# CITY OF RICHMOND, CA

RICHMOND WATER POLLUTION CONTROL PLANT

ODOR EVALUATION REPORT

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1.0 INTRODUCTION

1.1 Background

The City of Richmond (City) owns the Richmond Water Pollution Control Plant (RWPCP), which provides wastewater treatment for the Richmond Municipal Sewer District 1 service area. The City has a long-term agreement with Veolia Water North America – West, LLC (Veolia) to operate, maintain and manage capital improvements to the plant.

Odors from the RWPCP result in some odor complaints from residents in the community near the plant. The City and Veolia desire to control odor emissions from the RWPCP and to prevent odor emissions from being a nuisance to current and future developments in the communities near the plant. Figure 1 is an aerial photograph of the RWPCP and surrounding area.

Veolia retained Webster Environmental Associates, Inc. (WEA) to conduct a plant-wide odor evaluation at the RWPCP and the drying beds controlled by the West County Wastewater District (WCWD).

1.2 Objectives

The primary objectives of this odor evaluation are to:

- Quantify odor emissions from the RWPCP
- Identify and prioritize specific processes contributing to odor problems, including the planned dewatering processes
- Determine impacts of plant odors on existing and potential future receptors near the RWPCP
- Evaluate odor control technology alternatives
- Recommend odor control systems needed for specific process areas
- Provide capital and operating cost estimates for the recommended odor control system alternatives
Figure 1
Richmond WPCP & Surrounding Area
1.3 Richmond WPCP Description

The original RWPCP was constructed in 1958 and provided influent pumping, grit removal, comminution, chlorination, and discharge to San Francisco Bay. The plant was upgraded to provide primary sedimentation treatment with anaerobic sludge digestion in 1961. Secondary activated sludge treatment was added in 1968. A pipeline to pump plant effluent from the West County Wastewater District’s WPCP to the RWPCP confluence structure for combined discharge through a new outfall was completed in 1980. A pipeline to pump digested sludge from the RWPCP to the WCWPCP sludge drying beds was completed in 1982. This pipeline is also used to pump landfill leachate from the landfill near the WCWPCP to the RWPCP for treatment. Projects to provide capacity expansion, conversion to hypochlorite and bisulfite, and wet weather blending were completed in 1993.

The RWPCP has a current design treatment capacity of 16 million gallons per day (MGD). The annual daily flow averages approximately 8.7 MGD, with average summer flows of 6.5 MGD and average winter flows of 11 MGD.

Figure 2 shows the RWPCP liquid process flow schematic. Wastewater influent flows through a mechanical bar screen before entering the Influent Pump Station (IPS) wet well for pumping to the grit removal structure. Wastewater flows by gravity through the remaining plant processes, which include primary sedimentation, aeration basins, secondary clarifiers, and chlorine contact tanks for disinfection. The plant effluent flows to the effluent confluence structure, mixes with WCWPCP effluent, and is pumped to the San Francisco Bay via the outfall pipeline.

Figure 3 shows the RWPCP solids process flow schematic. Primary sludge from the Primary Sedimentation Tanks is pumped through sludge heaters and to the digesters. Waste activated sludge from the Secondary Clarifiers is pumped to the Dissolved Air Flotation Thickener (DAFT) for thickening. Thickened Waste Activated Sludge (TWAS) is pumped from the DAFT, mixes with the primary sludge, and flows through the sludge heaters and on to the digesters. Digested sludge is pumped approximately 4.5 miles through a six inch pipeline to the WCWPCP drying beds. The sludge is pumped every other day. Landfill leachate is pumped through the same pipeline from the WCWPCP on the alternating days.

In addition to the existing processes, a centrifuge dewatering process is currently in the planning phase for the RWPCP. The dewatering facility will be located in the area currently occupied by the sludge heating building and old digesters. The dewatering process will eventually eliminate the need to pump digested sludge to
Figure 2
Richmond WPCP Liquid Process Flow Schematic
Figure 3
Richmond WPCP Solids Process Flow Schematic
the WCWPCP drying beds. An odor control system is planned to treat odorous air from the dewatering processes.

2.0 ODOR GENERATION AND CHARACTERIZATION OF ODORS

2.1 Odor Generation

Odor-producing substances found in domestic wastewater and sludge are small, relatively volatile molecules with a molecular weight of 30 to 150 pounds (lbs) per pound mole. Most of these substances result from the anaerobic decomposition of organic matter containing sulfur and nitrogen. Inorganic gases produced from domestic wastewater decomposition commonly include hydrogen sulfide, ammonia and carbon dioxide. In addition, wastewater processes often generate odorous organic compounds, such as indoles, skatoles, mercaptans and nitrogen-bearing organics.

Hydrogen sulfide (H2S) is the most commonly known and prevalent odorous gas associated with domestic wastewater collection and treatment systems. It is a colorless gas, has a characteristic rotten egg odor, and is directly corrosive to metals and indirectly corrosive to concrete. H2S can be oxidized to sulfuric acid, which causes corrosion of concrete, metals and other materials.

Many of the odors detected in wastewater collection and treatment systems result from the presence of sulfur-bearing compounds. A list of common malodorous sulfur-bearing compounds is shown in Table 1. The lower the molecular weight of a compound, the higher the volatility and potential for emission to the atmosphere. Substances of high molecular weight are usually not perceptibly odorous and are neither volatile nor soluble. It should be noted that organic chemicals of industrial origin, particularly solvents, are highly volatile as well as odorous and may contribute to overall odor emissions. Presence of turbulent or splashing conditions, such as overflow weirs in grit chambers and primary clarifiers increase the release of volatile odorous molecules. On the other hand, if the wastewater is aerobic and such odorous compounds are not present, such turbulence is beneficial because it promotes reaeration and the addition of dissolved oxygen, and thus prevents formation of odorous compounds associated with anaerobic conditions.

Perceived odors are often complex mixtures of odorous compounds acting together to create "an odor" which may have characteristics significantly different from each of the individual components. For this reason, attempts to identify the specific compounds present in an odorous air sample may not be justified when evaluating odor control alternatives, although analytical instruments can be used to identify the presence of certain common odorous compounds such as H2S which can provide useful information regarding the character of the odor and the need for treatment.
### TABLE 1
ODOROUS SULFUR COMPOUNDS IN WASTEWATER

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>FORMULA</th>
<th>CHARACTERISTIC ODOR</th>
<th>ODOR THRESHOLD (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allyl Mercaptan</td>
<td>CH$_2$=CH-CH$_2$-SH</td>
<td>Strong garlic-coffee</td>
<td>0.00005</td>
</tr>
<tr>
<td>Amyl Mercaptan</td>
<td>C$_3$H$_7$-SH</td>
<td>Unpleasant-putrid</td>
<td>0.0003</td>
</tr>
<tr>
<td>Benzyl Mercaptan</td>
<td>C$_6$H$_5$CH$_2$-SH</td>
<td>Unpleasant-strong</td>
<td>0.00019</td>
</tr>
<tr>
<td>Crotyl Mercaptan</td>
<td>CH$_3$-CH=CH-CH$_2$-SH</td>
<td>Skunk-like</td>
<td>0.000029</td>
</tr>
<tr>
<td>Dimethyl Sulfide</td>
<td>CH$_3$-S-CH$_3$</td>
<td>Decayed-vegetables</td>
<td>0.0001</td>
</tr>
<tr>
<td>Dimethyl Disulfide</td>
<td>CH$_3$-S-CH$_3$-S</td>
<td>Decayed-vegetables</td>
<td>0.0001</td>
</tr>
<tr>
<td>Ethyl Mercaptan</td>
<td>CH$_3$-CH$_2$-SH</td>
<td>Decayed-cabbage</td>
<td>0.00019</td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>H$_2$S</td>
<td>Rotten eggs</td>
<td>0.00047</td>
</tr>
<tr>
<td>Methyl Mercaptan</td>
<td>CH$_3$SH</td>
<td>Decayed-cabbage</td>
<td>0.0011</td>
</tr>
<tr>
<td>Propyl Mercaptan</td>
<td>CH$_3$-CH$_2$-CH$_2$-SH</td>
<td>Unpleasant</td>
<td>0.000075</td>
</tr>
<tr>
<td>Sulfur Dioxide</td>
<td>SO$_2$</td>
<td>Pungent, irritating</td>
<td>0.009</td>
</tr>
<tr>
<td>Tert-butyl Mercaptan</td>
<td>(CH$_3$)$_3$C-SH</td>
<td>Skunk, unpleasant</td>
<td>0.00008</td>
</tr>
<tr>
<td>Thiocresol</td>
<td>CH$_3$-C$_6$H$_4$-SH</td>
<td>Skunk, rancid</td>
<td>0.000062</td>
</tr>
<tr>
<td>Thiophenol</td>
<td>C$_6$H$_5$SH</td>
<td>Putrid, garlic-like</td>
<td>0.000062</td>
</tr>
</tbody>
</table>

Odor Threshold – lowest concentration at which compound may be detected by a person with an average to above average sense of smell.

2.2 Odor Panel Procedures

Odor panels involve human panelists who participate in a series of scientifically controlled sensory tests.

Common sensory properties used to characterize odors are:

- Odor detectability reported as Detection Threshold (DT)
- Odor recognition reported as Recognition Threshold (RT)
- Odor intensity or dose-response
- Hedonic tone (HT) or pleasantness/unpleasantness
- Odor character (word descriptors)

DT and RT were the only sensory properties evaluated in this study. DT values are used as inputs to the odor dispersion modeling, as discussed later in this report. Testing for the remaining sensory properties was not deemed necessary or cost effective for purposes of this odor evaluation.

A six to eight member odor panel consists of trained personnel who are scientifically screened to determine their smelling acuity to butanol. The odor panel testing, although subjective, is conducted under strictly controlled “clean” conditions to produce statistically valid results.

The odor evaluations are conducted in accordance with ASTM Standard Practice E679-91 (Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series of Limits) and E544-99 (Referencing Suprathreshold Odor Intensity).

