

SECTION 4

REFERENCE MATERIALS

MSDS:

<i>ECOSORB 206</i>	4.2
<i>ECOSORB 606</i>	4.4

Papers:

<i>CONTROL OF MALODORS USING ECOSORB, A NATURAL PRODUCT</i>	4.6
<i>THE USE OF ECOSORB 206 IN CONTROLLING STYRENE ODORS</i>	4.15
<i>EFFECT OF ECOSORB 206 ON THE SOLUBILITY OF BENZENE</i>	4.28

Letters:

<i>UNITED STATES DEPARTMENT OF AGRICULTURE REGARDING AUTHORIZATION FOR USE</i>	4.39
<i>T. R. WILBURY LABORATORIES, INC. REGARDING FINAL REPORT ON TOXICITY TESTING</i>	4.40

Lab reports:

<i>TOX MONITOR LABORATORIES, INC.</i>	4.41
<i>PACE INC.</i>	4.43
<i>CHEMICAL WASTE MANAGEMENT, INC.</i>	4.45
<i>CARTER ANALYTICAL LABORATORY, INC.</i>	4.48
<i>SOUTHERN PETROLEUM LABORATORIES:</i>	
<i>Examination of the Effect of Ecosorb 606 on Ammonia</i>	4.51
<i>Examination of the Effect of Ecosorb 606 on Selected Sulfur Compounds</i>	4.58

Industry Bulletins

Case Studies



Material Safety Data Sheet for Ecosorb 206

Material Safety Data Sheet May be used to comply with OSHA's Hazard Communication Standard, 29 CFR 1910.1200. Standard must be consulted for specific requirements		U.S. Department of Labor Occupational Safety and Health Administration (Non-Mandatory Form) Form Approved OMB No. 1218-0072	
IDENTITY (As Used on Label and List) Ecosorb 206		Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.	
SECTION I			
Manufacturer's Name Odor Management, Inc.		Emergency Telephone Number (800) 662-6367	
Address (Number, Street, City, State and Zip Code) 18-3 East Dundee Road, Suite 202 Barrington, IL 60010		Telephone Number for Information (847) 304-9111	
		Date Prepared 01-21-01	
SECTION II - Hazardous Ingredients/Identity Information			
Hazardous Components (Specify Chemical Identity: Common Name(s))		N/A OSHA PEL ACGIH TLV Other Limits Recommended %	
<p>Product is a proprietary blend of essential oils, surfactant, and water. All constituents are not considered hazardous according to the Federal Hazard Communications Standard (29 CFR 1910.1200)</p> <p>Product has been tested for toxicity according to United States Environmental Protection Agency Guidelines Acute Oral Toxicity Study per EPA Guideline 81-1 - Not toxic by oral ingestion Acute Dermal Toxicity Study per EPA Guideline 81-2 - Not toxic by dermal application Acute Inhalation Toxicity Study per EPA Guideline 81-3 - Not toxic by inhalation Primary Eye Irritation Study per EPA Guideline 81-4 - Product not an eye irritant Primal Dermal Irritation Study per EPA Guideline 81-5 - Product is not dermal irritant Dermal Sensitization Study per EPA Guideline 81-6 - Product is not a dermal sensitizing agent</p> <p>All Ingredients are on the TSCA Chemical Substance Inventory</p>			
SECTION III - Physical/Chemical Characteristics			
Boiling Point 208 deg F		Specific Gravity (H2O) = 1) 0.963	
Vapor Pressure .7 - .9 psia		Freezing Point 30 F	
Vapor Density (Air = 1) Approximately same as water		pH 5.52	
Solubility in Water Soluble		Percent Volatile <1.5	
Appearance and Odor Milky white/opaque white, slight citrus or floral odor			
SECTION IV - Fire and Explosion Hazard Data			
Flash Point (Method Used) None		Flammable Limits LEL N/A UEL N/A	
Extinguishing Media Does not burn			
Special Fire Fighting Procedures None		Unusual Fire and Explosion Hazards None	

SECTION V - Reactivity Data			
Stability	Stable		
Incompatibility (Materials to Avoid)	Strong oxidizing agents		
Hazardous Decomposition or By-products	None known		
Hazardous Polymerization	Will not occur		
SECTION VI - Health Hazard Data			
Route(s) of Entry	Inhalation? Yes	Skin? Eyes	Ingestion?
Health Hazards (Acute and Chronic)	Seek medical attention if symptoms persist		
Carcinogenicity:	NTP? No	IARC Monographs? No	OSHA Regulated? No
Signs and Symptoms of Exposure	None		
Medical Conditions Generally Aggravated by Exposure	None known		
Emergency and First Aid Procedures	Eyes - wash with water 15 minutes		
SECTION VII - Precautions for Safe Handling and Use			
Steps to be Taken in Case Material is Released or Spilled	Flush to drain with large quantities of water		
Waste Disposal Method	Flush with water to drain		
Precautions to Be Taken in Handling and Storing			
Other Precautions	Wash with soap and water if exposed		
SECTION VIII - Control Measures			
Respiratory Protection (Specify Type)	None required		
Ventilation	Good ventilation		
Eye Protection	None required		
Gloves/Other Protective Clothing or Equipment	None required		
Work/Hygienic Practices	Wash with soap and water before eating or smoking		

Material Safety Data Sheet for Ecosorb 606

Material Safety Data Sheet May be used to comply with OSHA's Hazard Communication Standard, 29 CFR 1910.1200. Standard must be consulted for specific requirements		U.S. Department of Labor Occupational Safety and Health Administration (Non-Mandatory Form) Form Approved OMB No. 1218-0072	
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SECTION III - Physical/Chemical Characteristics			
Boiling Point 212 deg F		Specific Gravity (H₂O) = 1) 0.962	
Vapor Pressure .7 - .9 psia		Melting Point 32 F	
Vapor Density (Air = 1) Approximately same as water		pH 6.7	
Solubility in Water Soluble		Percent Volatile <1.5	
Appearance and Odor Milky white/opaque white, slight citrus or floral odor			
SECTION IV - Fire and Explosion Hazard Data			
Flash Point (Method Used) None		Flammable Limits LEL UEL N/A N/A	
Extinguishing Media Does not burn			
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SECTION V - Reactivity Data			
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Route(s) of Entry	Inhalation? Yes	Skin? Eyes	Ingestion?
Health Hazards (Acute and Chronic)	Seek medical attention if symptoms persist		
Carcinogenicity:	NTP? No	IARC Monographs? No	OSHA Regulated? No
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Medical Conditions Generally Aggravated by Exposure	None known		
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Other Precautions	Wash with soap and water if exposed		
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Ventilation	Good ventilation		
Eye Protection	None required		
Gloves/Other Protective Clothing or Equipment	None required		
Work/Hygienic Practices	Wash with soap and water before eating or smoking		

Control of Malodors using Ecosorb® “A Natural Product”

**Sulfur Dioxide, Hydrogen Sulfide, and Ammonia
Mechanisms for their removal**

Ying Zhang, M.S.
R.W. Hurd, M.S.
Donald R. Wilkinson, Ph.D.

Delaware State University
March 1997

ABSTRACT

Ecosorb removes many malodors, including sulfur dioxide, hydrogen sulfide and ammonia, from the environment. It is made up of a combination of essential oils consisting of an equilibrium of neutral organic compounds and organic buffers. Its pH ranges from 4.0 to 6.8.

Acidic malodors such as hydrogen sulfide and sulfur dioxide are removed by at least four mechanisms including solubility, oxidation/reduction, neutralization and addition across double bonds. Basic malodors such as ammonia and other amines are removed by at least three mechanisms including solubility, addition and neutralization. In all cases the final products consist of organic salts, newly formed organic compounds, very weak natural organic acids (those that were present in the original essential oil mixture), and malodors dissolved in the water/oil mixture. Resulting organic compounds are frequently subjected to oxidation or reduction when in solution. In the case of sulfur dioxide and hydrogen sulfide these reactions result in the formation of free sulfur, or higher oxidation states including SO_2 and SO_3 .

The removal efficiency is related to the interaction of the above-mentioned mechanisms, the atomizing efficiency (size and speed of droplets), humidity, temperature and reaction time.

INTRODUCTION

Malodors include acids, bases, and neutral compounds. Several of these are polar compounds and are water-soluble, others are non-polar and are soluble in other non-polar organic solvents. An example of using this solubility would be the scrubbing of ammonia gas from the atmosphere by misting it with water. Although this method can remove ammonia, the reaction is temperature dependent, reversible and not very efficient. The same statement could be made when applied to other soluble bases, soluble acids and even to some neutral compounds.

Some malodors, including sulfur compounds, can be oxidized by air when the compounds are in solution. During this process sulfur compounds can produce sulfur. This procedure is slow, not very efficient, and dependent on moisture content, temperature and mixing with air.

These mechanisms for odor removal can and will take place naturally, although inefficiently. Ecosorb contains a mixture of selected essential oils that can facilitate the efficient removal of many malodors.

Wilkinson and Zhang have broken the malodors down into four main groups which include bases, acids, neutrals and those that will not react with essential oils. A summary of this breakdown of 37 common malodors is shown in Table 1.

Table 1: Malodor Breakdown

MALODORS			
	Group	Reactions	Number of Compounds
A.	Bases	React by acid/base mechanism 13 compounds plus CH_3S , TME, and DMEA.	16
B.	Acids	(If they contain relatively small anions) 10 compounds including HCN and phenol, SO_2 , C_{12} react by addition to a double bond and by neutralization.	10
C.	Neutrals	Includes styrene, CO, CO_2 , acetaldehyde, ozone.	5
D.	Will not react	Possibly will not react with Ecosorb due to steric hindrance caused by large anion.	6
Total number of malodors			37

The groups include the following malodors:

Group A: ammonia, butylamine, cadaverine, dibutylamine, diisopropylamine, dimethylethylamine, diphenyl sulfide, ethylamine, indole, methylamine, putrescine, pyridine, skatole, triethylamine, trimethylamine

Group B: ethyl mercaptan, hydrogen sulfide, methylmercaptan, propylmercaptan, hydrogen cyanide, chlorophenol, sulfur dioxide, phenol and sulfurous acid

Group C: acetaldehyde, chlorine, ozone, carbon monoxide, dioxide, and styrene

Group D: allyl mercaptan, amyl mercaptan, crotyl mercaptan, tert-butyl mercaptan, thiophenol (Contain large anions, which cause steric hindrance. These are not as common or as volatile as other compounds in Group A and B.)

Dr. Sylvain Savard, a chemist and Project Leader of the Center of Industrial Research for Quebec, Canada, prepared a report on “The Operating Principles of the Ecosorb System to Neutralize Odors”¹. He pointed out that Ecosorb is a combination of volatile essential oils that are selected for their ability to neutralize odors. The composition of these essential oils can vary because of many factors including:

1. Type of soil in which the plant is cultivated.
2. Time of year of harvest.
3. Part of the plant used.
4. Amount of water in the plant.
5. Amount of exposure to the sun during growth process.
6. Storage conditions before distillation.

The solution contains approximately 30 major chemical compounds, and numerous minor compounds (major and minor in terms of concentration).

Dr. Savard reports that the solution can react through three mechanisms including: Van der Waals Forces, Zwaardemaker pairing and chemical reactions. The solution is mixed with water and sprayed into small droplets, which are in the form of a mist or fog and remain airborne for long periods of time. These small droplets represent a large surface area, which are covered, or partially covered with a film of essential oils. The electrostatic charges on the droplet surface attract gas molecules. When in contact, removal by one of three mechanisms can occur. Sometimes this reaction is slow and other times it is fast. Once captured, the odor is gone. The droplets can cluster, increase in mass and condense.

Wilkinson and Zhang have studied possible chemical reactions between selected essential oils and hydrogen sulfide, sulfur dioxide and ammonia. The essential oils being studied contain three types of substances: weak organic acids, weak organic bases and neutral organic compounds. The acids and bases react and end up as a buffer solution. The oil mixture has a pH of approximately 4.5. When diluted the pH is approximately 6.0. This final buffer like solution is fairly stable, but can change pH with time depending on its environment and how well it is sealed from its environment. We have found the mixture of essential oils to have a pH between 4.0 and 6.0 in the concentrated form.

¹Dr. Sylvain Savard, a chemist and Project Leader of the Center of Industrial Research for Quebec, Canada, “The Operating Principles of the Ecosorb System to Neutralize Odors.”

Based on experimental data already discussed, malodors can be classified into one of three categories: acids, bases and neutrals. Compounds such as hydrogen sulfide, sulfur dioxide, amine, ethyl amine, etc. are bases. Compounds such as styrene are neutral. Acids and bases will react with essential oil buffers in a normal acid/base reaction forming organic salts and water. Many of these acids and some bases will react with the selected essential oils by addition across conjugated double bonds. This has been shown to be the case with hydrogen sulfide. The question of neutral compounds is still to be studied. Whatever the chemical mechanism or mechanisms involved, the amount of malodor reacting with the essential oils (the bulk kinetic prediction) is much less than the amount of malodor removed (recalculated amount) because of oils.

Previous reports have shown the particular mixture of oils to be very efficient in removing hydrogen sulfide, sulfur dioxide, ammonia, mercaptans, and alkylamines.

Dr. Davidovits of Boston College has studied the effects of pH and Van der Waals' forces on sulfur dioxide.² His work is extremely important. He shows how pH greatly affects the amount of sulfur dioxide that remains dissolved in water droplets. He observed as much as a 300% increase in the amount of sulfur dioxide that remained in water if the pH was increased from 3.0 to 6.0. He further concluded that the size and speed of the droplet greatly affected the effectiveness of removing sulfur dioxide from the atmosphere. He also discusses the tremendous effect pH has on the distribution constant of sulfur dioxide in water.

If the work of Dr. Savard, Carter Laboratories, Dr. Davidovits, Boston College and Dr. Wilkinson and Ms. Zhang, Delaware State University are combined, overall mechanisms for the effectiveness of selected essential oils in removing malodors from the environment develops.

Of primary importance in odor removal is the formation of very small droplets with an initial high velocity. This will ensure a large surface area and increased opportunity for collisions with gas molecules. If we are using only water then the efficiency of removing gas molecules now depends on the solubility of each individual gas in water. The more soluble the gas the more readily it will dissolve. Once dissolved, the gas will begin to leave the droplet and establish an equilibrium (according to Henry's Law) between its concentration in the gas phase and its concentration in the aqueous phase. The pH of the droplet will greatly affect this solubility by a factor of as much as 300. Some gases are readily soluble, and others only slightly soluble. When selected essential oils are added to the mix the droplets are covered, or partially covered with a thin layer of essential oils. These oils attract most gases to the droplet surface where chemical reactions and pH effects come into play. The oils greatly influence the initial attraction of gas molecules, the pH greatly influences the solubility (gas uptake), and chemical reactions "irreversibly" remove some of the gas molecules by forming new, less volatile compounds. The change in the organic content of the droplet and a resulting change in its polarity all cause a large increase in the distribution constant between gas molecules in the vapor and aqueous phases. This increase indicates that more of the gas remains trapped in the aqueous layer than would normally be trapped at a given temperature.

