C_4H_9)_2NH$	Fishy	0.016
Dimethylamine	$(CH_3)_2NH$	Putrid, fishy	0.047
Dimethyl Sulfide	$(CH_3)_2S$	Decayed vegetables	0.001
Diphenyl Sulfide	$(C_6H_5)_2S$	Unpleasant	0.000048
Ethylamine	$C_2H_5NH_2$	Ammoniacal	0.83
Ethyl Mercaptan	C_2H_5SH	Decayed cabbage	0.00019
Hydrogen Sulfide	H_2S	Rotten eggs	0.00047
Methyl Mercaptan	CH_5SH	Decayed cabbage	0.0011
Propyl Mercaptan	$CH_5CH_2CH_2SH$	Unpleasant	0.000075
Pyridine	C_6H_5N	Disagreeable, irritating	0.0037
Styrene	$C_cH_5CHCH_2$	Sharp, Sweet, Unpleasant	0.008
Tert-Butyl Mercaptan	$(CH_3)_3CSH$	Skunk, unpleasant	0.00008
Thiocresol	$CH_3C_6H_4SH$	Skunk, rancid	0.0001
Thiophenol	C_6H_5SH	Putrid, garlic-like	0.000062
Triethylamine	$(C_2H_5)_3N$	Ammoniacal, fishy	0.08

A4. Odor Transport

Odor compounds are released into the atmosphere as a vapor and may be transported by natural air currents to "receptor" at some distance. Site topography and predominant wind currents play a large role in the transport of odors. Odor must be (1) generated, (2) transported and (3) received for an odor problem to exist. There are many variables as listed in Table 2.

Table 2. Variables Impacting Odor Complaints

Factors Influencing Odor Generation	Factors Influencing Odor Transport	Factors Influencing Odor Reception
Amount and rate of solid waste processing	Wind direction variation and speed	Olfactory sensitivity of complainants
Location of processing operations	Relative humidity	Length of exposure
Time of day that processing takes place	Atmospheric conditions	Odor intensity as measured by ED_{50}
Duration and frequency of odor releases.	Climate	Time of day, Time of year (wind patterns, open windows, outdoor activities, etc)
Waste characteristics	Precipitation	Work and recreational patterns
Size, location, areal extent of odor producing operations	Local topography	Exposure history of complainant
Odor characteristics of odorous discharges	Seasonal variations in local climate	Location of complainants property
Type of daily cover		other odor-producing industries in the area
Open landfill face area		

A5. Odor Measurement

Odor from a single compound can be quantitatively measured in parts per million (ppm) or parts per billion (ppb) of that compound. However, odors associated with most solid waste operations are a combination of many different compounds. This must be qualitatively measured as “odor” rather than as a concentration of a specific compound. The following are suggested qualitative odor measurement aspects;

Odor Intensity: Measured on a 0-8 scale (8 being the strongest) and is based on the concentration of butyl alcohol or Butanol. Experience shows that odor complaints become common at Odor Intensities above 3.0 to 3.5.

Odor Character: A description of what the odor smells like. A person smelling the odor will list 4-6 odor characteristics out of a list of 120 to 150 specific scents or odors.

Odor Threshold: An estimate of the odor concentration correlated with the level at which most people can detect an odor and identify what it smells like.

A6. Odor Laws and Regulations

There are no Federal Laws, Regulations or Standards for odor. Most states have some type of odor regulations or standards that are usually enforced by state or local Air Pollution Control Agencies or other environmental authorities.

Odorous emissions or discharges are almost always regulated by means of a state or local (city or county government) “nuisance odor ordinance”. These ordinances are enforced by government agencies when they receive complaints from affected parties that can identify the source of the odor.

A7. Odor Complaints

Once an odor complaint is received, action should be taken as soon as possible.
The most common factors that associated with odor complaints are:

The intensity of the odor
The duration and frequency of odorous emissions
Perceived progress (or lack thereof) in eliminating or reducing odorous discharges

The most effective initial course of action is to adopt a strong proactive program to address odor complaints. The following are elements of an effective proactive odor control program that should be considered.

- Respond to complaints as soon as possible.
- Establish a single point of contact and/or a center of responsibility for dealing with odor complaints.
- Build a team composed of a key operations person, the “point of contact”, and the manager of the facility.

Set up meetings with local authorities and create a reliable response system to complaints. Document the efforts to fix the potential odor issue.