The dynamic dilution of odorous emissions is a physical process that occurs in the atmosphere down-wind of the odor source. An individual, or citizen from the community, sniffs the diluted odor. The number of dilutions needed to make the odor emission just detectable is known as the DT. The RT value is the dilution ratio at which the assessor first recognizes the odor’s character. For example, an odor panel’s response at DT may be “that smells” where the odor panel response at RT may be “that smells like a skunk”.

**Odor Detectability and Recognition**

DT values reported from the odor panel refer to the number of dilutions of an odorous air sample required before half the panel members are still able to detect the presence of the odor. RT refers to the number of dilutions of an odorous air sample required before half the panel members are still able to characterize or recognize the odor.
A high DT indicates a strong odor requiring many dilutions to render it undetectable. RT values are always less than DT values because it is easier to detect an odor than identify an odor. The relative magnitude of DT and RT values indicates the relative significance of odors from various odor sources.

2.3 Hydrogen Sulfide (H₂S) Measurements

H₂S can be measured in the field using H₂S analyzers that provide instantaneous readings and/or continuous data logging. Since it is easy to measure, H₂S is often used in wastewater situations as an odor indicator. In many cases if the H₂S is controlled, the odor problem will be eliminated. H₂S is slightly heavier than air and moderately soluble in water.

H₂S dissolves in water and disassociates in accordance with the following reversible reaction:

\[ \text{H}_2\text{S} \leftrightarrow \text{HS}^- + \text{H}^+ \]

The distribution of the above species is a function of pH, as shown graphically in Figure 4. The relative H₂S concentration increases with decreasing pH. Only the dissolved sulfides can escape from the liquid (as H₂S). Hydrogen sulfide is formed under anaerobic or septic (absence of oxygen) conditions.

During this evaluation, H₂S was measured using an Arizona Instruments Jerome 631X H₂S analyzer with a range of 0.003 to 50 parts per million (ppm). These measurements will be used to identify or confirm odor (and H₂S) sources at the plant. In addition, diurnal H₂S concentrations were logged in the influent screen channel and wet well room during the testing period using OdaLog H₂S analyzers. The data was downloaded to the PC for plotting the diurnal H₂S concentration profile at these locations.
2.4 Wastewater Analysis

Sulfides, which are the dissolved liquid form of hydrogen sulfide, are formed biologically in the wastewater collection system in the absence of dissolved oxygen. Sulfates are reduced to sulfides in the absence of oxygen or nitrates (anaerobic conditions) in the slime layer of force mains and gravity sewers. \(H_2S\) is moderately soluble in water.

The rate of sulfide production by the slime layer is related to the following factors:

- Wastewater organic strength
- Dissolved oxygen (D.O.)
- pH
- Temperature
- Velocity
- Detention time in the force main or gravity sewer
Within a D.O. range of 0.1 - 0.5 mg/L, anaerobic bacteria reduce sulfates to sulfides. Low velocities can promote the formation of thicker slime layers. As detention time increases, oxygen depletion occurs and the conditions favor sulfide production. The rate of sulfide production can double for every 10°C increase in temperature. pH governs the ratio of H₂S gas and ions in solution.

Sulfide generation is directly proportional to detention time in the sewer.

The formation of sulfides is an important parameter to measure to determine the potential for H₂S generation and release. In this study, samples for sulfide analyses were taken to assist in identifying the causes of odor problems. In addition to analytical testing for sulfides, field measurements of pH, dissolved oxygen (DO), oxidation reduction potential (ORP), and temperature were made. The following is a description of each parameter tested and the methods used for analysis:

Total and dissolved sulfide concentrations (mg/L) in the wastewater were measured using a LaMotte Pomeroy Sulfide Test Kit (Model CC-PS). The bacterial reduction of sulfates to sulfides occurs in the absence of dissolved oxygen and nitrates. Sulfides form dissolved hydrogen sulfide (H₂S) in the wastewater which can then be released at points of turbulence. Sulfides indicate the presence of H₂S in the wastewater and the potential for odor and corrosion problems. Dissolved sulfide represents the fraction that exists as dissolved H₂S, available to be released. Dissolved sulfide concentrations greater than 1.0 – 1.5 mg/L may contribute to odor and corrosion problems.

The oxidation reduction potential (ORP) of the wastewater was measured using a Digi-Sense Digital pH/ORP Meter (Model 5938-50). The ORP is measured in millivolts (mV) and is an indication of materials in the reduced form (sulfide) and in the oxidized form (sulfate). In an aerobic environment, bacteria use dissolved oxygen for respiration and sulfate is not reduced to sulfide. In an anaerobic environment with a low ORP (less than zero), bacteria use the sulfate for respiration, reducing the sulfate to sulfide. The following are ranges of ORP:

<table>
<thead>
<tr>
<th>ORP (mV)</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 50</td>
<td>No action by anaerobic bacteria</td>
</tr>
<tr>
<td>0</td>
<td>Poor anaerobic bacteria activity</td>
</tr>
<tr>
<td>-100 to -200</td>
<td>Maximum efficiency for anaerobic bacteria activity</td>
</tr>
<tr>
<td>-50 to -300</td>
<td>Favored by sulfate reducing bacteria for production of sulfide</td>
</tr>
</tbody>
</table>
The pH of the wastewater was measured using the Digi-Sense Digital pH/ORP Meter. The relative portions of H₂S and HS⁻ are dependent on pH, which is important in assessing the potential for H₂S gas release. A pH of less than 7 is conducive to sulfide generation and H₂S release.

3.0 DESCRIPTION OF ODOR TESTING AND MODELING

3.1 Overview of Sampling Program

Gas phase (odor) sampling was conducted over a two day period at the RWPCP and the WCWPCP drying beds. A total of fourteen (14) air samples for odor panel analyses were collected on June 26 – 27, 2007. Since landfill leachate is pumped into the plant influent on alternating days, several processes at the RWPCP were tested on both days to evaluate any differences in odor when the leachate is added to the wastewater flow. The WCWPCP drying bed receiving the RWPCP digested sludge was also tested on both days. The first day was during the sludge pumping operation and the second day was after pumping was completed the day before.

The odor samples were packaged and shipped daily by overnight express for odor panel analyses by St. Croix Sensory, Inc. in Lake Elmo, MN.

Field H₂S monitoring was conducted at the time each air sample was collected. Air samples were collected using grab and flux chamber methodology described herein. In addition, data logging H₂S analyzers (OdaLogs) were placed at two locations to record H₂S concentrations continuously.

Air samples were also collected for analyses of the reduced sulfur compounds (RSCs) that are a major source of odors. The samples were shipped via overnight express to Columbia Analytical Services, Inc. in Simi Valley, CA for GC/MS laboratory analyses.

Multiple liquid phase wastewater samples from the plant influent, plant recycle, and primary sedimentation effluent troughs were collected over the two day testing period. The wastewater samples were analyzed in the field with instruments and analyzers provided by WEA, including analyses for total and dissolved sulfides, pH, oxidation-reduction potential and temperature.

3.2 Air Sampling Protocol

Air samples for odor panel and RSC analyses were collected in 10 liter chemically inert Tedlar bags with a polypropylene access valve. Air samples from aerated tanks, like the biosolids holding tanks, were collected using a surface emission flux chamber (an EPA approved device used to measure emissions from
surfaces), vacuum chamber and small battery-operated Teflon pump connected by tubing as shown in Figure 5. Air samples from non-aerated surfaces such as the headworks channels, were collected in the same way except filtered sweep air was added to the flux chamber as shown on Figure 6. Air samples from point sources like the wet well room exhaust fan were collected in the tedlar bag using the vacuum chamber, but without the flux chamber as shown on Figure 7.

![Figure 5](image.png)

**Figure 5**
Gas Sampling Train for aerated surfaces

![Figure 6](image.png)

**Figure 6**
Gas Sampling Train for quiescent surfaces
In all cases, the sample container was filled with the sample and then purged to “condition” the container and remove any background container odor prior to collection of the final sample for odor panel analysis.

The air samples were collected from each source and shipped to the laboratory via overnight express courier where they were analyzed the following day.

**Figure 8** shows pictures of the locations where each of the samples were collected at the RWPCP and WCWPCP.

The flux chamber is an enclosed chamber used to isolate a surface and is set-up as a continuously stirred reactor. Sweep air is added to the chamber at a controlled, fixed rate of 5 liter per minute (L/min). The emission rate for hydrogen sulfide and odors is calculated by knowing the sweep air flow rate, concentration and the surface area exposed to the chamber.

The operation of the flux chamber involves:

1. Identifying the test area and placing the chamber
2. Initiating the sweep air (clean, filtered air) flow rate to the flux chamber
3. Operating the chamber for four residence times before collecting samples
4. Collecting exhaust gas for analysis
5. Decontaminating the chamber for the next test area

The sweep air flow rate using filtered air is adjusted and the time is recorded to monitor the number of chamber detention times. The samples for odor panel testing were collected at a rate less than 2.5 L/m after four (4) residence times.
Figure 8
Sampling Locations
Figure 8
Sampling Locations (continued)
The specific sizes of the flux chamber are:

- Chamber surface area = 0.13 square meters (m²)
- Chamber volume = 0.03 cubic meters (m³)

H₂S and odor emissions for each source are quantified with the flux chamber technique, using the following calculation:

\[
ER = Y \times Q \times \frac{A_2}{A_1} \times C
\]

where: ER = Emission Rate of compound or odor (lbs/hr for H₂S and DT * cfm for odor)

- Y = concentration of compound from air in the flux chamber (ppm or DT)
- Q = sweep air flow rate of filtered air into flux chamber (L/min)
- A₁ = surface area enclosed by the flux chamber (ft²)
- A₂ = surface area of odor source (ft²)
- C = correction factor for conversion from metric to English units

Hydrogen sulfide concentrations were measured from the sample bags with the Arizona Instruments Jerome 631X. This analyzer is sensitive down to 3 parts per billion (ppb). In addition, the App-Tek Odalog datalogger was used to continuously log H₂S concentrations in the air stream above the wastewater surfaces at the following locations:

- Directly above the Influent Screen Channel
- In the Wet Well Room near the exhaust fan

### 3.3 Wastewater Samples

Grab samples were collected from the Influent Screen Channel, Plant Recycle Return, and the Primary Sedimentation Effluent Troughs. Samples were collected two times from each of these locations over the two day testing period.

