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VAC*TRAX - Thermal Desorption for Mixed Wastes

Authors:

Michael J. McElwee
Carl R. Palmer

Contractor:

Rust Federal Services
100 Technology Drive
Anderson, South Carolina 29625

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DISCLAIMER

PI.15 VAC*TRAX — Thermal Desorption For Mixed Wastes

Michael J. McElwee (803-646-2413)
Carl R. Palmer (803-646-2413)
Rust- Clemson Technical Center
100 Technology Drive
Anderson, SC 29625

Abstract

The patented VAC*TRAX process was designed in response to the need to remove organic constituents from mixed waste, waste that contains both a hazardous (RCRA or TSCA regulated) component and a radioactive component. Separation of the mixed waste into its hazardous and radioactive components allows for ultimate disposal of the material at existing, permitted facilities.

The VAC*TRAX technology consists of a jacketed vacuum dryer followed by a condensing train. Solids are placed in the dryer and indirectly heated to temperatures as high as 260°C, while a strong vacuum (down to 50 mm Hg absolute pressure) is applied to the system and the dryer is purged with a nitrogen carrier gas. The organic contaminants in the solids are thermally desorbed, swept up in the carrier gas and into the condensing train where they are cooled and recovered. The dryer is fitted with a filtration system that keeps the radioactive constituents from migrating to the condensate. As such, the waste is separated into hazardous liquid and radioactive solid components, allowing for disposal of these streams at a permitted incinerator or a radioactive materials landfill, respectively. The VAC*TRAX system is designed to be highly mobile, while minimizing the operational costs with a simple, robust process. These factors allow for treatment of small waste streams at a reasonable cost.

The VAC*TRAX pilot system has proven effective at treating soil, sludge, and assorted debris streams, removing volatile and semi-volatile organic compounds, including polychlorinated biphenyls (PCBs), from the solid matrix. Removal efficiencies typically exceed 99%, and the system has repeatedly proven the ability to remove difficult components, such as PCBs, completely; PCBs were not detected in the product for a number of test runs on PCB contaminated soil and debris. Batch testing has indicated that the system may prove equally effective in treating streams contaminated with elemental mercury. In all cases involving mixed waste, the VAC*TRAX system demonstrated superior containment of the radioactive material within the solid matrix, with negligible partitioning of the material into the condensate.

This paper describes the VAC*TRAX thermal desorption process, as well as results from the pilot testing program. Also, the design and application of the full-scale treatment system is presented. Materials tested to date include spiked soil and debris, power plant trash and sludge contaminated with solvents, PCB contaminated soil, solvent-contaminated uranium mill-tailings, and solvent and PCB-contaminated sludge and trash. Over 70 test runs have been performed using the pilot VAC*TRAX system,

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with more than 80% of the tests using mixed waste as the feed material.

Introduction

The VAC*TRAX system was designed to meet the treatment needs of sites containing small volumes (10-4000 cubic meters) of hazardous and/or mixed waste materials, with the hazardous constituent consisting of organic or volatile contaminants. The process was designed for use on a wide variety of solid matrices, including soils, sludges, and contaminated debris from construction or clean-up operations. Through a Department of Energy (DOE) Program for Research and Development Announcement (PRDA) that is being managed by the Morgantown Energy Technology Center, the VAC*TRAX system has been successfully tested on RCRA and TSCA regulated streams, as well as RCRA mixed waste from the DOE. Rust has additionally proven the usefulness of the VAC*TRAX system on TSCA mixed waste sludge and debris, and batch testing indicates that elemental mercury removal from waste streams can likewise be performed to a high degree of efficiency.

The VAC*TRAX process thermally separates volatile or semi-volatile chemicals from contaminated solids; heating the solids under conditions of high vacuum, the contaminants are swept into a nitrogen carrier gas and conveyed to a series of heat exchangers, where they are condensed and recovered. The solid waste, once loaded into the VAC*TRAX dryer, is completely sealed from the atmosphere. This, combined with a strong vacuum pulled on the system and an aggressive pollution control set-up, provides the control needed for the handling of radioactive materials. The solids are heated indirectly, by hot oil that passes through metal jackets in the dryer, with the metal then heating the solids. Nitrogen purge gas, as well as the high vacuum on the dryer, prevent oxygen accumulation in the system, assuring that thermal desorption, not combustion, is the treatment operation. Based on the low flow-rate of carrier gas required for the system, HEPA filters and activated carbon beds can be economically used at the end of the condensing train, preventing the release of radioactivity and organic contaminants to the air.

