Instruction Session – Control Devices
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The use of control devices in RCRA applications can be difficult to understand, because the experience base in RCRA is generally limited to liquid and solid wastes, while control devices apply to air emissions. The chemistry of control devices and air emission control is similar to waste treatment, but the small differences associated with gas flow measurement can make the process daunting. No specific control device is required by the RCRA organic air emission rules, as long as either the control efficiency is reached or specific performance requirements are met.

First, define control device efficiency as the amount removed divided by the total original amount. Assuming constant volume, the air stream influent concentration, Cin, and the effluent concentration, Cout, may be used:

$$\text{Efficiency} = \frac{\text{Cin} - \text{Cout}}{\text{Cin}}$$ which is often expressed as a percentage.

RCRA air emission control regulations require a 95% reduction by the control device:

Cin = 100 ppm C95% reduction = 5 ppm

Cin = 20,000 ppm C95% reduction = 1000 ppm

Cin = 2 ppm C95% reduction = 0.01 ppm = 10 ppb

Units may also be reported as mg/l, mg/cubic meter, and ppmw. The metric system makes conversions much easier (1 cubic meter = 1000 liters, etc). Conversion problems usually occur where the units are weight/mass based or volume based, as most measurements for concentration are mixed: mass based for how much compound, volume based for how much overall fluid (gas or liquid). Convert to mass basis by multiplying the fluid volume by the fluid density to get fluid mass.

What is the typical application of control devices in the hazardous waste universe? Tank headspace vented to carbon canisters, mostly drum sized units which are 150 pounds of activated carbon. Calgon Carbon sells them under the name of VentSorb (www.calgoncarbon.com). Other makers include ICI America, Westvaco and Witco. Carbon canisters may be bigger than drum units, such as pallet sized, if more adsorptive capacity is required.

Usually, canisters are set up so the flow travels first through a primary unit then a secondary unit. The primary unit is the main line of defense, while the secondary unit provides for control if the primary unit malfunctions or reaches saturation. When the primary unit is removed for regeneration or disposal, the secondary unit is moved up in the treatment train to primary, and a new unit is installed as secondary, refreshing the insurance capability. Usually the change of a carbon unit from secondary to primary involves the simple turning of a valve so that the flow enters the former secondary unit first.

Compounds adsorb to activated carbon at different rates, and activated carbon type makes a difference too. While there is plenty of science that can be applied to adsorption theory, in general, carbon design is conducted as an experimental or observational approach: guidelines plus measurements. There is nothing like a good operational record. However, be aware that many factors can change the carbon performance, such as humidity, particulates in the airstream, coincidental compounds, or variations in the carbon activation process or carbon source.

The RCRA organic air emission requirements require monitoring and “proper operation” of control devices, which means that a facility must be monitoring the effluent concentrations carefully for a rise that indicates breakthrough (activated carbon saturation). The regulations require changing out the carbon before falling below the 95% removal level for the whole system. However a primary carbon canister may be allowed to not perform completely up to the removal level if sufficient secondary carbon exists until replacement carbon is installed. The measurements upstream and downstream of each carbon unit will determine when change-outs are required.

Note that activated carbon adsorption has a particular application that does not work well for organic air emission control. High flows of high concentration organic vapor phase may cause excess heat of adsorption in the carbon units, sufficient to reach spontaneous combustion. Flame arrestors and pre-wetting of the carbon are often required under these situations, however, RCRA organic air emission regulations simply do not allow the use of carbon for enclosures where conditions of high air flow would likely occur.

Condensers are another control device used to reduce organic air emissions in the control of hazardous waste. There are two forms of condensers - thermal condensers and contact condensers. Thermal condensers work by chilling organic compounds to below their boiling point, turning vapor into liquid. Contact condensers work by phase transfer of airborne volatile compounds into a dissolved state, using a liquid spray across the air flow (visualize a garden hose sprayer meeting the vacuum cleaner exhaust). Scrubbers for air pollution control are one type of contact condenser, using specific type of liquid spray to take out NOx and other types of inorganic pollutants.

Once a condenser achieves transfer of compounds from vapor to liquid state, the liquid can be treated by conventional wastewater treatment and released or disposed. Condensers of both types are highly dependent upon the compound chemistry and the consistency of the waste air stream. It is reported that the maximum effectiveness for a condenser is 92%, with typical operating efficiencies of 80 to 85% for well run systems. The low efficiency means that condensers cannot stand alone for organic air emission control under RCRA. Usually, condensers are followed by activated carbon adsorbers, and the efficiency of control is measured on the aggregate system.

Other organic air emission control devices include catalytic oxidizers, flares, and boilers and industrial furnaces (BIFs). These devices use some sort of combustion technique to destroy the organic compounds. While they usually work great, installation and operation are very expensive and there are significant issues with performance, particularly creation of undesirable byproducts. However, these combustion-type devices may be the only way to control organic air emissions from large and diverse flows. A review of the device costs may be helpful to understand some of the difficulty (these are very rough, based on anecdotal experience):

Control Device	Cost
Activated Carbon Adsorber	\$10,000 - \$50,000 per year
Condenser	\$50,000 - \$150,000 construction, plus \$10,000 - \$20,000 per year
Catalytic Oxidation Unit	\$130,000 - \$1.5 million installation
Flare	\$200,000, but difficult to permit
Boiler/Industrial Furnace	\$2 million? 3 to 10 years to permit