CONTROL AND EMISSIONS MODELING OF VOC, AMMONIA, AND ODOR FROM PROPOSED ABT-HASKELL AIRLANCE™ COMPOST FACILITY, REDLANDS, CALIFORNIA

PREPARED FOR:

ABT-Haskell

[redacted]

PREPARED BY:

Soil/Water/Air Protection Enterprise

[redacted]

June 8, 2005

TABLE OF CONTENTS

FIGURES

FIGURES CONTINUED

TABLES

APPENDICES

A: SCAQMD Rule 1133.2
B: Odor Detections Limits Ruth
C: San Joaquin Report
D: ECO Report
E: ISCST3 Model Outputs

ABBREVIATIONS

AB	Assembly Bill
ABT-Haskell	ABT-Haskell, LLC
BACT	Best Available Control Technology
°C	degrees Celsius
cfm	Cubic Feet Per Minute
CH_3CH_2COOH	Propionic Acid
$CH_3CH_2CH_2COOH$	Butyric Acid
CH_3CH_2SH	ethyl mercaptan
CH_3SH	methyl mercaptan
CH_3COOH	Acetic Acid
CIWMB	California Integrated Waste Management Board
DMS	Dimethyl Sulfide
°F	degrees Fahrenheit
GLCs	ground-level concentrations
HS^-	Sulfide
H_2S	Hydrogen Sulfide
ISCST3	Industrial Source Complex Short Term Model 3
MEK	Methyl Ethyl Ketone
$\mu g/m^3$	micrograms per cubic meter
NaOH	Sodium Hydroxide
NH_3	Ammonia
SB	Senate Bill
SCAQMD	South Coast Air Quality Management District
SO_4^{2-}	Sulfate
SWAPE	Soil/Water/Air Protection Enterprise
TGNMOC	total gaseous non-methane organic compounds
TMA	Trimethyl Amine
VFA	Volatile Fatty Acids
VOC	Volatile Organic Compound

EXECUTIVE SUMMARY

ABT-Haskell, LLC, a joint venture of American Bio Tech and The Haskell Company (ABT-Haskell) retained Soil/Water/Air Protection Enterprise (SWAPE) to prepare a report on the potential odor emissions from a proposed enclosed, in-vessel organic waste (biosolids, foodwaste, greenwaste and waste wood) composting facility located approximately one-quarter mile north of Palmetto Avenue and Alabama Street in Redlands, California (the Site). The proposed facility will be an enclosed processing center and will serve as a valuable asset to San Bernardino County in meeting the requirements of California State Assembly Bill (AB) 939. The facility will also exceed the requirements of South Coast Air Quality Management District (SCAQMD) Rule 1133.2. Moreover, the site location selected by ABT-Haskell is ideal for the proposed facility, for it is situated in close proximity to an existing wastewater treatment facility that processes sludge in the drying lagoons for open-pile composting. It is proposed and anticipated that the ABT-Haskell facility will form a cooperative agreement with the City of Redlands (operator of the wastewater treatment plant) resulting in the removal of the sludge drying lagoons and improving local air quality. Additionally, the City of Redlands has proposed that the facility utilized untapped electrical energy production that could be developed from the wastewater treatment facility's anaerobic digesters due to the production of additional methane.

Assembly Bill 939, known as the Integrated Waste Management Act, was passed in 1989 because of the statewide increases in waste stream and decreases in landfill capacity. As a result, the California Integrated Waste Management Board (CIWMB) was established. AB 939 mandates a reduction of waste being disposed in the state and mandated that jurisdictions meet diversion goals of 50% by the year 2000. The pending Senate Bill 420 has been proposed to increase the solid waste diversion rate to 75% by 2015. As of 2005, the City of Redlands is diverting only 34% of their waste according to the CIWMB. ABT-Haskell's proposed facility will assist the City of Redlands and other municipalities within San Bernardino County in meeting this goal.

SCAQMD rule 1133.2 was passed in 2003 and mandates that all compost facilities in the South Coast Air Basin: (a) conduct all active co-composting within the confines of an enclosure, (b) conduct all curing using an aeration system that operates under negative pressure for no less than 90 percent of its blower(s) operating cycle; and, (c) vent the exhaust from the enclosure and the aeration system to an emissions control system designed and operated with a control efficiency equal to or greater than 80 percent, by weight, for VOC emissions and 80 percent, by weight, for ammonia emissions.

ABT-Haskell has developed a unique and patented enclosed AirLance™ Composting Technology that uniformly keeps the compost oxidized with a mean oxygen concentration of 19%, which is far higher than any other compost process. As a result of this and other improvements in the composting process, it is likely that the SCAQMD and the CIWMB will find that American Bio Tech's AirLance™ Technology is suited to become the Best Available Control Technology (BACT) for reducing compost odor and VOC emissions.

The AirLance™ Composting Technology was utilized and constructed at two compost facilities with outstanding success in New York and Connecticut. The proposed facility in Redlands, California will process approximately 100,000 wet tons of organic waste and up to 50,000 tons of waste wood annually, and will treat the VOC, ammonia and odor emissions with the most sophisticated compost emission scrubbing system available in the United States. The proposed scrubbing system will have: (1) a heat exchanger, which will cool the exhaust air and condense or trap most of the odorants and VOCs in solution; (2) a biofilter that will oxidize much of the sulfur compounds; (3) a sulfuric acid trap that will remove any ammonia or amines that get through the condensation trap; (4) a base trap that will capture any volatile fatty acids; and (5) a sodium hypochlorite treatment train that will further oxidize any odorants, including sulfur compounds, and kill any bacteria that pass through the system.

The proposed ABT-Haskell facility in Redlands will have 16 cells with an odor control system maintaining over a 60 second contact time. Two similar facilities have been constructed in New York (with 4.5 compost cells) and Connecticut (with 20 compost cells). The New York and Connecticut facilities had simple acid and base wet scrubbing systems with only 6 to 7 second contact times, which were sufficient to control odor emissions. The proposed ABT-Haskell facility in Redlands (with 16 compost cells) will a employ a wet scrubbing system with three additional treatment trains (heat exchanger/condensation trap, biofilter, and sodium hypochlorite misting system), in addition to the acid and base wet scrubbing treatment. The contact time at the Redlands Facility will be approximately 9 to 10 times greater than the previously constructed facilities that successfully controlled odor. The proposed Redlands facility, with its increased contact time and three additional odor control processes, will ensure that the potential to produce odors which may impact the community is *de minimus*.

To estimate potential ground-level concentrations of odorants from the facility, SWAPE compiled "worst-case" scenario compost emission data from studies performed by the SCAQMD on the San Joaquin Composting, Incorporated (Lost Hills, California) and EKO Systems (Corona, California) open-pile facilities. The term "worst-case" scenario is used because open-pile composting has been shown to be a mostly anaerobic (lacking oxygen) process that is not directly applicable to the highly aerobic AirLance™ process. With this in mind, emission factors were derived for ammonia, sulfur compounds, amine compounds, and VOCs above those outlined in SCAQMD Rule 1133.2. SWAPE estimated the potential ground-level concentrations of each of the odorants of concern (sulfur compounds, ammonia, amines, and VOCs) using the Industrial Source Complex Short Term Model 3 (ISCST3) for a variety of periods (1-hour, 12-hour, and annual average) as well as for a variety of control conditions (80% control of emissions, 95% control of emissions, 99% control of emissions, and 99.9% control of emissions). The modeling demonstrated that when the system is operational the proposed ABT-Haskell composting facility will have a *de mininus* impact upon the Redlands Community with regard to odor and volatile organic compounds emissions. In conclusion, the County of San Bernardino should embrace the ABT-Haskell project, for it will facilitate a process for local municipalities to meet the requirements for waste diversion from landfills under AB 939 and the project will have a *de minimus* impact upon the community. Moreover, the County of San Bernardino can be a leader in California for organic waste recycling by supporting such a sophisticated green industrial recycling technology.

1 INTRODUCTION

Soil/Water/Air Protection Enterprise (SWAPE) has prepared this report to assist in evaluation of odor emissions from the proposed ABT-Haskell organic waste composting facility located approximately one-quarter mile north of Palmetto Avenue and Alabama Street in Redlands, California (the Site).

This report presents the following information:

1. A literature review of biosolids compost odorants;
2. Description of the AirLance™ Technology that maintains an aerobic environment ;
3. Description of the proposed air scrubber system that eliminates emissions/odors;
4. Compost facility emissions inventory;
5. Local meteorological data; and
6. Modeling of potential offsite emission/odors from the proposed facility

1.1 COMPOSTING PROCESS

SCAQMD defines composting as an aerobic (oxygen dependent) degradation process by which organic wastes decompose under controlled conditions[1]. Composting typically involves the mixing of digested sewage sludge and other organic wastes with a bulking agent at an approximate 50-50 ratio. The final compost product is stable, free of pathogens, and can be used as a soil amendment and fertilizer. The bacterial breakdown of substrates also produces by-product organic and inorganic gases[2]. Emissions monitored in studies by SCAQMD include ammonia, amines, total sulfur compounds, methane, and total gaseous non-methane organic compounds (TGNMOC).