Appendix B. Best Management Practices

The following BMPs provide a quick review of the most common types of odor problems and solutions affecting Waste Management. The BMP topics include:

- Hydrogen Sulfide Due to Wallboard/Gypsum Disposal
- Well Drilling and Waste Excavation
- Landfill Gas Control
- Misting System Nozzle Placement
- Special Waste and Sewage Sludge
- Weather Station

Best Management Practice	
Odor	
BMP Topic:	Hydrogen Sulfide Due to Wallboard/Gypsum Disposal
Issue:	Wallboard used in construction (also known as sheetrock or gypsum) is comprised of gypsum, chemical formula $CaSO_4 \cdot 2H_2O$. In a landfill, bacteria change calcium sulfate, the major component of wallboard, into hydrogen sulfide. If construction and demolition debris contain large quantities of wallboard, large amounts of hydrogen sulfide can be formed. Production is greatest when the wallboard is finely crushed and when there is little oxygen, such as when the debris is buried and soaked with water, conditions that can be common to both C&D and MSW landfills. Some sites used crushed C&D debris (including wallboard) as daily cover. Result can be elevated concentrations of H_2S in the landfill gas and/or odor. The characteristic odor of hydrogen sulfide is that of rotten eggs. Odor Threshold: 0.00047ppm (vol/vol)
Suggested management methods:	Divert wallboard type products to disposal sites that are unlikely to have odor/LFG issues. Avoid crushing the wallboard. This increases the surface area. Avoid using crushed wallboard as daily cover. Install or optimize the landfill gas collection system. Use Flares or engines to destroy collected gas as they typically provide good H_2S destruction efficiency. Place wallboard and other H2S generating wastes in segregated areas within the landfill.
Further Info:	http://www.atsdr.cdc.gov/

Best Management Practice	
Odor	
BMP Topic:	Well Drilling and Waste Excavation
Issue:	WM operating experience has shown that some landfill odor complaints can be traced drilling new gas wells and excavating waste during construction periods.
Suggested management methods:	Use phased construction planning for LFG additions, so that additions can be used for long term or permanent gas control. Minimize the working area as much as possible, limiting the amount of waste excavation during construction. Place adequate cover soils in close proximity to the construction area to ensure open waste durations are minimized. If waste relocation is needed, identify an area in close proximity to the construction area to quickly and efficiently dispose of the waste. Use perimeter and/or local odor neutralization chemical application.

Best Management Practice	
Odor	
BMP Topic:	Landfill Gas Control
Issue:	WM operating experience has shown that some landfill odor complaints can be traced to landfill gas (LFG) issues.
Suggested management methods:	Install WM “Pin Wells” in newer placed waste (<5 yrs) Agency approval required. Review LFG system and add additional wells if necessary. Check for and repair or remove water in wells and header pipes. Connect sideslope riser pipes and other landfill penetrations to the LFG system. Be careful to avoid routes of air entry into the landfill. Balance well field on a regular basis. Repair cracks in soil cap or add moisture to desiccated clay. Consider adding additional soil or a compost covers for problem areas, coupled with active gas control. Use phased construction planning for LFG additions, so that additions can be used for long term or permanent gas control. Use “Pin Wells” as temporary sacrificial wells and LFG components if necessary. Use barriers to prevent horizontal migration to adjacent areas of future cell development to “cut off” lateral outbreaks through permeable leachate collection zones. Use perimeter and/or local odor neutralization chemical application.

Best Management Practice	
Odor	
BMP Topic:	Misting System Nozzle Placement
Issue:	Landfills, transfer stations and other solid waste management sites may install a perimeter misting system for the distribution of water, vapor phase odor control chemistry or other products for the suppression of odor. These systems generally consist of hoses equipped with nozzles at regular intervals. They are often mounted on perimeter fencing or other convenient mounting locations. These mounting locations are not always optimal for odor control purposes and may result in wasted odor control product.
Suggested management method:	Conduct a smoke test to help visualize wind patterns across the facility. Notify neighbors and emergency responders as required so that the temporary smoke will not cause alarm. It is generally helpful to have the misting system close to the source of the odor as possible. It is often helpful to have the nozzles mounted high, e.g. on telephone poles. Fence level nozzles are often too low to allow good mixing of the odorous air and the chemistry. Misters are generally located downstream of the odor source, between the odor and the potential receptors. A water spray can be helpful in reducing light odors and in maintaining clean nozzles. Odor systems can be interfaced with the wind sensor of an on-site weather station to have the system automatically turn off when the wind is blowing away from potential receptors.

Best Management Practice	
Odor	
BMP Topic:	Special Waste and Sewage Sludge
Issue:	Odor complaints are sometimes related to the acceptance of non-hazardous industrial wastes and/or municipal sewage sludge. Special handling procedures may be required to prevent odor complaints.
Suggested management methods:	Mix sludge and special waste in with normal MSW receipts. Cover as quickly as feasible. Mix odor control chemicals into the waste or sludge at the plant where it is loaded. Divert particularly odorous loads to a less sensitive facility or to a remote working face. Use at-the-source odor control such as tractor sprayers, backpack sprayers, granular odor control, etc. Odor control chemistry that employs enzymes may be beneficial in controlling sludge odors. Treat haul trucks and containers with odor control chemistry (or wash out) to avoid residual odor along the route of the empty truck/container. Use disposable plastic truck bed liners. Perimeter and/or local odor neutralization chemical application.