The samples were analyzed in the field for total sulfides, dissolved sulfides, pH, ORP, and temperature. Sulfides are emitted as H₂S and are indicative of the sources of H₂S and the potential for odor and corrosion.
3.4 Odor Dispersion Modeling

3.4.1 Description of Modeling

Odor dispersion modeling has been used as a reliable and cost-effective approach for predicting off-site odor impacts from odor sources and evaluating odor mitigation alternatives.

The odor dispersion model is essentially a computer program designed to predict what impact an odor source, or group of odor sources, will have on an area based on a number of factors that are input into the program. The primary inputs include:

- Odor emission rates from individual odor sources
- Odor source dimensions and characteristics
- Historic meteorological data
- Local terrain data

The software used to complete the modeling is Breeze ISC GIS ProVersion 4.0.4 developed by Trinity Consultants Inc. This dispersion model is based on the U.S. Environmental Protection Agency’s (USEPA) Industrial Source Complex (ISC) model methodology.

Breeze is a Gaussian plume model that incorporates source-related factors (air flow rate, stack diameter, odor source area, contaminant concentration, and distance from the odor source to particular receptors) and meteorological factors to estimate contaminant concentrations from continuous sources.

The modeling in this study uses actual meteorological data, from the closest and the most recent full year surface and mixing height data available, obtained from the Trinity Consultants, Inc. The data includes the actual hourly meteorological data (wind speed, wind direction, temperature, cloud cover, ceiling height, and mixing height) from every hour of the year.

The information input into the model for this study was Odor Emission Rates (OER) for each point source (sources with stacks &/or exhaust fans); Odor Emission Rate per square foot for each area source (open channels and tanks); odor source locations, discharge heights and size; the local meteorological conditions from the Oakland airport; and digital terrain data. The OER is the Detection Threshold (DT) at the source multiplied by the air flow rate.
3.4.2 Modeling Output

The model output predicts the highest DT level, estimated over the area of analysis. The resulting peak DT levels are shown graphically on odor contour plots. Essentially, the model predicts the number of dilutions in the atmosphere in the downwind DT, or the detection threshold of the odor. In this study, the hourly average DT levels at particular receptor points were converted to peak DT levels by applying a multiplier to account for short exposure to odors (less than 15 seconds). The peak DT is more relevant for odors, since the odor plume meanders and is very transient. Perceived odor complaints are generally related to peak odor levels, as opposed to an hourly average odor level.

Another modeling routine also predicts the frequency of odor events for the areas surrounding the plant. In other words, it predicts the number of times per year odors may be detectable for at least a fifteen second period at any point in the study area. For example, a person standing at a point where a frequency of 100 is predicted would be expected to experience an odor that exceeds the selected odor detection threshold 100 times (or during 100 hours) per year. In this study, an odor detection threshold of seven (7) DT has been selected. An odor with a detection threshold of seven dilutions or less may not be detected because it could be overwhelmed by other natural odors in the area such as grass, trees, soil and flowers, or it may not be detectable at all.

3.4.3 Modeling Protocol

The modeling scenarios were completed with the following modeling protocol settings:

- Peak-to-mean multiplier of:
  \[(\text{Averaging Period} / \text{Peak Duration})^{0.5} = (60 \text{ min} / 15 \text{ sec})^{0.5} = 15.49,\]
  based on one hour averaging period, 15 second average peak duration, and 0.5 power factor.

- Elevated terrain option

- Digital local terrain data

- 2002 surface and mixing height meteorological data, collected from the Oakland airport (closest available meteorological data)

- Threshold of 7 DT used for the odor frequency modeling
4.0 PRESENTATION OF TESTING RESULTS

4.1 Air Sampling Test Results

4.1.1 Air Sampling Results Summary

A summary of the odor panel testing results for the RWPCP is provided on Table 2. The data includes H$_2$S concentrations, Detection Thresholds, Recognition Thresholds and RSC concentrations. The complete odor panel test report from St. Croix Sensory, Inc. is included in Appendix A. The complete RSC analysis report from Columbia Analytical Services, Inc. is also included in Appendix A.

The Primary Sedimentation Tank surface air sample had the highest DT value (16,000) at the plant, followed by the Primary Sedimentation Tank Effluent Troughs (15,000), the Grit Tank Surface (9,200), Screen Channel (4,200), Manhole near Admin Bldg (with digester supernatant) (4,200), Wet Well Room Exhaust (3,000), DAF Surface (1,300), and Aeration Tank Surface (120). All DT values exceeding 1,000 would be considered to be in the high range. The 120 value in the Aeration Tank Surface air sample would be considered in the low to moderate range, and is a typical value for well-operating aeration basins.

The WCWPCP drying bed air sample collected during digested sludge pumping had a very high DT value of 23,000. This compares to a DT value of 3,700 from the air sample collected during digested sludge pumping in 2003. The WCWPCP drying bed air sample collected the day after digested sludge pumping had a DT value of 2,400. This compares to a DT value of 1,200 from the air sample collected in “older” sludge in 2003.

Odor samples taken at the drying beds in both 2003 and 2007 were “snapshots” of odors on that day and may not represent an average over a sustained period or a trend. Reasons why the 2003 and 2007 results vary so widely may include:

- in 2003, readings may have been lower than normal;
- in 2007:
  - readings may have been higher than normal;
  - the pipeline from the RWPCP to the WCWD lagoons now transports both sludge and leachate, as compared to 2003 when only sludge was transported. This has caused a change in the way sludge is transported. In 2003, because the line was less congested, sludge could be transported in smaller batches as needed. In 2007, because sludge
### Table 2
Richmond WPCP
Odor Evaluation
Air Testing Results Summary

<table>
<thead>
<tr>
<th>Location</th>
<th>H$_2$S Concentration Measurements (ppm)</th>
<th>Odor Panel Testing</th>
<th>RSC Testing $^{(2)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Avg $^{(1)}$</td>
<td>Detection Threshold (DT)</td>
</tr>
<tr>
<td>Screen Channel</td>
<td>0 - 9.3</td>
<td>2.3</td>
<td>1,100</td>
</tr>
<tr>
<td>Screen Channel (with landfill leachate)</td>
<td>0 - 11.5</td>
<td>2.5</td>
<td>4,200</td>
</tr>
<tr>
<td>Wet Well Room Exhaust</td>
<td>0.1 - 4.7</td>
<td>1.0</td>
<td>3,000</td>
</tr>
<tr>
<td>Wet Well Room Exhaust (with landfill leachate)</td>
<td>0.1 - 3.5</td>
<td>1.1</td>
<td>2,100</td>
</tr>
<tr>
<td>Grit Tank Surface</td>
<td>13</td>
<td></td>
<td>9,200</td>
</tr>
<tr>
<td>Grit Tank Surface (with landfill leachate)</td>
<td>15</td>
<td></td>
<td>3,700</td>
</tr>
<tr>
<td>Primary Sedimentation Tank Surface</td>
<td>15</td>
<td>16,000</td>
<td>11,000</td>
</tr>
<tr>
<td>Primary Sedimentation Tank Effluent Trough</td>
<td>63</td>
<td>15,000</td>
<td>9,700</td>
</tr>
<tr>
<td>Pri. Sed. Tank Effl. Trough (with landfill leachate)</td>
<td>26</td>
<td>4,500</td>
<td>3,000</td>
</tr>
<tr>
<td>Aeration Tank Surface</td>
<td>0.0</td>
<td>120</td>
<td>90</td>
</tr>
<tr>
<td>DAF Surface</td>
<td>0.15</td>
<td>1,300</td>
<td>760</td>
</tr>
<tr>
<td>WCWD Drying Bed (during pumping)</td>
<td>530</td>
<td>23,000</td>
<td>16,000</td>
</tr>
<tr>
<td>WCWD Drying Bed (day after pumping)</td>
<td>1.0</td>
<td>2,400</td>
<td>1,300</td>
</tr>
<tr>
<td>Manhole near Admin Bldg entrance</td>
<td>14.5</td>
<td>4,200</td>
<td>2,600</td>
</tr>
</tbody>
</table>

**Notes:**

(1) The average H$_2$S values accompanied with a Range were collected using continuous data loggers during the June 25 - June 28 site visit. All other H$_2$S average values were based limited instantaneous measurements collected during the site visit.

(2) Laboratory Reduced Sulfur Compound (RSC) results are reported in parts-per-billion (ppb). Values left blank indicate either no sampling or testing was conducted, or the resulting measurements were below the detection limits of the laboratory instrumentation.

RSC Abbr. (odor threshold, ppb): H$_2$S = hydrogen sulfide (0.5), COS = carbonyl sulfide (100), MM = methyl mercaptan (0.5), DMS = dimethyl sulfide (0.1), CDS = carbon disulfide (25).
and leachate movement must be coordinated, sludge is transported in larger batches.

The highest H$_2$S concentrations measured at the plant were in the Primary Sedimentation Tank Effluent Troughs (63 ppm). Other high H$_2$S concentrations were measured in the Primary Sedimentation Tank Surface (15 ppm), Grit Tank Surface (15 ppm), Manhole near Admin Bldg (with digester supernatant) (14.5 ppm), and above the Screen Channel (11.5 ppm). Moderate H$_2$S concentrations were measured in the Wet Well Room Exhaust (4.7 ppm). The H$_2$S concentration measurements in the Aeration Basin surface and DAF surface were low (non-detectable and 0.15 ppm, respectively).

The WCWPCP drying bed air sample collected during digested sludge pumping had an extremely high H$_2$S concentration of 530 ppm. The WCWPCP drying bed air sample collected the day after digested sludge pumping had a moderate H$_2$S concentration of 1.0 ppm.

The diurnal H$_2$S concentration profiles generated from the Odalog data from above the Influent Screen Channel and Wet Well Room exhaust are included in Appendix B.

Moderate levels of methyl mercaptan (300 ppb) and low levels of dimethyl sulfide (26 ppb) concentrations were measured in the Primary Sedimentation Tank Effluent Trough air sample. These compounds should be considered during design of odor control systems for this process.

Moderate levels of methyl mercaptan (80 ppb) and carbonyl sulfide (79 ppb) concentrations were measured in the WCWPCP drying bed sample collected during digested sludge pumping.

### 4.1.2 Odor Emission Rates

The potential for off-site odors from the RWPCP was evaluated in this report by calculating “Odor Emission Rates” (OER), which is the product of DT times exhaust air flow rate, and then using the OER data in the dispersion modeling to predict off-site odors from individual sources as well as combined source groups.
The following methods were used to determine the air exhaust flow rates (cfm) from the sampled sources at the RWPCP:

1. Rated capacity or measured air flow rate of blower or exhaust fan

2. Estimate of the surface air emissions based on surface area of the source and the amount of sweep air added to the flux chamber. (See formula in Section 3).

Table 3 presents the results of the odor emission rate calculations for all odor sources evaluated during the odor testing.

The Wet Well Room Exhaust has the largest odor emission rate (OER) from all tested sources at the RWPCP. The OER from this exhaust is 32,100,000, which is approximately 54% of the total odor emissions from the plant. The Primary Clarifier Surfaces and Effluent Troughs have the next highest OER, totaling 23,563,008 or 39% of the total plant odor emissions. The only other significant processes, in terms of OER, are the Grit Tank surfaces and channels. The OER from these grit removal processes totaled 3,674,128 or approximately 6% of the total plant odor emissions. Each of the other plant processes contributes less than 1% to the total plant odor emissions, as shown on Table 3.
Table 3
Richmond WPCP
Odor Evaluation
Odor Emission Rates Inventory

<table>
<thead>
<tr>
<th>Location</th>
<th>Surface Area (ft²)</th>
<th>Air Flow Rate (cfm)</th>
<th>Detection Threshold (D/T)</th>
<th>Odor Emission Rate (D/T x cfm)</th>
<th>Percentage of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen Channel</td>
<td>191</td>
<td>24</td>
<td>4,200</td>
<td>101,077</td>
<td>0.2%</td>
</tr>
<tr>
<td>Wet Well Room Exhaust</td>
<td></td>
<td></td>
<td></td>
<td>32,100,000</td>
<td>53.6%</td>
</tr>
<tr>
<td>Grit Tank Surfaces</td>
<td>3.170</td>
<td>399</td>
<td>9,200</td>
<td>3,675,128</td>
<td>6.1%</td>
</tr>
<tr>
<td>Primary Sediment Tank Surfaces</td>
<td>9,888</td>
<td>1,246</td>
<td>16,000</td>
<td>19,934,208</td>
<td>33.3%</td>
</tr>
<tr>
<td>Primary Sediment Tank Effluent Troughs</td>
<td>1,920</td>
<td>242</td>
<td>15,000</td>
<td>3,628,800</td>
<td>6.1%</td>
</tr>
<tr>
<td>Aeration Tank Surfaces</td>
<td>18,150</td>
<td>2,287</td>
<td>120</td>
<td>274,428</td>
<td>0.5%</td>
</tr>
<tr>
<td>DAF Surface</td>
<td>962</td>
<td>121</td>
<td>1,300</td>
<td>157,594</td>
<td>0.3%</td>
</tr>
<tr>
<td>Manhole near Admin Bldg entrance</td>
<td>3</td>
<td>0.4</td>
<td>4,200</td>
<td>1,663</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>Total Plant Sources</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>59,872,898</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Surface Area (ft²)</th>
<th>Air Flow Rate (cfm)</th>
<th>Detection Threshold (D/T)</th>
<th>Odor Emission Rate (D/T x cfm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WCWD Drying Bed (during pumping)</td>
<td>148,500</td>
<td>18,711</td>
<td>23,000</td>
<td>430,353,000</td>
</tr>
<tr>
<td>WCWD Drying Bed (day after pumping)</td>
<td>148,500</td>
<td>18,711</td>
<td>2,400</td>
<td>44,906,400</td>
</tr>
<tr>
<td>WCWD Drying Bed (during pumping) (2003 Testing)</td>
<td>148,500</td>
<td>18,711</td>
<td>3,700</td>
<td>69,230,700</td>
</tr>
<tr>
<td>WCWD Drying Bed (&quot;older&quot; sludge) (2003 Testing)</td>
<td>148,500</td>
<td>18,711</td>
<td>1,200</td>
<td>22,453,200</td>
</tr>
</tbody>
</table>

Richmond WPCP Odor Emission Rates

![Circle Diagram showing percentages of odor emission sources]

- Primary Sediment Tanks: 39%
- Grit Tanks & Channels: 6%
- IPS Sources (Screen Channel & Wet Well Room Exhaust): 54%
- All Others: 1%
4.2 Wastewater Sampling Results

Wastewater sampling results from the wastewater sampling program are shown on Table 4.

Total and dissolved sulfide concentrations in the plant influent (screen channel) averaged 4.0 and 2.4 mg/L, respectively. This equates to moderately high sulfide loading in the influent wastewater. The pH in the plant influent averaged 7.2, which is in the neutral range. The ORP in the influent wastewater averaged -285 mV, which is in the range favored by sulfate reducing bacteria and conducive to sulfide generation.

Total and dissolved sulfide concentrations in the plant recycle were non-detectable. The pH in the plant recycle averaged 7.2, which is in the neutral range. The ORP in the plant recycle averaged -240 mV, which is in the range favored by sulfate reducing bacteria and conducive to sulfide generation.

Total and dissolved sulfide concentrations in the primary sedimentation effluent troughs averaged 2.4 and 1.4 mg/L, respectively. These concentrations were lower than the concentrations measured in the plant influent, indicating some sulfide reduction and no additional sulfide generation in the plant headworks, grit removal or primary sedimentation processes. The pH in the primary sedimentation effluent troughs averaged 7.1, which is in the neutral range. The ORP in the primary sedimentation effluent troughs averaged -223 mV, in the range conducive to sulfide generation.

4.3 Odor Dispersion Modeling

4.3.1 Description of Modeling Scenarios

Four primary modeling scenarios were evaluated in this odor evaluation. Following is a description of each of the modeling scenarios.

Existing Conditions

This scenario simulates the odor impact of all significant existing processes at the RWPCP, as tested on June 25 – 28, 2007. All significant existing plant processes are simulated in this modeling scenario, including the screen channels, wet well room exhaust, grit tanks and channels, primary sedimentation tanks and effluent troughs, aeration basins, DAF tank, and the manhole near the Administration Building entrance containing the digester supernatant drain. Some of these plant processes were tested twice, once with landfill leachate being pumped to the plant, and once without leachate being pumped to the plant. The worst case odor
<table>
<thead>
<tr>
<th>Location</th>
<th>Date</th>
<th>Time</th>
<th>pH</th>
<th>ORP (mV)</th>
<th>Total Sulfide (mg/L)</th>
<th>Dissolved Sulfide (mg/L)</th>
<th>T (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen Channel</td>
<td>6/26/07</td>
<td>6:00 AM</td>
<td>6.2</td>
<td>3.5</td>
<td>6.2</td>
<td>4.2</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>6/27/07</td>
<td>12:05 PM</td>
<td>1.8</td>
<td>1.2</td>
<td>1.8</td>
<td>1.2</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Averages</td>
<td></td>
<td></td>
<td>4.0</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>Plant Recycle</td>
<td>6/26/07</td>
<td>8:25 AM</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>6/27/07</td>
<td>12:30 PM</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Averages</td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Primary Sedimentation</td>
<td>6/26/07</td>
<td>8:40 PM</td>
<td>3.5</td>
<td>2.0</td>
<td>1.2</td>
<td>0.8</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>6/27/07</td>
<td>12:40 PM</td>
<td>1.2</td>
<td>0.8</td>
<td>1.2</td>
<td>0.8</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Averages</td>
<td></td>
<td></td>
<td>2.4</td>
<td>1.4</td>
<td>71</td>
</tr>
<tr>
<td>Effluent Trough</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

Table 4: Richmond WPCP Odor Evaluation Wastewater Testing Results Summary
condition was used in the modeling. All plant processes were operating in “normal” mode during the testing. The contributions of key individual sources and/or source groups were also evaluated in this scenario.

**Odor Control Scenario 1 (OC1)**

This scenario simulates the odor impact of the existing plant processes, assuming the screen channels are covered, with air collected from the channel headspace and combined with air collected from the wet well room. The odorous air from these two areas is ducted to a new odor control system for treatment prior to exhausting to the atmosphere. This scenario mitigates the area with the highest odor emission rate of all the plant processes.

**Odor Control Scenario 2 (OC2)**

This scenario includes the improvements described in OC1. In addition, the grit tanks and channels are covered, with air collected from the headspaces and combined with the air from the screen channels and wet well room. The odorous air from these areas is ducted to a new odor control system for treatment prior to exhausting to the atmosphere.

**Odor Control Scenario 3 (OC3)**

This scenario includes the improvements described in OC2. In addition, the primary sedimentation tanks are covered, with air collected from the headspaces and ducted to a separate new odor control system for treatment prior to exhausting to the atmosphere.

