Supplementary Information

Text S1. The effect of natural volatilization from the liquid surface of the aeration column.

During aeration, air bubbles pass through the water column in the form of numerous microbubbles, providing a relatively large air–water interfacial area compared to the liquid surface area. Consequently, bubble–water interfacial mass transfer is relatively strong, while volatilization from the liquid surface of the aeration column is comparatively minor. In the subsequent theoretical derivation, it is assumed that natural volatilization from the column surface has no effect on stripping performance. To verify the validity of this assumption, we experimentally investigated the natural volatilization of volatile compounds.

Chloroform was selected as the target compound, and a 2.55 L stock solution prepared with deionized water was placed in the aeration column, following the same procedure as in the aeration experiments. During the test, no air was introduced, and samples were taken at regular intervals. The chloroform concentration in the column was determined by liquid–liquid extraction followed by gas chromatography. The experimental results are presented in Table S1:

Table S1 Natural volatilization from the liquid surface of the aeration column

Time/min	Temperature/℃	Concentration of chloroform/μg·L^{-1}	C/C_0
0.00	28.5	286.80	1.000
10	28.2	296.25	0.995
20	28.2	281.08	0.971
30	28.2	287.98	1.024
40	28.4	289.18	0.991

Text S2. The influence of the mass transfer performance by the bubble characteristics.

The bubble size determines the specific interfacial area (a), and further determines the overall mass transfer coefficient (K_La). The bubble size was measured by photography. As shown in Fig. S1, the bubble sizes at the aeration rate of 100L/h, 75L/h, 50L/h were approximately the same, at an average diameter of 2mm.

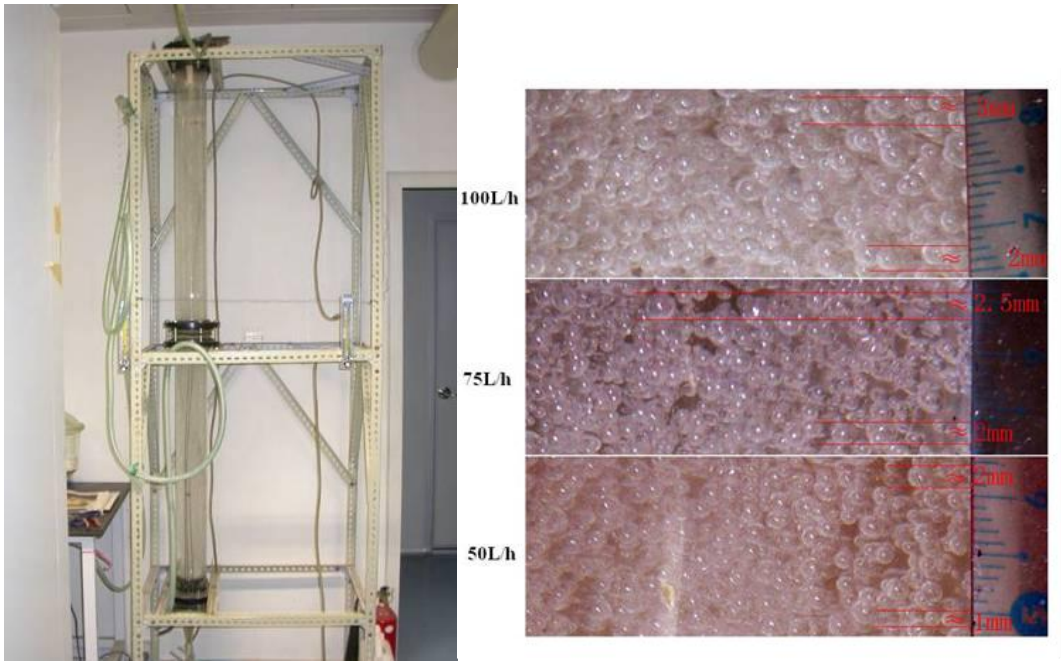


Fig. S1. Photographs of bubble sizes at different aeration rates

Text S3. The details of integration process of Equation 16

The equation of mass conservation of a CSTR is:

$$Q_{\mathrm{L}}C_{\mathrm{L},0}+Q_{\mathrm{G}}C_{\mathrm{G,in}}+Vr = Q_{\mathrm{L}}C_{\mathrm{L,out}}+Q_{\mathrm{G}}C_{\mathrm{G,out}}+V\frac{dC_{\mathrm{L,out}}}{dt} \quad \text{(Eq. S1)}$$

