

Air Stripping of Volatiles

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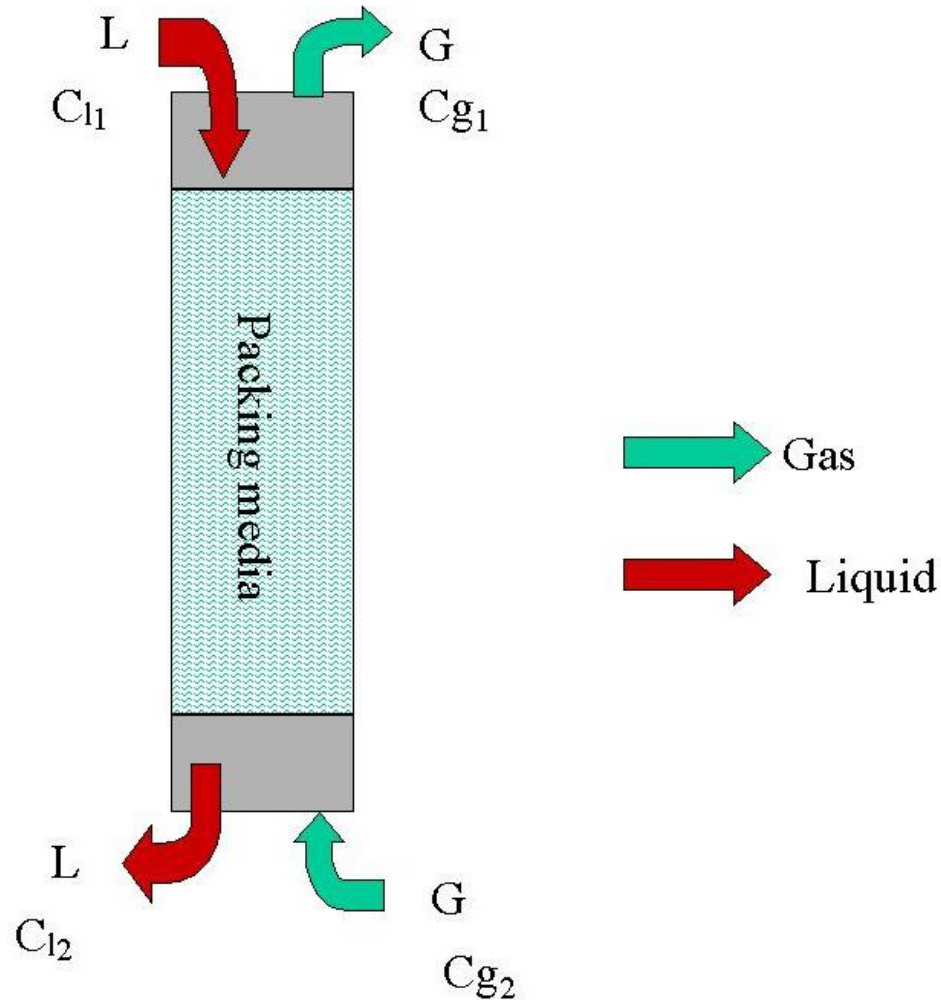
Sometimes volatile compounds (generally VOC's) can be removed from the aqueous phase by stripping the VOC's with an air flow. This air stripping is usually accomplished in air stripping towers. The towers serve to breakup the water into droplets and allow contact between the water and air with subsequent transfer of VOC to air phase. The premise is that the atmosphere can handle the VOC's (though sometimes AC adsorbers are required).

Packed tower air stripping is commonly used to remove volatile contaminants (e.g., tetrachloroethylene, trichloroethylene, benzene, ammonia) from contaminated waters.

Increasingly, it is being applied to the renovation of groundwaters that have become contaminated with volatile organic carbon (VOC) compounds from leaking underground storage tanks, spills, or improper disposal practices.

Two approaches to designing a stripping tower are; **equilibrium and dynamic**. First consider the equilibrium approach. This will only give an estimate of performance but it is fairly easy to perform.