The pilot equipment used for testing can achieve hot oil temperatures of 260-290°C and a vacuum down to 50 mm Hg absolute pressure. Agitation of the sample is provided by a heated, paddle-type agitator, and nitrogen carrier gas is also supplied to the system. These conditions provide the driving force required to desorb volatile and semi-volatile chemical compounds, including VOCs, PAHs, PCBs, and even elemental mercury within a reasonable batch-time. The pilot system has handled soil and sludge, as well as such debris as personal protective equipment (PPE), plastic bags, rubber hose, cloth filters, metal filter housings, rags, glass bottles, and various wood scraps. Some size reduction was required for the debris streams, but this was significantly less than what would be required for a continuous process utilizing screw conveyors and the like.

Technology Description - the VAC*TRAX Pilot System

The VAC*TRAX process is shown in Figure 1. As can be seen in the figure, material is loaded into the dryer through a flanged port. In the pilot unit, up to 31 L of material may be charged per batch. After loading, the inlet flange is sealed, the dryer is purged with nitrogen, and a strong vacuum is pulled on the system. The dryer is then heated by a conventional hot oil unit, circulating heated oil through an internal agitator and external jacket on the dryer. The heated dryer, in turn, heats the waste material charged to the system. The waste is heated at a time and temperature appropriate to the matrix and contaminants of concern: removing high concentrations of PCBs from soil would typically require heating the material at 260°C for at least 6-8 hours, while acetone or other volatile contaminants could be removed from the same matrix in less than half this time. After being heated for the required time, the vacuum on the system is reduced, and the product is dropped through a hinged door on the bottom of the dryer into a steel vessel that is fastened to the unit. The unit is then ready to begin another treatment cycle, and the solids from the previous batch may be sampled and/or disposed of, as appropriate.

The nitrogen is heated and introduced directly into the dryer. The desorbed vapors and nitrogen exit the dryer through an upper cupola section attached to the dryer. This cupola section is

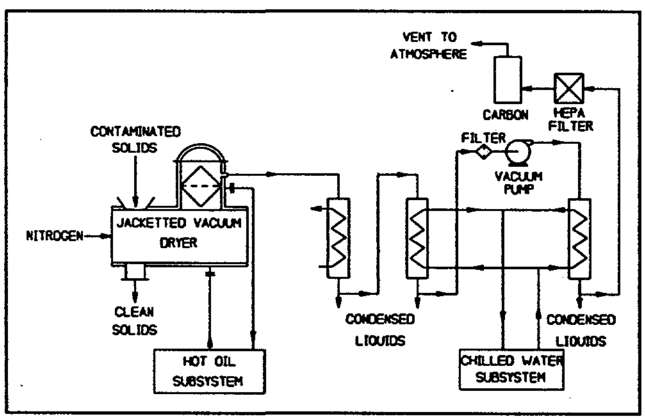

Fig. 1. VAC*TRAX℠ Process Flow Diagram

equipped with filter elements that remove entrained solids (dust) from the exiting gas stream. These solids are retained in the dryer and are returned to the treated product from the filters by sending a short burst of nitrogen through the filters and into the dryer, essentially "blowing back" the filters. The solids can then be emptied as previously mentioned. The gases are then condensed in a system employing three heat exchangers in series. The first heat exchanger rejects heat to ambient temperature, while the second and third exchangers are operated at near 0°C with a chiller system. These units condense the water and volatile contaminants that were removed from the waste in the dryer. The liquids drain to collection traps, where they are removed using double block valves. The remaining gas stream, essentially nitrogen with trace volatile constituents and oxygen, is then passed through a high efficiency particulate air (HEPA) filter to provide absolute removal of all remaining solid particles. The stream then passes through an activated carbon adsorption system, removing residual organic vapors that could not be condensed prior to venting of the stream to the atmosphere. Total hydrocarbon emissions from the unit are extremely low; in runs performed on debris spiked with volatile organic compounds, none of the spiked compounds were found in the process vent after the carbon adsorption system. Particulate (and radioactive) emissions are non-detectible.

Technology Description - the VAC*TRAX Full-scale System

Based on a market survey, it appears that there is a demand for two sizes of VAC*TRAX systems. These are a small (2-6 drum) unit to handle a large number of low-volume waste streams and a larger (40 drum) unit to handle significant quantities of waste present at a few DOE facilities. At present, the smaller unit is being designed. Rapid mobilization, with minimal cost for installation of utilities and other support facilities are key considerations for the unit. Additionally, the system will be designed to operate within presently existing structures, not requiring that a building be constructed to house this unit. The system is totally self-contained, except for the need for a propane or natural gas fuel source for the hot oil system. The system will be capable of processing waste within a week of arrival on-site, and will be designed for ease of decontamination to decrease demobilization time. These features combine to make the system an economical choice for small waste volumes.