²Davidovits, P. and Jayne, J.T., Department of Chemistry, Boston College, Chestnut Hill, Massachusetts and D.R. Worsnop, M.S. Zahniser, and C.E. Kolb of Aerodyne Research, Inc., Billerica, Massachusetts "Uptake of SO₂ (gas) by Aqueous Surfaces as a Function of pH: The Effect of Chemical Reaction at the Interface," Journal of Physical Chemistry 1990, 94, 6041-6048.

EXPERIMENTAL RESULTS

Mechanisms for Basic Malodors:

There are many amines that have been classified as malodors including triethylamine (TEA), and dimethylethylamine (DMEA), ammonia, and trimethylamine. These gaseous amines stimulate nerve endings in the nose and are irritants. They can lead to cell necrosis (cells swell and disintegrate) and increased permeability of the alveolar walls. They can cause flooding of the alveoli and produce a delayed pulmonary edema that may be fatal.

Ammonia is extremely soluble in water and will rapidly dissolve. The oils will have some effect on increasing the attraction of gas molecules to the droplet. A chemical reaction occurs between essential oil buffers and ammonia forming organic ammonium salts. Ammonia, which would normally easily leave the droplet, will now remain to a larger extent in the aqueous layer. This change in the distribution constant will keep the ammonia trapped in the water droplet until condensation occurs, affecting a very efficient removal of this gas from the environment. Since ammonia is a base, the oil mixture should be adjusted to a pH of approximately 4.0 to 6.2 to more effectively remove the gas. This would be true for any basic malodor (alkylamines, etc.). The pH of the essential oil mixture is typically in this range when used.

Ammonia (Fig. 1) is the most basic amine. It possesses a nitrogen atom containing a non-bonded electron pair. Its ability to donate this pair to other chemical compounds gives it the characteristic of a base. Notice that this is also true for trimethylamine (Fig. 2), as well as triethylamine (Fig. 3) and dimethylethylamine (Fig. 4).

Amines, being basic, will react with organic acids present in essential oils forming organic salts. The ease and rate of reaction is, in part, a function of the strength of the base. The strength of these bases can be measured by their equilibrium constant (K_b). The larger the value of K_b the more basic is the amine. Ammonia has a K_b of 1.8×10^{-5} (very weak), TME has a K_b of 6×10^{-1} (much stronger), DMEA has a K_b of approximately 2.3 (stronger than TME) and TEA has a K_b of 5.6 (slightly stronger than DMEA). Amines will readily react with the weak organic acids present in the selected essential oils. These weak organic acids are naturally occurring acids, which have proven not to be toxic or carcinogenic.^{3,4}

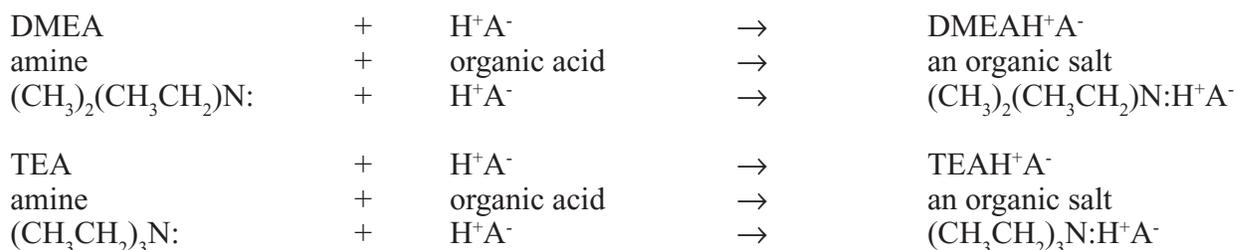
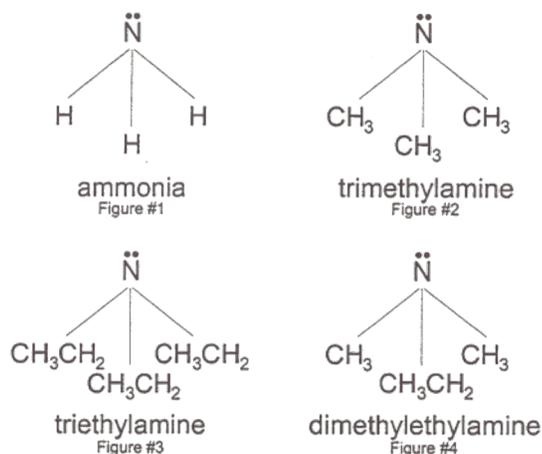


Figure 5: Chemical Reactions

³ Ecosorb was tested for toxicity in accordance with EPA Regulations and was found to have no positive eye irritation reactions, had a zero dermal irritation score. (Toxicity Category IV for skin effects), not to be toxic by oral ingestion at the 5 g/kg level (Toxicity Category IV), not toxic by dermal application (Toxicity Category IV), had no positive Buehler tests for skin sensitization, tested not detected for halogenated hydrocarbons and tested not detected for harmful volatile organics (protocol 624).

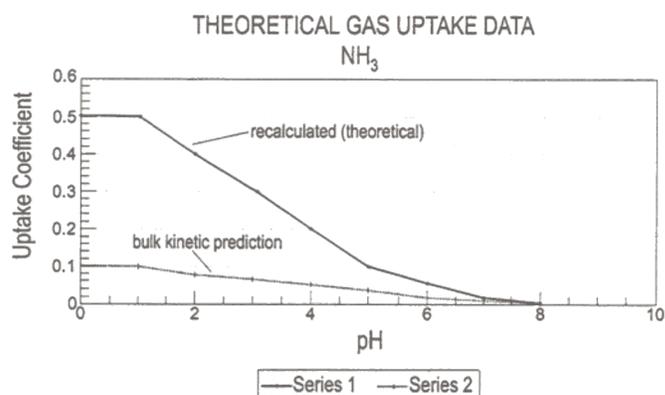
⁴ Results available on request.

Ammonium salts formed with essential oils are non-crystalline solids, have a low melting point, are yellow in color, are thermally unstable, are subject to air oxidation, and can undergo rearrangement to form more stable organic amines. The salts are formed by the reaction of the base with the acidic portion of the buffers, e.g. ammonium eugenolate, or ammonium acetate.

Ammonia has been found to be virtually 100% removed within 15 minutes after treatment with the oil mixture both in a laboratory and in actual situations. The oil mixture is more efficient in removing stronger bases such as TEA and DMEA, which may be present as malodors. Their concentration levels may be reduced to less than 0.1 ppm on contact.⁵ The essential oil mixture was titrated versus a standard solution of ammonia. It was found that 1 mL of the oil mixture was needed to neutralize 0.00012 g. of NH_3 . Because of the solubility and distribution factors mentioned previously, the total amount of NH_3 removed from the environment would be much larger than the amount predicted from chemical reactions alone. The number of g. of NH_3 removed by 1 mL of the oils may be as high as 0.012 g.

In the case of NH_3 we are dealing with a substance that is very soluble in water, and is very reactive at lower pH values. We therefore would expect the difference between the bulk prediction and recalculated values, which would correct for gas-phase diffusion neutralization due to NH_3 uptake, to be more pronounced. The increase in gas uptake would be a much larger factor, possibly as much as 20 or 100 times as great. In an attempt to visually see this effect a theoretical chart of expected values for NH_3 was constructed and is shown in Figure 6.

Figure 6: Theoretical Gas Uptake



It would seem that the efficiency of essential oils in holding onto gaseous substances such as SO_2 , H_2S , and NH_3 is a function of the misting efficiency (size and speed of the droplet), the solubility of the substance in water (which is facilitated by the organic nature of the essential oils a variable not studied in the above mentioned paper), and the chemical reactions (chemisorption) taking place between active ingredients in the oils and the gas.

Summary: Selected essential oils will effectively remove the basic malodors NH_3 , TEA and DMEA by a combination of mechanisms including an acid-base reaction, increased solubility due to pH factors, and changes in distribution constants. A portion of the amine forms a non-crystalline solid ammonium salt, which is readily removed from the air during the scrubbing process. The remaining amine dissolves in the essential oil/water droplet and is strongly held in the droplet due to changes in its solubility and distribution constant. Amines have been shown to be virtually removed within fifteen minutes after contact with the mixture.

Mechanisms for Acidic Malodors:

Acidic malodors include hydrogen sulfide, sulfur dioxide, chlorine, alkyl mercaptans, phenols and other volatile acids. An essential oil mixture will have the same general mechanism for attracting these acids as it does for ammonia. In this case the pH of the mixture should be adjusted to 6.0 - 6.2.

⁵ Carter Laboratories, California.

The higher the pH will more greatly affect the absorption of hydrogen sulfide, and other acidic gases. The gases will chemically react with the oil buffers forming organic salts, and by adding across double bonds in conjugated components of the oils, forming new, derivitized essential oils. The chemical reactions and pH adjustment will greatly increase the efficiency of removing acidic gases from the atmosphere. The pH of the essential oil mixture is typically at a pH of 6.0 when used.

Sulfur dioxide is an oxidant gas and exposure to it alters pulmonary immunologic responses and increases the host's susceptibility to bacterial infection. The gas reacts readily with water and forms sulfurous acid, which is an irritant.

The above-mentioned compounds are acids, or will form acids when in contact with water. The compound H_2S has been tested and believed to react with Ecosorb by addition across a double bond as well as by a neutralization mechanism. Several compounds in the mixture contain double bonds, which can react with acidic malodors.⁶ Compounds containing a conjugated system of double bonds, one of them being an electron-withdrawing group such as a carbonyl ($C=O$), which facilitates the addition, will more readily react with these acids. A solution of H_2S underwent a pH change from approximately 4.0 to 6.0 when it came in contact with the oils, indicating the elimination of this acid. Infrared studies of the reaction of H_2S with a conjugated aldehyde show loss of one of the aldehyde's double bonds. Experimental data indicates the H_2S is removed by the reaction shown in the following reaction. When the double bonds were removed through the addition of Br_2 , the oils proved to be less effective in removing these malodors.

Hydrogen sulfide, when in an aqueous media, can also be air oxidized to form free sulfur. This may also happen to organic sulfides. Mercaptans react using the mechanism illustrated in Figure 7. Ionization of these compounds is shown Figure 8. Malodors, such as hydrogen sulfide, that have not reacted chemically, but have dissolved in water droplets, will oxidize over a period of time. The oxidation products will be less volatile and therefore will no longer produce an odor problem.

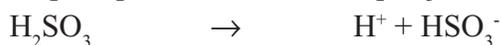
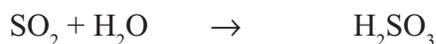


Figure 8: Ionization

Molecular models were constructed for Phenol, H_2S , H_2SO_3 , C_2H_5SH , and CH_3SH . These models were added on to a double bond in a model of a conjugated aldehyde. No steric hindrance

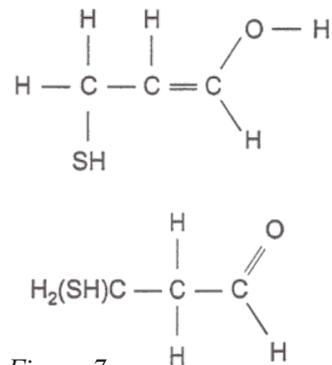
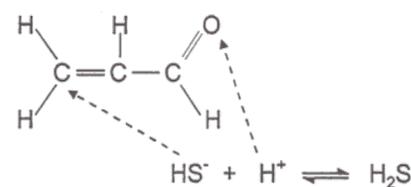
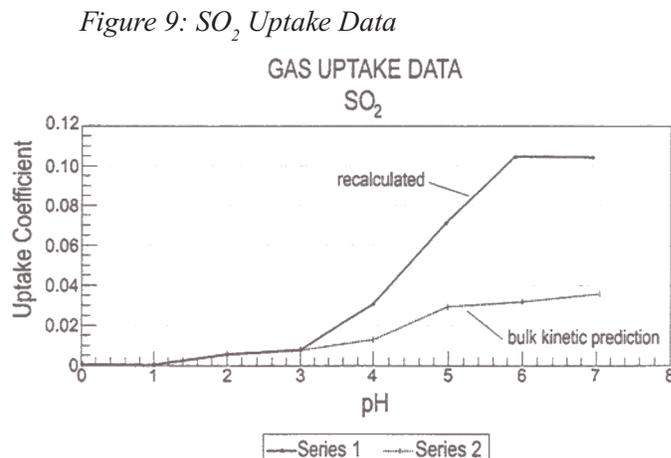


Figure 7

⁶Yet unpublished research by Wilkinson and Zhang.

was noted in the case of Phenol, H_2S , H_2SO_3 , and CH_3SH , and only slight hindrance in the case of $\text{C}_2\text{H}_5\text{SH}$. Models of higher molecular weight mercaptans showed considerable steric hindrance indicating difficulty in reacting by the suggested mechanism.

Acidic malodors will also react with the aforementioned buffers forming organic salts. It was found that 1 mL of Ecosorb reacted with 0.000118g. of SO_2 , and as in the case of NH_3 this value could be as high as 0.0118g. There are three major factors effecting the removal of an acidic gaseous malodor from the environment: (a) uptake as a function of pH, (b) modeling of the gas uptake (Henry's Law), and (c) interaction at the interface. Figure 9 was used to discuss the uptake of the gas SO_2 by fast moving water droplets.



The lower curve represents the bulk kinetics prediction, or the amount of SO_2 we anticipate being removed by liquid water. The Y-axis (uptake coefficient) relates to the relative amount of the gas being removed. Under normal conditions we would anticipate SO_2 dissolving into the droplets of water more efficiently at a pH of 4.0 to 7.0, since the gas is an acid anhydride and will react chemically much better as the pH increases. This lower curve considers primarily the solubility of SO_2 at the pH listed. The upper curve is what we actually find when studying removal of the gas under fast-moving droplet conditions. We observe a 4 fold increase in removal efficiency caused by a combination of the above listed factors:

- a) SO_2 is more soluble in water that is less acidic, reaching a maximum at a pH of 5.0. The fact that the droplets are small and fast moving causes more collisions, and increased surface resulting in a more efficient removal of the gas when using a mist.
- b) Because of the limited solubility of SO_2 in water, re-evaporation of the gas due to Henry's Law is important. A portion of the gas would be lost due to this equilibrium. However, it is believed that $\text{SO}_2(\text{g})$ enters the liquid droplet not as $\text{SO}_2(\text{aq})$, but via a surface complex. Under these conditions, since there is increased surface area, surface complex formation would be increased in the presence of a second chemical substance. This leads to:
- c) Interactions at the interface. This constitutes a chemisorption process in which, in the present case, $\text{SO}_2(\text{g})$ collides with a water molecule at the interface and forms a complex such as HSO_3^- . The effect of fast moving, extremely small droplets combined with the above mentioned three factors make the removal of SO_2 more efficient when the sample is misted with small droplets of water than when we look at reactions of water solutions (H_2SO_3) of the gas. In the article we find that the recalculated gas uptake values are greater than the bulk kinetic prediction by a factor of 4.