The initial conditions of the continuous flow stripping process are: $C_L=C_0$ when $t=0$; $C_L=C$ when $t>0$; $r=0$ and $C_{\mathrm{G,out}}=GC$ when $C_{\mathrm{G,in}}=0$.

With the initial conditions, equation A1 is simplified as:

$$Q_{\mathrm{L}}C_0 = Q_{\mathrm{L}}C+Q_{\mathrm{G}}GC+V\frac{dC}{dt} \quad \text{(Eq. S2)}$$

Since $Q_{\mathrm{G}}=q\ Q_{\mathrm{L}}$, $V=\Theta Q_{\mathrm{L}}$, then:

$$C_0 = C+GqC+\theta\frac{dC}{dt} \quad \text{(Eq. S3)}$$

$$\theta\frac{dC}{dt} = C_0 - (1+Gq)C \quad \text{(Eq. S4)}$$

$$\frac{\theta}{(1+Gq)}\frac{dC}{dt} = \frac{C_0}{(1+Gq)} - C \quad \text{(Eq. S5)}$$

$$\frac{1}{\frac{C_0}{(1+Gq)} - C}dC = \frac{(1+Gq)}{\theta}dt \quad \text{(Eq. S6)}$$

Integrate equation Eq. S6 with the initial condition of $t=0$, $C = C_0$:

$$\int_{C_0}^{C}\frac{1}{\frac{C_0}{(1+Gq)} - C}dC = \int_0^t\frac{(1+Gq)}{\theta}dt \quad \text{(Eq. S7)}$$

$$-ln\left[\frac{C_0}{(1+Gq)} - C\right] + ln\left[\frac{C_0}{(1+Gq)} - C_0\right] = \frac{(1+Gq)}{\theta}t \quad \text{(Eq. S8)}$$

$$-ln\left[\frac{C_0-(1+Gq)\ C}{C_0-(1+Gq)\ C_0}\right] = \frac{(1+Gq)}{\theta}t \quad \text{(Eq. S9)}$$

$$\frac{C_0-(1+Gq)\ C}{-GqC_0} = e^{-\frac{(1+Gq)}{\theta}t} \quad \text{(Eq. S10)}$$

$$C=C_0\frac{1}{1+Gq}[1+Gqe^{-(1+Gq)\frac{t}{\Theta}}] \quad \text{(Eq. S11)}$$

The integrated process of Equation 16 is demonstrated above.

Text S4. Prediction of the equilibrium height h* of VOCs

The overall mass transfer coefficients $K_La_{(20)}$ for bromodichloromethane, trichloroethylene, tetrachloroethylene, benzene, and toluene were experimentally determined at an aeration flow rate of 50 L/h, yielding values of 0.365 ± 0.016 min^{-1}, 0.752 ± 0.073 min^{-1}, 1.250 ± 0.090 min^{-1}, 0.681 ± 0.013 min^{-1}, and 0.823 ± 0.082 min^{-1}, respectively. Based on these data, the corresponding values of $K_LaV_L/(HQ_G)$ were calculated for a liquid depth of 130 cm and an airflow rate of 50 L/h, giving 14.84, 7.42, 7.21, 11.00, and 12.10, respectively. Using these $K_LaV_L/(HQ_G)$ values, a plot of gas saturation degree versus column height was constructed and is presented in Fig. S2.

