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: Mass on AC/mass AC = $K_f * C_w^{(1/n)}$
   - K_f is related to the sorption capacity
   - n relates to the adsorption bond

2. Langmuir Isotherm: Mass on AC/mass AC = $q_{max} * b * C_w / (1 + b*C_w)$
   - q_{max} = 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_{ac} / C_a is approx. K_{oc}/H' since $K_{oc} = C_c / C_w$ and $H' = C_a / C_w$

at equilibrium $C_w = C_a / H'$ so: Mass on AC/mass AC = $K_f (C_a/H')^{(1/n)}$?!

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_{air} / A_{col} = max sorptive capacity per bed volume * slope * depth AC in col / C_{in}

# of columns to operate in series = (AZ depth / 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 (CO_2 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:

C_xH_y + O_2 -> $CO_2 + H_2O + N_2$ + heat + (may be HCl, NO_x, SO_x)
representative toxic compound N_2
may also contain Cl, N, O, S, ... (air)

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

Example stoichiometry:

2,6-dinitrotoluene
C7H6N2O4 + 8.5 O2 -> 7 CO2 + 3 H2O + 2 NO2
(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)
CH4 + 2 O2 -> CO2 + 2 H2O

trichloroethene (TCE)
C2Cl3H + 1.5 O2 + H2O -> 2 CO2 + 3 HCl

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
immobile liquid
Cg<1 mg/L
H' < 10
Qg 100-200 m3/m3-hr

high gas:liquid surface area
low operating costs
poor control of reaction conditions
large area needed
retain slow growing bacteria
plugging/short-circuiting problems

Biotrickling Filters

immobile biomass
mobile liquid
Cg < 0.5 mg/L
H' < 1

better control of moisture, pH, nutrients
retain slow growing bacteria
lower surface area for mass transfer than biofilter
higher operating costs, due to liquid pumping
plugging/short-circuiting (can backwash)

Bioscrubber

suspended biomass
mobile liquid
two reactors

good control of reaction conditions
low pressure drop of gas
low mass transfer surface area

Cg < 5 mg/L	may washout slow growing bacteria
H’ < 1	biosolids disposal
Qg 20,000 to 40,000 m3/m2-hr	extra air needed when high degradation rates
	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)
Cg < 10 mg/L	extra air needed at high Cg-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