[1] SCAQMD. 1995. *Final Report: Emission Rate Characterization of Open Windrow Sludge Composting Operations*. South Coast Air Quality Management District. October, 1995. page 2

[2] SCAQMD. 1995. *Final Report: Emission Rate Characterization of Open Windrow Sludge Composting Operations*. South Coast Air Quality Management District. October, 1995 page 2

1.2 SCAQMD RULE 1133.2 -- EMISSION REDUCTIONS FROM CO-COMPOSTING OPERATIONS

Under SCAQMD Rule 1133.2 compositing facilities are to reduce volatile organic compounds (VOC) and ammonia (NH_3) emissions from co-composting operations[3]. A copy of Rule 1133.2 is attached as Appendix A. In addition to enclosing facilities, operators are required to have facilities in which:

(A)

(i) The inward face velocity of air through each opening in which air can enter the enclosure shall be a minimum of 100 feet per minute, unless the opening is equipped with a closure device that seals the opening in the event that the airflow direction changes.

(ii) The area of all openings in the enclosure through which air can enter the enclosure shall not exceed 2% of the surface area of the enclosure's four walls, floor, and ceiling.

(iii) The enclosure may be opened for brief time periods, not to exceed a total of 30 minutes per day for purposes of access or maintenance. These time periods do not need to be included in the face velocity determination or as an opening for the two percent criteria.

(iv) No measurable increase over background levels of ammonia or hydrocarbons outside the enclosure shall occur at any enclosure opening including any opening that occurs briefly for access or maintenance. A portable ammonia or hydrocarbon analyzer shall be used for these measurements. The portable ammonia analyzer shall be operated per manufacturer's instructions and calibrated with certified zero and 10 parts per million ammonia standards. The portable hydrocarbon analyzer shall be a flame ionization detector operated per manufacturer's instructions and calibrated with certified zero and 10 parts per million methane standards.

(B) Conduct all curing using an aeration system that operates under negative pressure for no less than 90 percent of its blower(s) operating cycle; and,

(C) Vent the exhaust from the enclosure and the aeration system to an emissions control system designed and operated with a control efficiency equal to or greater than 80 percent, by weight, for VOC emissions and 80 percent, by weight, for ammonia emissions.[4]

The practical result of the Rule is that all emissions from new composting facilities must be reduced by 80 percent (Paragraph (d)(2)). Paragraph (d)(3) of Rule 1133.2 allows existing composting facilities to reduce emissions to 70 percent.

Paragraph (d)(4) details baseline emission factors that may be used to determine the amount of VOC and NH_3 generated per ton of throughput (1.78 and 2.93 lbs per ton, respectively). These baseline emission factors may be used in lieu of specific emission factors when submitting a compliance plan for the proposed operations of new composting facilities. The emission factors represent non-controlled operations.

Conservative emission factors were derived from SCAQMD studies of open-pile composting systems for this assessment. This conservative approach will over-estimate the potential for emissions from the facility, providing a higher level of protection for the community by ensuring appropriate control measures are in place.

1.3 LANDFILL CAPACITY AND SOLID WASTE DIVERSION

Because of state-wide increases in solid waste streams and decreases in landfill capacity, the California legislature enacted Assembly Bill 939 (AB 939) and Senate Bill 1322 (SB 1322), known as the Integrated Waste Management Act, in 1989. The California Integrated Waste Management Board (CIWMB) was created as a result of this legislation and its authority and responsibilities were signed into law as the Integrated Waste Management Act of 1989.[5]

The Integrated Waste Management Act established a new approach to managing California's solid waste stream, the centerpiece of which was a mandated 25 percent diversion of each city's and county's waste from disposal by 1995, and 50 percent

[3] SCAQMD Rule 1133.2 - Reductions From Co-Composting Operations *(Adopted January 10, 2003)*
[4] SCAQMD Rule 1133.2 - Reductions From Co-Composting Operations *(Adopted January 10, 2003)*

[5] CALEPA. 2003. The History of the California Environmental Protection Agency, The Integrated Waste Management Board. http://www.calepa.ca.gov/About/History01/ciwmb.htm.

diversion in 2000, along with a process to ensure environmentally safe disposal of waste that could not be diverted.[6]

The Integrated Waste Management Act, along with Title 14 and Chapter 15 of California's environmental regulations, also provided the foundation to put the state on course to comply with federal standards (Title 40, Code of Federal Regulations, Part 258, Subtitle D) for managing solid waste, including the design, construction and operation of landfills. In 1993, California became one of the first states to receive federal approval to assume authority over its solid waste activities, having actually exceeded the federal standards through the adoption of more stringent State regulations. Since then, the environmental performance of waste handling facilities in California have steadily improved and today rank the State as a world leader.[7]

The statewide solid waste diversion rate reached approximately 37 percent in 1999, continuing an upward trend that started with a rate of about 10 percent in 1989. Recent legislation, namely in Senate Bill (SB) 420, has been proposed to increase the solid waste diversion rate to 75% diversion by 2015.[8] ABT-Haskell's proposed facility will assist San Bernardino County in meeting this goal by recycling organic and carbonous (wood) wastes that are currently being landfilled.

[6] CALEPA. 2003. The History of the California Environmental Protection Agency, The Integrated Waste Management Board. http://www.calepa.ca.gov/About/History01/ciwmb.htm.

[7] CALEPA. 2003. The History of the California Environmental Protection Agency, The Integrated Waste Management Board. http://www.calepa.ca.gov/About/History01/ciwmb.htm.

[8] Amended Senate Bill 420. March 29, 2005. http://info.sen.ca.gov/pub/bill/sen/sb_0401-0450/sb_420_bill_20050329_amended_sen.html

2 ODORANT LITERATURE REVIEW

2.1 ODORANT OVERVIEW

Odorous emissions from biosolids composting operations are believed to result primarily from sulfur and nitrogen compound emissions. Furthermore, ketones and volatile fatty acids have also been noted as odorant emissions from biosolids (Mosier et al., 1977).

Because each odorant has unique physical and chemical properties and odor characteristics or type (e.g. rotten vegetable, fishy), it is essential to correctly identify the odorants type in order to solve the problem and come up with an engineering solution. Moreover, it is important to identify individual chemicals responsible for the odor and conduct a health risk assessment in order to explain the relative risk to the community affected by the odor.

Odor has traditionally been evaluated using dilution-to-threshold olfactometry and via chemical analyses of common odorants. While dilution-to-threshold olfactometry is useful in determining the relative intensity of an odor, it does not address the relative offensiveness or character of the odor.

Odor emissions from biosolids composting are affected by (1) biosolids composition, (2) environmental variables, and (3) management practices. Different biosolids can have different chemical constituents, microbial communities, decomposition rates, odorous compounds, and odorant volatilization rates. Environmental variables that affect odor emissions include temperature, moisture, time, wind, redox potential, microorganisms, pH and structure (Miller, 1993).

2.2 ODORANT EMISSIONS FROM BIOSOLIDS

2.2.1 SULFUR EMISSIONS FROM BIOSOLIDS

Biosolids typically contain between 0.7 to 2.1% total elemental sulfur (Sommers et al., 1977), and some fraction of this sulfur volatilizes producing odor. Banwart and Bremner (1975) found that dimethyl disulfide accounted for 55-98% of total sulfur evolved from biosolids application to soil in aerobic conditions, which in many ways is similar to composting (Figure 2.1). Dimethyl disulfide is produced by many bacteria found in wastewater (Tornita et al., 1987) and fungi (Sunesson et al., 1995; Borjesson et al., 1993) and possesses a rotten cabbage odor with a low human detection limit of 0.1 micrograms per cubic meter ($\mu g/m^3$) (Ruth, 1986).

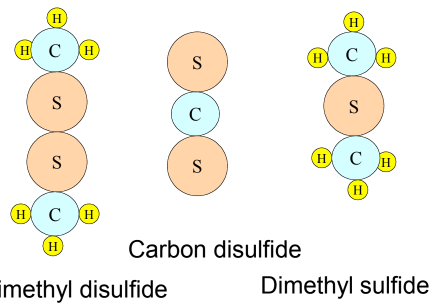


Figure 2.1: Sulfur Compounds

Dimethyl sulfide and carbon disulfide (Figure 2.1) are the other two most abundant sulfur emissions from biosolids application and composting in aerobic conditions (Banwart and Bremner, 1976). Dimethyl sulfide and carbon also possess a rotten cabbage smell, with human detection limits of 2.5 μg/m3 and 24.3 μg/m3 respectively (Ruth, 1986).

Sommers et al. (1977) characterized the forms of sulfur in 10 biosolids from different Indiana cities and found that approximately 65% of the sulfur was in the organic form. Organic-sulfur in biosolids can produce dimethyl disulfide, dimethyl sulfide and carbon disulfide (Banwart and Bremner, 1975). Sommers et al. (1977) found that approximately 35% total sulfur in biosolids was inorganic (with sulfide (HS-) accounting for 8.5% of total sulfur). Bacteria and fungi typically promote the methylation of HS- producing thiols and various methyl sulfides (Miller, 1993). The oxidation of methyl sulfides can produce dimethyl disulfide (Wilber et al., 1991).

Carbon disulfide has been documented to form in both aerobic and anaerobic environments via microbial decomposition of sulfide containing amino acids found in protein. Banwart and Bremner (1975a) reported that carbon disulfide emissions resulted from decomposition of cysteine, cystine, homocystine, lanthionine, and Djenkolic acid.