### 4.3.2 Discussion of Modeling Results

**Existing Conditions**

**Figures 9 & 10** show the Peak DT and Odor Frequency contour maps for this scenario.

The model predicts Peak DT values exceeding 100 in the neighborhoods to the northwest across the railroad tracks, to the north and northeast along West Cutting Blvd., to the south in the harbor area, and to the west in the Bay shoreline park area. These odor levels are considered moderately high and would be considered annoying. The model predicts odors from the plant could be detectable (> 7 DT) during over 100 – 200 hours per year in the northwest neighborhoods, during up to 200 hours per year along West Cutting Blvd., during up to 100 hours per year in the south harbor area, and up to 200 hours per year in the Bay shoreline park area.
Richmond WPCP
Existing Conditions
Peak DT Contours

Figure 9
Richmond WPCP
Existing Conditions
Frequency Contours
(Hrs/Yr > 7 DT)

Figure 10
Figure 11 shows the locations of odor complaints from 2002 to the present, along with the odor frequency contours for the existing conditions. This map shows most odor complaints are from locations along Canal Blvd. and the neighborhoods to the northeast of the plant. Figure 12 shows the locations of odor complaints from 2006 to the present, along with the odor frequency contours for the existing conditions. This odor complaint map shows odor complaints have decreased over the past two years.

Figures 12 - 14 show the individual contributions of key odor sources and/or source groups. These contours validate the primary sedimentation tanks have the highest odor impact on the surrounding community under existing conditions. The influent pump station sources (screen channels and wet well room) and the grit tanks and channels also contribute significantly to off-site odors, but to a lesser degree.

Figure 15 shows the individual contribution of an odor control system for the proposed dewatering processes. The odor control system assumed in this model is based on the dewatering alternative that produces the highest air flow to be treated. This dewatering alternative assumes all dewatering processes are enclosed in a building with 50,000 cfm (12 air changes per hour) of air exhausted from the building to an odor control air treatment system. These contours show the dewatering odor control system would not contribute significantly to off-site odors. To illustrate the insignificance of the proposed dewatering odor control system, Figures 16 & 17 show the Peak DT and Odor Frequency contours superimposed on the “Existing Conditions” contour maps.

**Odor Control Scenario 1 (OC1)**

Figures 18 & 19 show the Peak DT and Odor Frequency contour maps for this scenario.

This model scenario simulates elimination of over 50% of plant odor emissions. The model predicts Peak DT values are slightly reduced in the neighborhoods to the northwest across the railroad tracks, but remain in the 75 – 100 range. However, the model predicts a larger positive impact on odor frequency as odors from the plant could be detectable (< 7 DT) in 50 - 100 hours per year in this area. This frequency represents less than 1% of the time that odors could be detectable.

The model predicts Peak DT values are also slightly reduced to the north and northeast along West Cutting Blvd. Again, there is a larger positive impact on odor frequency, but odors from the plant could still be detectable (< 7 DT) in 100 – 200 hours per year in this area.
Richmond WPCP
Odor Complaints (2002 - Present) and Existing Conditions Frequency Contours

Legend
2002 Blue •
2003 Purple •
2004 Pink •
2005 Green •
2006 Orange •
2007 (to date) Red •

Figure 11
Richmond WPCP
Odor Complaints (2006 - Present) and Existing Conditions Frequency Contours

Legend
2006 Orange ●
2007 (to date) Red ●

Figure 12
Richmond WPCP
Existing Conditions
Influent Pump Station Only
Peak DT Contours

Figure 13
Richmond WPCP
Existing Conditions
Grit Tanks & Channels Only
Peak DT Contours

Figure 14
Richmond WPCP
Existing Conditions
Primary Sedimentation Tanks Only
Peak DT Contours

Figure 15
Richmond WPCP
Dewatering Odor Control System Only
Peak DT Contours

Figure 16
Richmond WPCP
Existing Conditions (White) & Proposed Dewatering Odor Control System (Orange) Peak DT Contours

Figure 17
Richmond WPCP
Existing Conditions (Yellow) & Proposed Dewatering Odor Control System (Orange)
Frequency Contours (Hrs/Yr > 7 DT)

Figure 18
Richmond WPCP
With IPS Odor Control System (OC1)
Peak DT Contours

Figure 19
Richmond WPCP
With IPS Odor Control System (OC1)
Frequency Contours
(Hrs/Yr > 7 DT)

Figure 20
The model predicts minor improvements in both Peak DT and odor frequencies to the south in the harbor area and to the west in the Bay Shoreline park area. Peak DT values remain close to 100 and odor frequencies are approximately 100 hours per year in these areas.

**Odor Control Scenario 2 (OC2)**

*Figures 21 & 22* show the Peak DT and Odor Frequency contour maps for this scenario.

The model predicts only minor improvements in both Peak DT and odor frequencies, compared to OC1, in all directions around the plant.

**Odor Control Scenario 3 (OC3)**

*Figures 23 & 24* show the Peak DT and Odor Frequency contour maps for this scenario.

The model predicts significant improvements in both Peak DT and odor frequencies. The model predicts Peak DT levels reaching only 7 – 10 in all areas around the plant. These levels would be barely, if at all, detectable under worst case conditions. In addition, the odor frequency contours show that odors from the plant would rarely, less than 50 hours per year, exceed the 7 DT detection threshold in all areas around the plant.

**Comparisons of All Scenarios**

*Figure 25* compares the 50 Peak DT contours for each modeling scenario.

*Figure 26* compares the 50 Hour Frequency contours for each modeling scenario.
Richmond WPCP
With IPS & Grit Structure Odor Control System (OC2)
Peak DT Contours

Figure 21
Richmond WPCP
With IPS & Grit Structure Odor Control System (OC2)
Frequency Contours
(Hrs/Yr > 7 DT)
Richmond WPCP
With IPS & Grit Structure Odor Control System
and Primary Clarifier Odor Control System (OC3)
Peak DT Contours

Figure 23
Richmond WPCP
With IPS & Grit Structure Odor Control System and Primary Sedimentation Odor Control System (OC3)
Frequency Contours
(Hrs/Yr > 7 DT)

Figure 24
Richmond WPCP
All Scenario Comparison
50 Peak DT Contours Only

Figure 25
Richmond WPCP
All Scenario Comparison
50 Frequency Contours Only
(Hrs/Yr > 7 DT)

Figure 26
5.0 SUMMARY OF CONCLUSIONS

The following is a summary of the primary conclusions from the odor evaluation and odor dispersion modeling study:

1. Odor emissions from the RWPCP are significant beyond the plant fence line under existing conditions. The modeling indicates odor levels can be moderately high under worst case conditions in all directions around the plant. The model indicates the plant odor detectability frequency is low to moderate in all directions around the plant.

2. The Influent Pump Station (IPS) odor sources (Wet Well Room exhaust and influent channels) and the Primary Sedimentation Tanks are the primary contributors to off-site odor emissions under existing conditions. The IPS odor sources account for over 54% of the total plant odor emissions, as tested during the odor evaluation. The Primary Sedimentation Tanks account for over 39% of the total plant odor emissions. The odor dispersion modeling shows the Primary Sedimentation Tanks have the highest odor impact on the surrounding community. The reason these tanks have a larger impact than the IPS odor sources is because they are large area sources and the air emissions do not disperse and dilute in the atmosphere as well as higher velocity point sources like the Wet Well Room exhaust.

3. The Grit Tanks and channels also contribute significantly to off-site odors, but to a much less degree than the IPS and Primary Sedimentation Tanks.

4. H₂S concentrations in the plant influent channels, wet wells, grit tanks and channels, and the primary sedimentation tanks can be high, with measurements in the 10 – 60 ppm range during the odor evaluation. H₂S, along with moderate concentrations of methyl mercaptan and dimethyl sulfide, are likely the primary compounds contributing to the high odor levels in these processes.

5. The landfill leachate pumped to the plant influent every other day does not increase plant odors, based on the data collected during this odor evaluation. The odor level was higher in the air sample collected from the screen channel during leachate pumping, but the odor levels in the air samples collected from the wet well room exhaust, grit tank surface and primary sedimentation tanks effluent troughs were actually lower during leachate pumping.

6. Odor levels measured in the aeration basins and DAF tank were low to moderate and do not contribute significantly to off-site odors.
7. Digester gas leaks can be odorous, however, there are no significant digester gas leaks and leak air volumes are low. Locations where digester gas leaks may occur include:
   - Dystor air level vents
   - Pressure relief valves
   - Minor cover leaks
   - Supernatant drains open to atmosphere (manhole in front of Admin Bldg)

Since these potential leak locations are small in air volume and infrequent, they do not appear to contribute significantly to off-site odors.

8. A biosolids dewatering facility is planned for the RWPCP. The proposed dewatering processes will include centrifuges, biosolids conveyors, and a truck loading bay. With the odor control system proposed for the dewatering alternative that produces the highest air flow to be treated, this facility is not expected to contribute significantly to off-site odors.

9. The ventilation system for the screen channel well is not working. The purpose of this ventilation system is to provide for a safe and comfortable working environment, as well as mitigation of H₂S corrosion of equipment in this area.

10. The exhaust ductwork from the wet well room exhaust fan is badly corroded and leaking significantly. This is a likely source of H₂S and raw sewer odors detected by workers in the office areas in the IPS building. The HVAC system for the office area in the IPS building is also not functioning.

11. The HVAC system for the Administration Building and Laboratory is not functioning. No significant H₂S concentrations were measured in the office and lab areas during the odor evaluation, however, plant odors can be annoying to workers in these office and lab areas. In addition, the drains in this building terminate in a manhole in front of the Admin Bldg that also contains the digester supernatant drain. It is possible for the odorous air in this manhole to back up through the drain lines, if drain traps are not functioning properly.

12. Odor testing was also conducted at the WCWPCP drying beds where the RWPCP digested biosolids is pumped. This testing was conducted to follow-up on testing WEA conducted for the WCWD in 2003. Odors and H₂S concentrations in the pumped biosolids measured during the current odor evaluation were higher than measured during the 2003 WCWD odor evaluation.
6.0 ODOR CONTROL TECHNOLOGY ALTERNATIVES

Biological odor control technologies (Biofilters and/or Biotrickling Scrubbers) are recommended for new air treatment systems at the Richmond WPCP applications. Biological air treatment systems have the following advantages over chemical scrubbers and carbon adsorption in these applications:

- Proven effectiveness in treating the moderate to high H₂S concentrations and H₂S-related odors in the plant influent, grit tanks and channels, and primary sedimentation tanks. Also, proven effectiveness in treating odorous air from dewatering processes.