Wilkinson and Zhang determined hydrogen sulfide levels in a field test using an MDA Zellweger monitoring device. This instrument produced higher readings at high humidity versus low humidity

using identical concentrations of hydrogen sulfide. Hydrogen sulfide levels apparently remained constant when sprayed with a water solution of essential oils when measured with the MDA device. However, when a filter containing silica gel was attached to the instrument's intake line hydrogen sulfide levels decreases from 15.7 ppm to approximately 1 ppm in twelve minutes. It is apparent that if one is interested in determining hydrogen sulfide gas alone and not in hydrogen sulfide dissolved in water, then a water-removing filter must be added to the system. For proper analysis of hydrogen sulfide gas in a gaseous sample an instrument must be used that: (a) does not use heat to vaporize the sample, (b) is specific for the gas only, and/or (c) contains a hydrophobic filter to prevent hydrogen sulfide dissolved in water from being analyzed as hydrogen sulfide gas.

Summary: Selected essential oils have been shown to be effective in removing the malodors Phenols, H_2S , SO_2 , C_2H_5SH , and CH_3SH from a contaminated atmosphere. Sulfur dioxide, methyl mercaptan, and ethyl mercaptan were reduced to less than 0.1 ppm on contact with Ecosorb. Hydrogen sulfide took as long as 15 minutes for removal. Selected phenols were also effectively removed. Acidic compounds capable of ionizing in water, and not having bulky anions which would cause steric hindrance, will react with specific compounds contained in the product. Compounds listed in this section meet these criteria. Acidic malodors will also react with the natural buffers to produce organic salts.

Mechanisms for Neutral Malodors:

Neutral compounds such as benzene and styrene are less soluble in water than acids and bases. They are also less chemically reactive with most essential oils. At the present time little research has been done on these compounds. It would seem that pH would have less of an effect on solubility and on the distribution constant. The electrostatic oil film around droplets would still act to facilitate the removal of these gases, but the overall effectiveness in removing the gases would be much less than with the aforementioned compounds. Styrene can react with itself under basic conditions to form polystyrene. There are compounds in the essential oil mixture that have a conjugated system similar to styrene. It is proposed that the mixture's pH be adjusted to levels of 8.0, 9.0, 10.0 to study the effect of these higher pH's on the removal of styrene. Additional modification of the scrubber and the oils will be made to increase the efficiency of removing styrene from the environment

CONCLUSIONS

The most universal scrubber for malodors is water. However, water offers some disadvantages including its rapid loss of dissolved gases. The uptake of a gas into water is a function of (a) pH, (b) gas phase diffusion, (c) re-evaporation due to Henry's Law, (d) change in polarity of water due to polarity modifiers and (e) interactions at the interface. Ecosorb facilitates the removal of malodors by chemically reacting with the gas itself, by changing the pH and affecting the solubility of the gas in water, by increasing the organic makeup of droplets of water, and by possibly increasing the distribution constant between the gas and water. The effectiveness of Ecosorb in removing high concentrations of malodors is measured more by its influence in solubility and the distribution constant of malodors in water than in its specific chemical reactions. The effectiveness of the product in removing low concentrations of malodors is related primarily to the chemical reactions involved, and less to pH and atomizing characteristic.

THE USE OF ECOSORB® 206 IN CONTROLLING STYRENE ODORS

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INTRODUCTION

Among environmental problems caused by pollution, in general, air pollution is one of our most serious concerns. Air pollution is defined as the presence of solid particles, liquid droplets, or gaseous compounds normally not present in air or which are present in concentrations greater than normal.¹ One of these gaseous pollutants is styrene.

Styrene monomer is a colorless to yellowish oily liquid with an aromatic, almost floral and penetrating odor. Styrene monomer is slightly soluble in water and cannot easily be removed from the environment. An appropriate way by which hazardous waste species may be reduced from the atmosphere is by dissolution in water in the form of a cloud of rain droplets.²

Styrene reacts with atomic oxygen or hydroxyl radicals in air.^{3,4} It is non-persistent in water and has a short half-life. As a proof, the concentration of styrene monomer found in fish tissues is somewhat higher than average concentrations of styrene in the water from which the fish were taken.⁵

In spite of its importance and usefulness, OSHA and EPA consider styrene as a hazardous substance. This chemical is also cited on the special Health Hazard Clean Air Act. The Clean Air Act of 1990⁶ requires reductions in emissions of toxic VOCs like styrene. Although some urgency exists to develop systems capable of removing such contaminants down to very low levels, it is necessary to develop new means to reduce styrene concentration in different wastes where present. Reduction of styrene concentration in the milieu is not only of benefit for all users of the environment, but also it will financially help industries by transforming these wastes into non-toxic and possibly usable materials.

It is known that solubility depends on the ability of a solvent to interact with a solute more strongly than solute particles interact with each other. Whether water molecules can surround an organic compound is one of the key factors determining its environmental behavior and impact. Multifunctional oxygenated compounds can absorb water over the entire range of relative humidity.⁷ An appropriate way by which hazardous wastes species may be removed from the environment is by dissolution in water in form of cloud or rain droplets.⁸ Unfortunately, as said previously, styrene is not very soluble in water. As a result, this method may not be applicable for styrene.

Work at Delaware State University using Ecosorb (mixture of essential oils) to reduce malodors such as ammonia, hydrogen sulfide, and sulfur dioxide, demonstrated that these oils react through several mechanisms, the most important being solubility.

¹Zhang, Ying. Mechanism of Odor Control by Essential Oils, Master of Science Thesis, Delaware State University: Dover, April 1997, 1.

²Stanley, E. Manahan. Environmental Chemistry, 6th Ed, 1986, 569.

³Hoigne, J., Bader, H., Rate Constants of Ozone with Organic and Inorganic Compounds in Water. 1. Non-Dissolving Organic Compounds, *Water Res.* 1983, 17, 83-173.

⁴Brede, O., Helmstreit, W., Mehnert, R. Nanosekunden-Pulsradiolyse Von Styrol in Waessriger Loesung, *J. Prakt. Chem.* 1974, 316, 14-302.

⁵AQUIRE Database, ERL-Duluth, U.S.E.P.A.

⁶Amy, Hudson. Taking Control of Styrene Emissions, *Composites Technology*, Sept / Oct 1996.

⁷Irona, Nongkynrih and Mahendra, K. Quinolinium Dichromate Oxidations. Kinetics and Mechanism of the Oxidative Cleavage of Styrenes, *J. Org. Chem.* 1993, 58, 4925-49928.

⁸Hurd, C. D., Green, F. O., *J. Am. Soc.* 1939, 61, 2979.

As demonstrated, original Ecosorb is not as efficient in neutralizing chemicals such as styrene (only 10 - 30% reduction) and benzene because not only are these substances less soluble in water than are acids and bases, but they are also less chemically reactive. Because Ecosorb contains a mixture of both low and high molecular weight oils, as well both water-soluble and water insoluble oils, it was recommended that its composition be Modified to include fewer low molecular weight and fewer water soluble oils. These changes would make the new product, referred to as Ecosorb 206, less soluble in water, but also increase the solubility of styrene in the product. Initial tests were made on two different types of the modified product. One of the two samples was more promising than the other and was selected for further testing.

The main purpose of this research was to use this new product in an attempt to more efficiently reduce environmental styrene levels. This research included kinetic studies on possible styrene degradation once in solution and to isolate and identify degradation products.

EXPERIMENTAL

New product 1 (M69795) and new product 2 (M69794) are modified versions of Ecosorb. They are water suspensions of natural plant oils and are produced by Odor Management, Inc. of Barrington, IL. These experimental products are designed as styrene odor neutralizers and are non-toxic.

To identify product components, a method using a HP 5890 GC/MS, was created to separate components and to analyze data using the Wiley Library. The scan mode was used to detect total mass to charge (m/e) fragments. Chromatograms of the standard product, Ecosorb 606 and the new Ecosorb 206 were obtained and compared. Ecosorb 206 contained greater concentrations of less water soluble, high molecular weight components and lower concentrations of the more water soluble, lower molecular weight components.

Styrene, as a relatively non-polar, hydrophobic organic compound is only slightly soluble in water, having a solubility of 55 +/- 10 ppm (wt/vol.) at 24°C. Therefore, the relative insolubility of styrene in water involves the selection of a solvent (solution), which will increase styrene's solubility (Table 1). Previous studies by Delaware State University's chemistry department researchers demonstrated that styrene's solubility increases to approximately 4,000 ppm in water that was saturated with concentrated Ecosorb.⁹ However, this increased solubility was not sufficient to reduce styrene concentrations in a polluted environment. When water containing smaller amounts of Ecosorb 206 (suspended either with constant agitation, or dissolved with the aid of another organic solvent) the same styrene solubility was achieved. The use of smaller amounts of Ecosorb 206 than Ecosorb 606 affected a much larger dissolution of styrene making this new product a much more efficient scrubbing solution.

A Plexiglas/gas chamber, with a volume of approximately 1.12ft³, was used in this experiment. Air was passed through a bubbling tube containing styrene and a flow-controlled bypass. By clamping the bypass one could control styrene flow and thus total styrene concentration while maintaining a constant total flow rate.

⁹Zhang, Ying. *Mechanism of Odor Control by Essential Oils*, Master of Science Thesis, Delaware State University: Dover, April 1997, 1.

Misting experiments were carried out using 0.33 CFM, 1 CFM, and 5 CFM of air flow with a total styrene concentration of approximately 400 ppm (wt/vol.) and a misting rate of 6.6 mL/ min with dilutions of Ecosorb 206 in 35% isopropanol. The isopropanol was used to increase solubility of Ecosorb 206 in water and had a small affect on the overall solubility of styrene. The solution was diluted to 1/25, again to 1/50 and a third time 1/100 with water. The chamber was first sprayed with styrene under different flow rates (those cited before) until a constant concentration of approximately 400-ppm (wt/vol.) was reached. A 1 mL sample of styrene vapor was removed from the outlet of the chamber and was injected into the GC/MS as a standard. The chamber was misted separately with the different diluted solutions of Styrosorb using an adjustable pressure pump and nebulizer while maintaining a constant airflow. In each case outlet samples were removed after approximately 5 minutes, 10 minutes, 15 minutes, 20 minutes, 25 minutes and 30 minutes. Evaluation of styrene levels at the end of each experiment was made using heights of selected styrene fragments obtained from chromatograms. Average percent reductions of styrene were measured and confidence limits calculated at both 90% and 95% confidence levels. Results of these experiments are summarized in Tables 2-7.

Odor Management, Inc (OMI) in California manufactured a scrubber, similar to Delaware State University's prototype. Field tests at Molded FiberGlass Companies/ West in Adelanto, California and again at Lasco Bathware in Anaheim, California were arranged in an attempt to test the prototype scrubber in removing styrene from a fiberglass fabrication process. A Dyna-FID hydrocarbon gas analyzer with a flame ionization detector (FID), a total hydrocarbon gas analyzer, was used to determine styrene concentrations at MFG West. A similar Rat Fitsch analyzer was used at and provided by Lasco. The aim of these tests was to confirm laboratory findings in an actual field environment while using a greater airflow. The equipment was designed as a prototype model, not operating under realistic process volumetric airflow, but operating under acceptable airflow conditions to prove the concept. The prototype model system operated at approximately 650 CFM.

Air handling systems at MFG West were designed to discharge 75,000 CFM. Exhausts were on the roof and nearly inaccessible from the ground. To simplify the experiment, MFG/ West constructed a mock spray booth with two filter elements. The mock booth was attached to the scrubber blower assembly inlet with flexible metal ducting. MFG /West then provided a resin spray assembly and an operator. The scrubber assembly consisted of the blower, a contact / mixing chamber into which the product was atomized, and a filter assembly fixed down stream of the chamber. Liquid flow rates inside the chamber could be varied through the addition or removal of atomization nozzles and by changing nozzle orifice size. The field test at MFG West confirmed the lab findings; styrene can be removed from process air using Ecosorb 206 with a coalescing filter design

The second field test at Lasco was performed to confirm the findings of the experiment at MFG West while using actual process air and experiment with effluent recirculation. Lasco owned and provided the analyzer. Actual process exhaust gas was fed to the inlet of the scrubber blower via 75 feet of flexible ducting attached to a tap on one of the Lasco exhaust stacks.

Ecosorb solutions contain natural hydrocarbons. Therefore, the FID measured styrene and also the presence of these hydrocarbons in exhaust air of both field experiments. To avoid confusion in exhaust readings by the FID, each analysis was preceded with a measurement of background conditions. Given the system design, exhaust background was expected to remain constant and could be subtracted from the total yielding styrene exhaust count. Table 8 summarizes field test results at Lasco Bathware and shows a strong correlation between percent reduction of styrene in field tests with laboratory styrene reductions. The instruments were calibrated with methane and the actual ppm count is 1/8 of those shown (methane contains a single carbon and styrene contains eight).

Condensates from the successful California field tests were collected, shipped to Delaware State University and analyzed for the presence of styrene. This was done to confirm field-test data that styrene was collected. No styrene was found in any of three samples. Liquid condensates were decanted and residues, collected from the bottom of all containers, were analyzed and found to contain the styrene degradation byproducts shown in Figure 6.

The above results led to further laboratory investigations. At completion of laboratory tests involving misting styrene with Ecosorb 206 condensates were collected from the laboratory's experimental chamber for analysis. Then, 1 μ L of condensate was injected into a GC/MS at predetermined intervals over approximately fifteen minutes (15 min). A plot of log abundance vs. time for the first fifteen minutes showed first order kinetics. The average rate constant for the degradation of styrene in water was 0.270 and in Ecosorb 206 solution 0.278, or approximately equal rates of degradation. Figure 1, Figure 2. This is better illustrated in Figure 3 where the straight lines are parallel indicating equal rates of degradation. Over the next twenty-four hours the same test was repeated in order to determine styrene degradation with respect to time. Figure 4 and Figure 5 show this degradation.

