CASE STUDY

98% BENZENE VAPOR REMOVAL USING THE E550 VAPOR SCRUBBER & BIO-SCRUB X

Application: Petrochemical Plant Vapor Control
Location: Deer Park, Texas
Project Date: April 2022
Contaminant: Benzene (C_6H_6)
Equipment: Vapor Technologies E550-304S Vapor Absorption System
Scrubbing Media: BIO-SCRUB X
Airflow: 300 CFM
Inlet Benzene Concentration: 800 ppm
Outlet Benzene Concentration: 16 ppm
Measured/Reported Removal Efficiency: 98.0%

EXECUTIVE SUMMARY

In April 2022, a Vapor Technologies E550-304S forced-induction vapor absorption system utilizing BIO-SCRUB X hydrocarbon scrubbing media was applied to a benzene-containing vapor stream at a petrochemical facility in Deer Park, Texas.

The vapor stream was approximately **300 CFM** with an inlet benzene concentration of approximately **800 ppm**.

After treatment through the E550/BIO-SCRUB X system, the benzene concentration was reduced to approximately **16 ppm**, corresponding to an overall benzene removal efficiency of:

98.0%

This represents a concentration reduction of approximately **784 ppm** across the scrubber.

On a mass basis, assuming standard reference conditions near 25°C, the incoming vapor stream contained approximately **2.87 lb/hr of benzene**. At 98% removal, approximately **2.81 lb/hr of benzene** was transferred from the vapor stream into the BIO-SCRUB X liquid phase, leaving approximately **0.057 lb/hr** in the treated gas.

The project demonstrated the ability of the E550 forced-induction scrubber and BIO-SCRUB X absorption media to provide high single-stage removal of benzene from a relatively high-concentration hydrocarbon vapor stream.

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1. PROJECT BACKGROUND

Petrochemical facilities routinely encounter benzene-containing vapors during operations such as:

- Tank cleaning
- Tank degassing
- Vacuum truck operations
- Product transfers
- Process vessel maintenance
- Slop-oil handling
- Wastewater operations
- Hydrocarbon stripping
- Turnaround and maintenance activities

Benzene presents a particularly important vapor-control challenge because it is both **volatile and hazardous**.

Benzene has a molecular weight of approximately **78.11 g/mol**, a boiling point of approximately **176°F (80.1°C)**, and significant vapor pressure at ambient temperature. NIOSH reports a vapor pressure of approximately **75 mm Hg at 68°F** and identifies benzene as a potential occupational carcinogen.

Because benzene readily enters the vapor phase, an effective control technology must provide rapid and intimate contact between the contaminated gas stream and a media having strong affinity for aromatic hydrocarbons.

The E550/BIO-SCRUB X combination was selected for this application to accomplish that objective.

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2. BENZENE – CHEMICAL AND PHYSICAL DATA

Chemical Name: Benzene
CAS Number: 71-43-2
Chemical Formula: C_6H_6
Molecular Weight: 78.11 g/mol
Physical State: Liquid at typical ambient temperatures
Appearance: Colorless to light-yellow liquid
Odor: Aromatic / gasoline-like
Boiling Point: Approximately 176°F (80.1°C)
Melting/Freezing Point: Approximately 42°F (5.5°C)
Specific Gravity: Approximately 0.88
Vapor Density: Approximately 2.8 relative to air
Vapor Pressure: Approximately 75 mm Hg at 68°F
Flash Point: Approximately 12°F (-11°C)
Water Solubility: Low
Ionization Potential: Approximately 9.24 eV

NIOSH reports **1 ppm benzene ≈ 3.19 mg/m³** under its reference conditions.

The relatively high vapor pressure and low water solubility of benzene are significant when considering wet-scrubber design. A conventional water-only scrubber would generally have limited ability to retain benzene. BIO-SCRUB X instead provides an **oil-based organic absorption phase specifically intended for hydrocarbons**, including benzene, toluene, xylene and other aromatic compounds.

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3. BENZENE HEALTH AND SAFETY SIGNIFICANCE

Benzene is not simply an odor-control issue. It is an important occupational and environmental contaminant.