Consider an air stripping column schematically shown here:



G = gas flow rate (m^3/sec)

L = water flow rate (m^3/sec)

$C_{g1,2}$ = gas phase concentration of volatile substance at top and bottom of column, respectively (moles/m^3)

$C_{l1,2}$ = water phase concentration of volatile substance at top and bottom of column, respectively (moles/m^3)

If equilibrium is attained at every point in the tower then Henry's law predicts:

$$C_g = H_c C_l$$

A mass balance on the volatile material in the column gives:

$$L(C_{l1} - C_{l2}) = G(C_{g1} - C_{g2})$$

C_{g2} is generally zero (use clean gas for stripping).

Again at equilibrium:

$$C_{g1} = H_c C_{l1}$$

therefore:

$$L(C_{l1} - C_{l2}) = G(H_c \cdot C_{l1})$$

then:

$$\frac{G}{L} = \left\{ \frac{C_{l1} - C_{l2}}{C_{l1}} \right\} \cdot \frac{1}{H_c}$$

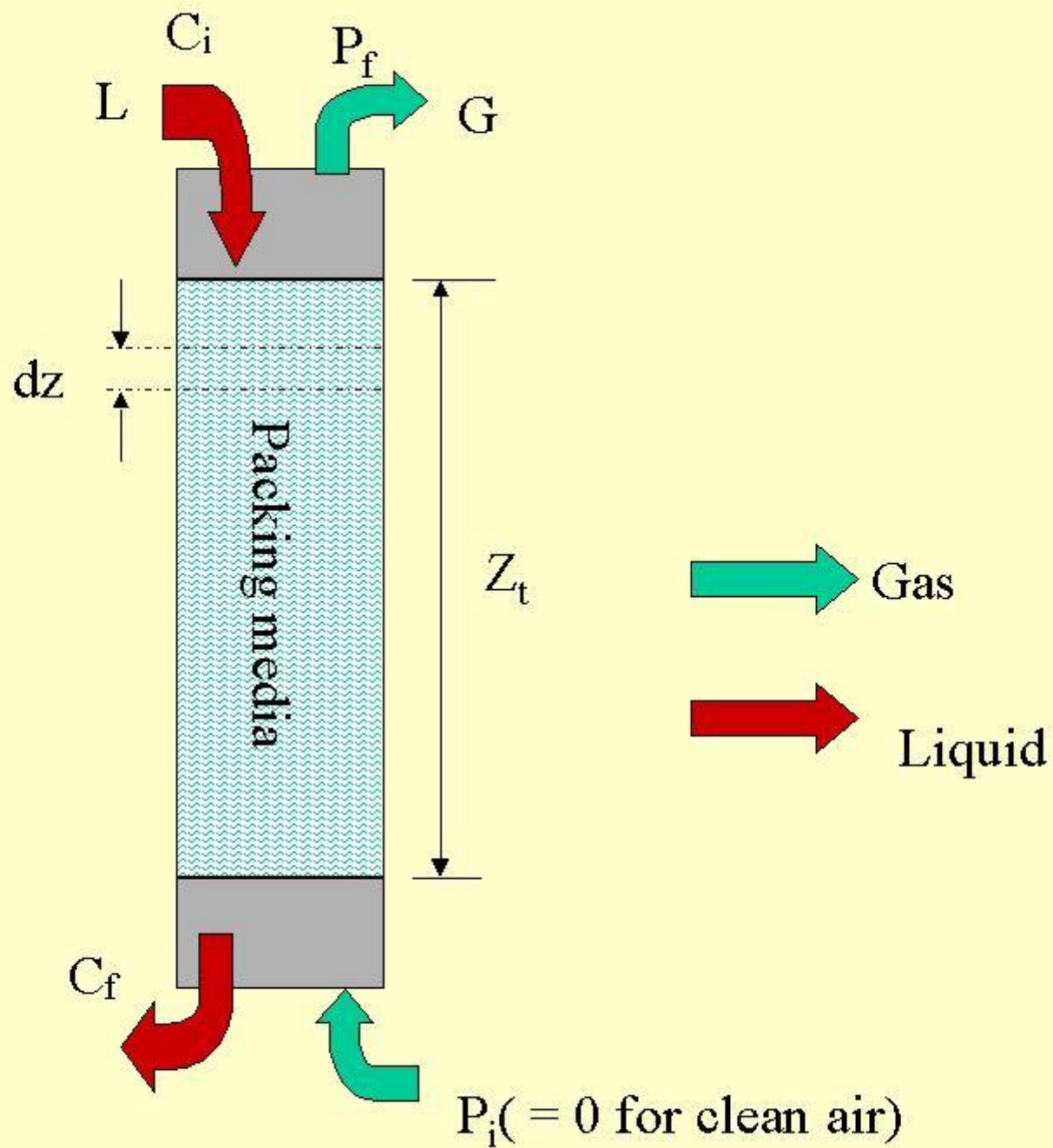
Since $C_{g2} = C_{l2} = 0$ (by Henry's law)