DISCUSSION

Ecosorb 206 contains plant extracts consisting of essential oils having functional groups able to react with malodors and a larger concentration of higher molecular weight oils. Therefore, essential oils in Ecosorb 206 are capable of removing styrene vapor once dispersed into the chamber. This dispersion is a major key in the effectiveness of the process involving essential oils. It was necessary to keep solutions agitated during the misting operation.

A general scrubber for the removal of pollutants (malodors) is water. The dissolution of gaseous molecules into liquids is a combination of four processes:

- Diffusion of gas molecules to the liquid surface
- Accommodation of gas molecules on the surface
- Possible chemical conversion to form a soluble product
- Liquid-phase diffusion of dissolved products away from the liquid surface

The connection of processes 2 and 3 with 4 is strongly dependent on solubility of the gas in the liquid (expressed by the Henry's law constant). If mass accommodation is faster than liquid diffusion the surface becomes saturated in the trace gas, leading to re-evaporation of dissolved trace gases, which reduces the net uptake rate. The ability of a gas to diffuse into water is greatly affected by the surface area of the water and the likelihood of collision. A large number of fine water droplets moving at a rapid velocity are major factors in the initial removal of malodors by misting techniques. If the surface of fast moving water droplets is modified by the addition of substances having various polarities (found in Ecosorb), the solubility of gases can be greatly changed, and these modifiers can intensely effect the distribution constant.

Misting chamber tests were made at total airflows of 0.33 CFM, 1 CFM, 5 CFM; styrene concentrations of 400 ppm (wt./vol.) and a misting rate of 6.6 mL/min were made using various Ecosorb concentrations.

It was found when analyzing our data that a 90 % confidence level, even though discarding many of the extreme data, produces a more realistic average. Therefore, considering the apparatus utilized, using a 90 % confidence level is more acceptable than using a 95% confidence level. Analysis of obtained data from the chamber test, indicated that a 1/50 solution of Ecosorb 206 is most efficient in removing styrene at any of the three flow rates tested. It is capable of removing styrene concentrations between 70% and 84% with 400-ppm styrene inlet conditions.

Compared to previous similar works, and as mentioned earlier, actual reduction of styrene concentrations observed during these experiments is explained by the following hypothesis: micro droplets of water are covered with a thin layer of the components of Ecosorb. This oil shell creates an electrostatic attraction for gas molecules in the general environment of the droplet. The malodor's molecules are attracted to the droplet surface where some of the molecules chemically react, while others dissolve in the droplet itself. Some of the more water-soluble oils dissolve in the water droplet thereby changing the polarity of the droplet and also changing the solubility of the malodor in the droplet. The overall effect of this change in polarity is to decrease the distribution constant between malodors in the vapor state and dissolved in water. A decrease in the distribution constant, resulting in a decreased loss of the malodor to the atmosphere, will also bring about a more irreversible absorption of the malodor in water, than would be experienced in water alone. In addition, the size and speed of the droplets intensely affected the potency of removing styrene from the chamber. Also, because of neutrality of styrene, pH of the actual mixture has less effect on solubility and on the distribution constant.

Data obtained from degradation of styrene were used to study its kinetics. Results indicated that styrene concentration decreased with time and concentrations of styrene dropped 96% after 24 hours most of this reduction occurring during the first fifteen minutes. These data yield straight lines when they are plotted as logarithms of styrene abundance versus time.

Constants of degradation (rate constant) k were determined. Rate constants are related to the speed of a chemical reaction. $k = 0.278$ when styrene reacted in water after 15 min. $k = 0.270$ when styrene reacted in an Ecosorb 206 / 2-propanol / water solution after 15 min. Because the rate constants are similar the degradation of styrene in water was similar to that in an Ecosorb 206 solution.

Equations of straight lines mentioned earlier represent kinetics of a one-compartment model. According to theory relative to compounds that can be described by one-compartment models, styrene elimination occurs through a first-order process. This means that rate of elimination of styrene at any time is proportional to its amount in the environment at that time. As styrene is eliminated by first- order kinetics, time required for styrene concentration to decrease by one-half is constant in each environment. Ecosorb 206 diluted 1/25 or 1/50 is approximately 4 times more efficient than Ecosorb 606 and 88 times more efficient than water in removal of styrene.

Condensate formed the next day consisted of a clear liquid. This can be explained by the fact that most molecules with higher molecular weights, that characterize insolubility of essential oils, are removed by falling out of suspension during coalescence. The present liquid contains only dissolved lower molecular weight or water-soluble oils, some higher molecular weight oils and dissolved styrene. Dissolved styrene increases solubility of all oils making the condensate clear. Previous degradation studies proved that styrene, present in the liquid rapidly degraded. Small amounts of this product injected into a GC/MS and then analyzed using a Wiley library permitted confirmation of the presence of benzoic acid, benzene dicarboxylic acid and bicyclo [4.2.0] octa-1,3,5-triene. Possible pathways of these products are shown in Figure 6. These compounds fall out of solution and were present at the bottom of the condensate container. Condensate samples did not reveal any of these

degradation products when injected into a GC/MS. They were removed by decanting all liquid, then dissolving the residue in methanol from the floor of the chamber and analyzing by GC/MS followed with a library search. Products obtained from the reaction between Ecosorb 206/water mixture and styrene have been confirmed when compared to products obtained when styrene was reacted with selected strong oxidants. Their formation is justified by the fact that one of the pathways of styrene alteration consists in catalytic oxidation of the side chain to styrene 7,8-oxide followed by catalyzed conversion by epoxide-hydrolase to phenyl glycol. The latter can be glucoronided directly and oxidized further to mandelic acid, phenylglyoxylic acid and benzoic acid. The similarity between obtained results and catalytic oxidations demonstrate the efficiency of using carefully blended essential oils such as Ecosorb 206 to reduce styrene levels in the environment.

Also, during biotransformation of styrene in humans approximately 90% of absorbed styrene is eliminated as mandelic acid and phenylglyoxylic acid in the urine.

CONCLUSIONS

Once in solution, styrene is rapidly degraded. Because of its poor solubility in water a major difficulty in removing styrene vapor is getting it into solution.

Absorption and chemical reactions help explain reduction of styrene from the environment using essential oils (Ecosorb). The rate-controlling step is adsorption of styrene on the surface of droplets of Ecosorb followed by dissolution. The latter depends on solubility of styrene, pH of the solvent and water-gas interaction.

As water solubility of a gas decreases, concentration of essential oils (Ecosorb) must increase. Styrene, a slightly water-soluble compound, is more readily removed using a new product, Ecosorb 206. Efficiency of Ecosorb is improved by adding 2-propanol as an additional solvent. This alcohol facilitates solubility of styrene even though it adds another hydrocarbon that can make the rate of removing difficult to measure when using analytical devices other than a GC/MS. Avoiding this addition will require slightly higher concentrations of Ecosorb with either constant agitation or modification with a surfactant to keep it suspended in water. Since styrene reduction is based on its solubility, it is helpful if a coalescing scrubber is used and condensate collected. In addition, this condensate may be recycled and after being used several times, treated as waste.

GENERAL COMMENTS:

- Ecosorb 206 diluted 1/25 is 4 times more efficient in getting styrene into solution than Ecosorb 606.
- Ecosorb 206 diluted 1/25 is 88 times more efficient in getting styrene into solution than water.
- Once in solution styrene degrades into one of 3 compounds (benzoic acid, benzene dicarboxylic acid and an intermediate bicyclo [4.2.0] octa-1,3,5 triene). This degradation is independent of the solution used to dissolve styrene. The intermediate is unstable and rapidly changes to benzene dicarboxylic acid, also named phthalic acid.

- Between 70% to 100% of styrene can be effectively removed from an environment by:
 - A) Forcing the styrene containing air through a scrubber.
 - B) Misting with fine droplets of water.
 - C) Coating these droplets with a carefully formulated mixture of essential oils.
 - D) Forcing the droplets to efficiently coalesce.
 - E) Collecting, enriching with new essential oils and recirculating the condensate.
 - F) Degrading the styrene to reduce hazardous waste concentrations.

Getting malodors into solution is of primary importance in their removal and subsequent degradation. Ecosorb 606 and Ecosorb 206 facilitate dissolution of water-soluble and/or water insoluble malodors, through chemical reactions increase degradation of acidic and basic malodors and assists in preventing the malodor's return to the vapor state.

TABLE 1: Solubility of Styrene in Various Liquids (ppm = g/10⁶mL)

H2O @ 24°C	35% 2-Propanol @ 24°C	Conc. Ecosorb @ 24°C	25% Ecosorb206 @ 24°C
55 ± 10ppm	165 ± 30ppm	4000 +/- 500ppm	4000 ± 700ppm

TABLE 2: Average reduction after measuring reduction every 10 minutes for 50 minutes - Using a Confidence Level of 90% and discarding values outside of the Confidence Limit using standard *t* table values.

Airflow = 0.33 CFM, Styrene conc. = 400 ppm (wt./vol.), Misting rate = 6.6 mL/min.

Ecosorb 206 dilution	Average % Reduction of Styrene
1/4	94.4
1/25	83.9
1/50	79.1
1/100	75.3

TABLE 3: Average reduction after measuring reduction every 10 minutes for 50 minutes - Using a Confidence Level of 95% and discarding values outside of the Confidence Limit using standard *t* table values.

Airflow = 0.33 CFM, Styrene conc. = 400 ppm (wt./vol.), Misting rate = 6.6 mL/min.

Ecosorb 206 dilution	Average % Reduction of Styrene
1/4	85.2
1/25	94.4
1/50	79.1
1/100	82.3

TABLE 4: Average reduction after measuring reduction every 10 minutes for 50 minutes - Using a Confidence Level of 90% and discarding values outside of the Confidence Limit using standard *t* table values.

Airflow = 1.0 CFM, Styrene conc. = 400 ppm (wt./vol.), Misting rate = 6.6 mL/min.

Ecosorb 206 dilution	Average % Reduction of Styrene
1/4	80.6
1/25	64.6
1/50	89.7
1/100	54.4

TABLE 5: Average reduction after measuring reduction every 10 minutes for 50 minutes - Using a Confidence Level of 95% and discarding values outside of the Confidence Limit using standard *t* table values.

Airflow = 1.0 CFM, Styrene conc. = 400 ppm (wt./vol.), Misting rate = 6.6 mL/min.

Ecosorb 206 dilution	Average % Reduction of Styrene
1/4	80.6
1/25	64.5
1/50	83.7
1/100	54.4

TABLE 6: Average reduction after measuring reduction every 10 minutes for 50 minutes - Using a Confidence Level of 90% and discarding values outside of the Confidence Limit using standard *t* table values

Airflow = 5.0 CFM, Styrene conc. = 400 ppm (wt./vol.), Misting rate = 6.6 mL/min.

Ecosorb 206 dilution	Average % Reduction of Styrene
1/4	75.5
1/25	45.4
1/50	73.5
1/100	43.4

TABLE 7: Average reduction after measuring reduction every 10 minutes for 50 minutes - Using a Confidence Level of 95% and discarding values outside of the Confidence Limit using standard *t* table values

Airflow = 5.0 CFM, Styrene conc. = 400 ppm (wt./vol.), Misting rate = 6.6 mL/min.

Ecosorb 206 dilution	Average % Reduction of Styrene
1/4	75.8
1/25	44.9
1/50	71.8
1/100	44.0

TABLE 8: Field Test Results - Lasco Bathware, November 4, 1998

Liquid Flow, gpm	Dilution	Inlet ppm	Outlet ppm Styrene	ppm Reduction	% Reduction
0.234	25:1	600	110	490	81.6%
		600	120	480	80.0%
		700	220	480	68.5%
		740	300	440	59.4%
0.198	50:1	600	110	490	81.6%
		600	120	480	80.0%
		700	220	480	68.5%
		740	300	440	59.4%
0.292	23:1	580	150	430	74.0%
		580	150	430	95.0%
		660	240	420	89.5%
		460*	240*	220*	79.0%*
0.422	50:1	400	20	380	95.0%
		380	40	340	89.5%
		440*	90*	350*	79.0%*

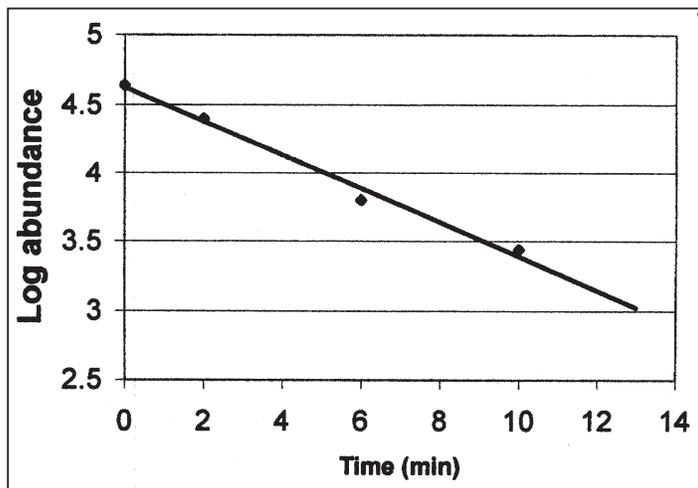
*Recirculated

Outlet ppm styrene is outlet total minus outlet background

ppm = wt/vol

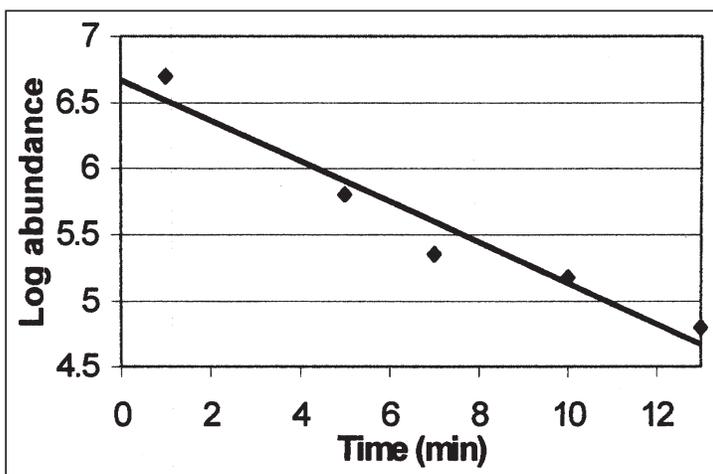
Data from Odor Management, Inc.