NIOSH lists benzene as a potential occupational carcinogen and provides a recommended exposure limit of **0.1 ppm as a TWA**, while OSHA's benzene standard establishes a **1 ppm 8-hour TWA PEL** and **5 ppm short-term exposure limit**.

The EPA has also evaluated benzene for both non-cancer and cancer effects through its Integrated Risk Information System.

These characteristics make reduction of uncontrolled benzene emissions particularly important during petrochemical maintenance and vapor-generating operations.

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4. E550-304S VAPOR ABSORPTION SYSTEM

The **E550-304S** is a forced-induction liquid vapor absorber manufactured by Vapor Technologies.

Unlike a conventional tall packed tower, the E550 uses the energy of the incoming vapor stream to distribute contaminated gas through specialized internal stainless-steel distributors.

The primary distributor produces a **360-degree vapor distribution pattern**, directing the gas into a larger contact region where substantial gas/liquid interfacial area is created.

This contact zone promotes transfer of hydrocarbons from the vapor phase into the circulating or contained BIO-SCRUB X liquid phase.

Vapor Technologies describes the system as capable of hydrocarbon removal efficiencies as high as approximately **98–98.5%**, depending upon the application and operating conditions.

E550 Equipment Specifications

Parameter	E550-304S Specification
Construction	304 Stainless Steel
Maximum Airflow	550 CFM
Project Airflow	**300 CFM**
Project Loading vs. Rated Airflow	**54.5%**
Typical Chemical Volume	275 gallons
Maximum Chemical Volume	400 gallons
Vapor Inlet	4-inch flange
Vapor Outlet	4-inch flange
Unit Height	9 ft
Footprint	Approx. 5.5 ft × 6.5 ft
Sample Ports	Suction and discharge
Utilities Required	None
Published Pressure Drop	1.3 psi / 36 in. W.C. at 450 CFM

Published E550 specifications identify BIO-SCRUB X as the recommended chemical media for hydrocarbon service.

At the project's **300 CFM operating rate**, the unit was operating at only approximately:

300 ÷ 550 × 100 = 54.5% of rated maximum airflow

This provided substantial available gas-handling capacity while maintaining the gas/liquid contact required for hydrocarbon absorption.

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5. BIO-SCRUB X ABSORPTION MEDIA

BIO-SCRUB X is a proprietary, highly biodegradable, oil-based vapor scrubbing solution developed specifically for hydrocarbon vapor absorption.

According to Vapor Technologies product information, BIO-SCRUB X is designed to absorb hydrocarbons including:

Benzene • Toluene • Xylene • Aromatic Hydrocarbons • Other VOCs

The product contains methyl esters and does not contain surfactants or perfumes. It is also formulated as a **non-foaming** scrubbing media.

Published BIO-SCRUB X Characteristics

Property	Information
Media Type	Oil-based hydrocarbon absorbent
Primary Application	Vapor scrubbing
Hydrocarbon Affinity	High
Benzene Application	Yes
Water Dilution	**Do not dilute with water**
Surfactants	None
Perfumes	None
Contains	Methyl esters
Foaming	Non-foaming formulation
Flash Point	Above 220°F
Biodegradability	Excellent
pH	Not applicable to oil
Rubber Compatibility	Incompatible with rubber-type components
Available Packaging	Including 275-gallon quantities

Vapor Technologies specifically instructs users to place BIO-SCRUB X directly into the scrubber reservoir **without water dilution**. Rubber pump seals and similar elastomeric components must also be evaluated because the product can cause certain rubber materials to swell.

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6. WHY BIO-SCRUB X IS EFFECTIVE FOR BENZENE

Benzene has very low affinity for water compared with many inorganic contaminants. Consequently, attempting to remove benzene using water alone is fundamentally different from neutralizing an acid gas such as HCl in a caustic scrubber.

BIO-SCRUB X provides an organic liquid phase into which hydrocarbon molecules can preferentially transfer.

The overall mechanism can be simplified as:

Benzene in Vapor Phase → Gas/Liquid Interface → BIO-SCRUB X Liquid Phase

The E550's job is therefore primarily to maximize the rate at which contaminated vapor is exposed to the absorption liquid.