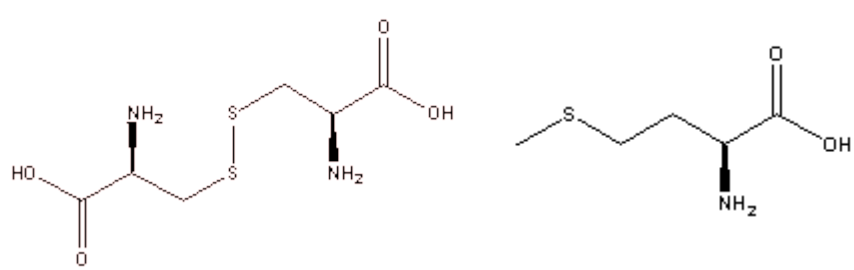
Hydrogen sulfide (H_2S) has not been found to volatilize following biosolids application to soil in aerobic conditions (Banwart and Bremner, 1976), and is not found in aerobic biosolids composting. Biosolids often have a pH around 8.5, and at this pH H2S (pKa=7.04) deprotonates to sulfide (HS-), a non-volatile ionic molecule. Furthermore

H2S is a polar molecule with a structure similar to water, and is held in solution via hydrogen bonding. In addition, H2S is readily oxidized in aerobic conditions (Paul and Clark, 1996). Bacteria and fungi can also remove HS- by promoting methylation, producing thiols and various methyl sulfides (Miller, 1993).

Finally, methyl mercaptan (CH_3SH) and ethyl mercaptan (CH_3CH_2SH) are not detected resulting from biosolids in aerobic conditions (Banwart and Bremner, 1976). Although these compounds are present in the ambient air near wastewater facilities, these compounds are highly reactive and are easily catalyzed forming disulfides (Huang, 1994).

Dimethyl sulfide (DMS) has been documented to form in both aerobic and anaerobic environments via microbial decomposition of sulfur containing amino acids found in protein. Banwart and Bremner (1975) reported that dimethyl sulfide emissions resulted from methionine and homocystine. The degradation of sulfur containing amino acids, specifically cystine and methionine can produce hydrogen sulfide and DMS under anaerobic conditions (Oho et al, 2000, Persson 1992).

Amino acids are the monomers of protein and both cysteine and methionine have been shown to be present in extracted from activated sludges and anaerobically digested sludges (Higgins and Novak, 1997). This mechanism would likely entail the sequential step of the breakdown of protein for form peptides and degradation of peptides for form these free amino acids which would then be broken down to from volatile sulfur compounds.



Cystine Methionine

Figure 2.2: Amino Acids

2.2.2 NITROGEN EMISSIONS

Ammonia and trimethyl amine comprise most of the odorous nitrogen emissions from biosolids composting (Figure 2.2). Ammonia produces a pungent medicinal odor with a human detection limit of 26 $\mu g/m^3$ (Ruth, 1986), while TMA produces a fishy odor with a human detection limit 100 times lower at only 0.8 $\mu g/m^3$ (Ruth, 1986).

The major biological forms of nitrogen include amino acids and nucleic acids (Paul and Clark, 1996). These materials are present in wastewater and mineralize, resulting in NH_4^+ formation (Mitsch and Gosselink, 1993). Anaerobically digested biosolids typically contain between 3 to 6% nitrogen, and 40 to 75% of nitrogen is organic-nitrogen, while the balance is NH_4^+-N (Kardos et al., 1977). Typically, the NH_4^+ ion in biosolids quickly deprotonates resulting in volatile NH_3. Ammonia emissions are reported to be highest during the first several days after biosolids application and then significantly drop off (Harmel et al., 1997). Furthermore, Beauchamp et al. (1978) found that temperature was the most important variable explaining NH_3 volatilization during the first few days after application.

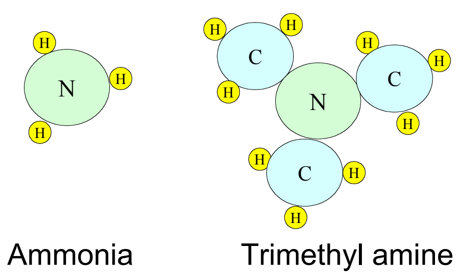


Figure 2.3: Nitrogen Compounds

Hutchenson et al. (1982) measured NH_3 and amine emissions above a cattle feedlot, finding that the NH3-N flux was equal to 99% of the total nitrogen-flux, while the amine flux was equal to approximately 1% of total nitrogen-flux. Of the amines, TMA was always present in highest concentrations and exceeded the sum of other atmospheric amines by sevenfold. Trisubstituted amines (such as TMA) are apparently less readily attacked than are monoamines by the microorganisms active in fecal protein catabolism (Thimann, 1963).

Schade and Crutzen (1995) investigated N emissions from chicken, cow, horse, and swine feces and found that the NH3-N flux was 99.3% of the N-flux, while amines were approximately 0.7% of the N-flux. The amine emissions consisted almost entirely of methyl amines and correlated with NH3 emissions. Of the amines, TMA exceeded the sum of other atmospheric amines by three times.

2.2.3 KETONE EMISSIONS

Humans are not particularly sensitive to acetone and methyl ethyl ketone (MEK), with human detection limits of 1100 μg/m^3 (Ruth, 1986) and 750 μg/m^3, respectively (Ruth, 1986). While the sweet solvent-like odors of ketones may not be perceived as unpleasant, mixed with other odorants they contribute to a generally unpleasant odor.

Ketones can be formed via anaerobic decomposition of cellulose, starch, hemicellulose, and pectins (Mosier et al., 1977). Clostridium sp. bacteria have been identified as acetone producers (Holdemand and Moore, 1973; El Ammouri, 1987; Martin, 1983) and are obligate anaerobes (Killham, 1994). Furthermore, Clostridium sp. has been identified in wastewater and biosolids (Gold et al., 1992; Garcia and Bacares, 1997; Edwards et al., 1998). Van Durme et al. (1992) identified a number of ketones including acetone and methyl ethyl ketone (MEK) as odorant emissions from composting of biosolids (Figure 2.4)

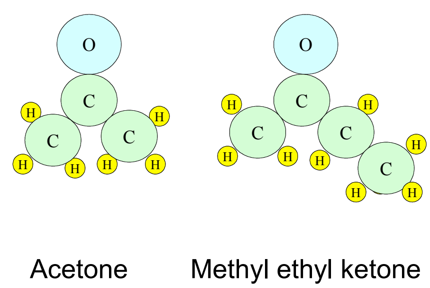


Figure 2.4: Ketones

2.2.4 VOLATILE FATTY ACID EMISSIONS

During wastewater treatment and the anaerobic digestion process, starch, cellulose and hemicellulose are broken down by acid forming bacteria into short chain volatile fatty acids (VFAs) (Figure 2.5). Methanogens, or methane producing bacteria, then convert VFAs into methane (Paul and Clark, 1996).

Thermophillically digested biosolids (50° to 55°C) usually produce more VFA emissions than mesophillically digested biosolids (30° to 35°C), resulting from both higher temperatures and shorter anaerobic digester detention times (Cecil et al., 1992). Volatile fatty acids seldom contribute to the odor from aerobic biosolids at room temperature, for the boiling points for acetic, propionic, and butyric acids are 118, 141, and 164°C, respectively. However, researchers have detected volatile fatty acids during heating of biosolids. For instance, acetic acid was the major VFA produced when diluted biosolids were heated to 121°C (Badawi, 1992). Acetic acid was found in high concentration when sewage sludge was pyrolized at 250°C (Conesa et al., 1998).

According to Mackie (1994), the greater the chain length and the more branching that exists in low molecular weight VFAs, the greater the offensiveness of the odor associated with these acids. For instance, the human detection limits for acetic (CH_3COOH), propionic (CH_3CH_2COOH), and butyric ($CH_3CH_2CH_2COOH$) acids are 2500, 84, 1 $\mu g/m^3$ respectively (Ruth, 1986).

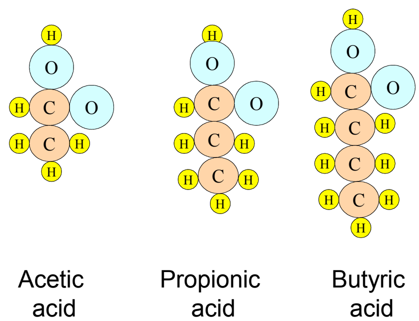


Figure 2.4: Volatile Fatty Acids

2.2.5 ODORANT DETECTION LIMITS

For a person to smell something, air containing odorant molecules must reach a tiny cluster of specialized nerve cells called olfactory neurons. Each nasal cavity has 5 million olfactory neurons, which can perceive 4000 different odors. However, the average individual can only name a handful of odors. This limitation is a result of an individual's inability to name a substance, rather than failure to detect the difference between odors (Ruth, 1986).

A classical definition of odor threshold is the minimum concentration of an odorant which produces a noticeable change in the odor of the system (Ruth, 1986). Odorous samples are presented to panelists by starting with a blank and increasing odorant concentration until odor is perceived. The lowest reported published human detection limits for various odorous compounds are listed in Table 2.1.

It must be noted that data in Table 2.1 are for single odorants when no other odorants are in the air. When two different odorants are introduced into a system, they can act in a synergistic, additive, independent, or counteractive way. To date, mixtures of chemicals have received very little study (Ruth, 1986) (Appendix B).