- Provide good pH and acid control even with higher H₂S concentrations

- Lower operating and maintenance costs, and lower overall life cycle costs, than chemical scrubbers

- Ease of operation and maintenance, especially compared to chemical scrubbers

- No ongoing chemical costs, storage or handling is required

- Current state-of-the-art medias last for a minimum of ten years before requiring replacement

While chemical scrubbers may have a slightly lower capital cost than the biological alternatives in these applications, the significantly lower costs for operating and maintaining the biological systems quickly makes up for the slightly higher capital cost in a life cycle cost comparison.

Detailed descriptions of the odor control technologies considered are included in Appendix D.

7.0 COST ESTIMATES

Table 5 shows the preliminary estimated capital, operating and life cycle costs for the three odor control scenarios described in the Odor Dispersion Modeling section of this report (Section 4.3.1). These estimates are based on equipment required for odor control systems only and do not include costs to improve the existing HVAC systems in the office areas.

The capital cost estimate for Odor Control Scenario 1 (OC1) is $727,000. The annual O&M cost estimate is $29,000. The total annual cost estimate is $92,000.
Table 5
Richmond WPCP
Odor Evaluation
Capital, Operating and Life Cycle Cost Estimates

<table>
<thead>
<tr>
<th>Capital Costs</th>
<th>OC1</th>
<th>OC2</th>
<th>OC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment</td>
<td>$338,440</td>
<td>$620,706</td>
<td>$1,468,336</td>
</tr>
<tr>
<td>Installation (30%)</td>
<td>$101,532</td>
<td>$186,212</td>
<td>$440,501</td>
</tr>
<tr>
<td>Contractor Overhead &amp; Profit (15%)</td>
<td>$65,996</td>
<td>$121,038</td>
<td>$286,326</td>
</tr>
<tr>
<td>Engineering (15%)</td>
<td>$75,895</td>
<td>$139,193</td>
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</tr>
<tr>
<td>Contingency (25%)</td>
<td>$145,466</td>
<td>$266,787</td>
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<tr>
<td><strong>Total Capital Cost</strong></td>
<td><strong>$727,000</strong></td>
<td><strong>$1,334,000</strong></td>
<td><strong>$3,156,000</strong></td>
</tr>
<tr>
<td>Principal</td>
<td>$727,000</td>
<td>$1,334,000</td>
<td>$3,156,000</td>
</tr>
<tr>
<td>APR</td>
<td>6.0%</td>
<td>6.0%</td>
<td>6.0%</td>
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<tr>
<td>Years</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td><strong>Amortized Capital Costs</strong></td>
<td><strong>$63,383</strong></td>
<td><strong>$116,304</strong></td>
<td><strong>$275,154</strong></td>
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**Annual O&M Costs**

<table>
<thead>
<tr>
<th>Description</th>
<th>OC1</th>
<th>OC2</th>
<th>OC3</th>
</tr>
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<tbody>
<tr>
<td>Electricity ($0.08/kWH)</td>
<td>$15,684</td>
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<tr>
<td>Water</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
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<tr>
<td>Nutrients</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
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<tr>
<td>Media Replacement (media cost only)</td>
<td>$2,587</td>
<td>$5,173</td>
<td>$10,346</td>
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<tr>
<td>Maintenance</td>
<td>$10,400</td>
<td>$13,000</td>
<td>$15,600</td>
</tr>
<tr>
<td><strong>Total Annual O&amp;M Costs</strong></td>
<td><strong>$29,000</strong></td>
<td><strong>$39,000</strong></td>
<td><strong>$68,000</strong></td>
</tr>
<tr>
<td><strong>Total Annual Costs</strong></td>
<td><strong>$92,000</strong></td>
<td><strong>$155,000</strong></td>
<td><strong>$343,000</strong></td>
</tr>
</tbody>
</table>

**Notes:**
1. Equipment costs include biotrickling scrubber odor control systems, ductwork, and all other equipment and materials necessary for a complete installation.
2. Amortized Capital Costs are based on a 20 year life and a 6.0% APR.
3. Water & nutrient costs assume secondary effluent used for biological systems irrigation.
The capital cost estimate for Odor Control Scenario 2 (OC2) is $1,334,000, which includes the improvements in OC1. The annual O&M cost estimate is $39,000. The total annual cost estimate is $155,000.

The capital cost estimate for Odor Control Scenario 3 (OC3) is $3,156,000, which includes the improvements in OC1 and OC2. The annual O&M cost estimate is $68,000. The total annual cost estimate is $343,000.

8.0 RECOMMENDATIONS

The following is a summary of the primary recommendations based on the odor evaluation and odor dispersion modeling study:

1. The City and Veolia should consider implementing Odor Control Scenario 3 (OC3) in order to effectively mitigate off-site odors from the RWPCP. This evaluation shows that OC1 & OC2 lessen the odor impacts both in strength and frequency in the communities surrounding the plant. However, the modeling indicates odors will still be detectable at nuisance levels in the surrounding communities in both the OC1 and OC2 scenarios. This evaluation shows that odors from the plant will rarely be at detectable levels in the surrounding communities in the OC3 scenario.

2. The IPS Building ventilation systems are in disrepair and the ventilation system in the screen channel well does not function at all. For reasons of worker safety and compliance with the ventilation requirements in the National Fire Protection Association Standard for Fire Protection in Wastewater Treatment And Collection Facilities (NFPA 820), these ventilation systems must be corrected. If a phased approach to implementing plant odor control systems is preferred, the OC1 scenario should be implemented first. This scenario provides improved ventilation in the IPS structure which will significantly improve worker safety in this building. Implementing this scenario will also lessen the odor impacts in the surrounding communities, as discussed above.

3. Odor mitigation should be considered during the design of the centrifuge dewatering facility. The recommended odor sources to be controlled in this facility include the centrate vents, biosolids conveyors, and truck loading bay.

4. Biological odor control technologies, such as biotrickling scrubbers and biofilters, should be considered for application at the RWPCP processes, including the future dewatering facility. Selection of a specific odor control system or systems would be made during the preliminary design process.
Advantages of biological odor control technologies compared to other odor control technologies include:

- Proven effectiveness in many wastewater treatment applications
- H₂S removal efficiencies typically greater than 99%
- Provides good pH and acid control, even with high H₂S concentrations
- Lower operating and maintenance costs, compared to chemical treatment technologies
- Ease of operation and maintenance, compared to chemical scrubbers
- No ongoing chemical costs, storage or handling required
- Long media life between replacements
- Biological air treatment is more environmentally friendly and safer than chemical treatment

Disadvantages of biological odor control technologies compared to other odor control technologies include:

- Higher capital costs, especially compared to carbon adsorbers and chemical feed systems
- Requires biological acclimation period for effective treatment
- May require ongoing nutrient addition, if secondary effluent does not contain sufficient nutrients

5. The HVAC systems for the Administration and Laboratory Building and the IPS Building office areas should be repaired or replaced to provide adequate heating, ventilation, and air conditioning for these office and lab areas. The improved ventilation will significantly improve the working environment in these areas by filtering plant odors from the make-up air.

6. The digested biosolids pumping to the WCWPCP should be discontinued as quickly as possible following the RWPCP dewatering facility installation to assist in mitigating the WCWPCP drying bed odors.
Appendix A

St. Croix Sensory, Inc. Reports

Columbia Analytical Services, Inc. Reports
## St. Croix Sensory, Inc. Odor Evaluation Report

**Client:** Webster Environmental  
**Project:** Richmond, CA

<table>
<thead>
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<th>Field No.</th>
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<td></td>
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<td>Recognition Threshold</td>
<td>Intensity</td>
<td>Dose-Response Slope</td>
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<td>500</td>
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<td>1,500</td>
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<td>6</td>
<td>6</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>WCWD Dyeing Bath</td>
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Sample bag was received without sample. Sample bag was split during shipment.
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<td>3</td>
<td>grit Tank Surface</td>
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**Transmittal**
- Requested By: Bus Rush
- Date: 4/26/07
- Time: 4:00pm

**Received at 5:00pm** 4/26/07

---

*St. Croix Sensory, Inc. 7949 Lakeview Boulevard North • Lake Elmo, MN 55042 U.S.A. • Phone: 651-439-1805 • Fax: 651-439-1806 • Email: info@stcroixsensory.com • Visit www.stcroixsensory.com

**Lab Copies White & Yellow Client Copy Pink**
St. Croix Sensory, Inc.

Webster Environmental
Richmond, CA
Odor Evaluation Report
Report No. 717901
06/28/07

Data Release Authorization:
M. McGinley
Melissa McGinley
Laboratory Associate

Reviewed and Approved:
Charles M. McGinley, P.E.
Technical Director

St. Croix Sensory is a laboratory dedicated to practicing state-of-the-art sensory evaluation and to advancing the science of sensory perception.

We are a family owned and operated business providing our clients with personal customer service, flexible scheduling, timely results.