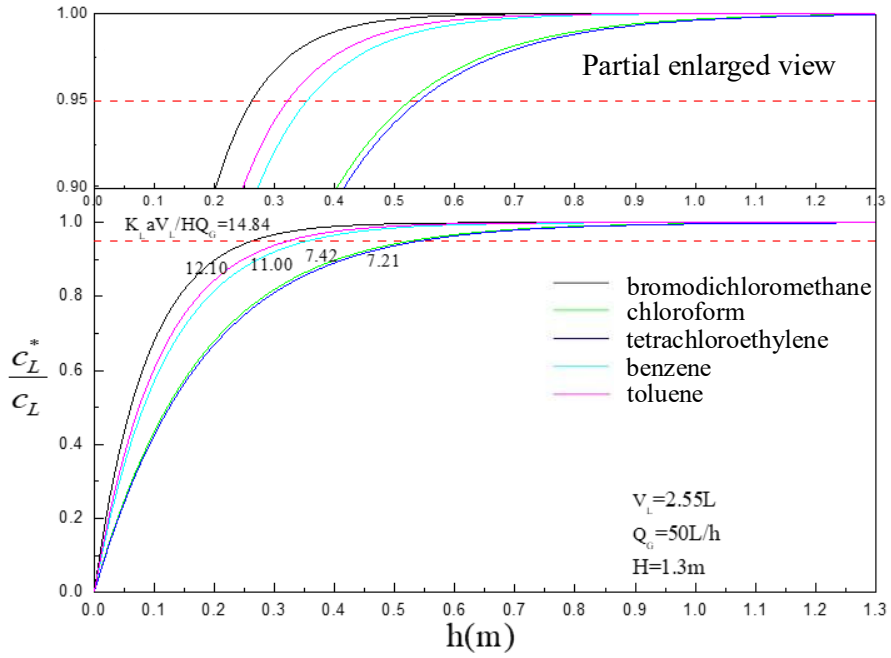


Fig. S2 The relationship between the saturation of VOCs concentration in bubbles and the height of the aeration column when h=130cm and Q_G=50L/h

From Fig. S2, it can be seen that by applying the experimentally measured K_La values to the batch stripping steady-state model, the phase-equilibrium heights for the five compounds can be predicted. Assuming that $c_L^*/c_L \approx 0.95$ indicates that the outlet gas is essentially saturated, the predicted equilibrium heights at 50 L/h for bromodichloromethane, trichloroethylene, tetrachloroethylene, benzene, and toluene were approximately 26, 52, 54, 35, and 32 cm, respectively. For comparison, the equilibrium heights determined experimentally were approximately 30–50, 40–50, 40–50, 30–40, and 30–40 cm, respectively. Although the values obtained by the two approaches differ to some extent, the discrepancies are not large and are considered acceptable for engineering applications. This implies that the phase equilibrium height *h* can be estimated solely from the experimentally determined overall mass transfer

coefficient K_La, thereby providing preliminary technical parameters for emergency response and guiding field operations.

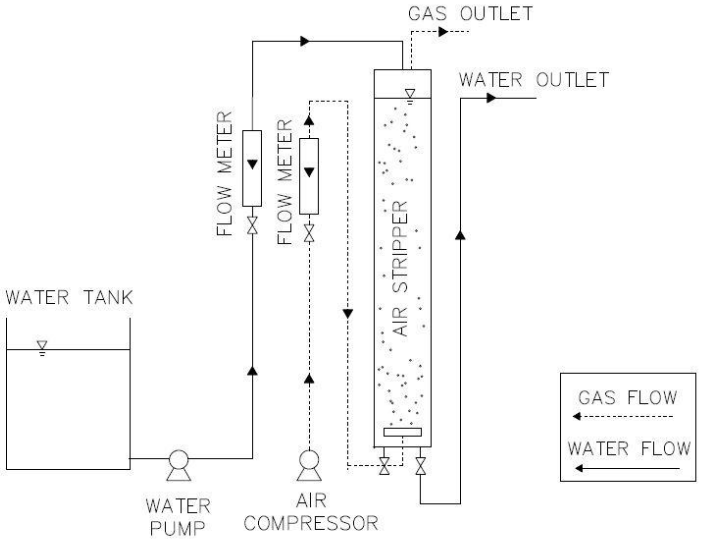


Fig. S3. Schematic diagram of aeration stripping system