Table 2.1: Published human detection limits for biosolids compost odorants

Compound	Odor Character	Low Odor Detection Limit (ug/m^3)	High Odor Detection Limit (ug/m^3)	Source
Dimethyl Disulfide	Rotten Cabbage	0.1	246	Ruth, 1986
Hydrogen Sulfide	Rotten Eggs	0.7	14	Ruth, 1986
Dimethyl Sulfide	Rotten Cabbage	2.5	50	Ruth, 1986
Carbon Disulfide	Rotten Cabbage	24	23100	Ruth, 1986
Ammonia	Medicinal	26.6	39600	Ruth, 1986
Trimethyl Amine	Fishy	0.8	0.8	Ruth, 1986
Methyl Ethyl Ketone	Sweet	750	737	Ruth, 1986
Acetone	Sweet	47466	1613860	Ruth, 1986
Acetic Acid	Vinegar	2500	250000	Ruth, 1986
Propionic Acid	Vinegar	84	60000	Ruth, 1986
Butyric Acid	Vinegar	1	900	Ruth, 1986

3 PROPOSED DEVELOPMENT USING AIRLANCE™ TECHNOLOGY

3.1 ABT-HASKELL DEVELOPMENT

ABT-Haskell is proposing to develop a completely enclosed organic waste composting facility in Redlands, California, utilizing AirLance™ Technology that will process approximately 100,000 wet tons of organic waste annually. Additionlly, the proposed facility will process between 25,000 and 50,000 tons of waste wood (green-waste) annually. The site selected by ABT-Haskell is ideal for the proposed facility, for it is in close proximity to a wastewater treatment facility with sludge drying lagoons, and is bordered by two solid waste landfills. It is anticipated that this proposed facility will result in removal of the sludge drying lagoons, thus improving local air quality. The facility will process compost in less time, produce fewer emissions, and subsequently fewer odors (detailed below).

The City of Redlands wastewater treatment facility is located at the north end of Nevada Street, on approximately 50 acres adjacent to the Santa Ana River (northwest of the proposed facility). The City of Redlands facility has been modified to provide secondary Wastewater treatment. Wastewater solids are settled in large tanks and then removed, dried and then composted at OneStop Landscape, an open pile composting facility located in Redlands, CA. The liquid portion is combined with "safe to humans" bacteria and processed further as the bacteria consume over 95% of the water born pollutants. The processed water is then percolated back into the groundwater basin. The City of Redlands facility has the ability to process 9.5 million gallons of wastewater per day, and is currently processing about 6 million gallons per day.

The ABT-Haskell plant will be equipped with an emission scrubbing system capable of treating VOC, ammonia, and odor emissions in excess of the requirements for emission controls as outlined in AB 1133.2. The facility will achieve emission controls in excess of 99% (detailed in section 4.0). The proposed scrubbing system will have: (1) a heat exchanger which will cool the exhaust air and condense or trap most of the odorants and VOCs in solution; (2) a biofilter that will oxidize much of the sulfur compounds; (3) a sulfuric acid trap that will remove any ammonia or amines that get through the condensation trap; (4) a base trap that will capture any volatile fatty acids; and (5) a sodium hypochlorite treatment train that will further oxidize any odorants including sulfur compounds and kill any bacteria that get through the system.

3.2 AIRLANCE TECHNOLOGY

The AirLance™ Process allows composting to be maintained at a maximum biological rate with minimal material handling and low energy consumption. Composting inside the cubical cells remains above 55 degrees Celsius for the full composting period, assuring that the composting process is rapid and cost effective. The compost remains in the system for 14 to 28 days, which is determined by the waste processed, and it leaves as a finished product.

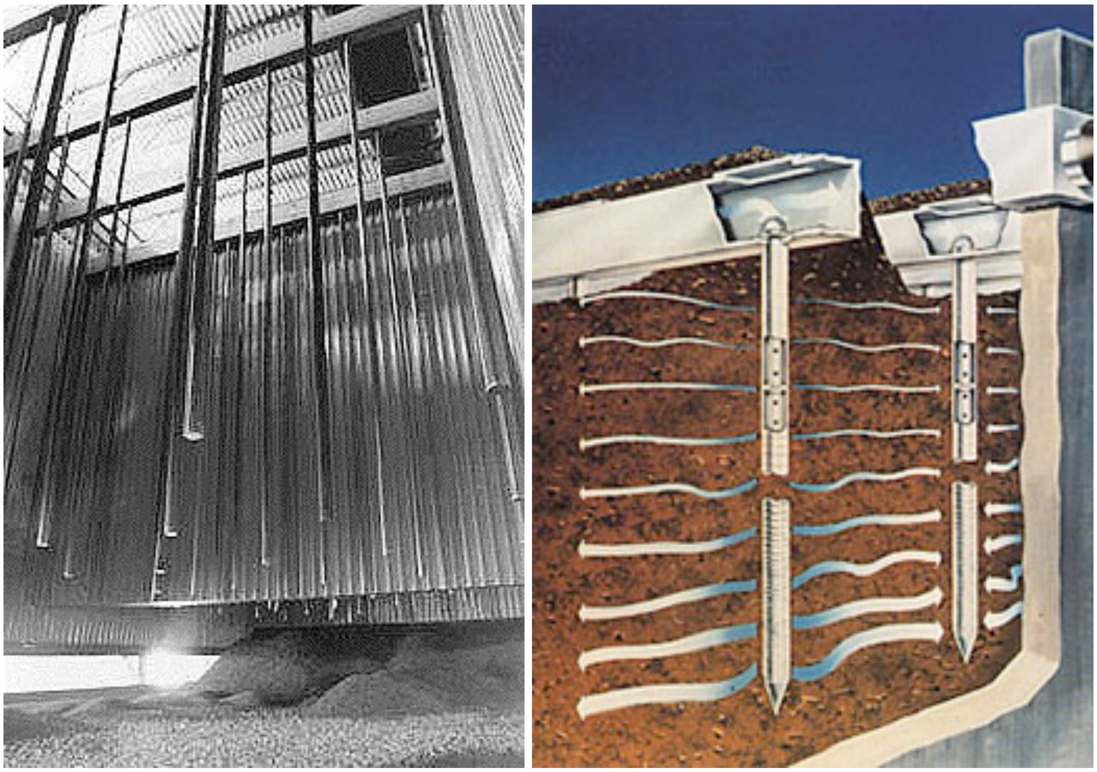


Figure 3.1 & 3.2: The figure on the left shows the Air Lance technology from the bottom of each cell. The figure on the right demonstrates how the air flow through the compost keeps the cells oxygenated

According to the designers, advantages of the AirLance™ Process over open-pile systems include:

1. Reduction in Material Handling

In the AirLance™ System the compost biomass mix is only handled twice during the composting process, loading and unloading the cell. The AirLance™ process does not require the compost to be re-piled and moved numerous times for curing, sorting, and screening.

2. Aerobic BioMass

The AirLance™ Process maintains aerobic conditions by uniformly aerating evenly throughout the biomass to maximize the rate of organic waste stabilization. What is often not realized is that within 20 minutes after making a conventional compost pile, the main mass is depleted of oxygen and the microbes are dying. The center only stays warm because it is well insulated. Daily mixing of windrow composting piles releases anaerobic odors, re-aerates, releases heat, and restarts the process. This is why windrow composting takes considerably longer to complete the process. Static pile composting doesn't significantly change this problem. Attempting to aerate a large pile from the bottom is not very effective. Fluid (air) will always find the path of least resistance and short circuit.

3. Process Time

In the AirLance™ Process all compost is contained inside the system for the full 14 to 28-day composting period. The compost is maintained at 55 to 80 degrees centigrade over the full period, assuring that the compost is a finished stabile product when it leaves the system. Many composting systems only contain the compost in their systems for a few days, and then they pile the compost outside to finish the process. Only because containing the compost for a full 14 to 28 days would make their systems far too expensive to build and operate.

4. Capacity Rating

The AirLance™ Process allows all compost to be loaded into the system as a fine and uniform product. Large chunks of waste to build pore space for aeration are not required. Large pieces only have to be removed later adding another step in the process. This also means that 100% of the product leaving the AirLance™ composting cell is finished, ready for use, and it does not require further screening or recycling.

When finished compost from a windrow composting operation needs to be re-screened to remove foreign material after the process; it also means you have wasted valuable space in the composting operation with non-compost product. A compost process should be capacity rated by the amount of compost it produces, not by what was loaded into the system, and later removed.

More important this means the AirLance™ process can process 2 to 4 times more compost in an equivalent size system. This unique ability of the AirLance™ System to compost a fine material becomes a significant economic advantage in the big picture.

5. Daily Mixing

In the AirLance™ Process all compost is remixed daily. By using gravity to accomplish the mixing action, it requires only 5 to 10% of the energy of other processes to mix. Compost is mixed daily without fear of extensive heat loss.

6. Material Handling Efficiency

The high material handling efficiency of the AirLance™ Process design frequently uses less than 10% of the time and energy for loading / unloading of other composting processes.

7. Aeration Efficiency

The high efficiency of the AirLance™ Aeration Process design greatly reduces energy cost for aeration, ventilation, and odor control compared to other composting processes.

8. Odor Control

The high efficiency of the AirLance™ Aeration Process design simplifies odor control. It reduces the volume of odorous air and allows for a much smaller and more effective odor control system to be built.

3.3 OXYGEN CONTENT AND ODOR EMISSIONS

Maintaining an oxygen content above 15% greatly reduces odor during composting. Ambient air contains 21% oxygen. When the oxygen content in a compost pile falls below 15% reduced sulfides form via reduction of sulfur, and volatile fatty acids, ketones and aldehydes form via incomplete oxidations of cellulose and other carbon substrates. Unfortunately, most composting processes have very low oxygen concentrations.