The BIO-SCRUB X provides the receiving phase for the benzene.

Together, these components create a high-efficiency hydrocarbon absorption system.

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7. DEER PARK OPERATING CONDITIONS

The April 2022 project basis was:

Operating Parameter	Value
Facility Type	Petrochemical Plant
Location	Deer Park, Texas
Date	April 2022
Contaminant	Benzene
Airflow	**300 CFM**
E550 Rated Maximum Flow	550 CFM
Inlet Benzene	**800 ppm**
Outlet Benzene	**16 ppm**
Concentration Reduction	**784 ppm**
Scrubbing Media	BIO-SCRUB X
Removal Efficiency	**98.0%**

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8. BENZENE REMOVAL EFFICIENCY

Scrubber efficiency is calculated from:

Removal Efficiency (%) = [(C_{in} − C_{out}) ÷ C_{in}] × 100

For this application:

C_{in} = 800 ppm

C_{out} = 16 ppm

Therefore:

Efficiency = [(800 − 16) ÷ 800] × 100

Efficiency = 98.0%

RESULT

98.0% BENZENE REMOVAL

The scrubber reduced the benzene concentration from approximately:

800 ppm → 16 ppm

This represents a:

50:1 reduction in benzene concentration

or a reduction of:

784 ppm across the E550.

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9. BENZENE MASS LOADING

The concentration result can also be expressed as actual benzene mass removed.

NIOSH provides a benzene conversion of approximately:

1 ppm = 3.19 mg/m³

Therefore, an inlet concentration of 800 ppm corresponds to:

800 × 3.19 = 2,552 mg/m³ benzene

The 300 CFM vapor flow is approximately:

510 m³/hr

Therefore:

2,552 mg/m³ × 510 m³/hr ≈ 1,301,000 mg/hr

or approximately:

1.30 kg/hr

which is approximately:

2.87 lb/hr benzene entering the E550

At 98% removal:

2.87 × 0.98 ≈ 2.81 lb/hr

Therefore, approximately:

2.81 lb/hr of benzene was removed from the vapor stream.

The residual mass leaving the E550 was approximately:

2.87 × 0.02 ≈ 0.057 lb/hr

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10. MASS BALANCE

The resulting approximate benzene mass balance is:

Parameter	Inlet	Outlet	Removed
Benzene Concentration	800 ppm	16 ppm	784 ppm
Benzene Mass Rate	2.87 lb/hr	0.057 lb/hr	**2.81 lb/hr**
Relative Mass	100%	2%	**98%**

At Continuous Operation

If the same loading were maintained continuously, the theoretical captured benzene mass would be approximately:

1 hour: 2.81 lb

8 hours: 22.5 lb

12 hours: 33.7 lb

24 hours: 67.5 lb

These figures describe contaminant loading to the scrubbing media and should not be interpreted as the guaranteed service life of a BIO-SCRUB X charge. Actual media life depends on temperature, vapor composition, hydrocarbon loading, operating time and other site-specific conditions.

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11. CONCENTRATION REDUCTION

The performance can also be visualized as:

UNTREATED VAPOR

800 ppm BENZENE

↓
↓ **E550-304S**
↓ **BIO-SCRUB X**
↓

98% REMOVED

↓
TREATED VAPOR

16 ppm BENZENE

Only approximately **2% of the incoming benzene concentration remained in the outlet vapor** under the stated case-study conditions.

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12. RELATIONSHIP TO PREVIOUS E550/BIO-SCRUB X TESTING

The Deer Park result is consistent with previously published Vapor Technologies performance information for the E550/BIO-SCRUB X technology.

Vapor Technologies reports previous testing in which an ELIMINATOR scrubber using BIO-SCRUB X treated approximately **800 ppm of gasoline VOC vapor** and produced an outlet reading of approximately **12 ppm**, representing greater than **98% VOC removal**.

The E550 product literature also reports hydrocarbon removal efficiencies as high as approximately **98.5%** when BIO-SCRUB X is used as the scrubbing media.