Our focus is to provide the best professional services available to help make your project or product a success.

www.fivesenses.com

3549 Lake Elmo Avenue North
P.O. Box 313
Lake Elmo, Minnesota 55042 U.S.A.

Tel: 800-879-9231
Fax: 651-439-1065

Email: stcroix@fivesenses.com
### Odor Evaluation Report

**Client:** Webster Environmental  
**Project:** Richmond, CA  
**Report No.:** 717901  
**Evaluation Date:** 06/28/07

<table>
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<td>Recognition Threshold</td>
<td>Intensity</td>
<td>Dose-Response Slope</td>
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<tr>
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<td>Grit Tank Surface #2</td>
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<tr>
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<td>7</td>
<td>Primary Sud. Effluent Trough</td>
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<td>3,000</td>
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F.O. Box 313, 3549 Lake Elmo Ave. N., Lake Elmo, MN 55042 U.S.A.  
Tel:800-879-233  
Fax:651-450-1055  
E-mail:store@stsens.com  
Web www.stsens.com
<table>
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<td>2</td>
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<td>0.15</td>
</tr>
<tr>
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<td>5</td>
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</tr>
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<td>6</td>
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<td>Manhole #2</td>
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</tbody>
</table>

Transmittal

Number of Shipping Boxes: 1

Received at: St. Croix Sensory Laboratory

Appendix B

OdaLog Charts
Appendix C

Odor Dispersion Modeling Data
## Richmond, CA WPCP Odor Modeling Data

### Model: Base

#### Existing WPCP Processes As Tested

<table>
<thead>
<tr>
<th>Point Sources</th>
<th>Easting</th>
<th>Northing</th>
<th>above MSL</th>
<th>above base</th>
<th>UTM X Coord (m)</th>
<th>UTM Y Coord (m)</th>
<th>Base Elev (ft)</th>
<th>Air Flow (cfm)</th>
<th>D/T (gpm)</th>
<th>OER (gph)</th>
<th>OER (gph)</th>
<th>Stack Height (ft)</th>
<th>Diameter (ft)</th>
<th>Temp (F)</th>
<th>Area (ft²)</th>
<th>Vel (fpm)</th>
</tr>
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<tbody>
<tr>
<td>WWERs</td>
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<td>1,187.151</td>
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<td>16.730</td>
<td>5.05</td>
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<td>15.150</td>
<td>120.234</td>
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<td>9</td>
<td>1.141</td>
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<tr>
<td>MH12</td>
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<td>4.200</td>
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<td>129.234</td>
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<td>0.72</td>
<td>50</td>
<td>6.4</td>
<td>100</td>
<td>0.4</td>
<td>1.141</td>
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<td>DigVent</td>
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<td>1,187.151</td>
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<td>0.72</td>
<td>50</td>
<td>6.4</td>
<td>100</td>
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<td>1.141</td>
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**Peak Factor:** 1.49

**Odor Threshold for Frequency Contours:** 7

**Flux Chamber air flow rate:** 0.126 cfm/ft²

### Rectangular Area/Line Sources

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<th>above base</th>
<th>UTM X Coord (m)</th>
<th>UTM Y Coord (m)</th>
<th>Base Elev (ft)</th>
<th>Air Flow (cfm)</th>
<th>D/T (gpm)</th>
<th>OER (gph)</th>
<th>OER (gph)</th>
<th>OER/ft²</th>
<th>Release Height (ft)</th>
<th>X Length (ft)</th>
<th>Y Length (ft)</th>
<th>Area (ft²)</th>
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<tbody>
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<td>4.200</td>
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<td>24</td>
<td>192</td>
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<td>4.200</td>
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<td>100</td>
<td>0.4</td>
<td>1.141</td>
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**MCVD Drying Bed #3 (during pumping):** 23,000

**MCVD Drying Bed #3 (drying after pumping):** 2,400

### Buildings/Structures

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<th>above base</th>
<th>UTM X Coord (m)</th>
<th>UTM Y Coord (m)</th>
<th>Base Elev (ft)</th>
<th>Height (ft)</th>
<th>X Length (ft)</th>
<th>Y Length (ft)</th>
<th>Angle</th>
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<td>381</td>
<td>1.63</td>
<td>0.6</td>
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<td>24</td>
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<tr>
<td>Admin</td>
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<td>1,187.151</td>
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<td>79</td>
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<td>0.72</td>
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**Angle:** 45°
Richmond, CA WPCP Odor Modeling Data  
9/28/2007

Model: BaseDW

### Existing WPCP Processes with Devatering Processes

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<th>Air Flow (m³/h)</th>
<th>D/T</th>
<th>OER (g)</th>
<th>OER (lb/hr)</th>
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<th>Air Flow (m³/h)</th>
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Peak Factor: 1.49
Odor Threshold for Frequency Contours = 7 DT
Flux Chamber air flow rate = 0.125 cfm²

Use 15 second averaging period

Richmond, CA WPCP Odor Modeling Data

Model: OC1

### Point Sources

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<th>Air Flow (cfm)</th>
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<th>OER (grt)</th>
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<th>Diamter (ft)</th>
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### Rectangular Area/Line Sources

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- **Peak Factor:** 13.75 (Use 15 second averaging period)
- **Odor Threshold for Frequency Contours:** 7 DT
- **Flux Chamber air flow rate:** 0.120 cm³/sec

### Buildings/Structures

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Richmond, CA WPCP Odor Modeling Data 8/21/2007

Model: OC2  
Odor Control for IPS + Grit Tanks & Channels

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### Richmond, CA WPCP Odor Modeling Data

#### Model: OC3

**Odor Control for IPS + Grit Tanks & Channels + Primary Sedimentation Tanks**

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**Peak Factor:** 15.40  **Use 15 second averaging period**

**Odor Threshold for Frequency Contours =** 7  **DT**

**Flux Chamber air flow ratio =** 0.126  **cfm²**

#### Rectangular Area/Line Sources

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**WCDW Drying Bed #1 (during pumping):**

**WCDW Drying Bed #2 (after pumping):** 2.496

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Appendix D

Odor Control Technology Descriptions
ODOR CONTROL TECHNOLOGY SUMMARY

Technology: BIOTRICKLING SCRUBBERS

Description:

Biotrickling Scrubbers are an odor treatment technology that utilizes biological processes, as opposed to chemical processes as their treatment mechanisms. They are similar to biofilters in this regard. Biotrickling scrubbers use artificial media and closed vessel construction, where biofilters often use natural media and open bed construction.
Biotrickling scrubbers have been growing in popularity in the U.S. over the past several years, and have proven effective in wastewater treatment plant applications, even for high strength odorous air streams. There are now many biotrickling scrubber manufacturers in the U.S., providing for significant competition in the biotrickling scrubber market.

The process involves intermittent spraying or recirculating biologically active, nutrient-rich scrubbing solutions over an artificial media while odorous air is forced upward through the media bed. The process is similar to that used in wet scrubbers, except it involves biological treatment instead of chemical treatment. The media provide sites for biological colonization and promote mass transfer from the air to the water film on the biomass where the biological oxidation occurs.

Biotrickling scrubber treatment may fall into two categories, based on the biological population. Autotrophic organisms remove hydrogen sulfide and other inorganic compounds. Heterotrophic organisms remove volatile organic compounds (VOC’s). The autotrophic organisms oxidize sulfides to either sulfate or elemental sulfur. The heterotrophic organisms remove the organic odors, but have little effect on hydrogen sulfide. The two systems may be combined into a two-stage system, where treatment of hydrogen sulfide and VOC’s is required.

The systems normally use intermittent irrigation, with the biologically active solution trickled over the media bed to keep the biomass wet, to promote sloughing of the biomass, and to supply fresh nutrients to the biomass.

Applicable treatment processes include all liquid treatment plant and collection system processes and biosolids processing.

Advantages of Biotrickling Scrubbers compared to other odor control technologies include:

- Proven effectiveness in many wastewater treatment applications
- H₂S removal efficiencies typically greater than 99%
- Can provide VOC treatment with higher EBRTs
- Provides good pH and acid control, even with high H₂S concentrations
- Lower operating and maintenance costs, compared to chemical treatment technologies
- Ease of operation and maintenance, compared to chemical scrubbers
- No ongoing chemical costs, storage or handling required
- Small footprint requirement
- Long media life between replacements
- Biological air treatment is more environmentally friendly and safer than chemical treatment

Disadvantages of Biotrickling Scrubbers compared to other odor control technologies include:

- Higher capital costs, especially compared to carbon adsorbers and chemical feed systems
- Requires biological acclimation period for effective treatment
• May require ongoing nutrient addition
• Tower heights of larger systems can be aesthetically displeasing in some locations
ODOR CONTROL TECHNOLOGY SUMMARY

Technology: BIOFILTERS

Description:

Biofilters are an odor treatment technology that utilizes biological processes as the treatment mechanism. Biofilters are considered to be a “green” approach to odor control, because they utilize microorganisms in media to oxidize odor and air emission compounds to carbon dioxide, water, biomass, and other benign by-products such as chloride and sulfate. The by-products are either emitted in the outlet air, drained from the biofilter, or consumed by the microorganisms. The biological activity in a biofilter is similar to the activities performed by the microorganisms in activated-sludge secondary wastewater treatment processes.

Biofilter (organic media)

Typical biofilter sections are shown below. Biofilters work by routing odorous air through a porous filter media. The media represents the contact surface area, on which the microorganisms live, where the biological oxidation described above can take place. The key to effective biofilter operation is maintaining a healthy environment for these microorganisms to thrive in. The most important parameters for maintaining a healthy environment is moisture content and
pH. The microorganisms need water to remain active, and the presence of water affects the transfer of the contaminants from the air to the media. The desired microorganisms thrive at neutral to moderately acidic pH levels.

Biofilter Sections

Biofilters are less control-dependent than chemical scrubbers, because the treatment system is more self-regulating. It is essentially a self-contained ecosystem, and is therefore likely to function longer, without excessive control. It is very important, however, to ensure moisture levels are controlled in the biofilter for it to function properly. Moisture content is assisted during dry periods by simple sprinkler systems and air humidification. The pH levels are often self-regulating within the ecosystem, and are assisted by proper choice of media. However, the reaction products in a biofilter treating hydrogen sulfide is sulfuric acid so preventing the formation of a very low pH is important and design should include corrosion protection on concrete and other materials.

Biofilters are typically good applications in dilute waste streams, like those typically found in wastewaters. The biggest drawback to this technology is the relatively large space requirement, compared to the technologies mentioned above. However, modular biofilter designs using synthetic, inorganic media require a much smaller footprint than the open-bed designs. Biofilters may also use more power than chemical scrubbers, but do not involve any chemical handling or storage.
Biofilter (modular, inorganic media)

Air streams with high concentrations of reduced sulfur compounds (RSC’s) such as mercaptans, dimethyl sulfide, dimethyl disulfide, diphenyl sulfide, carbonyl sulfide, and carbon disulfide can be treated in biofilters but the loading rates must be much lower than those required to treat H₂S.

Biofilter media types include wood-chip/bark media, soil media, and inorganic synthetic media.