Dr. Mike Robe (Robe, 2005) conducted experiments measuring the oxygen content throughout an windrow composting facility and found that the oxygen content dropped to below 5% within one hour of composting (Figures 3.3 and 3.4). Hence one can assume that the center of most windrow composting piles are anaerobic forming odorous reduced sulfides, ketones, aldehydes.

The AirLance™ Aeration Process eliminates this anaerobic process and effectively eliminates the formation of the most odorous compounds found in emissions from composting. Instead of reduced sulfides forming via anaerobic conditions, sulfate (SO_4^{2}) forms that is a non-volatile ion with no odor. Moreover, with sufficient oxygen, cellulose can break down all the way to CO_2 and H_2O rather than forming intermediate ketones, aldehydes and fatty acids.

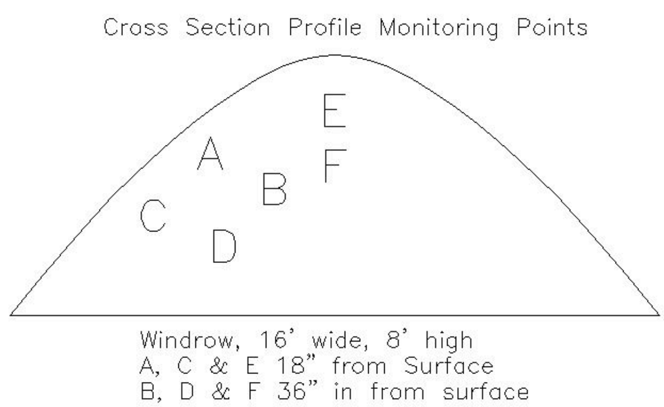


Figure 3.3: Cross Section Of Typical Windrow Composting (Robe, 2005)

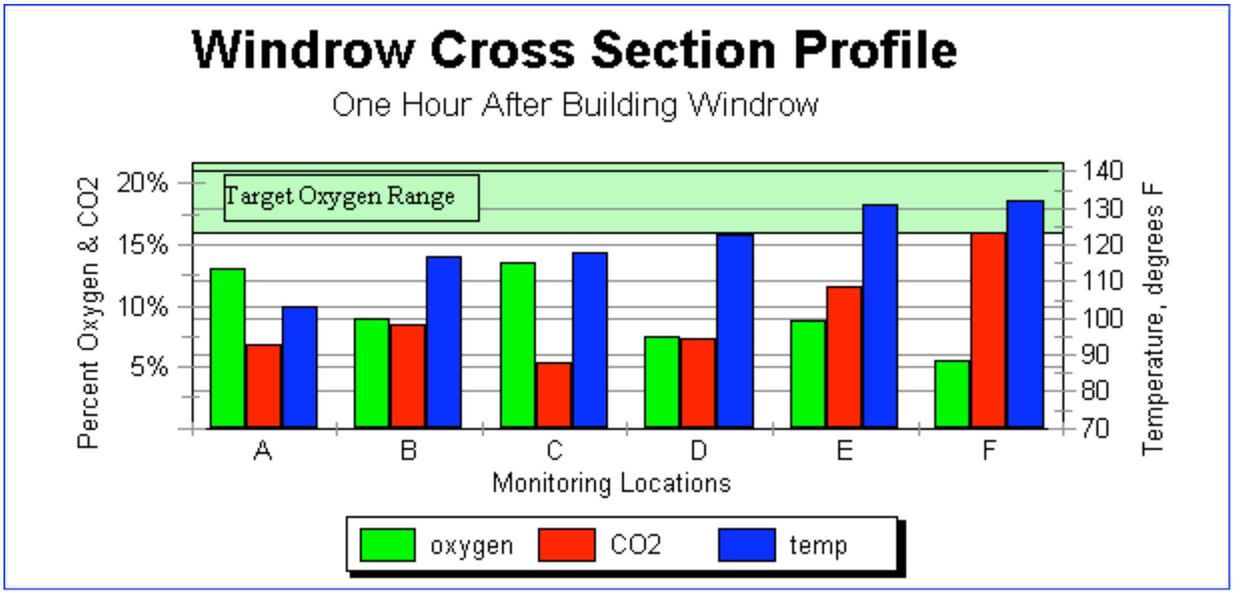


Figure 3.4: Oxygenc and Carbon In Relation To Cross Section In Figure 3.3 (Robe, 2005)

4 AIR SCRUBBER SYSTEM THAT ELIMINATES EMISSIONS/ODORS

ABT-Haskell has proposed to construct the largest and most advanced odor treatment system ever designed in the compost industry. The proposed air scrubbing system will have several stages and more than sixty (60) seconds of contact time. The treatment processes will include: (1) a heat exchanger and condensation trap; (2) a biofilter; (3) sulfuric acid wet scrubber; (4) a sodium hydroxide base wet scrubber; and (5) a sodium hypochlorite oxidizing wet scrubber. Each of these treatment processes are described below.

The proposed ABT-Haskell facility in Redlands will have 16 cells with an odor control system maintaining over a 60 second contact time. Two similar facilities have been constructed in New York (with 4.5 compost cells) and Connecticut (with 20 compost cells). The New York and Connecticut facilities had simple acid and base wet scrubbing systems with only 6 to 7 second contact times, which were sufficient to control odor emissions. The proposed ABT-Haskell facility in Redlands (with 16 compost cells) will a employ a wet scrubbing system with three additional treatment trains (heat exchanger/condensation trap, biofilter, and sodium hypochlorite misting system), in addition to the acid and base wet scrubbing treatment. The contact time at the Redlands Facility will be approximately 9 to 10 times greater than the previously constructed facilities that successfully controlled odor. The proposed Redlands facility, with its increased contact time and three additional odor control processes, will ensure that the potential to produce odors which may impact the community is *de minimus*.

4.1 HEAT EXCHANGER AND CONDENSATION TRAP

The heat exchanger will reduce the temperature of the influent to the scrubbing system from approximately 130 degrees Fahrenheit (°F) to 90 °F. Dew point is the temperature at which condensations forms. This component of the treatment system is designed to remove 99.9% of the ammonia. When air comes in contact with a surface that is at or below its dew point temperature, condensation will form on that surface. With a 100 percent relative humidity at 90 °F, all gasses should condense to liquid and fall out in the condensation trap.

4.2 BIOFILTER

A biofilter will be installed in line to oxidize a wide variety of odorants including any nitrogen, sulfur, ketone, and aldehyde compounds that get through the system. The biofiter polypropylene labyrnith with filter media allowing for bacterial populations to accumulate.

4.3 SULFURIC ACID

Sulfuric acid wet scrubbing will be used to trap any amines or ammonia that get through the heat exchanger and condensation trap, although the ammonia and amine concentrations should be at non-detect. Sulfuric acid reacts with ammonia gas (NH_3) by donating a proton, forcing ammonia gas to become ammonium (NH_4^+) that is then in solution as an ion. The sulfuric acid will be fine misted into the system.

4.4 SODIUM HYDROXIDE

Sodium hydroxide (NaOH) traps volatile fatty acids. The sodium hydroxide will be fine misted into the system.

4.5 SODIUM HYPOCHLORITE

Sodium hypochlorite or bleach will be used as an oxidizing agent for sulfur compounds, and any other odorants or bacteria that come into contact with this oxidizing agent. The sodium hyperchlorite will be fine misted into the system.

5 EMISSIONS INVENTORY

Potential emissions from the facility were derived from source test reports of open-pile composting systems completed by the SCAQMD. SCAQMD defines composting as an aerobic (oxygen dependent) degradation process by which organic wastes decompose under controlled conditions.[9] The final product is stable, free of pathogens, and can be used as a soil amendment and fertilizer. The bacterial breakdown of substrates also produces by-product organic and inorganic gases.[10] Emissions monitored in studies by SCAQMD include ammonia, amines, total sulfur compounds, methane, and total gaseous non-methane organic compounds (TGNMOC).

Methane is produced during the anaerobic decomposition of organic material.[11] According to SCAQMD, the amount of methane generated is a function of the fraction of the total waste that is available for anaerobic bacteria, temperature, and moisture.[12] For windrow operations, methane production is highest in the first 21 days of composting. Since the AirLance™ method involves aerobic composting, methane is not produced in the system. Therefore, methane will be excluded from the emission inventory for the proposed plant.

For the SCAQMD studies, sampling was performed in order to inventory emissions from sludge composting operations in the South Coast Air District in order to evaluate the impact of the operations for possible inclusion to the Air Quality Management Plan (AQMP).[13,14] The facilities had been volunteered for sampling by the owners. Emissions were collected from the piles at various points in the composting cycle. According to the reports, the days for sampling were chosen to represent the beginning

---

9 SCAQMD. 1995. *Final Report: Emission Rate Characterization of Open Windrow Sludge Composting Operations*. South Coast Air Quality Management District. October, 1995. page 2

10 SCAQMD. 1995. *Final Report: Emission Rate Characterization of Open Windrow Sludge Composting Operations*. South Coast Air Quality Management District. October, 1995 page 2

11 SCAQMD. 1995. *Final Report: Emission Rate Characterization of Open Windrow Sludge Composting Operations*. South Coast Air Quality Management District. October, 1995. page 12

12 SCAQMD. 1995. *Final Report: Emission Rate Characterization of Open Windrow Sludge Composting Operations*. South Coast Air Quality Management District. October, 1995. page 12

13 SCAQMD. 1996. *Source Test Report 96-0007/96-0008/96-0009 Conducted at San Joaquin Composting Inc, Holloway Road, Lost Hills, California, Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound (TGNMOC) Emissions from Composting Operations*. South Coast Air Quality Management District. November 16, 1996.