Figure 1: Degradation of Styrene in Water after 13 minutes – Determination of Initial Rate Constant



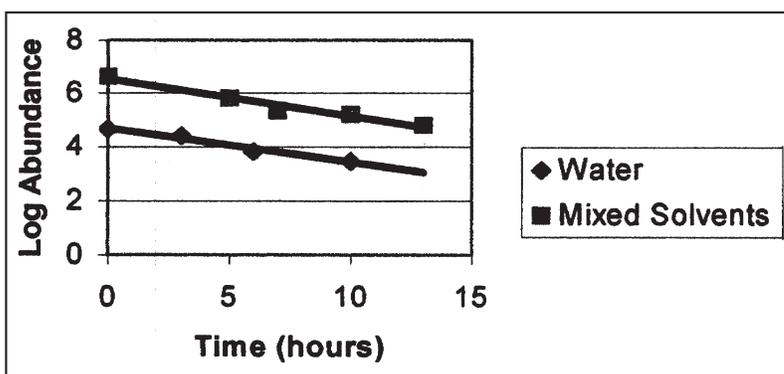
The initial styrene degradation rate is very rapid and follows first order kinetics. The average rate constant (k) for this reaction at 24°C was 0.270. Good linearity was obtained with a coefficient of correlation, R , equal to 0.9887 and $R^2 = 0.9993$.

Figure 2: Degradation of Styrene in Ecosorb 206 / 2-Propanol / Water after 13 Minutes - Determination of Initial Rate Constant



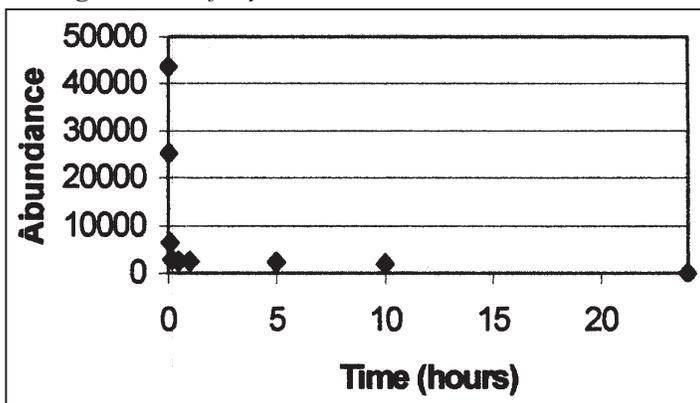
The initial styrene degradation rate is very rapid and follows first order kinetics. The average rate constant (k) for this reaction at 24°C was 0.278. Good linearity was obtained with a coefficient of correlation, R , equal to 0.9708 and $R^2 = 0.9424$.

Figure 3: Degradation of Styrene in Ecosorb 206 / 2-Propanol / Water and in Water after 13 Minutes - Determination of Initial Rate Constant



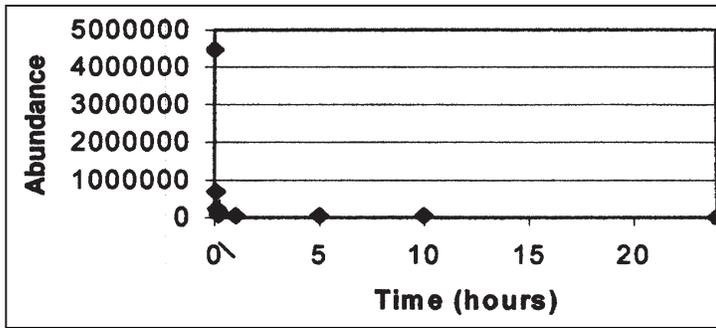
Styrene degrades rapidly when in solution. Rates of degradation are independent of the makeup solutions. The rate constants (k) for degradation of styrene in water and in a mixed solvent containing Styrosorb were 0.278 and 0.270 respectively (experimentally equal). This figure shows almost identical styrene degradation rates in the two solvents.

Figure 4: Degradation of Styrene in Water



There is an initial rapid styrene degradation followed by a slow degradation reaching the instrument's detection limit in 24 hours.

Figure 5: Degradation of Styrene in Ecosorb 206 / 2-Propanol / Water after 24 Hours



There is an initial rapid styrene degradation followed by a slow degradation reaching the instrument's detection limit in 24 hours.

Figure 6: Degradation of Styrene

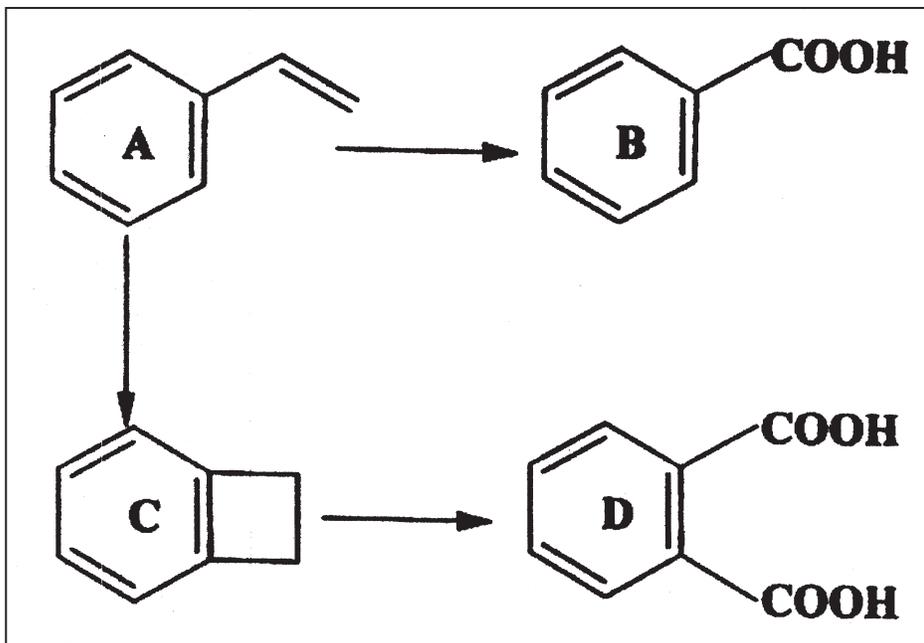
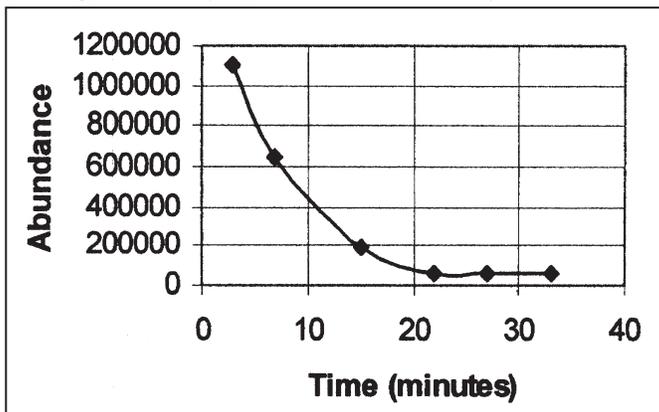


Figure 7: Degradation of Styrene in a Solution of Ecosorb 206 - Laboratory Test



Effect of Ecosorb 206 on the Solubility of Benzene

**TOXTRAP, Inc.
1059 Horsepond Rd.
Dover, DE 19901
USA**

July 11, 2000

TABLE OF CONTENTS

SOLUBILITY OF BENZENE IN WATER AT 23°C

SUMMARY-SOLUBILITY OF BENZENE IN SOLUTIONS CONTAINING ECOSORB 206

GRAPHS

DISCUSSION

DATA

FIGURES

TABLE 1: PEAK AREA VS. CONCENTRATION OF BENZENE IN ETHANOL

TABLE 2: 6 ML OF SOLUTION + 0.9 ML BENZENE

TABLE 3: 6 ML OF SOLUTION + 0.9 ML BENZENE (MADE BASIC WITH NaOH)

TABLE 4: 6 ML OF SOLUTION + 3.0 ML BENZENE

TABLE 5: 6 ML OF SOLUTION + 3.0 ML BENZENE (MADE BASIC WITH NaOH)

TABLE 6: 6 ML OF SOLUTION + 3.0 ML BENZENE IN 30% 2-PROPANOL

*FIGURE 2: DISTRIBUTION CONSTANT (K_d) FOR
BENZENE SOLUTIONS OF ECOSORB 206 @ 60°C*

SOLUBILITY OF BENZENE IN WATER AT 23°C

Three benzene standards prepared using ethanol as a solvent (g benzene/100 mL solution):

1. 0.036 %
2. 0.059 %
3. 0.098%

Each standard was injected into a HP 5890 Gas Chromatograph equipped with dual flame ionization detectors. Each injection was split into two different columns thereby producing four chromatograms per standard. Results are shown in Figure 1. Good linearity was obtained with a coefficient of correlation of 0.9935.

Two 100-mL water samples. At 23°C, were saturated with benzene and allowed to stand for two hours. The top ¼ layer was removed by aspiration (to remove any undissolved benzene), a 1-uL sample removed from the center of remaining solution and analyzed using the same protocol used with standards. Four chromatograms were obtained with each solution. The following results were obtained:

Benzene concentration in sample #1 = 0.070%

Benzene concentration in sample #2 = 0.082%

Average benzene solubility in water = 0.076% (@ 23°C)

*Columns: A. 30 m 0.53 mm ID, Restek RTX-BAC-1
B. 30 m 0.53 mm ID, Restek RTX-BAC-2

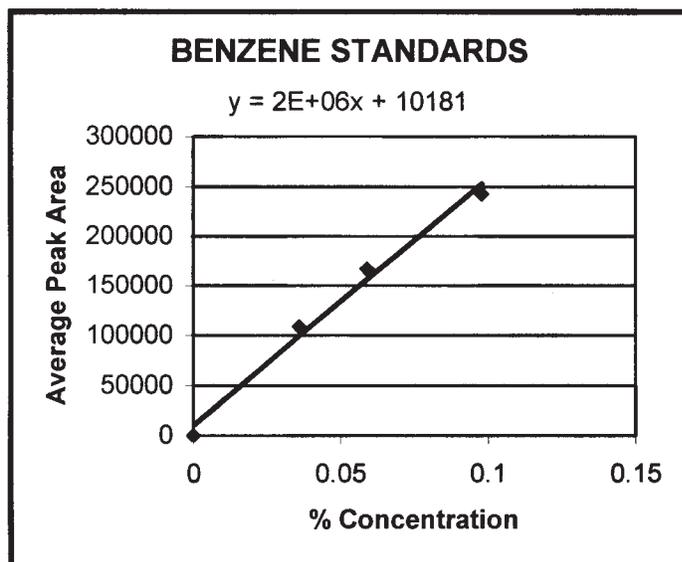


Figure 1 and Table 1: Peak Area vs. Concentration of Benzene in Ethanol

% CONC.	AREA
0	0
0.36	108631
0.59	167245
0.98	243055

SUMMARY:**Table 2-6: Solubility of Benzene in Solution Containing Ecosorb® 206**

Table 2

6 mL solution + 0.9 mL benzene			
	1/100	1/50	1/25
Mean solubility (% in g/100 mL)	2.26 +/- 0.17	5.43 +/- 0.56	6.75 +/- 2.04
Standard deviation	0.15	0.48	1.73
Percent standard deviation (CV)	6.43	8.79	25.66
Solution pH	4.3	4.2	3.7

Table 3

6 mL solution + 0.9 mL benzene (BASIC SOLUTION)			
	1/100	1/50	1/25
Mean solubility (% in g/100 mL)	6.17 +/- 0.87	5.10 +/- 0.34	11.47 +/- 0.84
Standard deviation	0.74	0.29	0.71
Percent standard deviation (CV)	11.95	5.75	3.21
Solution pH	7.7	7.7	7.7

Table 4

6 mL solution + 3.0 mL benzene			
	1/100	1/50	1/25
Mean solubility (% in g/100 mL)	12.56 +/- 4.59	16.49 +/- 3.36	28.83 +/- 3.97
Standard deviation	3.90	2.85	3.37
Percent standard deviation (CV)	31.07	17.30	11.69
Solution pH	4.3	4.2	3.7

Table 5

6 mL solution + 3.0 mL benzene (BASIC SOLUTION)			
	1/100	1/50	1/25
Mean solubility (% in g/100 mL)	4.27 +/- 0.84	11.77 +/- 5.37	10.03 +/- 1.68
Standard deviation	0.71	4.57	1.43
Percent standard deviation (CV)	16.65	38.80	14.24
Solution pH	7.7	7.7	7.7

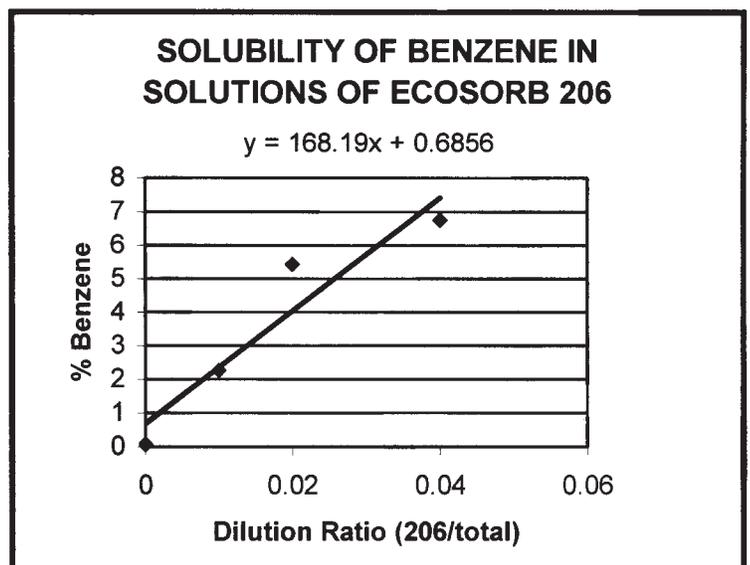
Table 6

6 mL solution + 3.0 mL benzene in 30% 2-propanol			
	1/100	1/50	1/25
Mean solubility (% in g/100 mL)	7.79 +/- 2.79	8.60 +/- 4.52	23.70 +/- 1.43
Standard deviation	2.37	3.84	1.22
Percent standard deviation (CV)	30.41	44.63	5.14
Solution pH	4.3	4.2	3.7

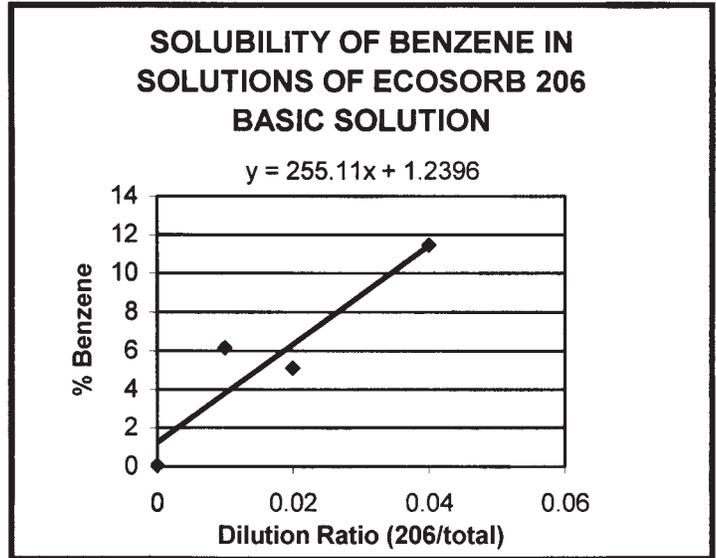
DISTRIBUTION CONSTANT (Kd):