Best Management Practice	
Odor	
BMP Topic:	Weather Station
Issue:	Optimum control of odor sources at solid waste facilities (landfills, transfer stations, compost facilities, etc) requires accurate weather information. Traditionally, sites have relied on nearby airports or other weather stations, which may not be applicable to the site..
Suggested management method:	Install an on-site weather station and record meteorological data. This can be used to verify odor complaints. Print and file a hard copy of the weather data at least once a week to serve as a backup to the electronic data. Select a weather station that can support sensors for monitoring: temperature, humidity, barometric pressure, wind speed and direction, and rainfall.
Further Info:	www.oregonscientific.com (Weather Station) http://www.rainwise.com/ (Weather Station) www.ambientweather.com (Weather Station Software)

Appendix C. Odor Control Products

Odor situations that cannot be adequately controlled by housekeeping and operational changes may require a more rigorous odor control system using commercially available products and distribution systems. Since 1998, WM has conducted a field odor survey, met with consultants and suppliers and thoroughly investigated odor control operations for solid waste operations. WM has concluded that vapor phase essential oil-based neutralizer chemistry distributed in a high pressure fogging system is the optimal odor control option for most company applications. The following sections provide additional information on the chemicals and distribution systems.

Use vapor phase essential oil-based neutralizer chemistry distributed in a high pressure fogging system for most WM odor control applications.

C1. Evaluating Suppliers and Products

There are over one hundred odor control product suppliers selling more than five hundred different product formulations. Some products work very well, but many are not effective. Some work well in certain applications, and very poorly in other applications. Most of these issues can be avoided by using a WM-approved supplier. Consider running a trial of products from various approved suppliers to verify that the product is effective for your site- specific situation.

The product type selected by WM as our primary odor control chemistry is known as a neutralizer. When sprayed, misted or fogged into the air these products are classified as “vapor phase neutralizers”. Vapor phase c neutralizers are specially formulated mixtures of chemical compounds in liquid form that are mixed or diluted with water and sprayed or fogged into the atmosphere to react with and reduce odorous compounds in the air. “Neutralizer” refers to product chemistry whereby there is a physical and chemical reaction that modifies odor molecules so that they are no longer perceived by the human olfactory system.

Neutralizer formulations vary widely between manufacturers or suppliers, but virtually all neutralizers contain:

A blend of a few or many essential oils. An essential oil is an extract of naturally occurring plant life. There are over 3,000 commercially available “essential oils”. Generally the more complex product chemistries are effective over a wider spectrum of odors. Examples of common essential oils are listed below.

Lime	Lemon Grass	Tea Tree
Limon	Cedar	Citronella
Grapefruit	Cinnamon	Water
Eucalyptus	Lavender	
Orange	Peppermint	

Neutralizers are not “masking agents” but they often have a fragrance when concentrated because

they are typically combinations of plant oils, such as lemon, lime, and other fragrant oils. A fragrance is sometimes added to odorless product formulations. Some neighbors want to smell the fragrance as verification that the odor control system is working.

Neutralizers combine with and react with an odor molecule. Masking agents add a fragrance to cover an unpleasant odor with a stronger, more pleasant odor.

"Standard Concentration" neutralizer formulations generally contain from 2 to 6% by weight of "active ingredients".

Neutralizer formulations are highly proprietary.

Odor chemistries usually require a high quality source of water for dilution. If the available water supply is high in hardness (> 100 ppm) or sediment (TSS), there may be problems with nozzle clogging. Consider pretreatment with a softener, scale inhibitor, filter or find another water source. This can be of particular concern at a landfill where pond or well water is used as a supply source.

C2. Physical and Chemical Reactions

The chemistry of neutralizer reactions with odors is complex, involving both physical and chemical reactions. The reactions may include:

Adsorption	(physical)
Oxidation or reduction	(chemical)
Polymerization	(chemical and physical)
Interference	(chemical and physical)
Combining reactions	(chemical and physical)

The dominant reaction for Neutralizers is interference. In interference reactions an essential oil molecule combines with an odorous molecule to render the combined pair of molecules non-odorous. Since essential oils do not mix well with water, and since the molecules must come in contact with each other in the atmosphere, Neutralizer formulations contain some form of solubilization chemistry or wetting agents (mostly detergents) and must be dispersed into the atmosphere through a fogging system that creates intimate contact. The essential oil is carried on the surface of a very small water droplet (< 10 microns) both of which evaporate into the atmosphere.

Appendix D. Odor Control Systems and Odor-Related Resources

D1. Equipment and Hardware

Most odor control product suppliers also supply delivery systems. No matter how good the odor control product, if it is not sufficiently misted into the atmosphere it will not effectively reduce odor.

The four basic rules for a successful vapor phase application are:

- Make sure the product (chemistry) works for the specific application.
- Make sure the distribution system allows adequate coverage.
- Make sure the dosage control is correct.
- Have someone take "ownership" of the system and continue "tweaking" until optimal efficiency is achieved.

The systems commonly used for dispersing neutralizers into the atmosphere vary widely. Nearly all suppliers supply one or more forms of dispersion systems. Typical components of a perimeter vapor- phase odor control delivery system include:

- High pressure pump(s)
- Filters on main water supply line (typically 5 micron cartridge filters for a 10 micron nozzle)
- Pre- and Post- filter pressure gauges (can be used to determine when to replace cartridge filters)
- Filter screens at nozzles
- Nozzles (brass, stainless steel or plastic)
- Chemical Metering Pump(s)
- Valves
- Hoses
- Crimps
- Static Mixers
- Pressure gauge(s)
- Controls including low water shut off and high temperature shut off.
- Electrical controls in weather proof NEMA 4X fiberglass box.
- Electric and water utilities, and for modem-connected systems, a dedicated phone line.

Typical system specifications are as follows:

High Pressure Fogging Systems (most widely used distribution system for landfill applications, may be used for transfer station applications)	
Pressure (psig)	400 to 1000
Nozzle size (inches)	0.005 to 0.008
Nozzle flow rate (gpm)	0.02 to 0.05 (depends on pressure)
Particle size (microns)	5-15 microns
Nozzle spacing (feet)	5 – 20 (depends on application)
Nozzle height (feet)	10-40 (depends on application)
Hose size (inch)	¼ to ¾ (depends on length of run and number of nozzles)

Low Pressure Fogging Systems (may be used for transfer station applications, less suitable for landfill applications)	
Pressure (psig)	50 to 400
Nozzle size (inches)	0.01 to 0.1
Nozzle flow rate (gpm)	0.5 to 10 gpm
Particle size (microns)	100-500
Nozzle spacing (feet)	10 – 30 (depends on application)
Nozzle height (feet)	10-40 (depends on application)
Hose size (inch)	½ to 1 (depends on length of run and number of nozzles)
Pneumatic System (Air Atomizing Nozzles) (used in some unique applications)	
Air Pressure (psig)	30-50
Liquid Pressure (psig)	30-50
Air Nozzle size (inches)	¼ - 2
Airflow rate, scfm	100 – 200
Air Piping size (inches)	3 – 6
Air Piping size (inches)	3 – 6

Other vapor phase dispersion systems include:

- Tractor mounted sprayers (used for small area application, such as working face or open trenches)
- Back pack sprayers (used to treat “hot spots”)
- Portable high and low pressure systems (may be skid or trailer mounted)
- Tank mounted on compactor, chemistry distributed by engine fan

A critical factor in determining the effectiveness of a vapor phase odor control system design is the arrangement including height and spacing of the nozzles, along with the flow rate of the nozzles to insure an optimum mix of the Neutralizer with the odorous air plume. It's especially important to evaluate the mixing characteristics under local wind direction, and speed and other climatic factors that prevail during the time of odor complaints. A simple and inexpensive smoke test can help to determine the correct placement of the nozzles. Both upwind and downwind mixing must be considered as well as micro atmospheric currents and disturbances. Proper location of the dispersion system and daily dosage control is necessary to produce maximum effectiveness.

The choice between available systems will depend on local site conditions and climate. Design precautions must be taken against freezing conditions. In some cases a pneumatic system may be selected in severe winter climates. Vapor phase misting systems are generally not effective at temperatures much below freezing (the system will turn into a snow-making machine). The effectiveness of the odor control chemistry is also reduced at low temperatures. Some odor chemistry formulations are rendered ineffective if frozen. Some formulations also have a shelf life beyond which their effectiveness is questionable.

D2. Odor Training

Specialized training is available in the science of odor. The Nasal Ranger ® program is offered by St. Croix Sensory. Training can be done locally.

D3. Weather Stations

A weather station is an inexpensive tool that can provide big benefits in odor control. The weather station selected should be able to provide and record data on precipitation, wind direction & speed, barometric pressure, relative humidity and temperature. Most systems can be set to record at various intervals. Recording every half or full hour is generally sufficient for WM odor documentation needs. The system can be connected to the odor chemistry delivery system so that, for example, the system is shut down when the wind is from a certain direction. Occasionally systems cycle on and off due to wind fluctuation so combine the wind sensor with a delay or timer function.