14 SCAQMD. 1996. *Source Test Report 95-0032/96-0003 Conducted at EKO Systems 8100-100 Chino-Corona Road, Corona, California, 91720, Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound (TGNMOC) Emissions from Composting Operations*. South Coast Air Quality Management District. May 16, 1996.

of the composting cycle, the peak temperature day, and the ending day of the composting cycle. The reported emissions were for windrows at the sites since sampling for curing piles emissions was not performed. Piles at the site were turned one to three times per week and samples were collected after turning had been completed. The turning process can release large quantities of emissions and sampling was performed after turning was completed.

The first study of the San Joaquin Composting, Incorporated[15] facility located on Holloway Road, in Lost Hills, California, measured the emission profile of the operation over the composting cycle. The facility composted piles of dewatered sewage sludge and green waste. Emissions were collected from the piles on days 3, 45, and 57 of the composting cycle. The estimated facility wide emissions did not include curing pile emissions and were calculated using the average of the three windrow ages[16].

Table 5.1: San Joaquin Composting, Incorporated Facility Average Emissions for 3, 45, and 57 Day Piles:

Chemical	Emissions per ton of Compost Mix
Ammonia	2.81 lbs/ton mix
Amines	0.19 lbs/ton mix
Total Sulfur Compounds	0.22 lbs/ton mix
TGNMOC	3.12 lbs/ton mix

The second study performed by SCAQMD was of the EKO Systems[17] facility located at 8100-100 Chino-Corona Road, Corona, California, measured the emission profile of the operation over the composting cycle. The facility composted piles of dewatered sewage sludge and manure. Emissions were collected from the piles on days 2, 20, and 50 of the composting cycle. According to the report, the days for sampling were chosen as the beginning of the composting cycle, the peak temperature day, and the ending day of

[15] SCAQMD. 1996. *Source Test Report 96-0007/96-0008/96-0009 Conducted at San Joaquin Composting Inc, Holloway Road, Lost Hills, California, Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound (TGNMOC) Emissions from Composting Operations*. South Coast Air Quality Management District. November 16, 1996.

[16] ibid

[17] SCAQMD. 1996. *Source Test Report 95-0032/96-0003 Conducted at EKO Systems 8100-100 Chino-Corona Road, Corona, California, 91720, Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound (TGNMOC) Emissions from Composting Operations*. South Coast Air Quality Management District. May 16, 1996.

the composting cycle. The reported emissions were for windrows at the site since sampling for curing piles emissions was not performed. Piles at the site were turned one to three times per week and samples were collected after turning had been completed. The estimated facility wide emissions did not include curing pile emissions and were calculated using the average of the three windrow ages[18].

Table 5.2: EKO Systems Average Emissions for 2-day, 20-day, and & 50-Day Piles:

Chemical	Emissions per ton of Compost Mix
Ammonia	3.28 lbs/ton mix
Amines	<0.0003 lbs/ton mix
Total Sulfur Compounds	0.015 lbs/ton mix
TGNMOC	1.70 lbs/ton mix

An average value from the two studies was estimated and used as the source term for the dispersion model. The average was used rather than the default emission factors listed in SCAQMD Rule 1133.2 since

1. The San Joaquin facility composted 50% biosolids and 50% greenwaste;
2. The EKO facility composted manure and biosolids; and
3. The feedstock of the proposed ABT-Haskell facility will be similar to a mixture of the San Joaquin and EKO facilities.

The average values are:

Table 5.3: Average Emissions for San Joaquin and EKO Studies:

Chemical	Emissions per ton of Compost Mix
Ammonia	3.045 lbs/ton mix
Amines	0.09515 lbs/ton mix
Total Sulfur Compounds	0.1175 lbs/ton mix

18 ibid

TGNMOC	2.41 lbs/ton mix

The proposed ABT-Haskell facility is capable of treating 100,000 tons of wet biosolids over the course of a year. The table below details the maximum emissions for 100,000 tons of wet biosolids being composted assuming no emission controls, 80% emission control (minimum requirement to meet SCAQMD Rule 1133), 95% emission control, 99% emission control, and 99.9% emission control (rated emission control for the ABT-Haskell AirLance™ System). These input values were used to derive ground level concentrations of chemicals potentially being emitted from the facility in the dispersion model.

Table 5.4: Annual Potential Emissions For 100,000 Tons of Biosolids:

	Pounds of Emissions Per Year			
Chemical	80% Control	95% Control	99% Control	99.9% Control
Ammonia	60,900	15,225	3,045	304.5
Amines	1,903	475.75	95.15	9.515
Total Sulfur Compounds	2,350	587.5	117.5	11.75
TGNMOC	48,200	1,2050	2,410	241

6 METEOROLOGICAL DATA

The climate in Los Angeles is characterized by moderate temperatures with comfortable humidities and limited precipitation. Temperatures are normally mild, with rare extremes above 100 °F or below freezing. Mean annual precipitation is approximately 14.5 inches, of which, approximately 12.2 inches occur from November through March.

For modeling purposes, the SCAQMD uses 1981 meteorological data (i.e., hourly winds, temperature, atmospheric stability, and mixing heights) from 35 sites in the district. The 1981 meteorological data are used because this data set represents the most complete and comprehensive data set currently compiled. These data are available at the SCAQMD's web site[19] and are in a format that can be directly read by ISCST3. The closest meteorological data station maintained by the SCAQMD was identified from the posted list of sites.

Table 6.1: Meteorological Data

Station ID			UTM (KM)			
SFc	Upper	City Name	E-W	N-S	Long	Lat
54144	99999	BANNING	510.5	3754.5	116:53:11	33:55:58
54149	99999	FONTANA	455.4	3773.9	117:29:01	34:06:24
54161	**99999**	**REDLANDS**	**486.2**	**3769.4**	**117:09:00**	**34:04:00**

Each data file contains preprocessed meteorological data, formatted into columns; one record per hour. The windrose, or visual display of the windpattern measured at Station 54161, is presented in Figure 6.1. The predominant windpattern in the vicinity of the Site is from the west-northwest during the daytime and from the east during the nighttime.

[19] www.aqmd.gov/metdata

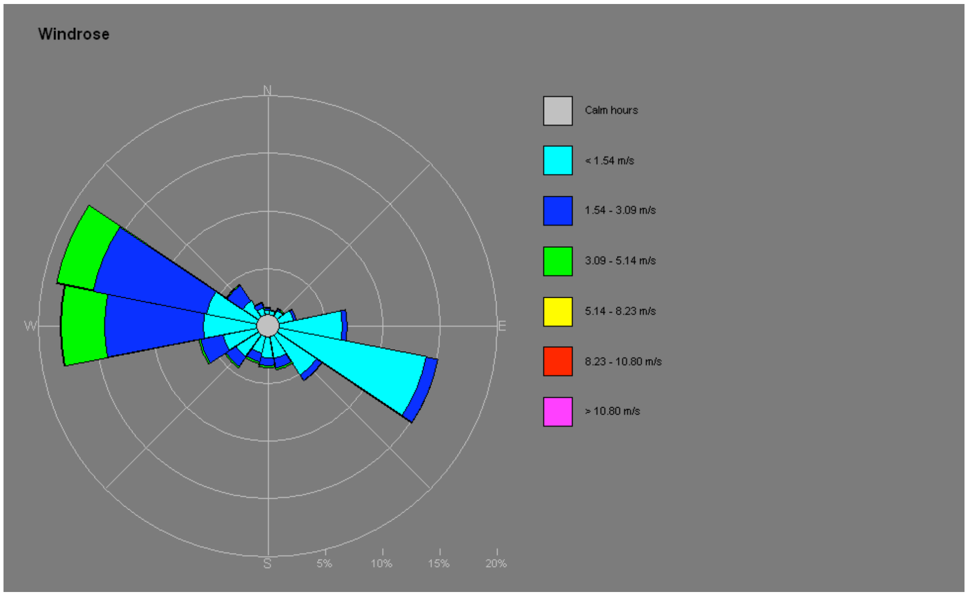


Figure 6.1: Annual Windpattern (Windrose) for Redlands, California

During the winter the predominant wind pattern is dominated by winds from the southeast (counter-current winds from high pressure systems to the west of the Los Angeles Coastal Basin). Frequent rains from December to February dominate the wet season for the Los Angeles Coastal Basin. Stronger winds from the west northwest occur less frequently.

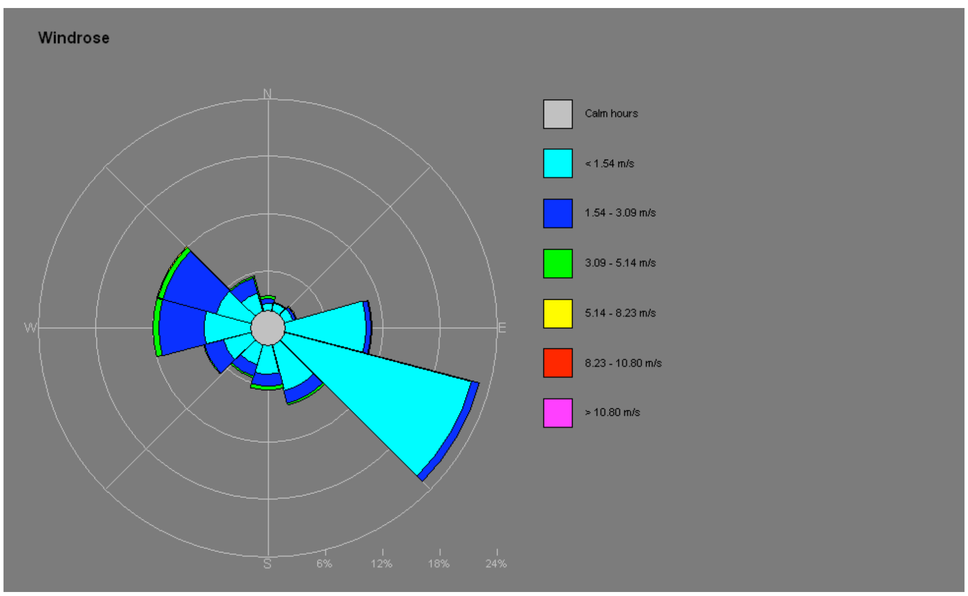


Figure 6.2: Winter Windpattern (Windrose) for Redlands, California

During the spring the predominant wind pattern is dominated by winds from the west-northwest (coastal onshore influence).