Wood-chip/bark media generally possess a large diversity and density of microorganisms, accepts moisture relatively well, has low initial costs, and is readily available. The normal lifetime for wood-chip/bark media is 2 – 4 years.

Soil media is a blended mix of soils, primarily sand-based. The primary advantage of soil media over wood-chip/bark media are their life expectancy. Soil has an estimated lifetime of over 30 years as a filter media. Soil is denser than wood-chip/bark media and therefore resists compaction, it resists acidification because of its inherent pH buffering properties, it is less difficult to rehydrate after drying out, and generally distributes the air more uniformly than wood-chip/bark media. The primary disadvantage is that it requires a smaller loading per square foot, and therefore may require a larger footprint and higher initial capital costs.
The inorganic synthetic media is newer to the market but well tested. It consists of strong, uniform sized gravel-like cores that do not compact as easily as organic media. This type of media may be used in the modular designs because it allows greater media depth and a smaller footprint. The cores are commonly coated with nutrient rich organic and inorganic adsorbents. The media typically comes with a 10 year life guarantee.

**Applicable Treatment Processes:**

All liquid treatment plant processes, pump stations, sludge thickening, sludge dewatering.

**Typical Design Criteria:**

| Surface Loading (Wood-Chip media) | 3 - 4 cfm per sf media |
| Surface Loading (Soil media)     | 2 cfm per sf media     |
| Inorganic, synthetic media       | 10-12 cfm/ft²          |
| Media Bed Depth (Wood-chip/Soil media) | 3 ft.             |
| Media Bed Depth (Inorganic, synthetic media) | 5 ft.             |
| Detention Time (Wood-chip/Soil media) | ≥ 60 seconds         |
| Detention Time (Inorganic, synthetic media) | 20 - 30 seconds |
| Pressure Drop                     | 6” – 12”               |
| H₂S removal efficiency            | 99%                    |

**Major Design Considerations:**

a. **Methods of air flow distribution and media support:**

Air flow through the biofilter may be distributed by several methods. The outer walls of the air plenum may be formed by earth berms, concrete walls, or other support mechanisms. A plenum lining provides for proper drainage of the biofilter. The air plenum below the media bed may be open air space formed by the walls with grating forming the top, with railroad ties forming the support and top of the plenum, or it could be formed with perforated air distribution piping buried in a coarse rock bed. If a rock bed is used, special consideration must be given to the type of rock. Limestone and other soft rock can not be used because it breaks down in the acidic environment and may obstruct air flow.

b. **Media selection**

Media may be purchased from manufacturers, or blended based on a recipe from locally available media constituents, such as wood chips, bark, and various soil media constituents. Media replacement frequency is affected by media selection, as mentioned above.
c. **Moisture Control**

Moisture control may be accomplished by pre-humidification of the air in a mist chamber with spray nozzles, with a packed tower humidification chamber, by keeping the media wet using soaker piping within the media bed, surface irrigation with spray nozzles, or a combination of these methods. Moisture sensors have not proven to be extremely reliable, therefore manual operator monitoring is typically used to ensure adequate moisture content.

d. **Loadings**

Loading of biofilters should be properly designed to prevent acid formation, corrosion problems, premature compaction of the media, short-circuiting the media bed, inadequate biological activity, and other problems which can result in sub-standard performance of the biofilter.

e. **Corrosion Protection**

Due to the formation of sulfuric acid as a byproduct in hydrogen sulfide treatment, the following corrosion protection should be included in the biofilter design:

- Liners or protective coatings on concrete
- Installation of pH probes in drain water to measure pH
ODOR CONTROL TECHNOLOGY SUMMARY

Technology: CHEMICAL SCRUBBERS

Description:

Chemical scrubbers are a common odor control technology. The basic objective of a scrubber is to provide contact between odorous air, water, and chemicals to provide oxidation or entrainment of the odorous compounds. The odorous compounds are absorbed into the scrubber liquid, where they are oxidized and/or removed from the scrubber as an overflow or blowdown stream.

Chemical Scrubbers

The basic components of the scrubber are the vessel; packing material; liquid recirculation system with spray nozzles, recirculation pump, a sump; and a mist eliminator. A fan draws or pushes the odorous air into the scrubber. The air passes through the packing bed where it comes in contact and is absorbed into the liquid solution sprayed from nozzles above the packing bed. The liquid solution, after passing through the packing bed, falls into the sump, where it is recirculated or discarded. The air exits the packing bed and is routed through the mist eliminator to minimize liquid droplets from exiting the scrubber.

Typical chemicals used in the liquid solution to oxidize hydrogen sulfide and other reduced sulfur compounds include sodium hypochlorite (bleach) and sodium hydroxide (caustic). The oxidation reactions are dependent on pH, with the optimum scrubber solution pH being in the 9.5 – 10.5 range. In this range, hydrogen sulfide is absorbed into the recirculation liquid. As pH decreases below the optimum range, the hydrogen sulfide solubility decreases and is not effectively absorbed into the scrubber solution. As pH increases above the optimum range, more chemical is used than necessary, and more carbon dioxide is scrubbed from the air stream. The scrubber chemical concentrations
are typically automatically controlled by monitoring the liquid solution pH and ORP (Oxidation-Reduction Potential). A pH probe and controller maintain the proper pH by regulating the rate sodium hydroxide is added to the solution. An ORP probe and controller maintain the proper chlorine residual by regulating the rate sodium hypochlorite is added to the solution. Make-up water is continuously fed to the scrubber to force out contaminants that accumulate in the sump out the overflow.

Where removal of ammonia and other nitrogen compounds is required, a two-stage scrubber system using a dilute sulfuric acid solution in the first stage is typically used. The ammonia reacts with the sulfuric acid to form ammonium sulfate, a soluble, non-volatile salt, which is removed from the scrubber effluent through the overflow.

Wet scrubbers are a proven odor control technology which can remove up to 99.5% of hydrogen sulfide, even at high concentrations. They require a relatively small footprint, but require significant operational and maintenance attention, chemical handling and storage, and require disposal of scrubber effluent wastewater. Due to the special handling requirements of the chemicals involved, extensive training of operators of these systems is required. They are not considered to be effective for removal of volatile organic compounds (VOC’s) and are also not effective where odorous organic compounds are to be treated.

**Applicable Treatment Processes:**

All liquid treatment plant processes, pump stations, sludge thickening, sludge dewatering.

**Typical Design Criteria:**

- Air flow velocity: < 8.5 feet/sec (500 fpm)
- Detention time (in packing): 1.5 - 2 sec
- Packing depth: 6 – 10 feet (dependent on contaminant loading)
- H₂S removal efficiency: 99%

**Major Design Considerations:**

a. **Contaminants to be removed**

   Chemical treatment selection is based on contaminants to be removed. Hydrogen sulfide may be treated using a solution of sodium hypochlorite and sodium hydroxide. Ammonia may be treated using a dilute solution of sulfuric acid. VOC’s are not effectively treated in wet chemical scrubber systems.
b. **Number of stages required**

A multiple stage scrubber system may be required for removal of multiple contaminants such as hydrogen sulfide and ammonia. Multiple stages may also be used for treatment of very high contaminant concentrations. Two and three stage systems are common.

c. **Liquid solution controls**

The liquid solution must be properly monitored and controlled to ensure proper pH and ORP levels are maintained in the scrubber solution for efficient operation. Liquid levels must also be monitored and controlled.

d. **Packing material**

Packing should possess high surface area to volume ratio and possess shapes and sizes to provide a tortuous path for adequate detention time, while minimizing pressure drop. Materials vary dependent on contaminants being treated and the temperature of the air.
ODOR CONTROL TECHNOLOGY SUMMARY

Technology: CARBON ADSORPTION

Description:

Carbon adsorbers are a common odor control technology. The basic objective of carbon adsorbers is to act as a dry adsorption filter for odorous air before emitting to the atmosphere. The odorous compounds are adsorbed to the surface of the carbon, which has a high surface-to-volume ratio. The carbon is then replaced or regenerated when it becomes saturated and odor breakthrough occurs. Carbon adsorbers are typically used for low concentration airstreams. They may be used either for primary odor control or for a polishing stage following a chemical scrubber or biological treatment system. They may be cost prohibitive for high concentration applications due to the high cost of carbon.
Carbon adsorbers typically include fiberglass vessels, which house carbon between perforated plates. A fan draws or pushes the air through the carbon adsorber.

The carbon can be impregnated with sodium hydroxide (caustic) for improved adsorption of hydrogen sulfide. The impregnated carbon can be regenerated with caustic when breakthrough occurs, but this is a very difficult process and is rarely done. Some manufacturers now offer a carbon that can be regenerated by washing with water. The carbon typically needs to be replaced after 4 – 5 regenerations.

Carbon adsorbers are easy to install and maintain, require no chemical storage or handling, require a relatively small footprint, and typically guarantee 99.9% hydrogen sulfide removal efficiencies. Disadvantages include the high cost of carbon and the required disposal of used carbon. Carbon is also not recommended with high moisture air, which saturates the carbon bed too quickly. Carbon is commonly used in remote locations such as pumping station wet wells.

**Applicable Treatment Processes:**

All liquid treatment plant processes, pump stations, sludge thickening, sludge dewatering.

**Typical Design Criteria:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air flow velocity</td>
<td>50 – 75 fpm</td>
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<tr>
<td>Detention time</td>
<td>3 - 4 sec</td>
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<tr>
<td>Carbon bed depth</td>
<td>3 feet</td>
</tr>
<tr>
<td>( \text{H}_2\text{S} ) removal efficiency</td>
<td>&gt; 99%</td>
</tr>
</tbody>
</table>

**Major Design Considerations:**

a. **Carbon selection**

The type of carbon should be selected based on the individual application.

b. **Carbon bed depth**

Bed depth is dependent on odorous compound concentrations. Dual beds may be designed for higher air flows where there are site size restrictions.

c. **Vessel size**

A 12 foot diameter vessel, the largest sized vessel that can economically be transported by truck, can effectively treat up to approximately 8,000 cfm in a single bed unit and up to 16,000 cfm in a dual bed unit.