- 1/100 causes a 15.54% decrease in benzene release to the atmosphere.
- 1/50 causes a 17.34% decrease in benzene release to the atmosphere.
- 1/25 causes a 22.97% decrease in benzene release to the atmosphere

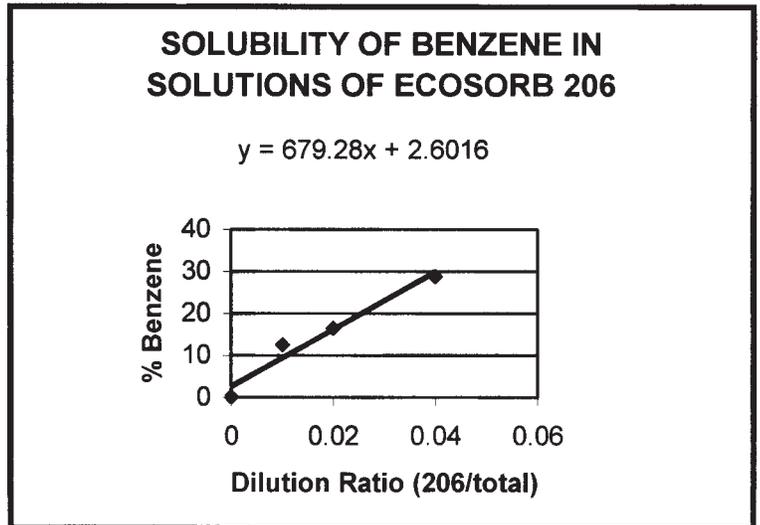
Figure 2: 6 mL of Solution
+ 0.9 mL Benzene



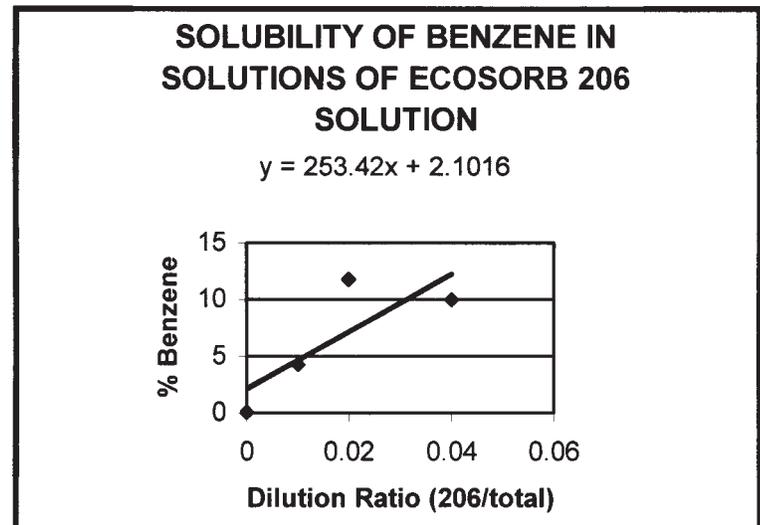
**Figure 3: 6 mL of Solution
+ 0.9 mL Benzene
(made Basic with NaOH)**



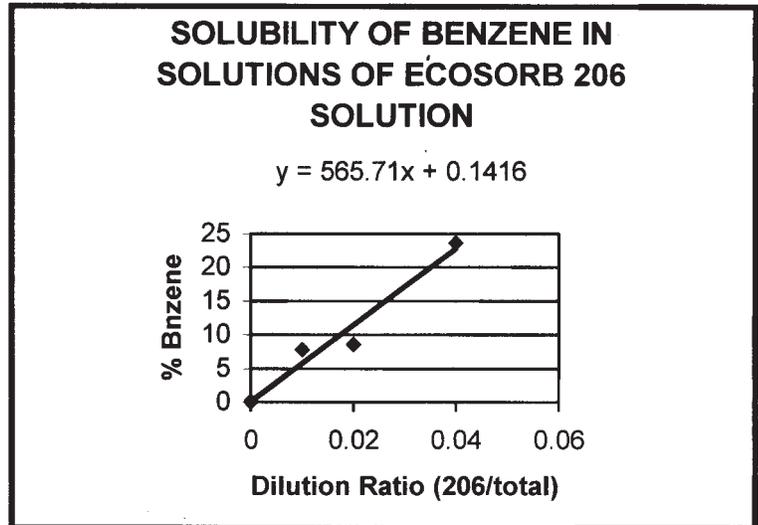
**Figure 4: 6 mL of Solution
+ 3.0 mL Benzene**



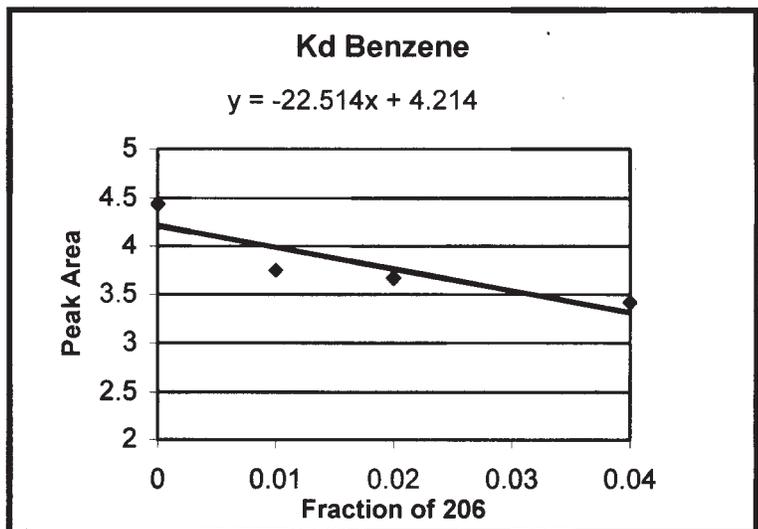
**Figure 5: 6 mL of Solution
+ 3.0 mL Benzene
(made basic with NaOH)**



**Figure 6: 6 mL of Solution
+ 3.0 mL Benzene in
30% 2-propanol**



**Figure 7: Distribution Constant
(Kd) for Benzene Solutions of
Ecosorb 206 @ 60°C.**



DISCUSSION

Solubility Data:

Six studies: 6 mL of various dilutions of Ecosorb 206:

1. Added 0.9 mL of benzene (note pH of each solution).
2. Added 0.9 mL of benzene and sufficient dilute NaOH to change pH to 7.7.
3. Added 3.0 mL of benzene
4. Added 3.0 mL of benzene and sufficient dilute NaOH to change pH to 7.7.
5. Added 3.0 mL of benzene to soln. made to equal 30% 2-propanol
6. Determined distribution constant ratios of benzene in various concentrations of Ecosorb206.

The following statistical data were calculated:

- % benzene,
- standard deviation,
- confidence limit at 90% confidence level, and
- coefficient of variation (% relative standard deviation).

When benzene was added, samples were mixed, allowed to stand for 2 hours and the top ¼ to 1/3 removed by aspiration. (to remove un-dissolved benzene from surface).

In all cases % benzene in solution increased with an increase in concentration of Ecosorb 206. Graphs contain equation of trend line. The slope is indicative of effect of increasing concentration of 206 as related to total concentration of benzene.

When 0.9 mL of benzene was added a larger increase (> slope & % benzene values) occurred when solution was made basic. Basic solutions also had a tighter range (lower CV). No free benzene was observed and it was assumed that solutions were not yet saturated with benzene.

When 3.0 mL of benzene was added to 6 mL of solutions an obvious two-layer interface occurred, indicating that an excess of benzene was present. After two hours, the upper ¼ to 1/3 was removed by aspiration. In this study acidic solutions had much greater concentrations of benzene, again indicated by % benzene values and a larger slope. CV values were slightly better in acidic solutions.

Solutions containing 30% 2-propanol efficiently dissolved benzene, but with inconsistent results.

As Ecosorb 206 concentrations increased, the amount of benzene remaining in solution, compared to benzene released to the environment, increased. Or conversely, as Ecosorb 206 concentrations increase, less benzene is released (a negative slope).

As benzene was added to solutions of Ecosorb 206, solutions became milky white indicating that benzene was both dissolved and suspended (emulsified). Total efficiency is the sum of these two factors. In high benzene concentrations, increasing pH made little contribution in benzene removal. Dilutions of 1/00 contained 8-16 % benzene, 1/50 dilution contained 23-30% and 1/25 contained 24-32%. Once trapped, benzene will begin to leave the solution and reach equilibrium between benzene in liquid and benzene in vapor (Kd). When this factor is studied with benzene in water and compared to equal amounts of benzene in various solutions of Ecosorb 206 we found 1/100 206 caused a 15.54% decrease in benzene release, 1/50 caused a 17.34% decrease and 1/25 caused a 22.97% decrease.

Solutions of 1/100 increase benzene removal by approximately by a factor of 165, 1/50 by a factor of 217 and 1/25 by a factor of 377 or 37.700%.

Based on this study, Ecosorb 206 should greatly improve removal of benzene and assist in preventing benzene vapors from returning to the environment. A dilution of 1/100 would appear to be efficient in removing small amounts of benzene, while 1/50 may be required for higher benzene concentrations.

SOLUBILITY OF BENZENE**Tables 7-11: Solubility of Benzene**

6 mL of solution + 0.9 mL benzene						
<i>Standard Average concentration/Area Ratio = 3.72E - 07</i>						
		1/100		1/50		1/25
pH		4.3		4.2		3.7
	Area	%	Area	%	Area	%
	6.47E + 06	2.41	1.61E + 07	5.99	1.48E + 07	5.51
	5.82E + 06	2.17	1.49E + 07	5.54	1.37E + 07	5.10
	6.31E + 06	2.35	1.44E + 07	5.36	2.34E + 07	8.7
	5.65E + 06	2.10	1.30E + 07	4.84	2.07E + 07	7.7
Mean %		2.26		5.43		6.75
Standard deviation		0.15		0.48		1.73
C.L.		0.17		0.56		2.04
CV		6.43		8.79		25.66

6 mL of solution + 3.0 mL benzene						
<i>Standard Average concentration/Area Ratio = 3.72E - 07</i>						
		1/100		1/50		1/25
pH		4.3		4.2		3.7
	Area	%	Area	%	Area	%
	4.39E + 07	16.33	3.92E + 07	14.58	7.08E + 07	26.34
	4.17E + 07	15.51	3.65E + 07	13.58	6.88E + 07	25.59
	2.58E + 07	9.60	5.24E + 07	19.49	8.71E + 07	32.40
	2.37E + 07	8.82	4.92E + 07	18.30	8.33E + 07	30.99
Mean %		12.56		16.49		28.83
Standard deviation		3.90		2.85		3.37
C.L.		4.59		3.36		3.97
CV		31.07		17.30		11.69

6 mL of solution + 3.0 mL benzene						
<i>Standard Average concentration/Area Ratio = 3.72E - 07</i>						
		1/100		1/50		1/25
pH		4.3		4.2		3.7
	Area	%	Area	%	Area	%
	4.39E + 07	16.33	3.92E + 07	14.58	7.08E + 07	26.34
	4.17E + 07	15.51	3.65E + 07	13.58	6.88E + 07	25.59
	2.58E + 07	9.60	5.24E + 07	19.49	8.71E + 07	32.40
	2.37E + 07	8.82	4.92E + 07	18.30	8.33E + 07	30.99
Mean %		12.56		16.49		28.83
Standard deviation		3.90		2.85		3.37
C.L.		4.59		3.36		3.97
CV		31.07		17.30		11.69

6 mL of solution + 3.0 mL benzene (BASIC SOLUTION)						
<i>Standard Average concentration/Area Ratio = 3.72E - 07</i>						
		1/100		1/50		1/25
pH		7.7		7.7		7.7
	Area	%	Area	%	Area	%
	1.10E + 07	4.09	4.38E + 07	16.29	3.14E + 07	11.68
	9.09E + 06	3.38	4.06E + 07	15.10	2.88E + 07	10.71
	1.36E + 07	5.06	2.21E + 07	8.22	2.48E + 07	9.23
	1.22E + 07	4.54	2.01E + 07	7.48	2.29E + 07	8.52
Mean %		4.27		11.77		10.03
Standard deviation		0.71		4.57		1.43
C.L.		0.84		5.37		1.68
CV		16.65		38.80		14.24

6 mL of solution + 3.0 mL benzene in 30% 2-propanol						
<i>Standard Average concentration/Area Ratio = 3.72E - 07</i>						
		1/100		1/50		1/25
pH		4.3		4.2		3.7
	Area	%	Area	%	Area	%
	1.62E + 07	6.03	1.50E + 07	5.58	6.72E + 07	25.00
	1.48E + 07	5.51	1.35E + 07	5.02	6.52E + 07	24.25
	2.74E + 07	10.19	3.33E + 07	12.39	6.28E + 07	23.36
	2.54E + 07	9.45	3.07E + 07	11.42	5.96E + 07	22.17
Mean %		7.79		8.60		23.70
Standard deviation		2.37		3.84		1.22
C.L.		2.79		4.52		1.43
CV		30.41		44.63		5.14

Table 12: Distribution Constant

Distribution Constant Study using Headspace Analysis		
	Area	Mean
1 mL water + 1 mL std. Benzene solution	4.61E + 06	4.44E + 06
	4.27E + 06	
1 mL 1/100 Ecosorb 206 + 1 mL std. Benzene solution	3.92E + 06	3.75E + 06
	3.57E + 06	
1 mL 1/50 Ecosorb 206 + 1 mL std. Benzene solution	3.62E + 06	3.67E + 06
	3.72E + 06	
1 mL 1/25 Ecosorb 206 + 1 mL std. Benzene solution	3.47E + 06	3.42E + 06
	3.36E + 06	



United States
Department of
Agriculture

Food Safety
and Inspection
Service

Regulatory Programs
Building 306, BARC-East
Beltsville, MD 20705

June 24, 1992

Mr. John Tsatsos
Odor Management, Inc.
2720 Nevada Avenue North
New Hope, MN 55427

Dear Mr. Tsatsos:

This is in reply to your request for compound authorization received on May 20, 1992 for your product Ecosorb.