$$\frac{G}{L} = \frac{1}{H_c}$$

This G/L ratio predicts gas to liquid flows required to get complete removal of the volatile material. However, equilibrium (Henry's law) is never attained in a typical stripping column. This ratio is only an estimate of actual gas/liquid flow rates required.

Dynamic Analysis of Stripping column

In its most efficient form, the packed tower is operated in a *counter-current* manner: the contaminated water is loaded to the top of the tower, while fresh air is blown in from the bottom.



The packing generally consists of plastic pieces, approximately 1 to 2 inches in nominal size, which are randomly dumped into the column structure (hence the term, "dumped packing"). Common varieties include "rings" and "saddles". There are also some unusual, honey-combed, "structured packings" being sold (at rather high cost) by manufacturers for VOC applications. Whatever its type, the packing is supported by a retention structure; the liquid is distributed over the packing using either nozzles or trays.

Derivation of performance equation for this type of stripping column follows.

First define the following terms.

L = liquid flow rate (m^3/min);

G = air flow rate (m^3/min);

C = concentration of volatile solute in the liquid (mol/m^3);

P = partial pressure of the volatile solute in the gas phase (atm);

Z_t = total height of packing (m);

A_x = cross-sectional area of tower (m²);

a = true interfacial area per unit bulk volume of packing (m⁻¹) (*affects $K_L a$*) ;

R = universal gas constant = 8.2056×10^{-5} m³-atm/mol-°K.

Performing a mass balance on the volatile solute entering and leaving the tower yields:

$$L(C_i - C_f) = \frac{G(P_f - P_i)}{R \cdot T_g} \quad (1)$$

Note that P_i is approximately zero if clean air enters the column.

Consider a differential height element, dz , as shown in the above diagram. The differential transfer rate, dN (mol/min) through the element is given by:

$$dN = K_L a (C - C^*) A_X \cdot dz \quad (2)$$

C = liquid phase concentration of the volatile compound in the element dz (mol/m³);

C^* = hypothetical liquid phase concentration which would be at equilibrium with the gas-phase partial pressure, P in the element (mols/m³);

$$C^* = P / H.$$

Integration over the total packing height, Z_t , yields:

$$L(C_i - C_f) = K_L a (\overline{C - C^*})_L \cdot A_x \cdot Z_t \quad (3)$$

$(\overline{C - C^*})_L =$ log-mean driving force for mass transfer across the tower

$$= \frac{(C_i - C_i^*) - (C_f - C_f^*)}{\ln \left[\frac{(C_i - C_i^*)}{(C_f - C_f^*)} \right]}$$

Substituting eq (3) into equation (1) with rearranging, yields:

$$\frac{C_i}{C_f} = \frac{\exp \left[\frac{Z \cdot A}{L} \left(1 - \frac{L \cdot R \cdot T}{G \cdot H} \right) \cdot K_l \right] \cdot \frac{L \cdot R \cdot T}{G \cdot H}}{1 - \frac{L \cdot R \cdot T}{G \cdot H}}$$

The above performance equation allows for estimation of the required packed volume necessary to achieve a desired removal, given C_i and L for different choices of G .