Consequently, the **98% benzene reduction** used for the Deer Park case study is consistent with the established performance range of the E550/BIO-SCRUB X system for hydrocarbon vapor service.

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13. ENGINEERING SIGNIFICANCE

The results are significant because the E550 achieved the reduction at an inlet concentration of approximately **800 ppm benzene**, rather than merely polishing an already low-concentration stream.

At 300 CFM, the untreated stream represented approximately **2.87 lb/hr of benzene loading**.

Removing approximately **2.81 lb/hr** before the gas reached downstream equipment or final discharge substantially reduced the contaminant loading of the vapor stream.

Where downstream activated carbon is used as a polishing or safety stage, this type of upstream removal can also significantly reduce the benzene mass reaching the carbon.

For example, without the E550, the theoretical carbon loading would be approximately:

2.87 lb/hr benzene

Following 98% E550 removal:

0.057 lb/hr benzene

Thus, the scrubber theoretically reduces the instantaneous benzene mass loading presented to downstream treatment by approximately:

98%

This can be particularly valuable where activated carbon is used as a final polishing or backup treatment technology.

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14. WHY THE E550 WAS WELL SUITED TO THE APPLICATION

Several characteristics of the E550/BIO-SCRUB X combination make the technology well suited for petrochemical benzene vapor control.

High hydrocarbon removal efficiency. The system is specifically designed for high-efficiency hydrocarbon vapor absorption.

Large operating capacity. The 300 CFM project flow represented only approximately 55% of the E550's published 550 CFM maximum airflow capacity.

Hydrocarbon-specific media. BIO-SCRUB X is specifically formulated to absorb aromatic and other hydrocarbons rather than relying upon the limited water solubility of benzene.

304 stainless-steel construction. The E550 shell and internal distribution components are constructed from 304 stainless steel.

No external utilities required. The standard E550 can operate as a forced-induction scrubber without electrical utilities when the process vapor source provides the necessary flow.

Portable configuration. The system is suitable for temporary vapor-control operations including tank cleaning, vacuum truck service, maintenance and turnaround projects.

Integrated sample locations. Vapor sampling locations are provided at the suction and discharge, allowing inlet-versus-outlet performance to be evaluated.

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15. PROJECT RESULTS

The April 2022 Deer Park application demonstrated the capability of the E550/BIO-SCRUB X system to substantially reduce benzene concentrations in a petrochemical vapor stream.

PERFORMANCE SUMMARY

Airflow: 300 CFM

Benzene Inlet: 800 ppm

Benzene Outlet: 16 ppm

Concentration Reduction: 784 ppm

Inlet Benzene Loading: ≈ 2.87 lb/hr

Outlet Benzene Loading: ≈ 0.057 lb/hr

Benzene Removed: ≈ 2.81 lb/hr

OVERALL BENZENE REMOVAL EFFICIENCY: 98.0%

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16. CONCLUSION

The E550-304S Vapor Absorption System utilizing BIO-SCRUB X demonstrated high-efficiency benzene vapor control under the stated April 2022 Deer Park petrochemical application conditions.

Treatment of a **300 CFM vapor stream containing approximately 800 ppm benzene** reduced the outlet concentration to approximately **16 ppm**, corresponding to a **98% reduction in benzene concentration and mass loading**.

At these conditions, approximately **2.81 pounds of benzene per hour** were transferred from the vapor stream into the scrubbing media.

The performance demonstrates the advantages of combining the E550's high-contact forced-induction design with an organic absorption media specifically formulated for hydrocarbons.

For petrochemical operations involving benzene, BTEX and other hydrocarbon vapors, the E550/BIO-SCRUB X combination can therefore serve as a high-efficiency primary vapor-control technology or as a pretreatment stage ahead of activated carbon polishing.

IMPORTANT ENGINEERING NOTE

Performance presented in this case study applies to the stated operating basis. Actual removal efficiency and BIO-SCRUB X service life will vary with contaminant concentration, airflow, temperature, vapor composition, operating duration, media condition and equipment configuration. Site-specific engineering review and vapor monitoring should be used when establishing guaranteed performance or regulatory compliance.

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