This product is acceptable for use in inedible product processing areas, nonprocessing areas, and/or exterior areas of official establishments operating under the Federal meat, poultry, shell egg grading, and egg products inspection programs provided that it is not used to mask odors resulting from insanitary conditions, and that any characteristic odor or fragrance does not penetrate into an edible product area.

Permission for the use of this compound on loading docks and other similar areas is left to the discretion of the inspector in charge of the establishment.

Acceptance of compounds by this Department is in no way to be construed as an endorsement of the compounds or of any claims made for them.

If any change is made in the labeling information or formulation, the authorization for use in official plants becomes void immediately.

Sincerely,

John M. Damare, Chief
Compounds and Packaging Branch
Product Assessment Division

T. R. WILBURY LABORATORIES, INC.

40 DOAKS LANE
MARBLEHEAD, MASSACHUSETTS 01945

TELEPHONE (617) 631-2923
FAX (617) 631-3638

April 2, 1993

John Tsatsos
Odor Management, Inc.
2720 Nevada Avenue North
New Hope, MN 55427

Dear Mr. Tsatsos:

I have enclosed final reports for the toxicity tests with Ecosorb that we conducted with daphnids, fathead minnows, and rainbow trout. As the reports point out, Ecosorb was not toxic to any of the tested organisms.

Please let me know if you have any questions or require any additional information. Thank you again for selecting us to conduct these tests.

Sincerely,


Timothy J. Ward

Tox Monitor Laboratories, Inc.

33 West Chicago Avenue
Oak Park, Illinois 60302
(708) 345-6970

REPORT NO. TM 91-104

CLIENT: Odor Management, Inc., of Plymouth, Minnesota.

SAMPLE: Ecosorb Extra Strength

TESTS PERFORMED:

Acute Eye Irritation - EPA Guideline 81-4
Primary Dermal Irritation - EPA Guideline 81-5
Acute Oral Toxicity: EPA Guideline 81-1
Acute Inhalation Toxicity: EPA Guideline 81-3
Acute Dermal Toxicity: EPA Guideline 81-2
Sensitization: EPA Guideline 81-6

SUMMARY AND CONCLUSION:

Odor Management, Inc., sample of Ecosorb Extra Strength, was tested for toxicity in accordance with EPA Regulations. Listed below are brief summaries of the results of these studies.

EYE IRRITATION:

There were no positive eye irritation reactions in any of the test subjects, classifying the sample in Toxicity Category III for eye effects.

PRIMARY DERMAL IRRITATION:

The maximum primary dermal irritation score was found to be 0, classifying the sample in Toxicity IV for skin effects.

Odor Management
Page "2"

ACUTE ORAL TOXICITY:

The acute oral LD50 of sample was found to be greater than 5 g/kg body weight, indicating that the sample is not toxic by oral injection at this dosage level. Classifying the sample in Toxicity Category IV.

ACUTE INHALATION TOXICITY:

The acute inhalation of the test article at 5.30 mg/L of air for a 4 hour period, produced no toxic effects in the test subjects, classifying the sample in Toxicity Category IV.

ACUTE DERMAL TOXICITY:

The acute dermal LD50 of sample was found to be greater than 2 g/kg body weight, indicating that the sample is not toxic by dermal application. Classifying the sample in Toxicity Category IV.

SKIN SENSITIZATION:

Application of sample by dermal contact using a modified Buehler test, produced no positive reactions, indicating that the sample is not a skin sensitizing agent.


Michael Kukulinski
Study Director



REPORT OF LABORATORY ANALYSIS

Eco Sorb
120 Magnolia Lane
Plymouth, MN 55441

November 07, 1991
PACE Project Number: 911022513

Attn: Mr. John Tsatsos

Client Reference: Eco Sorb Lot 932

PACE Sample Number: 10 0376434
Date Collected: 10/18/91
Date Received: 10/22/91
Client Sample ID: Ecosorb
Extra

<u>Parameter</u>	<u>Units</u>	<u>MDL</u>	<u>Strenght</u>
------------------	--------------	------------	-----------------

ORGANIC ANALYSIS

VOLATILE ORGANICS-624

<u>Parameter</u>	<u>Units</u>	<u>MDL</u>	<u>Strenght</u>
Date Analyzed			10/24/91 R
Benzene	ug/L	140	ND
Bromodichloromethane	ug/L	220	ND
Bromoform	ug/L	200	ND
Bromomethane	ug/L	360	ND
Carbon tetrachloride	ug/L	190	ND
Chlorobenzene	ug/L	120	ND
Chloroethane	ug/L	200	ND
2-Chloroethylvinyl ether	ug/L	320	ND
Chloroform	ug/L	220	ND
Chloromethane	ug/L	240	ND
Dibromochloromethane	ug/L	150	ND
1,2-Dichlorobenzene	ug/L	480	ND
1,3-Dichlorobenzene	ug/L	480	ND
1,4-Dichlorobenzene	ug/L	600	ND
1,1-Dichloroethane	ug/L	220	ND
1,2-Dichloroethane	ug/L	200	ND
1,1-Dichloroethylene	ug/L	320	ND
Trans-1,2-dichloroethylene	ug/L	180	ND
1,2-Dichloropropane	ug/L	150	ND
Cis-1,3-dichloropropene	ug/L	70	ND
Trans-1,3-dichloropropene	ug/L	100	ND
Ethyl benzene	ug/L	210	ND
Methylene chloride	ug/L	500	ND
1,1,2,2-Tetrachloroethane	ug/L	90	ND

MDL Method Detection Limit
ND Not detected at or above the MDL.
R Interregional work is verified by the laboratory managers in the region in which the work was performed.

1710 Douglas Drive North
Minneapolis, MN 55422
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REPORT OF LABORATORY ANALYSIS

Mr. John Tsatsos
Page 2

November 07, 1991
PACE Project Number: 911022513

Client Reference: Eco Sorb Lot 932

PACE Sample Number: 10 0376434
Date Collected: 10/18/91
Date Received: 10/22/91
Client Sample ID: Ecosorb
Extra

Parameter	Units	MDL	Strength
-----------	-------	-----	----------

ORGANIC ANALYSIS

VOLATILE ORGANICS-624

Tetrachloroethylene	ug/L	360	ND
Toluene	ug/L	220	ND
1,1,1-Trichloroethane	ug/L	220	ND
1,1,2-Trichloroethane	ug/L	160	ND
Trichloroethylene	ug/L	180	ND
Trichlorofluoromethane	ug/L	300	ND
Vinyl chloride	ug/L	300	ND

MDL Method Detection Limit
ND Not detected at or above the MDL.

These data have been reviewed and are approved for release.

Liesa A. Shanahan
Organic Chemistry Manager

1710 Douglas Drive North
Minneapolis, MN 55422
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ANALYTICAL LABORATORY REPORT

Prepared For

Odor Management Inc.
120 Magnolia Ln
Plymouth, MN 55411
Attn: John Tsatsos
L03309
Copy to: Ken Wiggs

December 3, 1991

Prepared By

Chemical Waste Management, Inc.
Western Region Laboratory
P.O. Box 4249
1400 Carpenter Lane, Suite D
Modesto, California 95352
Telephone (209) 527-4050
FAX (209) 527-6041



Report Approved By Lab Director

Certificate Of Analysis

EPA Method 8260 Volatile Organics By GC/MS			
Laboratory Sample ID		L03309-1	
Date Received		Not Given	
Date Collected		11/15/91	
Your Sample ID		Ecosorb Lot # 932	
Parameter	Units	Results	Det. Limit
Chloromethane	mg/L	ND	1.
Bromomethane	mg/L	ND	1.
Vinyl Chloride	mg/L	ND	1.
Chloroethane	mg/L	ND	1.
Methylene Chloride	mg/L	ND	0.5
Trichlorofluoromethane	mg/L	ND	0.5
1,1-Dichloroethene	mg/L	ND	0.5
1,1-Dichloroethane	mg/L	ND	0.5
<i>trans</i> -1,2-Dichloroethene	mg/L	ND	0.5
<i>cis</i> -1,2-Dichloroethene	mg/L	ND	0.5
Chloroform	mg/L	ND	0.5
1,2-Dichloroethene	mg/L	ND	0.5
1,1,1-Trichloroethane	mg/L	ND	0.5
Carbon Tetrachloride	mg/L	ND	0.5
Bromodichloromethane	mg/L	ND	0.5
1,2-Dichloropropane	mg/L	ND	0.5
<i>trans</i> -1,3-Dichloropropene	mg/L	ND	0.5
Trichloroethene	mg/L	ND	0.5
Dibromochloromethane	mg/L	ND	0.5
Carbon Disulfide	mg/L	ND	0.5
Vinyl Acetate	mg/L	ND	1.
1,1,2-Trichloroethane	mg/L	ND	0.5
Benzene	mg/L	ND	0.5
<i>cis</i> -1,3-Dichloropropene	mg/L	ND	0.5
2-Chloroethylvinyl Ether	mg/L	ND	1.
Bromoform	mg/L	ND	0.5
Tetrachloroethene	mg/L	ND	0.5
1,1,2,2-Tetrachloroethane	mg/L	ND	0.5
Toluene	mg/L	ND	0.5
Chlorobenzene	mg/L	ND	0.5
Ethylbenzene	mg/L	ND	0.5
Styrene	mg/L	ND	0.5
<i>m,p</i> -Xylenes	mg/L	ND	0.5
<i>o</i> -Xylene	mg/L	ND	0.5

Certificate Of Analysis

EPA Method 8260 Volatile Organics By GC/MS			
Laboratory Sample ID		L03309-1	
Date Received		Not Given	
Date Collected		11/15/91	
Your Sample ID		Ecosorb Lot # 932	
Parameter	Units	Results	Det. Limit
1,2-Dichlorobenzene	mg/L	ND	0.5
1,3-Dichlorobenzene	mg/L	ND	0.5
1,4-Dichlorobenzene	mg/L	ND	0.5
Acetone	mg/L	ND	1.
2-Butanone (MEK)	mg/L	ND	1.
4-Methyl-2-Pentanone (MIBK)	mg/L	ND	1.
2-Hexanone (MBK)	mg/L	ND	1.

CARTER ANALYTICAL LABORATORY, INC.

590 DIVISION STREET • CAMPBELL, CA 95008 • (408) 364-3030 • FAX (408) 866-0319

REPORT FOR John Tsatsos J0032
Odor Management, Inc ORDER NO. 12453-MH DATE 04/22/92
 SUBJECT Analysis of Liquid

Liquid was analyzed for its ability to reduce the concentration of hydrogen sulfide in air. A testing protocol was designed and verified specifically for the purpose of this analysis. The sample was identified as follows.

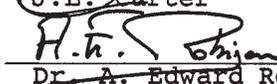
<u>Sample</u>	<u>Customer Label</u>	<u>Description</u>
L1	Ecosorb	Odor Asorbent

Measurement of Hydrogen Sulfide

A controlled amount of hydrogen sulfide was introduced into a glove box and the stability of the concentration checked by testing at time zero and after 30 minutes. A similar procedure was followed to test the sample's ability to reduce hydrogen sulfide concentration. The initial concentration was determined, 1 fluid ounce of sample (with and without dilution) was introduced by spraying from a manual atomizer and hydrogen sulfide levels measured at five and fifteen minutes. The results are summarized as follows and charts are also attached.

Run 1:	<u>Blank</u>		<u>Undiluted Sample</u>	
	<u>Time (min)</u>	<u>H₂S Concentration (ppm)</u>	<u>Time (min)</u>	<u>H₂S Concentration (ppm)</u>
	0	48	0	40
	30	48	5	7
			15	< 2

Run 2:	<u>Blank</u>		<u>1:100 Diluted Sample</u>	
	<u>Time (min)</u>	<u>H₂S Concentration (ppm)</u>	<u>Time (min)</u>	<u>H₂S Concentration (ppm)</u>
	0	40	0	36
	30	41	5	21
			15	9

REPORT APPROVED BY  TITLE QAQC Manager
 TITLE Laboratory Manager

This report completes this order. If you are not completely satisfied with the results stated in this report, or the charges for services rendered, submit your detailed comments in writing to this lab within 10 days. Upon acceptance of this report, its contents and related charges, the invoice is due and payable within 30 days from the invoice date.

CARTER ANALYTICAL LABORATORY, INC.

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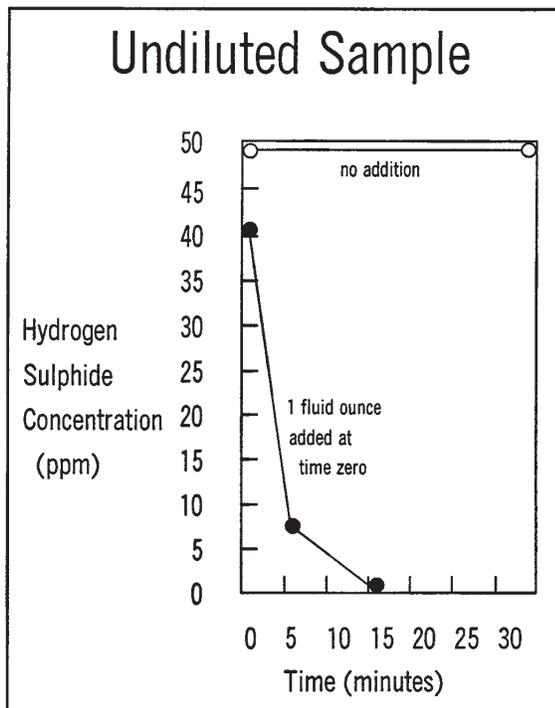
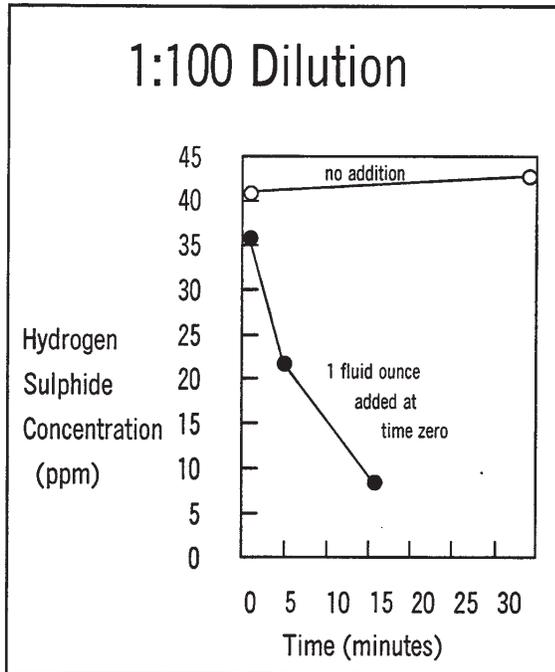
Page 2 of 2
Order 12453

Conclusion

The results of this analysis show a pronounced affect of the sample on hydrogen sulfide concentration in air. The undiluted sample was able to reduce the concentration more than 24 times, from 48 ppm to below the detection limit of 2 ppm in only 15 minutes. While a 1:100 dilution was not as effective, it still reduced the concentration by a factor of 4 in the same time period.