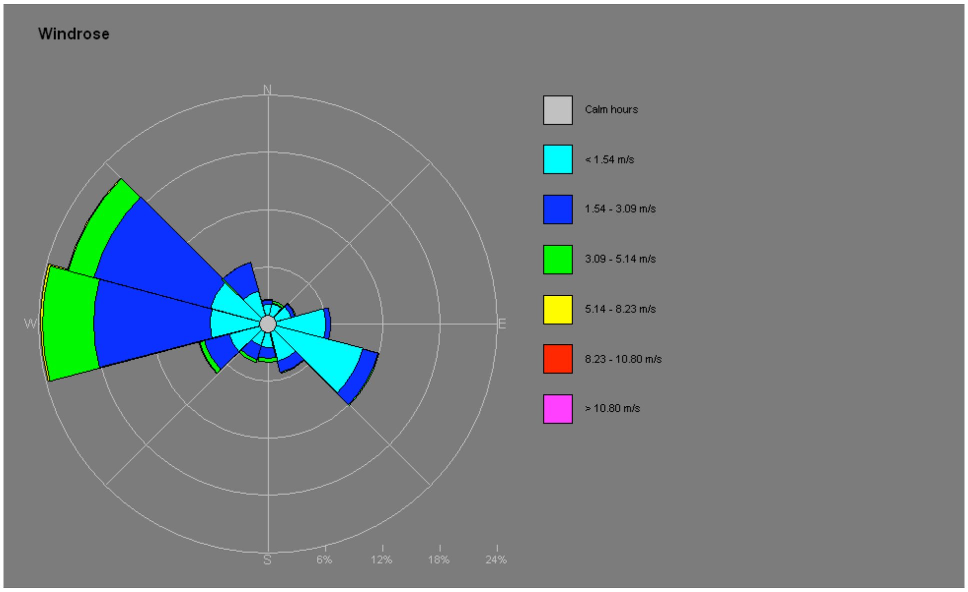


Figure 6.3: Spring Windpattern (Windrose) for Redlands, California

During the summer the predominant wind pattern is dominated by winds from the west-northwest (coastal onshore influence).

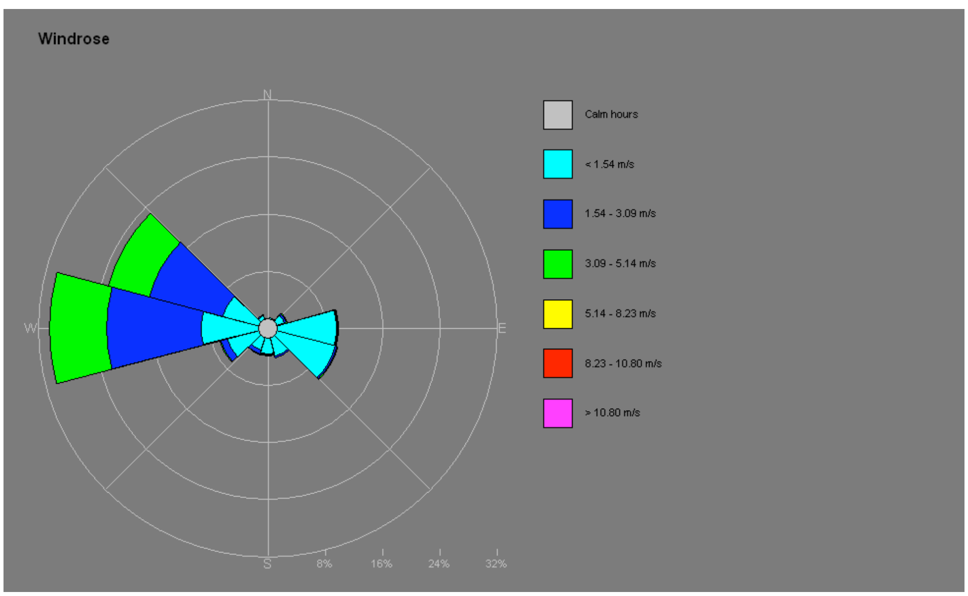


Figure 6.4: Summer Windpattern (Windrose) for Redlands, California

During the fall the predominant wind patterns shift from a strong west-northwest flow to a east-southeasterly flow. This shift highlights the end of the dry season and the start of the winter wet season.

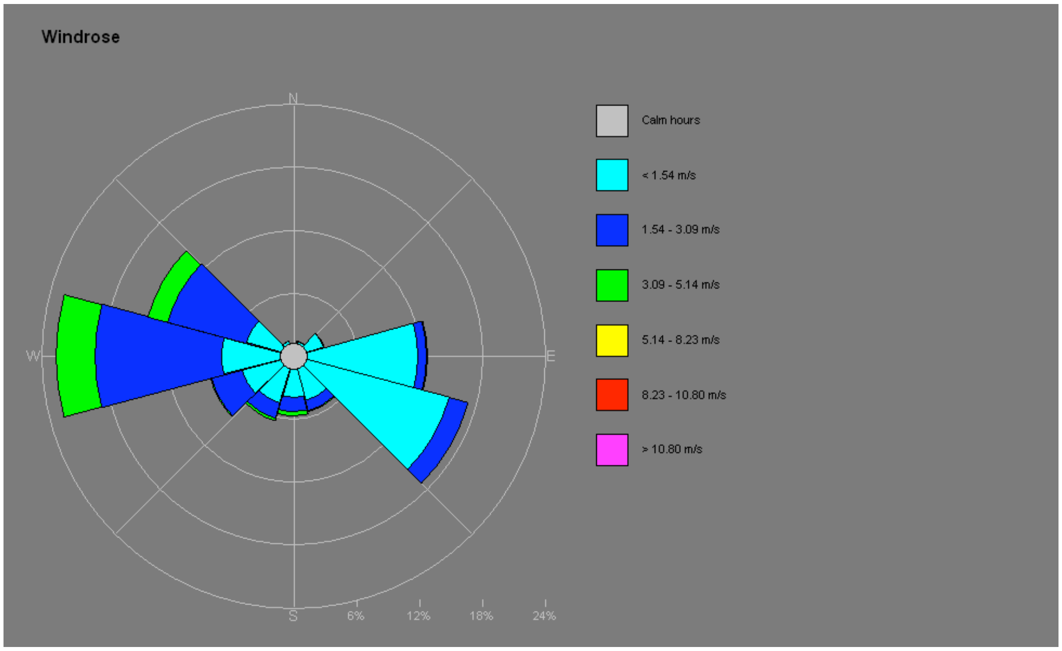


Figure 6.5: Fall Windpattern (Windrose) for Redlands, California

7 ISCST3 MODELING

The Industrial Source Complex-Short Term (ISCST3) model was performed on potential emissions from the ABT-Haskell facility and ground-level concentrations (GLCs) of each compound were calculated for a ½ mile radius of the Site. The model is a steady state Gaussian plume model and is approved by the U.S. EPA for estimating ground level impacts from point and fugitive sources in simple and complex terrain. This model can account for the following: settling and dry deposition of particles; downwash; point, area, line, and volume sources; plume rise as a function of downwind distance; separation of point sources; and limited terrain adjustment. ISCST3 operates in both long-term and short-term modes.

For this study, the dispersion of chemicals was modeled from a point source at the facility. Preliminary designs for the facility show a 54 inch stack from the filtration system exiting at a height of approximately 50 feet above ground surface. The estimated exit velocity for gases from the stack will be approximately 65,000 cubic feet per minute (cfm). Gases were also assumed to be exiting the stack at a temperature of 90 °F. The source terms or concentration of chemicals being emitted from the facility were assumed to be equivalent to the concentrations achieved from 80%, 95%, 99%, and 99.9% control via the previously described scrubber system.

Table 7.1: Annual Potential Tons of Emissions For 100,000 Tons of Biosolids:

			Tons of Emissions Per Year			
Chemical	Tons of Emissions per ton of Compost Mix	Tons of Emissions Without Control	80% Control	95% Control	99% Control	99.9% Control
Ammonia	0.0015225	152	30	7.6	1.52	0.152
Amines	0.000047575	5	1	0.2	0.05	0.005
Total Sulfur Compounds	0.00005875	6	1	0.3	0.06	0.006
TGNMOC	0.001205	121	24	6.0	1.21	0.121

A receptor grid was placed over the system with cells 100 meters by 100 meters. The receptor grid was approximately 3100 meters by 2100 meters in dimension.