Accomplishments

Over five-hundred hours of testing on spikes, RCRA and TSCA waste, RCRA mixed waste, and TSCA mixed waste have been performed using the VAC*TRAX system. Over 80% of the test runs have been performed on mixed waste. Excellent removal efficiencies have been demonstrated for volatiles, semi-volatiles and PCBs, as shown in Table 1. Even at low temperatures (100°C), the VAC*TRAX system was able to reduce volatiles in a F002 debris waste to below the regulatory level. At 240-260°C, PCBs have been successfully removed from sludge and debris, with starting levels as high as 10% PCBs (100,000 ppm).

In addition to excellent removal efficiencies, the VAC*TRAX system has proven its other main goal, containment of radioactive material within the dryer. For six distinct radioactive waste streams, the condensate recovered from VAC*TRAX testing was found to be non-radioactive based on gross alpha/beta analysis for waste. These results are summarized in Table 2.

Table 1. Contaminant Removal Efficiencies using the VAC*TRAX Process

Contaminant	Solids Matrix	Final Solid Temp (°C)	Time at Temp (min)	Init. Conc.[5] (ppm)	Ending Conc. (ppm)	Removal (%)
Volatiles						
Acetone[1]	Soil/Clay	239	45	1,644	5.98	99.6
Acetone	Debris	101	240	7.51	BQL(0.4)	> 94.5
Carbon Tetrachloride[1]	Soil/Clay	239	45	105	BQL(0.2)	> 99.8
2-hexanone	Debris	101	240	5.93	0.2	96.6
Toluene	Debris	104	360	6.7	0.055	99.2
Tetrachloroethene[1]	Soil/Clay	239	45	118	BQL(0.2)	> 99.8
Tetrachloroethene[2]	Soil/Lint	257	360	1,000	J(0.003)	>99.99997
Tetrachloroethene[2]	Sludge	243	210	272	BQL(1)	> 99.6
Ethylbenzene[1]	Soil/Clay	239	45	630	BQL(0.2)	> 99.97
Ethylbenzene	Debris	104	360	20	0.075	99.6
MIBK	Debris	104	360	15	0.14	96.8
Xylene[1]	Soil/Clay	239	45	2,672	BQL(0.2)	> 99.993
Xylene	Debris	104	360	110	0.092	99.92
Styrene[1]	Soil/Clay	239	45	461	BQL(0.2)	> 99.96
Styrene	Debris	104	360	230	0.14	99.94
Trichlorofluoromethane	Sludge	243	210	2,701	BQL(1)	> 99.92
Semi-volatiles						
Bis(2-ethylhexyl)phthalate[1]	Soil/Clay	239	45	577	1.05	99.8
Pentachlorophenol	Soil/Clay	247	90	581	126	83.2
PCBs						
Arochlor 1242	Soil/Clay	260	600	990	BQL(1)	> 99.90
Arochlor 1242	Soil/Clay	257	240	760	BQL(1)	> 99.87
Arochlor 1254	Sludge	241	1710[4]	107,000	BQL(0.5)	>99.9995
Arochlor 1254	Debris	241	270	500	BQL(0.5)	> 99.90
Arochlor 1260	Debris	241	350	178	BQL(0.5)	>99.7
Elemental Mercury[3]	Soil	252	360	70,700	8,800	87.6

Notes:

1. Test Performed on spike sample
2. Test performed on mixed waste
3. Test performed in a vacuum oven test; the VAC*TRAX system is known to perform significantly better for most contaminants.
4. Test run divided over 4 days of operation
5. All results are converted to a dry weight basis

BQL(A) = Below quantitation limit; A = quantitation limit

J(A) = Estimated value of A, below quantitation limit

Table 2. Containment of Radioactivity within the VAC*TRAX Dryer

Radioactive Constituent	Average Level in Feed	Level in Composited Condensate	% Radioactivity carried to condensate
Co-57 pCi/g	16.91	BQL(0.2)	< 1.2
Co-60 pCi/g	44,000	BQL(0.16)	< 0.00037
Cs-134 pCi/g	25.0	BQL(0.16)	< 0.64
Cs-137 pCi/g	1,195	BQL(0.2)	< 0.017
Sb-125 pCi/g	19.5	BQL(0.48)	< 2.5

Future Expectations

Construction of the small (2 to 6 drum) commercial unit is expected to begin in October of this year. Applications for the required permits will be produced and submitted along a parallel track, thus limiting any unnecessary delays. Demonstration of the full-scale system is expected to first be performed during the fall or winter of 1996. After this, the unit will be used for the remediation of various DOE mixed waste streams. Construction of the large (40 drum) unit will depend on the market demand for the system.

Acknowledgements

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