Samples not collected within a two week period of time following the completion of analysis will be discarded unless otherwise specified.

If you would like to discuss the contents of the report, please contact your Technical Sales Representative.





Examination of the Effect of Ecosorb 606 on Ammonia

Testing Completed By
Southern Petroleum Laboratories



METHOD

The gas to be tested would be supplied using permeation tubes manufactured by GC Industries, Chatsworth, CA.

Measurements would be monitored using Sensidyne 3 La (2.5- 200 ppm) length of stain tubes.

The testing would be conducted using Ecosorb 606 (2% by volume Ecosorb concentrate in water).

A glass container/reactor was chosen as the reaction vessel for testing, its volume was approximately ten liters (see Figure 1). Air from the permeation tube calibrator containing the contaminant was charged to the reactor near the bottom, Ecosorb 606 was charged into the reactor from an Ecosorb air aspirated nozzle misting unit in a 1 minute time burst presenting the Ecosorb 606 to the gas in 10 micron particles at the top of the reactor.

When the inlet and outlet sample analysis' were near constant the Ecosorb 606 was charged. Exit samples were taken immediately after application of Ecosorb, again after 2 minutes, and finally at 15 minutes. Exit samples were taken from the side of the reactor at the top of a small cyclone separator.

The pollutant concentration and the flow rate of the contaminants were kept constant through each test.

Since ammonia is toxic, we felt that for the experiment to be a success it had to be lowered to a value at or below the eight hour Time Weighted Average (TWA in ppm). Table I lists the TWA and the Threshold Limit Value.

**Table I
Exposure Limits to Various Malodorants**

Malodorant	8 Hr. TWA (ppm)	TLV (ppm)
Ammonia	50.0	50.0



The ammonia was supplied at a calculated 97 ppm from GC Industries Ammonia Tube S/N 1177.
Concentration was calculated as follows:

$$C = (K \times P) / F$$

C = Concentration

K = Factory Determined 1.437

P = Permeation Rate at Temperature, nanogram/minute

F = Flow Rate, ml/minute

$$C = 1.437 \times 54,000 / 800 = 97 \text{ ppm at } 20^\circ \text{ Celcius}$$



ECOSORB CONTACT TESTING PROCESS

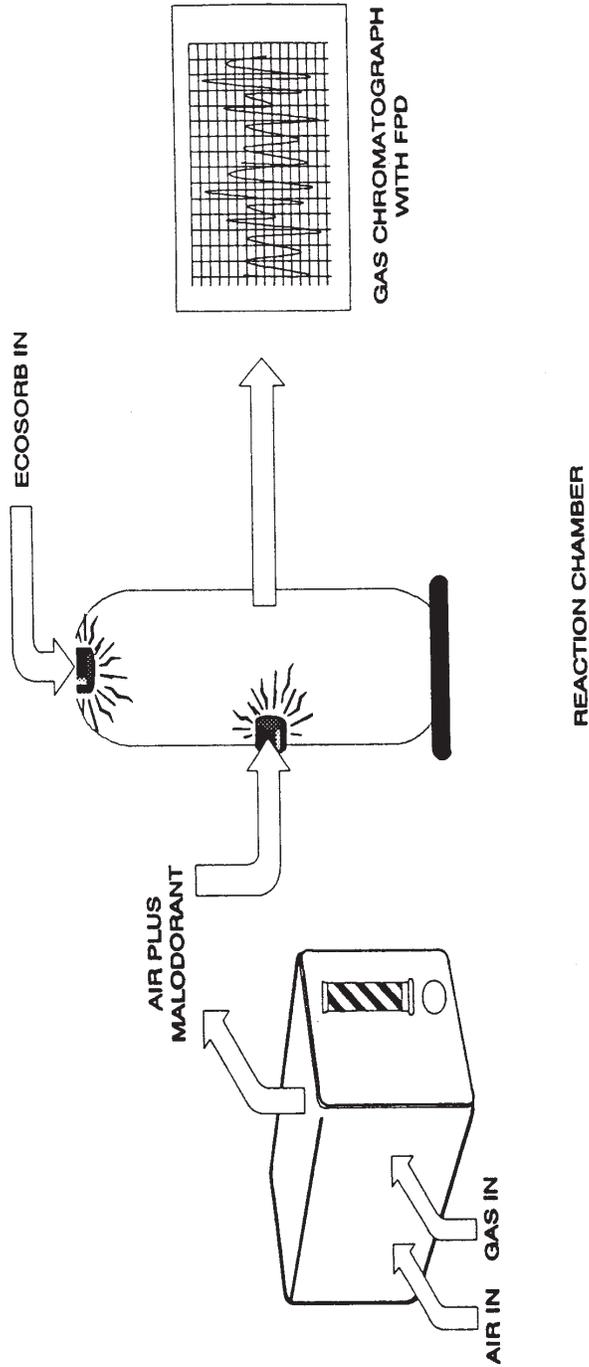


FIGURE 1



Table II
Ammonia Solubility in Water

Malodorant	Solubility in Water
Ammonia	89 grams/100 cc @ Deg. C.

Table III
Permeation Tube Properties

Tube	Serial No.	Shipment Date	Wt. @ Shipment	Empty Weight	Perm Rate @ 25 C. (P)	Wt. @ Run End	Air Flow Rate (F)	K	ppm Mal-odorant
Ammonia	1177	01/18/93	307.93100	275.73	50,700	300.2	800	1.437	90.00

Concentration ppm vol = (K x P) / F

Table III is a list of permeation tubes using in data for their output. All of the permeation tubes were obtained from:

GC Industries
8967 OSO Avenue
Chatsworth, CA 91311
Phone: 510/226-1329



RESULTS

The permeation tubes were adjusted for flow rates to produce the satisfactory concentration of odor level. Several reactor volumes were passed through the reactor and samples were withdrawn to check for the ammonia content.

The ammonia was measured with Sensidyne 3 La (2.5- 200 ppm) length of stain tubes. When the reactor inlet was at a satisfactory level, a 1 minute application of the reagent was applied and a reactor outlet sample was analyzed. A second outlet sample was taken in about 2 minutes and analyzed, and again at 15 minutes.

The results are contained in Table IV.

Table IV

Ammonia Results

Component	ppm/vol Perm Tube	ppm/vol Reactor out	ppm/vol concentration after treatment		
			Immed.	1 min	15 min
Ammonia	97	103	68	8 *	38 *

* Note: The gradual increase of the contamination level *after* the injection of the Ecosorb reflects the residual effect of the Ecosorb on the constant incoming gas.

The ammonia flow was started into the reactor at 09:19 hours and allowed to flow undisturbed until 09:30 hours. An ammonia test was made with the Sensidyne Tube at the nozzle opening and 103 ppm of ammonia was found. The nozzle opening was plugged with a rubber stopper and ammonia concentration checked at the cyclone separator outlet. Again we found 103 ppm of ammonia. With a check on original concentration of ammonia, the spray nozzle was placed in its opening with no Ecosorb 606 flow. Ecosorb 606 at maximum flow was pumped into the reactor at a rate of 21.08 grams/minute for one minute. At this time an ammonia concentration was determined to be 68 ppm. We continued for an additional minute and ammonia was found at 8 ppm. The Ecosorb 606 was shut off and ammonia tested again after two minutes and was found to be 5 ppm. Ecosorb 606 remained off for a total of 15 minutes and ammonia was found to be 38 ppm.



Testing was discontinued and the permeation tube was weighed and found to weigh 299.40 grams. Empty weight is 275.73 grams.

The nozzle was tested before and after the test for rate of delivery of atomized water.

The nozzle originally delivered 18.9 cc/minute (0.30 gallon/hour) and at the end of the run the delivery was 21.08 cc/minute (0.33 gallon/hour).

Sincerely

A handwritten signature in cursive script that reads "Fred DeAngelo".

Fred DeAngelo
Director Houston Hydrocarbon Services
Southern Petroleum Laboratories, Inc.



Examination of the Effect of Ecosorb 606 on Selected Sulfur Compounds

Testing Completed by
Southern Petroleum Laboratories, Houston, Texas.



METHOD

The analytical methods for the project were chosen based upon SPL's many years of experience with the analysis of sulfur compounds in hydrocarbons.

The gas to be tested would be supplied using permeation tubes manufactured by GC Industries, Chatsworth, CA.

Measurements would be monitored using flame photometric detection gas chromatography (FPD).

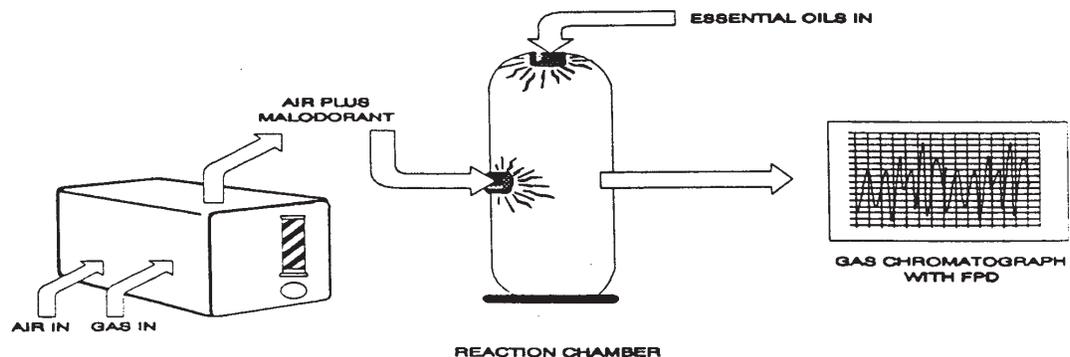
The FPD was selected over using length of stain tubes as it has been our experience that these strips do not always accurately register the reduction in sulfur compounds.

The testing would be conducted using Ecosorb 606 (2% by volume Ecosorb concentrate in water).

A glass container/reactor was chosen as the reaction vessel for all tests, its volume was approximately ten liters (see Figure 1). Air from the permeation tube calibrator containing the contaminant was charged to the reactor near the bottom, Ecosorb 606 was charged into the reactor from the top using an air aspirated nozzle-misting unit in a 10 second time burst presenting the Ecosorb 606 to the gas in 5-15micron particles (75% efficient).

FIGURE 1.

ESSENTIAL OIL CONTACT TESTING PROCESS





When the gas levels (ppm) at the inlet and outlet sample points were constant the Ecosorb 606 was charged. Exit samples were taken immediately after application of the Ecosorb, a second sample was taken after 4 minutes, and the final sample was taken at 18 minutes. Exit samples were taken from the side of the reactor at the top of a small cyclone separator.

The pollutant concentration and the flow rate of the contaminants were maintained at a constant level until the final samples were taken at 18 minutes.

In some cases, because the odor bodies were so completely destroyed we rechecked the permeation tube inlet to be sure that the malodorant was still being fed to the reactor.

Since all of the materials being tested were toxic, we felt that for the experiment to be a success the malodorant had to be lowered to a value at or below the eight hour Time Weighted Average (TWA in ppm). Table I lists the TWA and the Threshold Limit Value. GC Industries' permeation tubes easily achieve these levels.

Table I

Exposure Limits to Various Malodorants

Malodorant	8 Hr. TWA (ppm)	TLV (ppm)
Sulfur Dioxide	5.0	3.0
Hydrogen Sulfide	10.0	-
Methyl Mercaptan	0.5	10.0
Ethyl Mercaptan	0.5	10.0



Table II
Permeation Tube Properties

Tube	Serial No.	Shipment Date	Wt. @ Shipment	Empty Weight	Perm Rate @ 25 C. (P)	Wt. @ Run End	Air Flow Rate (F)	K	ppm Mal-odorant
Sulfur Dioxide	930	11/25/92	184.92930	176.57	14,500	184.2	200	0.382	25.78
Hydrogen Sulfide	933	11/25/92	309.06800	284.02	40,100	305.7	800	0.718	36.00
Methyl Mercaptan	932	11/25/92	150.10950	149.52	1,260	150.0	200	0.509	3.20
Ethyl Mercaptan	757	10/27/92	181.84943	175.36	11,350	181.8	400	0.394	3.97

Concentration ppm vol = (K x P) / F

All of the permeation tubes were obtained from:

GC Industries, Inc.
8967 OSO Avenue
Chatsworth, CA 91311
Phone 510/226-1329



The solubility of the various malodorants should also be considered in evaluating the effects of the ECOSORB 606. Table III lists the solubility of the various gasses tested.

Table III
Solubility in Water of Various Malodorants

Malodorant	Solubility in Water
Sulfur Dioxide	10.2 Wt. % @ 20 Deg. C.
Hydrogen Sulfide	2.6 Vol. Gas/Vol. Water @ 20 Deg. C.
Methyl Mercaptan	2.4 Wt. % @ 15 Deg. C.
Ethyl Mercaptan	1.3 Wt. % @ 15 Deg. C.

RESULTS

The various permeation tubes were adjusted for flow rates to produce the desired concentration of odor level. Several reactor volumes were passed through the reactor and samples were withdrawn to check for the malodorant by GC using FPD (Sulfur Specific) detection.

The inflow of gas into the reaction chamber was kept constant for the duration of the test and the gas levels were measured on contact with Ecosorb, again after four minutes and once more at 18 minutes. The dilution effect from the air nozzle having dissipated the results now show that any continuing reduction of the gas indicates the residual oils still present in the chamber were continuing to act on the contaminants being presented.



The results of these examinations are contained in Table IV following:

Table IV

Component	ppm/vol Perm Tube	ppm/vol Reactor Out	ppm/vol - Concentration after treatment		
			Immed.	4 min.	18 min.
Hydrogen Sulfide	36.00	36.00	20.04	36.00*	
Sulfur Dioxide	26.00	26.00	< 0.01	4.40*	
Methyl Mercaptan •	3.20	3.20	< 0.01		< 0.1*
Ethyl Mercaptan •	3.92	3.92	< 0.1		< 0.1*

• Disulfides were present that were also removed.

*** Note: The gradual increase of the contamination level after the injection of the Ecosorb reflects the residual effect of the Ecosorb on the constant incoming gas.**

Sincerely

A handwritten signature in cursive script, appearing to read "Fred DeAngelo".

Fred DeAngelo
 Director Houston Hydrocarbon Services
 Southern Petroleum Laboratories, Inc.