Additionally, a fence-line receptor system was set along the property boundary. GLCs were calculated for each of the chemicals, assuming 80%, 95%, 99%, and 99.9% control. The model was run iteratively to determine the maximum 1-hour, 12-hour, and annual average GLCs within the receptor system.

The ISCST3 model output files are presented in Appendix F. Predicted mass GLCs corresponding to the model output values expressed in micrograms per cubic meter (ug/m^3) were derived.

The GLCs were compared to the lowest odor threshold for ammonia as reported by Ruth (1986). Indicator compounds and odor thresholds used in this analysis for amines, sulfur compounds, and TGNMOC are shown in Table 7.2.

Table 7.2: The indicator compounds and the odor threshold

Chemical	Surrogate	Odor Detection Limit
Sulfur	DMDS	0.1 ug/m^3
Amines	TMA	0.8 ug/m^3
Ammonia	NH_3	26.6 ug/m^3
TGNMOC	Phenol	178 ug/m^3

The results of the modeling are presented in Figures 7.1 through 7.49 of the Figure Section.

Sulfur compounds have the lowest odor detection threshold, driving the resulting analysis. While the annual average for the 80% control of sulfur compounds did not exceed the odor threshold on or off the site (Figure 7.10), 1-hour and 12-hour maximums did exceed the odor threshold for receptors on and off-site (Figures 7.2 and 7.6).

For the 95% control scenario of sulfur compounds, the annual average and 12-hour maximum analysis did not exceed the odor threshold for sulfur compounds (Figures 7.11 and 7.7). The 1-hour maximum average did exceed the odor threshold for receptors on and off-site (Figure 7.3).

For the 99% and 99.9% control scenarios, the odor threshold was not exceeded for the annual average, 12-hour maximum, or the 1-hour maximums for receptors on or off-site (Figures 7.4, 7.5, 7.8, 7.9, 7.12, and 7.13).

For amines, ammonia, and TGNMOCs, the analyses show that for all of the control scenarios evaluated (80%, 95%, 99%, and 99.9%) odor thresholds were not exceeded (Figures 7.14 through 7.49).

8 CONCLUSION

The proposed ABT-Haskell facility will be a valuable asset to San Bernardino County in meeting the requirements of AB 939 and will meet the requirements of South Coast Air Quality Management District (SCAQMD) Rule 1133.2.

Dispersion modeling of potential emissions from the proposed facility show that when the system is operational the proposed ABT-Haskell composting facility will have a *de mininus* impact upon the Redlands Community with regard to odor and volatile organic compounds emissions.

9 REFERENCES

Badawi, M. A., El Shinnawi M. M., Blanc F. C., Wise D. L., El Shimi S. A. (1992). Production of acetic acid from thermally treated sewage sludge in an upflow anaerobic reactor. Resources Conservation and Recycling 7. 1-3, 201-212.

Banwart W. L. and Bremner J. M. (1975) Formation of volatile sulfur compounds by microbial decomposition of sulfur-containing amino acids in soils. Soil Biol. Biochem. 7. 359-364.

Beauchamp, E. G., Kidd, G. E., and Thurtell, G. (1978) Ammonia volatilization from sewage sludge applied in the field. J. Environ. Qual. 7, 141-146.

Borjesson, T. S., U. M. Stollman, J. L. Schnuerer. (1993) Off odorous compounds produced by molds on oatmeal agar; Identification and relation to other growth characteristics. Journal of Agricultural and Food Chemistry. 41, 11, 2104-2111.

Cecil L.H., Zenz, D.R., Kuchenrither, R. (1992) Water Quality Management Library Volume 4. Municipal Sewage Sludge Management, Processing, Utilization and Disposal. Technomic Publishing Co. Inc. Lancaster Pennsylvania. pp. 185.

Conesa, J. A., Marcilla A., Moral R., Moreno Caselles J., Perez Espinosa A.: 1998. Evolution of gases in the primary pyrolysis of different sewage sludges. Thermochimica Acta. 313,1:63-73.

Edwards D. D., McFeters G. A. Venkatesan M. I. (1998) Distribution of Clostridium perfringens and fecal sterols in a benthic coastal marine environment influenced by the sewage outfall from McMurdo Station Antarctica. Applied and Env. Microbio. 64, 7, 2596-2600.

El Ammouri, G. M. (1987) Effects of butyric and acetic acid on acetone-butanol formation by Clostridum acetobutylicum. BIOCHIMIE. 69, 2, 109-114.

Garcia, M. and Bacares, E. (1997) Bacterial removal in three pilot-scale wastewater treatment systems for rural areas. Water Science and Technology. 35, 11-12, 197-200.

Gold, A. J., Lamb B. E. Loomis, G. W., Boyd. J. R. Cabelli, V. I., and McKiel C. G. (1992) Wastewater renovation in buried and recirculating sand filters. J. Env. Qual. 21, 4, 720-5

Harmel, R. D., R. E. Zartman, C. Mouron, D. B. Wester, and R. E. Sosebee. (1997) Modeling Ammonia Volatilization from Biosolids Applied to Semiarid Rangeland. Soil Sci. Soc. Am. 61, 1794-1798.

Higgins, M.J. and Novak, J.T. (1997) Characterization of exocellular protein and its role in bioflocculation. J. Environ. Engr. ASCE, 123, 479-485.

Holdemand, L. V. and Moore, W. E. C. (1973) Anaerobe Laboratory manual. 2nd ed. VPI Anaerobe Lab., Virginia Polytechnic Institute and State University, Blackburg Va.

Huang, Y. (1994) Removal of odorous compounds in wastewater using activated carbon, ozonation, and aerated biofilter. Wat. Res. 28, 11, 2309-2319.

Hutchenson, G. L.. Mosier A .R, and Andre C. E. (1982) Ammonia and amine emissions from a large cattle feedlot. J. Env. Qual. 11, 2, 288-293.

Kardos, L. T., Scarsbrook, C.E., and Volk V.V. (1977) Recycling elements in wastes through soil-plant systems. In Soil for Management of Organic Waste and Waste Waters. Soil Science Society of America. Madison, Wisconsin.

Killham, K. (1994) Soil Ecology. Cambridge University Press. Cambridge, England. pp. 42.

Mackie, R. I..: 1994. Microbial production of odor components p.18-19. In Proc. Of International Round Table on Swine Odor Control, Ames, IA. 13-15 June 1994. Iowa State Univ., Ames.

Martin, J. R. (1983) Effects of acetic and butyric acids on solvents production by Clostridium acetobytylicum. Biotechnology Letters 5, 2, 89-94.

Miller, F. C. (1993) Minimizing odor generation. In Science and engineering of compost design, environmental, microbiological and utilization aspects. Edited by H.A. J. Hoitink and H. M. Keene. Ohio Agriculture and Development Center. Ohio State University. Wooster, Ohio. pp.223.

Mitsch W. J. and J. G. Gosselink.: (1993) Wetlands. Second Edition. Van Nostrand Reinhold. New York. NY. pp 129.

Mosier, A. R., Morrison, S. M., Elmond G. K. (1977) Odors and emissions from organic wastes. In Soil for Management of Organic Waste and Waste Waters. Soil Science Society of America. Madison, Wisconsin. pp. 532-569.

Oho, T. Saito, T., Koa, T. (2000) Formation of MM from L-methionine by porphyromonas gingivalis. Infect. Immun. 68, 6912-6916.

Paul, E.A., and Clark F.E. (1996) Soil Microbiology and Biochemistry. Academic Press Limited. London, England. pp. 27.

Persson, S. (1992) H2S and MM in periodontal pockets. Oral Microbiology and Immunology. 7, 378.

Robe, M. (2005). http://www.magicsoil.com/Composting%20Introduction/index.htm

Ruth, J. H., (1986). Odor thresholds and irritation levels of several chemical substances: a review. Am. Ind. Hyg. Assoc. 47, 142-151

Schade, G.W. and Crutzen P.J.: 1995. Emissions of Aliphatic Amines From Animal Husbandry and their Reactions: Potential Source of N_20 and HCN. Journal of Atmospheric Chemistry 22:319-346.

Sommers, L.E. M.A. Tabatabai, and D.W. Wilson. (1977) Forms of Sulfur in Sewage Sludge. J Environ. Qual., 6, 1, 42-46.

Sunesson , A. L., W. H. J. Vaes, C. A. Nilsson, G. Blomquist, B. Andersson, R. Carlson. (1995) Identification of volatile metabolites from five fungal species cultivated on two media. Applied Environmental Microbiology. 61, 8, 2911-2918.

Thimann, K.V.: 1963. The life of bacteria. The MacMillan Company, New York, NY.

Tornita, B., Inouse, H., Chaya K., Nakamura A., Hamamura N. (1987) Identification of Dimethyl disulfide forming bacteria isolated from Activated Sludge. Applied and Environmental Microbiology AEMIDF. 53, 7, 1541-1547.

Wilber, C. and Murray, C. (1991) Odor Source Evaluation. In The Biocycle Guide to the Art and science of Composting. Edited by the staff of BioCycle. JG Press Inc. Emmaus, PA

Van Durme, G. P., McNamara, B. F., McGinley, C. M. (1992) Bench scale removal of odor and volatile organic compounds at a composting facility. Water Environment Research. 64, 1, 19-27.

APPENDIX A: SCAQMD RULE 1133.2

APPENDIX B: ODOR DETECTIONS LIMITS RUTH

APPENDIX C: SAN JOAQUIN REPORT

APPENDIX D: EKO REPORT

APPENDIX E: ISCST3 MODEL OUTPUTS

(See attached CD)

FIGURES