

Options for treatment of gas extracted from SVE systems:

1. carbon adsorption
2. incineration
3. catalytic oxidation
4. biotreatment
5. (wet scrubbing / absorption) uncommon for SVE gas containing toxic organic compounds

CARBON ADSORPTION

text gives isotherms which describe the equilibrium partitioning of compounds from liquid onto activated carbon

1. Freundlich Isotherm: $\text{Mass on AC}/\text{mass AC} = K_f * C_w^{(1/n)}$
Kf is related to the sorption capacity
n relates to the adsorption bond
2. Langmuir Isotherm: $\text{Mass on AC}/\text{mass AC} = q_{\text{max}} * b * C_w / (1 + b * C_w)$
qmax = saturated concentration
b = represents energy of adsorption

Isotherm constants are often measured for water:activated carbon.

Can these relationships be applied to air:activated carbon equilibrium?

$C_{\text{ac}} / C_{\text{a}}$ is approx. K_{oc}/H' since $K_{\text{oc}} = C_{\text{c}} / C_{\text{w}}$ and $H' = C_{\text{a}} / C_{\text{w}}$

at equilibrium $C_{\text{w}} = C_{\text{a}} / H'$ so: $\text{Mass on AC}/\text{mass AC} = K_f (C_{\text{a}}/H')^{(1/n)}$?!

BUT treatment columns do not operate under “equilibrium” conditions.

There are dynamic changes in sorbed concentrations over time as the contaminants partition onto the carbon as they flow through the column. The region of the carbon “bed” in the column which is actively adsorbing the contaminant is defined as the “active zone”; in this region the gas concentration ranges from 90% to 10% of the column inlet concentration. The LaGrega text contains relevant formulas:

Use pilot-scale data to determine the depth of the active zone in the column.

Determine the flowrate that gas should flow through the column for optimal treatment:

$$Q_{\text{air}} / A_{\text{col}} = \text{max sorptive capacity per bed volume} * \text{slope} * \text{depth AC in col} / C_{\text{in}}$$

of columns to operate in series = $(AZ \text{ depth} / \text{total depth AC in column}) + 1$

rounded UP to the nearest whole number (therefore, never less than 2 columns)

INCINERATION

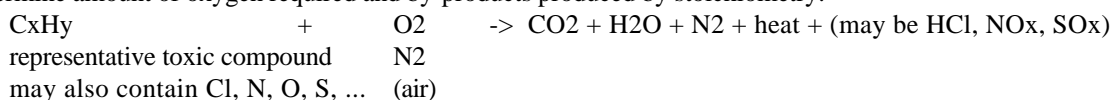
best for high concentrations of contaminants in the gas, also for large gas flowrates

can reliably achieve 99.99% (“4 nines”) to 99.9999% (“6 nines”) removal of contaminants

drawback: very expensive!

Goal: convert organic compounds to inorganic compounds (CO₂ and water) by high temperature environment (1200-1600°F) in the presence of oxygen

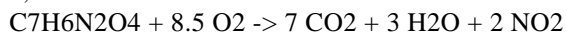
Can determine amount of oxygen required and by-products produced by stoichiometry:



To design: run a mass balance (what goes in must come out ... in some form) and heat balance

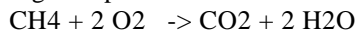
Example stoichiometry:

2,6-dinitrotoluene

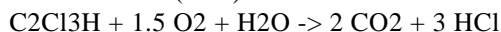


(if incinerated in excess O₂ environment, assume all N goes to NO₂)

natural gas (fuel source, since the toxic organics in the SVE gas alone not enough energy released to maintain high temperature environment required for efficient incineration)



trichloroethene (TCE)



For efficient incineration, usually want to supply 10-50% excess oxygen (beyond the stoichiometric requirement)

Incineration is widely used for hazardous waste, but more frequently for soil treatment than gases

~1300 incinerators in the US partially burn haz waste

used at about 56 Superfund sites for >2 M tons of soil (30 mobile incinerators)

CATALYTIC OXIDATION

requires a lower temperature than incinerators (500-700°F), so less fuel burning needed (cost savings)

converts toxic organic compounds to CO₂, water (similar to incineration) in the presence of a catalyst

the catalyst is a metal compound, which may need to be replaced every 2-5 years (cost)

can achieve 90-98% removal reliably (higher efficiency at lower gasflow rates being treated)

better than incineration for treating low concentrations of VOCs

VAPOR PHASE BIOREACTORS

Summary of Characteristics of Biological Gas Tmt Reactors

Biofilters

immobile biomass	high gas:liquid surface area
immobile liquid	low operating costs
C _g < 1 mg/L	poor control of reaction conditions
H' < 10	large area needed
Q _g 100-200 m ³ /m ³ -hr	retain slow growing bacteria plugging/short-circuiting problems

Biotrickling Filters

immobile biomass	better control of moisture, pH, nutrients
mobile liquid	retain slow growing bacteria
C _g < 0.5 mg/L	lower surface area for mass transfer than biofilter
H' < 1	higher operating costs, due to liquid pumping plugging/short-circuiting (can backwash)

Bioscrubber

suspended biomass	good control of reaction conditions
mobile liquid	low pressure drop of gas
two reactors	low mass transfer surface area

$C_g < 5 \text{ mg/L}$ may washout slow growing bacteria
 $H' < 1$ biosolids disposal
 Q_g 20,000 to extra air needed when high degradation rates
40,000 $\text{m}^3/\text{m}^2\text{-hr}$ high capital investment and operating costs

Suspended Sparged Reactor

suspended biomass good control of reaction conditions
mobile liquid wash out slow growing bacteria (control by SRT)
 $C_g < 10 \text{ mg/L}$ extra air needed at high C_g -contam
 $H' < 0.5$ biosolids disposal
(in order to maintain shallow depth and high gas treatment efficiency)

COMPARATIVE COSTS

capital:

incineration (capital cost does not change for different inlet gas concentrations) \$300,000 for 4000-16,000 scfm
carbon adsorption (capital cost increases for higher inlet gas concentrations) \$70K to \$100K for 4000-16,000 scfm
biological treatment (capital cost increases with higher inlet gas concs) \$60K to \$80K for 4000-16,000 scfm

annual O&M costs: \$20-150 / cfm for incineration; \$15-\$90/cfm for catalytic oxidation, \$20-\$35/cfm for carbon adsorption; \$10-\$35/cfm for biotreatment