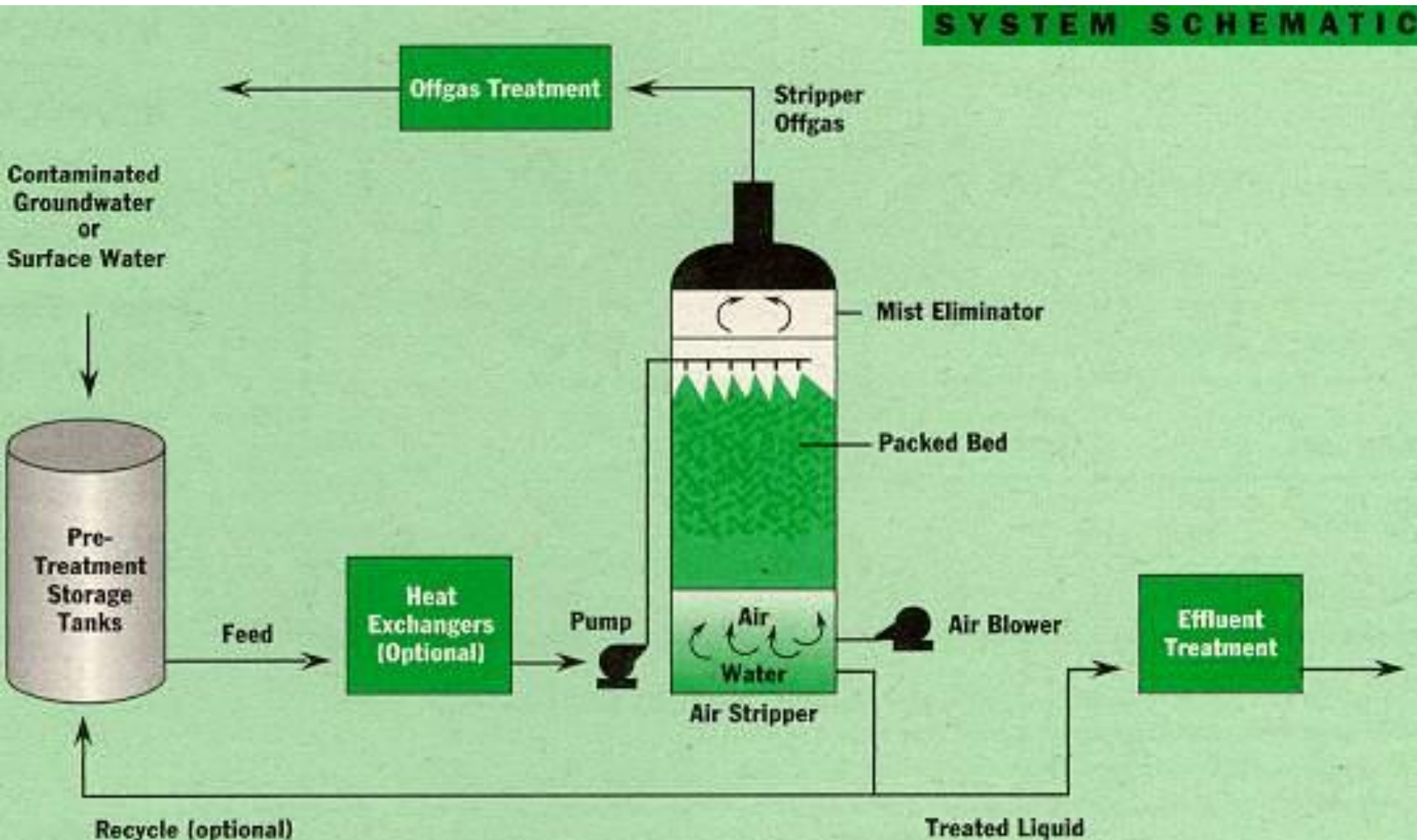
We can define a "stripping factor"

$$\equiv F_s \equiv \frac{G \cdot H}{L \cdot R \cdot T} = H_c \left(\frac{G}{L} \right)$$

g

The inverse of the stripping factor appears in three places in the performance equation. F_s characterizes the capacity for transfer, relative to equilibrium conditions. If $F_s < 1$, there exists a limited degree of removal, for a fixed G/L , which cannot be surpassed, regardless of how large a tower is employed (i.e., even if the exit gas stream achieves equilibrium with the entering liquid stream, removal will be limited by insufficient gas).

A typical application scheme for a stripping column is demonstrated in the following schematic:



Some typical stripping columns:





