APPENDIX A:

CHEMICAL VOLATILIZATION DATABASE

Equations to Solve Mass Transfer Parameters in Database

General Equations Applied to All Applicable Sources:

Chemical Stripping Efficiency = $$\eta = \left(1 - \frac{C_l}{C_{l,in}}\right) \times 100\%$$

Variables		Units
C_l =	chemical concentration in liquid phase out of system	mg/L
$C_{l,in}$ =	chemical concentration in liquid phase entering system	mg/L

Mass Closure Estimate = $$\%\ \text{mass recoverd} = \frac{V_l C_{l,2} + V_g C_{g,2} + Q_g \int_{t_1}^{t_2} C_g dt}{V_l C_{l,1} + V_g C_{g,1}}$$

Variables		Units
V_l =	liquid volume	L
$C_{l,1}$ =	chemical concentration in liquid phase at time 1	mg/L
$C_{l,2}$ =	chemical concentration in liquid phase at time 2	mg/L
V_g =	headspace volume	L
$C_{g,1}$ =	chemical concentration in gas phase at time 1	mg/L
$C_{g,2}$ =	chemical concentration in gas phase at time 2	mg/L
Q_g =	ventilation rate of system	L/min
t_1 =	time 1	min
t_2 =	time 2	min

k_g/k_l Matrix Method

K_LA_j \ K_LA_i	Chemical 1	Chemical 2	Chemical 3	Chemical 4	Chemical n
Chemical 1	1				
Chemical 2		1			
Chemical 3			1		
Chemical 4				1	
Chemical n					1

Variables		Units
K_LA_i =	overall mass transfer value for chemical "i"	L/min
K_LA_j =	overall mass transfer value for chemical "j"	L/min
Ψ_l =	$(D_{li}/D_{lj})^{n1}$	
D_{li} =	liquid-phase diffusion coefficient for chemical "i"	cm^2/sec
D_{lj} =	liquid-phase diffusion coefficient for chemical "j"	cm^2/sec
n_{1} =	liquid-phase power constant	
Ψ_g =	$(D_{gi}/D_{gj})^{n2}$	
D_{gi} =	gas-phase diffusion coefficient for chemical "i"	cm^2/sec
D_{gj} =	gas-phase diffusion coefficient for chemical "j"	cm^2/sec
n_{1} =	liquid-phase power constant	
H_{ci} =	Henry's law constant for chemical "i"	m^3_{liq}/m^3_{gas}
H_{cj} =	Henry's law constant for chemical "j"	m^3_{liq}/m^3_{gas}
k_{gj}/k_{lj} =	ratio of liquid- and gas-phase mass transfer coefficients for chemical "j"	

Three n x n matrices were filled with the following values:

Matrix 1: Ratio of measured K_LA_j/K_LA_i values for all chemicals and single experimental condition

Matrix 2: Ratio of predicted K_LA_j/K_LA_i values for all chemicals using an assumed k_g/k_l value in the following equation:

$$\frac{K_L A_i}{K_L A_j} = \Psi_l \Psi_g \left\{\frac{H_{ci}}{H_{cj}}\right\} \left\{\frac{1 + \left[\frac{k_{gj}}{k_{lj}}\right] H_{cj}}{\Psi_l + \Psi_g H_{ci} \left[\frac{k_{gj}}{k_{lj}}\right]}\right\}$$

Matrix 3: Normalized residual between values in corresponding cells of Matrix 1 and Matrix 2.
Each column and row of this matrix was added to find the total residual to be minimized.
The value of k_g/k_l used to predict K_LA values in Matrix 2 was used to minimize total residual. Minimum residual value corresponded to "best" k_g/k_l value.

Use k_g/k_l value and $$\frac{1}{K_L A} = \frac{1}{k_L A} + \frac{1}{k_g A \bullet H_c}$$ to solve for liquid-phase mass transfer coefficient (k_lA) and gas-phase mass transfer coefficient (k_gA)

Solution Methods for Values of K_LA Referenced in Database

Method #

1 **Applicable Sources:** Shower, Flow-through Bathtub

Model Equation: $$C_{l,out} = C_{l,in}\exp\left(-\frac{K_L A}{Q_l}\right) + \left(\frac{C_g}{H_c}\right)\left(1-\exp\left(-\frac{K_L A}{Q_l}\right)\right)$$

Predicts $C_{l,out}$

Variables		Units
$C_{l,out}$ =	chemical concentration in liquid-phase exiting system	mg/L
$C_{l,in}$ =	chemical concentration in liquid-phase entering system	mg/L
K_LA =	overall mass transfer coefficient multiplied by interfacial area	L/min
Q_l =	system liquid flowrate	L/min
C_g =	chemical concentration in gas-phase of system at time t	mg/L
H_c =	Henry' law coefficient of chemical	(L_{liq}/L_{gas})

Solution Technique: Solve for K_LA by minimizing normalized residual between measured $C_{l,out}$ and predicted $C_{l,out}$: $$\left[\frac{\left(C_{l,out,measured} - C_{l,out,predicted}\right)}{C_{l,out,measured}}\right]^2$$

2 **Applicable Sources:** Shower, Flow-through Bathtub

Model Equation: $$C_g = \frac{a}{b} + \left(C_{g,in} - \frac{a}{b}\right)\exp(-bt)$$

Predicts C_g

where: $$a = \frac{\left(Q_l C_{l,in}\left(1-\exp\left(-\frac{K_L A}{Q_l}\right)\right) + Q_g C_{g,il}\right)}{V_g}$$

$$b = \frac{\left(\frac{Q_l}{H_c}\right)\left[\left(1-\exp\left(-\frac{K_L A}{Q_l}\right)\right) + Q_g\right]}{V_g}$$

Variables		Units
C_g =	chemical concentration in gas-phase	mg/L
$C_{g,in}$ =	chemical concentration in gas-phase at start of experiment	mg/L
Q_l =	system liquid flowrate	L/min
$C_{l,in}$ =	chemical concentration in liquid-phase entering system	mg/L
K_LA =	overall mass transfer coefficient multiplied by interfacial area	L/min
Q_g =	system ventilation rate	L/min
V_g =	headspace volume	L
H_c =	Henry's law constant of chemical	(L_{liq}/L_{gas})

Solution Technique: Solve for K_LA by minimizing normalized residual between measured C_g and predicted C_g: $$\left[\frac{\left(C_{g,measured} - C_{g,predicted}\right)}{C_{g,measured}}\right]^2$$

3 **Applicable Sources:** Washing Machine Fill Cycle, Filling Bathtub

Model Equations:

Predicts C_l and C_g

Discretized Equations:

$$C_l^{n+1} = \left[\frac{Q_l C_{l,in}}{V_l^n} - \frac{Q_l C_l^n}{V_l^n} - \frac{K_L A C_l^n}{V_l^n} + \frac{K_L A C_g^n}{V_l^n H_c}\right]\Delta t + C_l^n$$

$$C_g^{n+1} = \left[\frac{-Q_g C_g^n}{(V_t - V_l^n)} + \frac{Q_l C_g^n}{(V_t - V_l^n)} + \frac{K_L A C_l^n}{(V_t - V_l^n)} - \frac{K_L A C_g^n}{(V_t - V_l^n) H_c}\right]\Delta t + C_g^n$$

2nd Order Runge-Kutta Technique:

$$C^{n+1} = C^n + \frac{\Delta t}{2}\left\{f(t^n, C^n) + f\left[t^n + \Delta t, C^n + \Delta t f(t^n, C^n)\right]\right\}$$

Variables

		Units
C_l^n =	chemical concentration in liquid phase at time step n	mg/L
C_l^{n+1} =	chemical concentration in liquid phase at time step n+1	mg/L
V_l^n =	liquid volume at time step n	L
V_t =	total volume of system	L
K_LA =	overall mass transfer coefficient multiplied by interfacial area	L/min
Q_l =	system liquid flowrate	L/min
$C_{l,in}$ =	chemical concentration in liquid-phase entering system	mg/L
H_c =	Henry's law constant of chemical	(L_{liq}/L_{gas})
C_g^n =	chemical concentration in gas phase at time step n	mg/L
C_g^{n+1} =	chemical concentraiton in gas phase at time step n-1	mg/L
Q_g =	system ventilation rate	L/min
Δt =	differential time step	min

Solution Technique: Solve for K_LA by minimizing normalized residual between measured C_l^{n+1} or C_g^{n+1} and predicted values at associated time steps.
Note: Liquid-phase concentration equation is dependent on gas-phase concentration

$$\left[\frac{(C_{l,measured} - C_{l,predicted})}{C_{l,measured}}\right]^2$$

4 **Applicable Sources:** Dishwasher, Washing Machine Wash/Rinse Cycle, Handwashing Dishes in Kitchen Sink, Bathing

Model Equation: Predicts C_l

$$C_l = C_{l,0}\left[\exp\left(-\frac{D}{2}t\right)\cosh\left(\left(\sqrt{\frac{D^2}{4} - E}\right)t\right)\right] + \left(\frac{BF}{Z} + \frac{EC_{l,0}}{Z} - \frac{DC_{l,0}}{2}\right)\left[\frac{1}{\left(\sqrt{\frac{D^2}{4} - E}\right)}\exp\left(-\frac{D}{2}t\right)\sinh\left(\left(\sqrt{\frac{D^2}{4} - E}\right)t\right)\right]$$

where:

$$Z = \frac{K_L A}{V_l} \qquad B = \frac{K_L A}{V_l H_c} \qquad X = \frac{K_L A}{V_g}$$

$$Y = \frac{Q_g}{V_g} + \frac{K_L A}{V_g H_c} \qquad D = Z + Y \qquad E = ZY - BX$$

$$F = ZC_{g,0} + XC_{l,0}$$

Variables

		Units
C_l =	chemical concentration in liquid phase	mg/L
$C_{l,0}$ =	initial chemical concentration in liquid phase	mg/L
K_LA =	overall mass transfer coefficient multiplied by interfacial area	L/min
V_l =	system liquid volume	L
H_c =	Henry's law constant of chemical	(L_{liq}/L_{gas})
V_g =	system headspace volume	L
Q_g =	system ventilation rate	L/min
$C_{g,0}$ =	initial chemical concentration in gas phase	mg/L
t =	time	min

Solution Technique: Solve for K_LA by minimizing residual between measured C_l and predicted C_l:

$$\left[\frac{(C_{l,measured} - C_{l,predicted})}{C_{l,measured}}\right]^2$$

5 **Applicable Sources:** Dishwasher, Washing Machine Wash/Rinse Cycle, Handwashing Dishes in Kitchen Sink, Bathing

Model Equation: Predicts C_g

$$C_g = C_{g,0}\exp\left(-\frac{D}{2}t\right)\cosh\left(\left(\sqrt{\frac{D^2}{4}-E}\right)t\right)+\left(F-\frac{DC_{g,0}}{2}\right)\left[\frac{1}{\left(\sqrt{\frac{D^2}{4}-E}\right)}\exp\left(-\frac{D}{2}t\right)\sinh\left(\left(\sqrt{\frac{D^2}{4}-E}\right)t\right)\right]$$

where:

$$Z = \frac{K_L A}{V_l} \qquad B = \frac{K_L A}{V_l H_c} \qquad X = \frac{K_L A}{V_g}$$

$$Y = \frac{Q_g}{V_g}+\frac{K_L A}{V_g H_c} \qquad D = Z + Y \qquad E = ZY - BX$$

$$F = ZC_{g,0} + XC_{l,0}$$

Variables		Units
C_g =	chemical concentration in gas phase	mg/L
$C_{g,0}$ =	initial chemical concentration in gas phase	mg/L
K_LA =	overall mass transfer coefficient multiplied by interfacial area	L/min
V_l =	system liquid volume	L
H_c =	Henry's law constant of chemical	(L_{liq}/L_{gas})
V_g =	system headspace volume	L
Q_g =	system ventilation rate	L/min
$C_{l,0}$ =	initial chemical concentration in liquid phase	mg/L
t =	time	min

Solution Technique: Solve for K_LA by minimizing residual between measured C_g and predicted C_g:

$$\left[\frac{\left(C_{g,measured} - C_{g,predicted}\right)}{C_{g,measured}}\right]^2$$

6 **Applicable Sources:** Kitchen Sink (with recirculating batch reactor experimental design)

Model Equation: Predicts C_l

$$C_l = C_{l,0}\exp(-K_L a t)$$

Variables		Units
C_l =	chemical concentration in liquid phase at time t	mg/L
$C_{l,0}$ =	initial chemical concentration in liquid phase	mg/L
K_La =	overall mass transfer coefficient multiplied by interfacial area/liquid volume	min^{-1}
t =	time	min

Solution Technique: Slope of best curve fit of $\ln(C_l/C_{l,0})$ vs. time equal to K_La

Chemical stripping efficiencies also solved using best fit equation to measured liquid data according to:

$$C_l = C_{l,0}\exp\left(-\frac{t}{\theta_H}\eta\right)$$

168

SHOWER DATABASE

STUDY: Howard and Corsi
Study year: 1997
Solution Methods: Method 1 for acetone, ethyl acetate, toluene, ethylbenzene, cyclohexane
Assumptions: None
Comments: Values of η and K_LA are averages of values determined for three separate time periods within experiment.
Mass closure based on liquid standard curve created using well-dissolved tracer bag.

*** = unable to be determined with available data, n/m = not measured**

Entry # 1

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	coarse		H_c @ 21 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	21	Acetone	0.0010	1.1×10^{-5}	0.11	38	34 - 37	0	0.036	6.3	1.8	13	1986	153	99
Liquid Flowrate (L/min) =	9.1	Ethyl Acetate	0.0042	9.5×10^{-6}	0.092	26	20 - 24	0	0.068	15	2.9	7.3	1111	153	100
Gas Flowrate (L/min) =	370	Toluene	0.24	9.1×10^{-6}	0.085	4.5	1.8	0	0.041	61	8.8	9	1380	153	90
Shower Stall Volume (L) =	1745	Ethylbenzene	0.27	8.4×10^{-6}	0.077	6.1	2.3	0	0.029	62	8.9	9.1	1395	153	77
Person Present =	No	Cyclohexane	6.5	9.0×10^{-6}	0.088	1.8	0.63	0	0.0069	65	9.6	9.6	1468	153	78

2

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	fine		H_c @ 22 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	22	Acetone	0.0011	1.1×10^{-5}	0.11	42	35 - 40	0	0.041	8.4	3.0	16	3519	223	97
Liquid Flowrate (L/min) =	9.1	Ethyl Acetate	0.0044	9.5×10^{-6}	0.092	22	16 - 20	0	0.081	15	4.0	8.1	1807	223	104
Gas Flowrate (L/min) =	343	Toluene	0.25	9.1×10^{-6}	0.085	7.0	2.3	0	0.057	68	11	11	2434	223	82
Shower Stall Volume (L) =	1745	Ethylbenzene	0.27	8.4×10^{-6}	0.077	7.3	2.3	0	0.032	68	11	11	2384	223	66
Person Present =	No	Cyclohexane	6.6	9.0×10^{-6}	0.088	3.3	0.88	0	0.0097	73	12	12	2652	223	68

3

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	coarse		H_c @ 21 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	21	Acetone	0.0010	1.1×10^{-5}	0.11	42	36 - 39	0	0.035	9.1	1.4	8.6	1723	200	98
Liquid Flowrate (L/min) =	6.1	Ethyl Acetate	0.0044	9.5×10^{-6}	0.092	26	19 - 22	0	0.057	20	2.3	5.1	1030	200	98
Gas Flowrate (L/min) =	360	Toluene	0.24	9.1×10^{-6}	0.085	7.0	2.6	0	0.029	63	6.2	6.4	1274	200	82
Shower Stall Volume (L) =	1745	Ethylbenzene	0.26	8.4×10^{-6}	0.077	7.5	2.8	0	0.011	63	6.0	6.2	1234	200	64
Person Present =	No	Cyclohexane	6.3	9.0×10^{-6}	0.088	3.0	1.0	0	0.0079	66	6.5	6.5	1305	200	77

4

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	fine		H_c @ 22 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	22	Acetone	0.0011	1.1×10^{-5}	0.11	43	37 - 41	0	0.037	9.3	1.5	8.8	1720	195	98
Liquid Flowrate (L/min) =	6.1	Ethyl Acetate	0.0044	9.5×10^{-6}	0.092	31	22 - 26	0	0.083	20	2.5	5.3	1031	195	101
Gas Flowrate (L/min) =	360	Toluene	0.25	9.1×10^{-6}	0.085	6.1	2.2	0	0.036	64	6.4	6.5	1275	195	92
Shower Stall Volume (L) =	1745	Ethylbenzene	0.28	8.4×10^{-6}	0.077	5.5	2.0	0	0.018	63	6.2	6.3	1232	195	76
Person Present =	No	Cyclohexane	6.7	9.0×10^{-6}	0.088	2.0	0.67	0	0.0063	66	6.7	6.7	1309	195	85

5

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	coarse		H_c @ 35 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	35	Acetone	0.0022	1.1×10^{-5}	0.11	42	34 - 38	0	0.077	13	2.8	14	1548	111	97
Liquid Flowrate (L/min) =	9.1	Ethyl Acetate	0.0077	9.5×10^{-6}	0.092	24	16 - 19	0	0.13	27	5.5	12	1322	111	102
Gas Flowrate (L/min) =	379	Toluene	0.37	9.1×10^{-6}	0.085	6.4	2.0	0	0.056	68	11	11	1223	111	77
Shower Stall Volume (L) =	1745	Ethylbenzene	0.54	8.4×10^{-6}	0.077	8.0	2.5	0	0.032	68	11	11	1188	111	68
Person Present =	No	Cyclohexane	10	9.0×10^{-6}	0.088	2.6	0.63	0	0.0093	75	13	13	1439	111	66

6

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	fine		H_c @ 34 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	34	Acetone	0.0021	1.1×10^{-5}	0.11	40	34 - 38	0	0.071	11	3.4	16	2095	131	99
Liquid Flowrate (L/min) =	9.1	Ethyl Acetate	0.0074	9.5×10^{-6}	0.092	24	15 - 18	0	0.12	28	6.9	14	1852	131	100
Gas Flowrate (L/min) =	354	Toluene	0.35	9.1×10^{-6}	0.085	5.3	1.3	0	0.053	75	13	14	1776	131	94
Shower Stall Volume (L) =	1745	Ethylbenzene	0.51	8.4×10^{-6}	0.077	4.6	1.1	0	0.031	75	13	13	1708	131	81
Person Present =	No	Cyclohexane	9.6	9.0×10^{-6}	0.088	1.6	0.35	0	0.0054	77	14	14	1786	131	74

7

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	fine		H_c @ 34 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	34	Acetone	0.0021	1.1×10^{-5}	0.11	40	32 - 37	0	0.071	12	3.7	15	2316	153	99
Liquid Flowrate (L/min) =	9.1	Ethyl Acetate	0.0074	9.5×10^{-6}	0.092	25	15 - 19	0	0.13	29	6.7	13	1945	153	102
Gas Flowrate (L/min) =	373	Toluene	0.36	9.1×10^{-6}	0.085	5.2	1.3	0	0.058	74	12	13	1930	153	90
Shower Stall Volume (L) =	1745	Ethylbenzene	0.52	8.4×10^{-6}	0.077	3.8	1.0	0	0.031	74	12	12	1855	153	78
Person Present =	No	Cyclohexane	9.8	9.0×10^{-6}	0.088	0.71	0.17	0	0.0065	77	13	13	1950	153	85

8

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	coarse		H_c @ 36 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	36	Acetone	0.0024	1.1×10^{-5}	0.11	41	32 - 36	0	0.054	16	2.2	11	1169	110	96
Liquid Flowrate (L/min) =	6.1	Ethyl Acetate	0.0080	9.5×10^{-6}	0.092	24	14 - 17	0	0.081	32	3.8	8.2	901	110	99
Gas Flowrate (L/min) =	364	Toluene	0.38	9.1×10^{-6}	0.085	5.6	1.5	0	0.036	74	8.4	8.6	949	110	98
Shower Stall Volume (L) =	1745	Ethylbenzene	0.57	8.4×10^{-6}	0.077	5.3	1.4	0	0.023	73	8.2	8.3	917	110	86
Person Present =	No	Cyclohexane	10	9.0×10^{-6}	0.088	1.9	0.46	0	0.0054	76	8.6	8.6	943	110	77

9

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	fine		H_c @ 35 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	35	Acetone	0.0022	1.1×10^{-5}	0.11	42	33 - 37	0	0.079	14	2.3	9.6	1380	143	102
Liquid Flowrate (L/min) =	6.1	Ethyl Acetate	0.0077	9.5×10^{-6}	0.092	24	14 - 18	0	0.12	33	4.7	9.0	1292	143	108
Gas Flowrate (L/min) =	371	Toluene	0.36	9.1×10^{-6}	0.085	6.0	1.6	0	0.048	73	8.1	8.3	1189	143	88
Shower Stall Volume (L) =	1745	Ethylbenzene	0.53	8.4×10^{-6}	0.077	5.6	1.5	0	0.029	72	7.9	8.0	1139	143	92
Person Present =	No	Cyclohexane	10	9.0×10^{-6}	0.088	1.8	0.43	0	0.0060	75	8.4	8.4	1203	143	81

10

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	fine		H_c @ 34 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	34	Acetone	0.0021	1.1×10^{-5}	0.11	40	32 - 37	0	0.081	15	2.5	11	1507	138	103
Liquid Flowrate (L/min) =	6.1	Ethyl Acetate	0.0074	9.5×10^{-6}	0.092	24	14 - 16	0	0.13	36	5.3	10	1443	138	106
Gas Flowrate (L/min) =	367	Toluene	0.36	9.1×10^{-6}	0.085	5.4	1.3	0	0.047	77	9.2	9.3	1291	138	88
Shower Stall Volume (L) =	1745	Ethylbenzene	0.53	8.4×10^{-6}	0.077	4.5	1.1	0	0.027	75	8.8	8.9	1227	138	75
Person Present =	No	Cyclohexane	9.9	9.0×10^{-6}	0.088	0.84	0.17	0	0.0057	80	9.9	9.9	1366	138	80

STUDY: Keating, McKone, and Gillett
Study year: 1997
Reference: *Atmospheric Environment, Vol. 31, No. 2,* 1997, pp. 123-130.
Solution Methods: Method 1
Assumptions: $C_{g,in} = 0$
Comments: $C_{g,end}$ values picked off graph presented in paper.
$C_{l,out}$ and $C_{l,in}$ were measured in triplicate at 2, 4, and 8 minutes at the drain and shower nozzle, respectively.
Resulting measurements at each sample location, respectively, were not found to be statistically different, so values listed are averages for three sample times.
Results for studies 11, 12, 14 and 16 are based on three different experiments.
Results for studies 13 and 15 are based on two different experiments. (Individual results not given in paper - only averages).
Liquid flowrate value of 3.5 L/min is average of range of values given in paper (3.1 L/min to 3.8 L/min).

*** = unable to be determined with available data, n/m = not measured**

11

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	"spray"		H_c @ 40 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	40	Chloroform	0.37	9.7×10^{-6}	0.10	64	11	0	0.31	83	6.7	*	*	*	52
Liquid Flowrate (L/min) =	3.5	Chloroform	0.37	9.7×10^{-6}	0.10	57	20	0	0.31	65	3.8	*	*	*	74
Gas Flowrate (L/min) =	195														
Shower Stall Volume (L) =	1530														
Person Present =	No														

12

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	"jet"		H_c @ 40 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	40	Chloroform	0.37	9.7×10^{-6}	0.10	56	18	0	0.44	68	4.2	*	*	*	88
Liquid Flowrate (L/min) =	3.5														
Gas Flowrate (L/min) =	195														
Shower Stall Volume (L) =	1530														
Person Present =	No														

13

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	1800 μm		H_c @ 35 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	35	Chloroform	0.29	9.7×10^{-6}	0.10	57	6.4	0	0.58	89	9.1	*	*	*	84
Liquid Flowrate (L/min) =	3.5														
Gas Flowrate (L/min) =	195														
Shower Stall Volume (L) =	1530														
Person Present =	No														

14

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	1800 μm		H_c @ 45 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	45	Chloroform	0.47	9.7×10^{-6}	0.10	59	5.1	0	0.48	91	9.7	*	*	*	67
Liquid Flowrate (L/min) =	3.5														
Gas Flowrate (L/min) =	195														
Shower Stall Volume (L) =	1530														
Person Present =	No														

15

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	300 μm		H_c @ 35 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	35	Chloroform	0.29	9.7×10^{-6}	0.10	60	14	0	0.53	77	5.5	*	*	*	87
Liquid Flowrate (L/min) =	3.5														
Gas Flowrate (L/min) =	195														
Shower Stall Volume (L) =	1530														
Person Present =	No														

16

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	300 μm		H_c @ 45 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	45	Chloroform	0.47	9.7×10^{-6}	0.10	51	10	0	0.54	80	6.0	*	*	*	95
Liquid Flowrate (L/min) =	3.5														
Gas Flowrate (L/min) =	195														
Shower Stall Volume (L) =	1530														
Person Present =	No														

STUDY: Giardino and Andelman
Study year: 1996
Reference: *Journal of Exposure Analysis and Environmental Epidemiology , Vol. 6, No. 4* , 1996, pp. 413-423
Solution Method: Method 1
Assumptions: $C_{g,in}$ = 0.
No $C_{l,out}$ values were reported, assumed it equal to (1-η) x $C_{l,in}$, where η is given in paper.
$C_{l,out}$ remained relatively constant for entire experiment.
Comments: $C_{l,in}$ is reported average value for ten-minute experiment. Thus, η is an average value for ten-minute period.
*** = unable to be determined with available data, n/m = not measured**

17

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 27 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	23	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	27	Trichloroethene	0.46	9.4×10^{-6}	0.084	0.49	0.160	0	0.020	67	6.3	*	*	*	121
Liquid Flowrate (L/min) =	5.0														
Gas Flowrate (L/min) =	88														
Shower Volume (L) =	1500														
Person Present =	No														

18

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 22 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	22	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	22	Trichloroethene	0.35	9.4×10^{-6}	0.084	0.96	0.380	0	0.014	60	5.0	*	*	*	99
Liquid Flowrate (L/min) =	5.1														
Gas Flowrate (L/min) =	270														
Shower Volume (L) =	1500														
Person Present =	No														

19

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 21 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	21	Trichloroethene	0.33	9.4×10^{-6}	0.084	0.49	0.210	0	0.043	57	12	*	*	*	125
Liquid Flowrate (L/min) =	9.9														
Gas Flowrate (L/min) =	28														
Shower Volume (L) =	1500														
Person Present =	No														

20

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 19 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	19	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	19	Trichloroethene	0.30	9.4×10^{-6}	0.084	0.42	0.180	0	0.0015	57	9.6	*	*	*	112
Liquid Flowrate (L/min) =	10														
Gas Flowrate (L/min) =	240														
Shower Volume (L) =	1500														
Person Present =	No														

21

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 46 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	19	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	46	Trichloroethene	1.1	9.4×10^{-6}	0.084	0.92	0.180	0	0.042	81	8.9	*	*	*	129
Liquid Flowrate (L/min) =	5.0														
Gas Flowrate (L/min) =	83														
Shower Volume (L) =	1500														
Person Present =	No														

22

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 44 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	19	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	44	Trichloroethene	1.0	9.4×10^{-6}	0.084	0.59	0.110	0	0.014	81	8.5	*	*	*	119
Liquid Flowrate (L/min) =	5.0														
Gas Flowrate (L/min) =	270														
Shower Volume (L) =	1500														
Person Present =	No														

23

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 33 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	19	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	33	Trichloroethene	0.62	9.4×10^{-6}	0.084	0.52	0.130	0	0.055	74	20	*	*	*	124
Liquid Flowrate (L/min) =	10														
Gas Flowrate (L/min) =	28														
Shower Volume (L) =	1500														
Person Present =	No														

24

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 32 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	19	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	32	Trichloroethene	0.59	9.4×10^{-6}	0.084	0.88	0.30	0	0.033	66	12	*	*	*	107
Liquid Flowrate (L/min) =	9.9														
Gas Flowrate (L/min) =	225														
Shower Volume (L) =	1500														
Person Present =	No														

25

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 25 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	19	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	25	Trichloroethene	0.41	9.4×10^{-6}	0.084	0.79	0.330	0	0.058	59	12	*	*	*	112
Liquid Flowrate (L/min) =	9.9														
Gas Flowrate (L/min) =	33														
Shower Volume (L) =	1500														
Person Present =	No														

26

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 26 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	11	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	26	Chloroform	0.18	9.7×10^{-6}	0.10	0.63	0.360	0	0.011	44	3.2	*	*	*	116
Liquid Flowrate (L/min) =	5.0														
Gas Flowrate (L/min) =	70														
Shower Volume (L) =	1500														
Person Present =	No														

27

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 42 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	11	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	42	Chloroform	0.35	9.7×10^{-6}	0.10	0.58	0.220	0	0.016	62	5.3	*	*	*	131
Liquid Flowrate (L/min) =	5.0														
Gas Flowrate (L/min) =	65														
Shower Volume (L) =	1500														
Person Present =	No														

28

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 27 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	11	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	27	Chloroform	0.19	9.7×10^{-6}	0.10	0.56	0.27	0	0.0077	52	4.0	*	*	*	117
Liquid Flowrate (L/min) =	5.0														
Gas Flowrate (L/min) =	228														
Shower Volume (L) =	1500														
Person Present =	No														

29

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 28 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	11	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	28	Chloroform	0.20	9.7×10^{-6}	0.10	0.68	0.370	0	0.0025	46	7.9	*	*	*	109
Liquid Flowrate (L/min) =	10														
Gas Flowrate (L/min) =	25														
Shower Volume (L) =	1500														
Person Present =	No														

30

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 29 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	11	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	29	Chloroform	0.20	9.7×10^{-6}	0.10	1.1	0.570	0	0.0020	49	3.7	*	*	*	113
Liquid Flowrate (L/min) =	5.0														
Gas Flowrate (L/min) =	75														
Shower Volume (L) =	1500														
Person Present =	No														

31

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 27 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	27	1,2-Dibromo-	0.01	7.6×10^{-6}	0.056	1.7	1.5	0	n/m	10	0.84	*	*	*	*
Liquid Flowrate (L/min) =	5.0	3-chloropropane													
Gas Flowrate (L/min) =	55														
Shower Volume (L) =	1500														
Person Present =	No														

32

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 51 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	14	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	51	1,2-Dibromo-	0.05	7.6×10^{-6}	0.056	1.6	1.1	0	n/m	31	2.7	*	*	*	*
Liquid Flowrate (L/min) =	5.0	3-chloropropane													
Gas Flowrate (L/min) =	58														
Shower Volume (L) =	1500														
Person Present =	No														

33

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 30 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	14	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	30	1,2-Dibromo-	0.01	7.6×10^{-6}	0.056	1.6	1.3	0	n/m	17	1.2	*	*	*	*
Liquid Flowrate (L/min) =	5.0	3-chloropropane													
Gas Flowrate (L/min) =	308														
Shower Volume (L) =	1500														
Person Present =	No														

34

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 42 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	12	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	42	1,2-Dibromo-	0.03	7.6×10^{-6}	0.056	1.7	1.3	0	n/m	20	1.6	*	*	*	*
Liquid Flowrate (L/min) =	5.0	3-chloropropane													
Gas Flowrate (L/min) =	53														
Shower Volume (L) =	1500														
Person Present =	No														

35

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 29 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	11	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	29	1,2-Dibromo-	0.012	7.6×10^{-6}	0.056	1.5	1.4	0	n/m	5.5	5.5	*	*	*	*
Liquid Flowrate (L/min) =	10	3-chloropropane													
Gas Flowrate (L/min) =	28														
Shower Volume (L) =	1500														
Person Present =	No														

36

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 32 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	11	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	32	1,2-Dibromo-	0.015	7.6×10^{-6}	0.056	2.8	2.4	0	n/m	13	0.97	*	*	*	*
Liquid Flowrate (L/min) =	5.0	3-chloropropane													
Gas Flowrate (L/min) =	88														
Shower Volume (L) =	1500														
Person Present =	No														

STUDY: Giardino and Hageman
Study year: 1996
Reference: *Environmental Science & Technology, Vol. 30,No. 4,* 1996, pp.1242-1244.
Solution Method: Method 1
Assumptions: No $C_{l,out}$ values were reported, assumed it equal to (1-η) x $C_{l,in}$, where η is given in paper.
Comments: The reported value of η is an average value based on pairs of influent and effluent liquid samples taken during experiment.

Liquid-phase diffusion coefficient estimated using relationship $\frac{D_{l,Rn}}{D_{l,toluene}} = \left(\frac{MW_{toluene}}{MW_{Rn}}\right)^{0.5}$

*** = unable to be determined with available data, n/m = not measured**

37

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 22 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	22	Radon	4.4	5.2×10^{-6}	*	1.1×10^{4}	3.6×10^{3}	0	48	67	4.5	*	*	*	51
Liquid Flowrate (L/min) =	4.0														
Gas Flowrate (L/min) =	32														
Shower Volume (L) =	1510														
Person Present =	No														

38

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 22 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	22	Radon	4.4	5.2×10^{-6}	*	3.7×10^{4}	1.1×10^{3}	0	17	70	4.9	*	*	*	49
Liquid Flowrate (L/min) =	4.0														
Gas Flowrate (L/min) =	36														
Shower Volume (L) =	1510														
Person Present =	No														

39

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 22 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	22	Radon	4.4	5.2×10^{-6}	*	2.1×10^{4}	8.3×10^{2}	0	3.6	61	1.9	*	*	*	53
Liquid Flowrate (L/min) =	2.0														
Gas Flowrate (L/min) =	37														
Shower Volume (L) =	1510														
Person Present =	No														

40

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 22 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	22	Radon	4.4	5.2×10^{-6}	*	3.1×10^{4}	1.1×10^{3}	0	9.5	64	2.0	*	*	*	62
Liquid Flowrate (L/min) =	2.0														
Gas Flowrate (L/min) =	39														
Shower Volume (L) =	1510														
Person Present =	No														

STUDY: Bernhardt and Hess
Study year: 1995
Reference: Bernhardt's Master's Thesis for The University of Maine
Solution Method: Method 1
Assumptions: Shower stall and bathroom volumes were not given, so assumed a typical bathroom volume of 10000 L.
Shower curtain open for all experiments, thus used bathroom volume for V_g.
$Q_g = 0$
$C_{g,in} = 0$
Exact water temperature not given, so assumed T = 23 C for "cold" water.
Comments: Liquid-phase diffusion coefficient estimated using relationship given for Giardino and Hageman (1996)
*** = unable to be determined with available data, n/m = not measured**

41

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	18	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Radon	4.4	5.2×10^{-6}	*	5.3×10^4	1.5×10^4	0	90	71	2.5	*	*	*	76
Liquid Flowrate (L/min) =	2.0														
Gas Flowrate (L/min) =	0														
Bathroom Volume (L) =	10000														
Person Present =	No														

42

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Radon	4.4	5.2×10^{-6}	*	4.9×10^4	5.7×10^3	0	110	88	6.4	*	*	*	87
Liquid Flowrate (L/min) =	3.0														
Gas Flowrate (L/min) =	0														
Bathroom Volume (L) =	10000														
Person Present =	No														

43

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Radon	4.35	5.2×10^{-6}	*	4.1×10^4	9.0×10^3	0	300	78	8.3	*	*	*	156
Liquid Flowrate (L/min) =	5.5														
Gas Flowrate (L/min) =	0														
Bathroom Volume (L) =	10000														
Person Present =	No														

44

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	13	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Radon	4.35	5.2×10^{-6}	*	860	280	0	3.8	67	4.2	*	*	*	122
Liquid Flowrate (L/min) =	3.8														
Gas Flowrate (L/min) =	0														
Bathroom Volume (L) =	10000														
Person Present =	No														

45

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	12	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Radon	4.35	5.2×10^{-6}	*	1.0×10^3	290	0	3.5	71	4.0	*	*	*	119
Liquid Flowrate (L/min) =	3.2														
Gas Flowrate (L/min) =	0														
Bathroom Volume (L) =	10000														
Person Present =	No														

46

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	9	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Radon	4.35	5.2×10^{-6}	*	860	110	0	3.0	87	6.7	*	*	*	132
Liquid Flowrate (L/min) =	3.2														
Gas Flowrate (L/min) =	0														
Bathroom Volume (L) =	10000														
Person Present =	No														

47

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	11	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Radon	4.35	5.2×10^{-6}	*	750	200	0	3.1	73	4.3	*	*	*	142
Liquid Flowrate (L/min) =	3.2														
Gas Flowrate (L/min) =	0														
Bathroom Volume (L) =	10000														
Person Present =	No														

48

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	13	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Radon	4.35	5.2×10^{-6}	*	840	350	0	7.8	58	5.2	*	*	*	161
Liquid Flowrate (L/min) =	6.0														
Gas Flowrate (L/min) =	0														
Bathroom Volume (L) =	10000														
Person Present =	No														

49

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Radon	4.35	5.2×10^{-6}	*	1.4×10^3	590	0	9.0	58	5.1	*	*	*	150
Liquid Flowrate (L/min) =	6.0														
Gas Flowrate (L/min) =	0														
Bathroom Volume (L) =	10000														
Person Present =	No														

50

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	11	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Radon	4.35	5.2×10^{-6}	*	1.4×10^{3}	300	0	8.4	78	8.6	*	*	*	122
Liquid Flowrate (L/min) =	5.7														
Gas Flowrate (L/min) =	0														
Bathroom Volume (L) =	10000														
Person Present =	No														

51

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Radon	4.35	5.2×10^{-6}	*	1.3×10^{3}	380	0	13	71	4.9	*	*	*	279
Liquid Flowrate (L/min) =	4.0														
Gas Flowrate (L/min) =	0														
Bathroom Volume (L) =	10000														
Person Present =	No														

STUDY: Hopke *et al.*
Study year: 1994
Reference: In Morawska *et al. Indoor Air: An Integrated Approach,* Elsevier Science Ltd., 1995, pp. 107 - 110.
Solution Method: N/A
Assumptions: $C_{g,in} = 0$
Comments: Liquid-phase diffusion coefficient estimated using relationship given for Giardino and Hageman (1996)
CPM = counts per minute measured with a liquid scintilation counter.
Not enough information given to calculate K_LA or mass closure.

*** = unable to be determined with available data, n/m = not measured**

52

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 32 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	15	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	32	Radon	4.4	5.2×10^{-6}	*	260	80	0	n/m	69	*	*	*	*	*
Liquid Flowrate (L/min) =	not given														
Gas Flowrate (L/min) =	5														
Shower Volume (L) =	1765														
Person Present =	No														

53

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 21 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	15	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	21	Radon	4.4	5.2×10^{-6}	*	130	37	0	n/m	71	*	*	*	*	*
Liquid Flowrate (L/min) =	not given														
Gas Flowrate (L/min) =	20	Radon	4.4	5.2×10^{-6}	*	280	99	0	n/m	65	*	*	*	*	*
Shower Volume (L) =	1765														
Person Present =	No														

STUDY: Keating and McKone
Study year: 1993
Reference: *Modeling of Indoor Air Quality and Exposure, ASTM STP 1205* , 1993, pp. 14-24
Solution Method: Method 1
Assumptions: $C_{g,in} = 0$
Comments: $C_{g,end}$ values visually picked off graph in paper.
Values for each nozzle represent average of three simulations.
*** = unable to be determined with available data, n/m = not measured**

54

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	1500 μm		H_c @ 45 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	45	Trichloroethene	0.86	9.4×10^{-6}	0.084	0.21	0.030	0	0.0050	86	8.8	*	*	*	109
Liquid Flowrate (L/min) =	4.2														
Gas Flowrate (L/min) =	65														
Shower Stall Volume (L) =	1050														
Person Present =	No														

55

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	300 μm		H_c @ 45 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	45	Trichloroethene	0.86	9.4×10^{-6}	0.084	0.22	0.0063	0	0.0037	97	14	*	*	*	86
Liquid Flowrate (L/min) =	2.8														
Gas Flowrate (L/min) =	65														
Shower Stall Volume (L) =	1050														
Person Present =	No														

56

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	1000 μm		H_c @ 45 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	5	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	45	Trichloroethene	0.86	9.4×10^{-6}	0.084	0.21	0.22	0	0.0032	72	15	*	*	*	72
Liquid Flowrate (L/min) =	6.0														
Gas Flowrate (L/min) =	65														
Shower Stall Volume (L) =	1050														
Person Present =	No														

STUDY: Giardino, Esmen, and Andelman
Study year: 1992
Reference: *Environmental Science and Technology, Vol. 26* , 1992, pp.1602-1606
Solution Method: N/A
Assumptions: No $C_{l,out}$ values were reported, assumed it equal to (1-η) x $C_{l,in}$, where η is given in paper.
Comments: Shower had a vertical spray with no water impacting stall walls.
Not enough information given in the paper to calculate K_LA values or mass closure
Gas-phase concentration reported is average value for entire experiment.
*** = unable to be determined with available data, n/m = not measured**

57

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	standard		H_c @ 22 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	not given	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	22	Trichloroethene	0.37	9.4×10^{-6}	0.084	0.46	0.15	0	0.025	67	*	*	*	*	*
Liquid Flowrate (L/min) =	5														
Gas Flowrate (L/min) =	70														
Shower Stall Volume (L) =	not given														
Person Present =	No														

58

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	standard		H_c @ 21 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	not given	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	21	Trichloroethene	0.36	9.4×10^{-6}	0.084	0.78	0.32	0	0.080	59	*	*	*	*	*
Liquid Flowrate (L/min) =	10														
Gas Flowrate (L/min) =	26														
Shower Stall Volume (L) =	not given														
Person Present =	No														

STUDY: Tancrede, Yanagisawa, and Wilson
Study year: 1992
Reference: *Atmospheric Environment, Vol. 26A, No. 6* , 1992, pp. 1103-1111
Solution Method: Method 1
Assumptions: $C_{g,in}$ = 0
Comments: $C_{l,in}$ is average of showerhead liquid samples collected at 2, 6 and 11 minutes.
$C_{l,out}$ is average of drain liquid samples collected at 8 and 12 minutes.
One C_g sample was collected at 10 minutes at nose level in the shower stall.
*** = unable to be determined with available data, n/m = not measured**

59

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 25 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	25	CCl_4	1.2	9.2×10^{-6}	0.072	8.2×10^{-5}	5.0×10^{-5}	0	1.4×10^{-6}	39	7.0	7.2	205	29	82
Liquid Flowrate (L/min) =	13.6	PCE	0.74	8.5×10^{-6}	0.077	1.1×10^{-4}	4.9×10^{-5}	0	2.7×10^{-5}	56	12	13	365	29	345
Gas Flowrate (L/min) =	34.8	Trichloroethene	0.42	9.4×10^{-6}	0.084	0.0016	6.8×10^{-4}	0	4.9×10^{-5}	58	14	16	446	29	80
Shower Stall Volume (L) =	1491	Chloroform	0.17	9.7×10^{-6}	0.10	0.0026	0.0015	0	7.8×10^{-5}	42	11	13	372	29	94
Person Present =	No	TCPA	0.012	7.9×10^{-6}	0.073	0.092	0.073	0	3.9×10^{-4}	21	2.5	9.8	281	29	85

60

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 33 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	33	CCl_4	1.7	9.2×10^{-6}	0.072	1.0×10^{-4}	2.5×10^{-5}	0	4.6×10^{-6}	76	21	22	412	19	78
Liquid Flowrate (L/min) =	13.5	PCE	1.1	8.5×10^{-6}	0.077	2.6×10^{-4}	8.6×10^{-5}	0	8.3×10^{-6}	67	17	17	329	19	72
Gas Flowrate (L/min) =	34.8	Trichloroethene	0.57	9.4×10^{-6}	0.084	0.0031	0.0012	0	1.2×10^{-4}	61	15	17	314	19	85
Shower Stall Volume (L) =	1491	Chloroform	0.26	9.7×10^{-6}	0.10	0.0015	7.0×10^{-4}	0	5.0×10^{-5}	53	14	17	325	19	88
Person Present =	No	TCPA	0.013	7.9×10^{-6}	0.073	0.090	0.071	0	6.6×10^{-4}	21	2.7	17	325	19	88

61

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 42 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	42	CCl_4	2.3	9.2×10^{-6}	0.072	9.4×10^{-5}	2.2×10^{-5}	0	4.3×10^{-6}	77	21	21	371	17	80
Liquid Flowrate (L/min) =	13.4	PCE	1.6	8.5×10^{-6}	0.077	2.4×10^{-4}	7.8×10^{-5}	0	7.8×10^{-6}	68	16	17	293	17	73
Gas Flowrate (L/min) =	34.8	Trichloroethene	0.78	9.4×10^{-6}	0.084	0.0028	0.0010	0	1.3×10^{-4}	64	16	17	295	17	93
Shower Stall Volume (L) =	1491	Chloroform	0.41	9.7×10^{-6}	0.10	0.0014	6.7×10^{-4}	0	5.6×10^{-5}	52	12	14	236	17	97
Person Present =	No	TCPA	0.017	7.9×10^{-6}	0.073	0.089	0.073	0	0.0010	18	3.7	16	282	17	96

62

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 43 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	43	CCl_4	2.4	9.2×10^{-6}	0.072	8.1×10^{-5}	3.3×10^{-5}	0	2.0×10^{-6}	59	8.9	9.0	329	36	83
Liquid Flowrate (L/min) =	9.7	PCE	1.6	8.5×10^{-6}	0.077	1.3×10^{-4}	4.0×10^{-5}	0	3.2×10^{-6}	69	12	12	445	36	73
Gas Flowrate (L/min) =	34.8	Trichloroethene	0.79	9.4×10^{-6}	0.084	0.0018	5.5×10^{-4}	0	5.5×10^{-5}	69	13	13	483	36	83
Shower Stall Volume (L) =	1491	Chloroform	0.42	9.7×10^{-6}	0.10	0.0025	9.2×10^{-4}	0	7.5×10^{-5}	63	12	12	446	36	88
Person Present =	No	TCPA	0.017	7.9×10^{-6}	0.073	0.082	0.058	0	8.0×10^{-4}	29	4.0	10	377	36	87

STUDY: Giardino and Andelman
Study year: 1991
Reference: Poster paper for the Annual Conference of the American Water Works Association, 1991
Solution Method: Method 1
Assumptions: $C_{g,in}$ =0
Comments: All values from Little, J.C. (1992), *Environmental Science and Technology*, Vol. 26, No. 7, pp. 1341-1349.
$C_{l,out}$ is an average value based on reported volatilization value.

*** = unable to be determined with available data, n/m = not measured**

63

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 46 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	11	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	46	Trichloroethene	0.89	9.4×10^{-6}	0.084	0.92	0.17	0	not reported in Little	82	9.2	*	*	*	*
Liquid Flowrate (L/min) =	5														
Gas Flowrate (L/min) =	66														
Shower Stall Volume (L) =	1200														
Person Present =	No														

64

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 42 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	11	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	42	Chloroform	0.41	9.7×10^{-6}	0.10	0.58	0.26	0	not reported in Little	55	4.4	*	*	*	*
Liquid Flowrate (L/min) =	5														
Gas Flowrate (L/min) =	52														
Shower Stall Volume (L) =	1200														
Person Present =	No														

65

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 42 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	11	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	42	1,2-Dibromo-	0.050	7.6×10^{-6}	0.056	1.7	1.3	0	not reported in Little	23	1.6	*	*	*	*
Liquid Flowrate (L/min) =	5	3-chloropropane													
Gas Flowrate (L/min) =	42														
Shower Stall Volume (L) =	1200														
Person Present =	No														

STUDY: McKone and Knezovich
Study year: 1991
Reference: *Journal of the Air and Waste Management Association, Vol. 40* , 1991, pp. 282-286
Solution Method: Method 1
Assumptions: $C_{g,in} = 0$
Comments: Studies #66 and #67 based on 4 experiments, respectively.
$C_{l,out}$ predicted based on reported average stripping efficiency in paper.
*** = unable to be determined with available data, n/m = not measured**

66

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 22 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	20	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	22	Trichloroethene	0.37	9.4×10^{-6}	0.084	0.10	0.042	0	n/m	58	8.7	*	*	*	*
Liquid Flowrate (L/min) =	9.5														
Gas Flowrate (L/min) =	460														
Shower Stall Volume (L) =	2300														
Person Present =	No														

67

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 37 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	20	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	37	Trichloroethene	0.65	9.4×10^{-6}	0.084	0.10	0.037	0	n/m	63	9.8	*	*	*	*
Liquid Flowrate (L/min) =	9.5														
Gas Flowrate (L/min) =	460														
Shower Stall Volume (L) =	2300														
Person Present =	No														

STUDY: Jo, Weisel, and Lioy
Study year: 1990
Reference: *Risk Analysis, Vol. 10, No.4* , 1992, pp.581-585
Solution Method: Method 2
Assumptions: $C_{g,in}$ = 0.
Q_g = 0.
Assumed shower air concentration increased linearly such that average gas-phase concentration of entire shower event occurred at the midpoint.
Comments: Experiments were started two minutes after starting water through shower nozzle.
Gas samples are average value of 10 minute sample collection.
*** = unable to be determined with available data, n/m = not measured**

68

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 40 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	40	Chloroform	0.37	9.7×10^{-6}	0.10	0.013	n/m	0	6.9×10^{-5}	*	2.0	*	*	*	*
Liquid Flowrate (L/min) =	8.7	Chloroform	0.37	9.7×10^{-6}	0.10	0.013	n/m	0	5.8×10^{-5}	*	1.6	*	*	*	*
Gas Flowrate (L/min) =	0	Chloroform	0.37	9.7×10^{-6}	0.10	0.020	n/m	0	1.2×10^{-4}	*	2.4	*	*	*	*
Shower Stall Volume (L) =	1666	Chloroform	0.37	9.7×10^{-6}	0.10	0.021	n/m	0	9.09×10^{-5}	*	1.6	*	*	*	*
Person Present =	No	Chloroform	0.37	9.7×10^{-6}	0.10	0.023	n/m	0	9.0×10^{-5}	*	1.4	*	*	*	*
		Chloroform	0.37	9.7×10^{-6}	0.10	0.024	n/m	0	1.2×10^{-4}	*	1.8	*	*	*	*
		Chloroform	0.37	9.7×10^{-6}	0.10	0.024	n/m	0	2.0×10^{-4}	*	3.4	*	*	*	*
		Chloroform	0.37	9.7×10^{-6}	0.10	0.025	n/m	0	1.7×10^{-4}	*	2.8	*	*	*	*
		Chloroform	0.37	9.7×10^{-6}	0.10	0.027	n/m	0	1.7×10^{-4}	*	2.4	*	*	*	*
		Chloroform	0.37	9.7×10^{-6}	0.10	0.028	n/m	0	2.0×10^{-4}	*	2.8	*	*	*	*
		Chloroform	0.37	9.7×10^{-6}	0.10	0.031	n/m	0	2.0×10^{-4}	*	2.5	*	*	*	*
		Chloroform	0.37	9.7×10^{-6}	0.10	0.032	n/m	0	2.3×10^{-4}	*	2.8	*	*	*	*
		Chloroform	0.37	9.7×10^{-6}	0.10	0.040	n/m	0	3.3×10^{-4}	*	3.3	*	*	*	*

69

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 40 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	40	Chloroform	0.37	9.7×10^{-6}	0.10	0.022	n/m	0	1.3×10^{-4}	*	2.2	*	*	*	*
Liquid Flowrate (L/min) =	8.7	Chloroform	0.37	9.7×10^{-6}	0.10	0.023	n/m	0	1.2×10^{-4}	*	1.9	*	*	*	*
Gas Flowrate (L/min) =	0	Chloroform	0.37	9.7×10^{-6}	0.10	0.025	n/m	0	1.3×10^{-4}	*	2.0	*	*	*	*
Shower Stall Volume (L) =	1666	Chloroform	0.37	9.7×10^{-6}	0.10	0.029	n/m	0	2.0×10^{-4}	*	2.6	*	*	*	*
Person Present =	Yes	Chloroform	0.37	9.7×10^{-6}	0.10	0.029	n/m	0	2.3×10^{-4}	*	3.1	*	*	*	*
		Chloroform	0.37	9.7×10^{-6}	0.10	0.036	n/m	0	3.1×10^{-4}	*	3.6	*	*	*	*

STUDY: Giardino, Andelman, Borrazzo, and Davidson
Study year: 1988
Reference: *Journal of the Air Pollution Control Association, Vol. 38, No. 3*, 1988, pp. 278-280
Solution Method: Method 1
Assumptions: $C_{g,in} = 0$
$Q_g = 0$
Comments: $C_{l,out}$ is average value based on volatilization value reported in paper.
*** = unable to be determined with available data, n/m = not measured**

70

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 21 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	17	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	21	SF_6	185	1.02×10^{-5}	*	18	10	0	n/m	44	3.5	*	*	*	*
Liquid Flowrate (L/min) =	6.0	SF_6	185	1.02×10^{-5}	*	8.8	5.6	0	n/m	36	2.7	*	*	*	*
Gas Flowrate (L/min) =	0	SF_6	185	1.02×10^{-5}	*	18	8.5	0	n/m	52	4.4	*	*	*	*
Shower Stall Volume (L) =	1100	SF_6	185	1.02×10^{-5}	*	26	13	0	n/m	51	4.3	*	*	*	*
Person Present =	No	SF_6	185	1.02×10^{-5}	*	24	12	0	n/m	48	3.9	*	*	*	*
		SF_6	185	1.02×10^{-5}	*	15	9.2	0	n/m	39	3.0	*	*	*	*
		SF_6	185	1.02×10^{-5}	*	19	9.4	0	n/m	50	4.2	*	*	*	*
		SF_6	185	1.02×10^{-5}	*	20	11	0	n/m	45	3.6	*	*	*	*

STUDY: Hodgson, Garbesi, Sextro, and Daisey
Study year: 1988
Reference: Lawrence Berkeley Laboratory Report, Contract No. DE-Ac03-76SF00098, 1988
Solution Method: Method 1
Assumptions: Assumed entire bathroom including shower stall was well-mixed, such that only bathroom measurements were used to predict K_LA.
Comments: For Freon-12, used Henry's law constant given in paper, remaining chemical Henry's law constants using Ashworth *et al*. correlations.
*** = unable to be determined with available data, n/m = not measured**

71

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 40 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	40	Freon - 12	32	1.0×10^{-4}	*	0.073	0.010	4.2×10^{-6}	4.3×10^{-5}	86	27	*	*	*	23
Liquid Flowrate (L/min) =	13.7	Freon - 11	6.8	9.0×10^{-6}	0.084	0.011	0.0010	4.0×10^{-6}	1.1×10^{-5}	91	33	34	149	4.4	24
Gas Flowrate (L/min) =	51	PCE	1.4	8.5×10^{-6}	0.077	0.018	0.0032	6.0×10^{-6}	2.5×10^{-5}	82	24	28	122	4.4	38
Bathroom Volume (L) =	10900	TCA	1.2	9.0×10^{-6}	0.080	0.0034	5.0×10^{-4}	1.4×10^{-6}	6.6×10^{-5}	85	27	32	140	4.4	43
Person Present =	No	Trichloroethene	0.73	9.4×10^{-6}	0.084	0.0027	4.0×10^{-4}	0	n/m	85	27	35	154	4.4	*

72

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 40 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	40	Freon - 12	32	1.0×10^{-4}	*	0.094	0.018	6.6×10^{-6}	6.7×10^{-5}	81	23	*	*	*	30
Liquid Flowrate (L/min) =	13.7	Freon - 11	6.8	9.0×10^{-6}	0.084	0.0094	0.0018	4.5×10^{-6}	1.2×10^{-5}	81	23	*	*	*	37
Gas Flowrate (L/min) =	51	PCE	1.4	8.5×10^{-6}	0.077	0.029	0.0042	3.6×10^{-6}	2.2×10^{-5}	86	27	*	*	*	26
Bathroom Volume (L) =	10900	TCA	1.2	9.0×10^{-6}	0.080	0.0031	8.0×10^{-4}	6.6×10^{-6}	9.6×10^{-6}	74	19	*	*	*	57
Person Present =	Yes	Trichloroethene	0.73	9.4×10^{-6}	0.084	0.0030	4.0×10^{-4}	0	n/m	87	28	*	*	*	*

STUDY: Hess *et al.*
Study year: 1982
Reference: *Environment International, Vol. 8* , 1982, pp. 59-66.
Solution Method: N/A
Assumptions: Stripping efficiency is value reported in paper. No data was given to confirm.
Comments: Stripping efficiency based on four measurements.

Not enough data collected to calculate K_LA or mass closure.

*** = unable to be determined with available data, n/m = not measured**

73

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 25 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	not given	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	n/m	Radon	4.4	5.2×10^{-6}	*	*	*	*	*	65	*	*	*	*	*
Liquid Flowrate (L/min) =	n/m														
Gas Flowrate (L/min) =	n/m														
Bathroom Volume (L) =	n/m														
Person Present =	No														

STUDY: Gesell and Prichard
Study year: 1980
Reference: In *Natural Radiation Environment III, Vol. 2,* Houston: Technical Information Center, U.S. Department of Energy, pp. 1347-1363.
Solution Method: N/A
Assumptions: Stripping efficiency is value reported in paper. No data was given to confirm.
Comments: Liquid-phase diffusion coefficient estimated using relationship given for Giardino and Hageman (1996)
Not enough data collected to calculate K_LA or mass closure.

*** = unable to be determined with available data, n/m = not measured**

74

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Spray Type =	unknown		H_c @ 25 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	not given	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	n/m	Radon	4.4	5.2×10^{-6}	*	1000	*	*	*	65	*	*	*	*	*
Liquid Flowrate (L/min) =	n/m														
Gas Flowrate (L/min) =	n/m														
Bathroom Volume (L) =	n/m														
Person Present =	No														

STUDY: Partridge *et al.*
Study year: 1979
Reference: Data in Nazaroff *et al., Health Physics, Vol. 52, No. 3,* 1987, pp. 281-295.
Solution Method: N/A
Assumptions: Stripping efficiency is value reported in paper. No data was given to confirm.
Comments: Liquid-phase diffusion coefficient estimated using relationship given for Giardino and Hageman (1996)
Not enough data collected to calculate K_LA or mass closure.

*** = unable to be determined with available data, n/m = not measured**

75

Operating Conditions		**Chemical Properties**				**Chemical Concentrations**				**Mass Transfer Parameters**					
Spray Type =	unknown		H_c @ 25 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	not given	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	n/m	Radon	4.4	5.2×10^{-6}	*	*	*	*	*	71	*	*	*	*	*
Liquid Flowrate (L/min) =	n/m														
Gas Flowrate (L/min) =	n/m														
Bathroom Volume (L) =	n/m														
Person Present =	No														

BATHTUB DATABASE

STUDY: Howard and Corsi
Study year: 1997
Solution Methods: Method 1 for ethyl acetate, toluene, ethylbenzene, cyclohexane
Method 2 for acetone
Assumptions: None
Comments: Values of η and K_LA are averages of values determined for three separate time periods within experiment
*** = unable to be determined with available data**

Entry # 1

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Flow-through		H_c @ 22 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	22	Acetone	0.0011	1.1×10^{-5}	0.11	52	50	0	0.019	3.8	0.11	2.9	108	37	98
Liquid Flowrate (L/min) =	9.1	Ethyl Acetate	0.0044	9.5×10^{-6}	0.092	25	24	0	0.028	6.1	0.64	4.5	168	37	98
Gas Flowrate (L/min) =	355	Toluene	0.25	9.1×10^{-6}	0.085	4.9	3.6	0	0.019	26	2.9	3.2	117	37	89
Shower Stall/Bathtub Volume (L) =	1745	Ethylbenzene	0.28	8.4×10^{-6}	0.077	3.9	2.9	0	0.012	27	2.9	3.1	117	37	86
Person Present =	No	Cyclohexane	6.7	9.0×10^{-6}	0.088	0.94	0.68	0	0.0031	28	3.1	3.1	115	37	85

2

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Flow-through		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Acetone	0.0011	1.1×10^{-5}	0.11	40	39	0	0.016	3.1	0.15	3.2	136	43	99
Liquid Flowrate (L/min) =	9.1	Ethyl Acetate	0.0046	9.5×10^{-6}	0.092	25	23	0	0.027	4.7	0.49	3.0	126	43	102
Gas Flowrate (L/min) =	345	Toluene	0.26	9.1×10^{-6}	0.085	6.4	4.9	0	0.019	24	2.4	2.6	111	43	92
Shower Stall/Bathtub Volume (L) =	1745	Ethylbenzene	0.30	8.4×10^{-6}	0.077	4.9	3.8	0	0.0088	24	2.4	2.6	109	43	88
Person Present =	No	Cyclohexane	6.9	9.0×10^{-6}	0.088	1.4	1.0	0	0.0032	29	2.9	2.9	126	43	88

3

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Flow-through		H_c @ 36 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	36	Acetone	0.0024	1.1×10^{-5}	0.11	39	37	0	0.036	5.3	0.54	6.0	249	42	99
Liquid Flowrate (L/min) =	9.1	Ethyl Acetate	0.0080	9.5×10^{-6}	0.092	24	21	0	0.059	11	1.2	4.9	205	42	102
Gas Flowrate (L/min) =	359	Toluene	0.38	9.1×10^{-6}	0.085	6.7	4.1	0	0.037	38	4.5	4.8	198	42	94
Shower Stall/Bathtub Volume (L) =	1745	Ethylbenzene	0.58	8.4×10^{-6}	0.077	5.9	3.6	0	0.022	39	4.5	4.7	196	42	87
Person Present =	No	Cyclohexane	10	9.0×10^{-6}	0.088	2.3	1.3	0	0.0074	38	5.1	5.1	211	42	82

4

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Flow-through		H_c @ 25 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	25	Acetone	0.0013	1.1×10^{-5}	0.11	40	40	0	0.017	1.7	0.18	2.4	159	66	102
Liquid Flowrate (L/min) =	6.1	Ethyl Acetate	0.0050	9.5×10^{-6}	0.092	25	24	0	0.029	4.5	0.32	1.3	86	66	103
Gas Flowrate (L/min) =	350	Toluene	0.27	9.1×10^{-6}	0.085	5.2	4.0	0	0.013	22	1.6	1.7	110	66	95
Shower Stall/Bathtub Volume (L) =	1745	Ethylbenzene	0.32	8.4×10^{-6}	0.077	4.0	3.1	0	0.0077	22	1.5	1.6	106	66	92
Person Present =	No	Cyclohexane	7.2	9.0×10^{-6}	0.088	1.1	0.81	0	0.0029	22	1.7	1.7	110	66	96

5

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Flow-through		H_c @ 36 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	36	Acetone	0.0024	1.1×10^{-5}	0.11	48	46	0	0.034	4.3	0.43	2.4	227	96	101
Liquid Flowrate (L/min) =	6.1	Ethyl Acetate	0.0080	9.5×10^{-6}	0.092	25	22	0	0.043	14	1.1	2.4	234	96	101
Gas Flowrate (L/min) =	361	Toluene	0.38	9.1×10^{-6}	0.085	6.0	4.2	0	0.023	30	2.2	2.2	214	96	107
Shower Stall/Bathtub Volume (L) =	1745	Ethylbenzene	0.58	8.4×10^{-6}	0.077	4.0	3.1	0	0.017	29	2.1	2.2	207	96	100
Person Present =	No	Cyclohexane	10	9.0×10^{-6}	0.088	1.1	0.77	0	0.0038	27	1.9	1.9	182	96	103

6

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Flow-through		H_c @ 37 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	37	Acetone	0.0025	1.1×10^{-5}	0.11	40	38	0	0.033	4.8	0.46	4.2	211	50	101
Liquid Flowrate (L/min) =	6.1	Ethyl Acetate	0.0084	9.5×10^{-6}	0.092	23	21	0	0.049	10	0.79	2.7	135	50	105
Gas Flowrate (L/min) =	365	Toluene	0.39	9.1×10^{-6}	0.085	6.0	3.7	0	0.023	38	2.9	3.1	152	50	92
Shower Stall/Bathtub Volume (L) =	1745	Ethylbenzene	0.59	8.4×10^{-6}	0.077	5.9	3.7	0	0.015	38	2.9	3.0	151	50	85
Person Present =	No	Cyclohexane	11	9.0×10^{-6}	0.088	2.0	1.2	0	0.0038	41	3.2	3.2	161	50	85

STUDY: Howard and Corsi
Study year: 1997
Solution Methods: Method 3
Assumptions: None
Comments:
*** = unable to be determined with available data**

7

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Fill		H_c @ 24 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	24	Acetone	0.0012	1.1×10^{-5}	0.11	41	39	0	0.018	4.9	0.45	7.1	395	56	97
Liquid Flowrate (L/min) =	9.1	Ethyl Acetate	0.0013	9.5×10^{-6}	0.092	25	24	0	0.030	3.0	1.0	4.9	274	56	103
Final Liquid Volume (L) =	73	Toluene	0.27	9.1×10^{-6}	0.085	8.0	5.6	0	0.029	31	4.1	4.4	244	56	89
Gas Flowrate (L/min) =	373	Ethylbenzene	0.31	8.4×10^{-6}	0.077	9.8	6.7	0	0.020	33	4.4	4.6	257	56	82
Shower Stall/Bathtub Volume (L) =	1745	Cyclohexane	7.1	9.0×10^{-6}	0.088	3.1	1.8	0	0.0063	46	7.1	7.1	396	56	73

8

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Fill		H_c @ 35 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	35	Acetone	0.0022	1.1×10^{-5}	0.11	43	40	0	0.031	5.2	0.53	9.3	253	27	98
Liquid Flowrate (L/min) =	9.1	Ethyl Acetate	0.0077	9.5×10^{-6}	0.092	24	23	0	0.045	5.3	1.4	8.3	228	27	106
Final Liquid Volume (L) =	73	Toluene	0.36	9.1×10^{-6}	0.085	6.2	4.0	0	0.036	30	5.3	5.8	159	27	93
Gas Flowrate (L/min) =	379	Ethylbenzene	0.54	8.4×10^{-6}	0.077	6.3	3.9	0	0.024	32	5.9	6.3	172	27	81
Shower Stall/Bathtub Volume (L) =	1745	Cyclohexane	10	9.0×10^{-6}	0.088	2.0	0.85	0	0.0074	47	11	11	311	27	68

9

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Fill		H_c @ 36 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	8	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	36	Acetone	0.0024	1.1×10^{-5}	0.11	40	39	0	0.032	2.0	0.64	5.9	303	51	101
Liquid Flowrate (L/min) =	9.1	Ethyl Acetate	0.0080	9.5×10^{-6}	0.092	23	22	0	0.044	3.1	1.5	5.3	269	51	107
Final Liquid Volume (L) =	73	Toluene	0.38	9.1×10^{-6}	0.085	6.3	4.5	0	0.037	31	3.7	3.8	193	51	101
Gas Flowrate (L/min) =	373	Ethylbenzene	0.58	8.4×10^{-6}	0.077	5.4	3.8	0	0.024	32	3.8	4.0	202	51	93
Shower Stall/Bathtub Volume (L) =	1745	Cyclohexane	10	9.0×10^{-6}	0.088	1.2	0.66	0	0.0074	46	7.4	7.4	376	51	87

10

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Fill		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	12	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Acetone	0.0011	1.1×10^{-5}	0.11	41	39	0	0.019	5.8	0.39	4.7	365	77	96
Liquid Flowrate (L/min) =	6.1	Ethyl Acetate	0.0046	9.5×10^{-6}	0.092	26	25	0	0.032	3.1	0.71	2.7	208	77	104
Final Liquid Volume (L) =	73	Toluene	0.26	9.1×10^{-6}	0.085	6.8	4.9	0	0.034	29	2.6	2.7	208	77	101
Gas Flowrate (L/min) =	370	Ethylbenzene	0.30	8.4×10^{-6}	0.077	7.3	5.1	0	0.023	31	2.7	2.8	220	77	88
Shower Stall/Bathtub Volume (L) =	1745	Cyclohexane	6.9	9.0×10^{-6}	0.088	3.0	1.8	0	0.0078	43	4.4	4.4	344	77	84

11

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Fill		H_c @ 35 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	11.4	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	35	Acetone	0.0022	1.1×10^{-5}	0.11	40	37	0	0.032	7.7	0.39	4.2	191	46	98
Liquid Flowrate (L/min) =	6.1	Ethyl Acetate	0.0077	9.5×10^{-6}	0.092	23	22	0	0.047	7.0	1.0	3.8	175	46	108
Final Liquid Volume (L) =	69	Toluene	0.37	9.1×10^{-6}	0.085	5.0	3.5	0	0.026	30	2.7	2.8	129	46	106
Gas Flowrate (L/min) =	377	Ethylbenzene	0.56	8.4×10^{-6}	0.077	4.2	3.0	0	0.015	29	2.5	2.6	121	46	96
Shower Stall/Bathtub Volume (L) =	1745	Cyclohexane	10	9.0×10^{-6}	0.088	1.2	0.63	0	0.0041	46	5.4	5.4	245	46	75

STUDY: Howard and Corsi
Study year: 1997
Solution Methods: Method 4 for toluene, ethylbenzene, and cyclohexane
Method 5 for acetone and ethyl acetate
Assumptions: None
Comments: Stripping efficiencies for entries 12 - 14 based on gas-phase data
*** = unable to be determined with available data**

12

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Bathing		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	20	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Acetone	0.0011	1.1×10^{-5}	0.11	40	39	0.021	0.0030	0.6	*	*	*	*	99
Liquid Volume (L) =	73	Ethyl Acetate	0.0046	9.5×10^{-6}	0.092	25	25	0.035	0.0023	1.6	*	*	*	*	100
Gas Flowrate (L/min) =	370	Toluene	0.26	9.1×10^{-6}	0.085	4.9	5.1	0.037	3.8×10^{-4}	7.9	*	*	*	*	96
Shower Stall/Bathtub Volume (L) =	1745	Ethylbenzene	0.3	8.4×10^{-6}	0.077	5.1	5.3	0.025	4.2×10^{-4}	5.1	*	*	*	*	100
Person Present =	No	Cyclohexane	6.9	9.0×10^{-6}	0.088	1.8	1.9	0.009	0	4.7	*	*	*	*	99

13

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Bathing		H_c @ 34 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	20	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	34	Acetone	0.0012	1.1×10^{-5}	0.11	39	39	0.016	0.0033	2.5	*	*	*	*	101
Liquid Volume (L) =	69	Ethyl Acetate	0.0048	9.5×10^{-6}	0.092	24	24	0.027	0.0034	5.9	*	*	*	*	102
Gas Flowrate (L/min) =	377	Toluene	0.26	9.1×10^{-6}	0.085	3.3	3.5	0.021	9.2×10^{-4}	13	*	*	*	*	110
Shower Stall/Bathtub Volume (L) =	1745	Ethylbenzene	0.31	8.4×10^{-6}	0.077	2.9	2.7	0.013	5.1×10^{-4}	7.6	*	*	*	*	96
Person Present =	No	Cyclohexane	7.1	9.0×10^{-6}	0.088	0.65	0.74	0.0040	1.4×10^{-4}	13	*	*	*	*	117

14

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Bathing		H_c @ 34 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	20	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	34	Acetone	0.0021	1.1×10^{-5}	0.11	37	38	0.032	0.012	2.7	*	*	*	*	104
Final Liquid Volume (L) =	73	Ethyl Acetate	0.0074	9.5×10^{-6}	0.092	22	22	0.047	0.0091	6.4	*	*	*	*	105
Gas Flowrate (L/min) =	377	Toluene	0.36	9.1×10^{-6}	0.085	3.6	3.6	0.026	0.0016	14	*	*	*	*	99
Shower Stall/Bathtub Volume (L) =	1745	Ethylbenzene	0.52	8.4×10^{-6}	0.077	3.1	2.7	0.015	0.0010	8.3	*	*	*	*	86
Person Present =	No	Cyclohexane	9.8	9.0×10^{-6}	0.088	0.64	0.59	0.004	2.4×10^{-4}	15	*	*	*	*	93

15

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Bathing		H_c @ 24 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	20	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	24	Acetone	0.0012	1.1×10^{-5}	0.11	39	38	0.007	0.011	1.6	0.11	1.8	97	54	103
Final Liquid Volume (L) =	73	Ethyl Acetate	0.0048	9.5×10^{-6}	0.092	24	23	0.009	0.016	3.4	0.24	1.2	63	54	109
Gas Flowrate (L/min) =	373	Toluene	0.26	9.1×10^{-6}	0.085	5.7	3.9	0.009	0.0092	32	1.2	1.3	69	54	90
Shower Stall/Bathtub Volume (L) =	1745	Ethylbenzene	0.31	8.4×10^{-6}	0.077	6.9	4.7	0.006	0.0059	32	1.2	1.3	68	54	83
Person Present =	Yes	Cyclohexane	7.1	9.0×10^{-6}	0.088	1.7	1.0	0.002	0.0014	39	1.4	1.4	76	54	82

16

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Bathing		H_c @ 33 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	20	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	33	Acetone	0.0020	1.1×10^{-5}	0.11	41	39	0.012	0.023	4.5	0.25	1.8	143	35	100
Final Liquid Volume (L) =	73	Ethyl Acetate	0.0071	9.5×10^{-6}	0.092	23	21	0.013	0.027	9.8	0.49	1.4	107	35	104
Gas Flowrate (L/min) =	379	Toluene	0.35	9.1×10^{-6}	0.085	4.2	3.1	0.007	0.0091	27	1.2	1.2	97	35	100
Shower Stall/Bathtub Volume (L) =	1745	Ethylbenzene	0.50	8.4×10^{-6}	0.077	4.1	3.0	0.005	0.0063	26	1.1	1.1	88	35	92
Person Present =	Yes	Cyclohexane	9.6	9.0×10^{-6}	0.088	1.0	0.59	0.002	0.0018	41	2.0	2.0	156	35	80

17

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Operation =	Bathing		H_c @ 35 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	20	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	35	Acetone	0.0022	1.1×10^{-5}	0.11	41	38	0.01	0.026	7.3	0.23	1.6	122	78	98
Final Liquid Volume (L) =	73	Ethyl Acetate	0.0077	9.5×10^{-6}	0.092	22	20	0.008	0.028	8.9	0.40	1.1	84	78	105
Gas Flowrate (L/min) =	373	Toluene	0.36	9.1×10^{-6}	0.085	4.7	3.3	0.005	0.011	30	1.2	1.2	97	78	96
Shower Stall/Bathtub Volume (L) =	1745	Ethylbenzene	0.54	8.4×10^{-6}	0.077	4.0	2.9	0.003	0.0061	29	1.1	1.1	88	78	88
Person Present =	Yes	Cyclohexane	10	9.0×10^{-6}	0.088	0.73	0.51	3.8×10^{-3}	0.0016	30	1.2	1.2	94	78	91

KITCHEN SINK DATABASE

STUDY: Howard and Corsi
Study year: 1996
Reference: *Journal of the Air and Waste Management Association, Vol. 46* , 1996, pp. 830-837.
Solution Method: Method 6
Assumptions: C_g assumed to be negligible
$C_{g,in} = 0$
Comments: Mass transfer values based on recirculating flow.
*** = unable to be determined with available data**

Entry # 1

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Aerator Type =	None		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Liquid Temperature (C) =	23	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Flowrate (L/min) =	4.8	Acetone	0.0011	1.1×10^{-5}	0.11	93	45	0	0	4.9	0.24	1.3	136	104	*
Hydraulic Residence Time (min) =	10	Toluene	0.26	9.1×10^{-6}	0.085	11	0.44	0	0	21	1.0	1.0	108	104	*
Dishes =	None	Cyclohexane	6.9	9.0×10^{-6}	0.088	7.2	0.18	0	0	24	1.2	1.2	125	104	*

2

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Aerator Type =	None		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Liquid Temperature (C) =	23	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Flowrate (L/min) =	7.9	Acetone	0.0011	1.1×10^{-5}	0.11	56	41	0	0	2.2	0.17	1.7	88	51	*
Hydraulic Residence Time (min) =	6.3	Toluene	0.26	9.1×10^{-6}	0.085	14	1.2	0	0	17	1.3	1.4	72	51	*
Dishes =	None	Cyclohexane	6.9	9.0×10^{-6}	0.088	12	0.74	0	0	19	1.5	1.5	77	51	*

3

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Aerator Type =	Screen		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Liquid Temperature (C) =	23	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Flowrate (L/min) =	4.8	Acetone	0.0011	1.1×10^{-5}	0.11	70	53	0	0	1.7	0.080	1.0	41	43	*
Hydraulic Residence Time (min) =	10	Toluene	0.26	9.1×10^{-6}	0.085	9.4	0.84	0	0	13	0.65	0.7	30	43	*
Dishes =	None	Cyclohexane	6.9	9.0×10^{-6}	0.088	7.7	0.30	0	0	19	0.90	0.9	38	43	*

4

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Aerator Type =	Screen		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Liquid Temperature (C) =	23	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Flowrate (L/min) =	7.9	Acetone	0.0011	1.1×10^{-5}	0.11	58	49	0	0	1.1	0.090	1.6	44	27	*
Hydraulic Residence Time (min) =	6.3	Toluene	0.26	9.1×10^{-6}	0.085	12	1.5	0	0	14	1.2	1.4	37	27	*
Dishes =	None	Cyclohexane	6.9	9.0×10^{-6}	0.088	8.4	0.64	0	0	18	1.4	1.4	38	27	*

5

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Aerator Type =	Bubble Aerator		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Liquid Temperature (C) =	23	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Flowrate (L/min) =	4.8	Acetone	0.0011	1.1×10^{-5}	0.11	54	42	0	0	1.4	0.065	1.8	31	18	*
Hydraulic Residence Time (min) =	10	Toluene	0.26	9.1×10^{-6}	0.085	6.5	0.11	0	0	23	1.1	1.3	24	18	*
Dishes =	None	Cyclohexane	6.9	9.0×10^{-6}	0.088	4.2	0.010	0	0	33	1.6	1.6	28	18	*

6

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Aerator Type =	Bubble Aerator		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Liquid Temperature (C) =	23	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Flowrate (L/min) =	6.3	Acetone	0.0011	1.1×10^{-5}	0.11	56	45	0	0	1.5	0.090	2.4	43	18	*
Hydraulic Residence Time (min) =	8.1	Toluene	0.26	9.1×10^{-6}	0.085	7.0	0.2	0	0	22	1.4	1.7	31	18	*
Dishes =	None	Cyclohexane	6.9	9.0×10^{-6}	0.088	4.3	0.013	0	0	35	2.2	2.2	41	18	*

7

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Aerator Type =	Bubble Aerator		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Liquid Temperature (C) =	23	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Flowrate (L/min) =	7.9	Acetone	0.0011	1.1×10^{-5}	0.11	58	54	0	0	1.6	0.13	3.6	63	18	*
Hydraulic Residence Time (min) =	6.3	Toluene	0.26	9.1×10^{-6}	0.085	9.8	2.8	0	0	23	1.9	2.3	41	18	*
Dishes =	None	Cyclohexane	6.9	9.0×10^{-6}	0.088	7.2	0.70	0	0	44	3.5	3.5	62	18	*

8

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Aerator Type =	Bubble Aerator		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Liquid Temperature (C) =	23	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Flowrate (L/min) =	4.8	Acetone	0.0011	1.1×10^{-5}	0.11	68	57	0	0	1.3	0.060	2.1	29	14	*
Hydraulic Residence Time (min) =	10	Toluene	0.26	9.1×10^{-6}	0.085	5.0	2.8	0	0	24	1.2	1.5	21	14	*
Dishes =	Yes	Cyclohexane	6.9	9.0×10^{-6}	0.088	3.8	0.015	0	0	40	1.9	1.9	26	14	*

9

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Aerator Type =	Bubble Aerator		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Liquid Temperature (C) =	23	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Flowrate (L/min) =	6.3	Acetone	0.0011	1.1×10^{-5}	0.11	81	59	0	0	3.4	0.21	2.8	106	38	*
Hydraulic Residence Time (min) =	8.1	Toluene	0.26	9.1×10^{-6}	0.085	8.1	0.44	0	0	26	1.6	1.8	68	38	*
Dishes =	Yes	Cyclohexane	6.9	9.0×10^{-6}	0.088	4.2	0.020	0	0	48	2.9	2.9	112	38	*

STUDY: Wooley and Nazaroff
Study year: 1990
Reference: *Journal of the Air and Waste Management Association, Vol. 40*, 1990, pp.1114-11120
Solution Method: Method 8
Assumptions: Only significant mass transfer occurring due to wash solution with added ethanol.
Comments: There is not enough information given to consider additional emissions due to rinsing of dishes.
Mass closure values based on numbers given in paper.
*** = unable to be determined with available data**

10

Operating Conditions		**Chemical Properties**				**Chemical Concentrations**				**Mass Transfer Parameters**					
Aerator Type =	unknown		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Liquid Temperature (C) =	43	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Volume (L) =	7.6	Ethanol	0.0012	1.3×10^{-5}	0.12	113	101	0	0	11	0.084	*	*	*	94
Duration (min) =	10	Ethanol	0.0012	1.3×10^{-5}	0.12	113	105	0	0	7.1	0.055	*	*	*	96
Dishes =	Yes	Ethanol	0.0012	1.3×10^{-5}	0.12	113	99	0	0	12	0.10	*	*	*	92

11

Operating Conditions		**Chemical Properties**				**Chemical Concentrations**				**Mass Transfer Parameters**					
Aerator Type =	unknown		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Liquid Temperature (C) =	55	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Volume (L) =	7.6	Ethanol	*	1.3×10^{-5}	0.12	278	279	0	0	-0.4	-5.1×10^{-4}	*	*	*	106
Duration (min) =	70	Ethanol	*	1.3×10^{-5}	0.12	278	283	0	0	-1.8	-0.0020	*	*	*	106
Dishes =	Yes	Ethanol	*	1.3×10^{-5}	0.12	278	278	0	0	0	0	*	*	*	105

WASHING MACHINE DATABASE

STUDY: Howard and Corsi
Study year: 1997
Solution Method: Method 3
Assumptions: None
Comments: One gas sample collected for duration of experiment and one gas sample collected at end of experiment.
Values of k_g/k_l based solely on toluene, ethylbenzene, and cyclohexane data.

*** = unable to be determined with available data**

Entry # 1

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	fill for rinse		H_c @ 19 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	3.3	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	19	Acetone	0.00089	1.1×10^{-5}	0.11	55	55	0	0.042	2.1	0.23	*	*	*	99
Liquid Flowrate (L/min) =	14.6	Toluene	0.22	9.1×10^{-6}	0.085	7.5	6.8	0	0.28	9.8	1.8	2.9	21	7.1	108
Gas Flowrate (L/min) =	55	Ethylbenzene	0.23	8.4×10^{-6}	0.077	6.7	6.0	0	0.18	9.5	1.7	2.8	20	7.1	102
Final Headspace Volume (L) =	101	Cyclohexane	6.0	9.0×10^{-6}	0.088	2.5	2.1	0	0.074	15	2.8	2.9	21	7.1	98
Clothes Present =	No														

2

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	fill for rinse		H_c @ 21 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	3.3	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	21	Acetone	0.0010	1.1×10^{-5}	0.11	55	55	0	0.067	1	*	*	*	*	100
Liquid Flowrate (L/min) =	13.7	Toluene	0.24	9.1×10^{-6}	0.085	8.5	7.3	0	0.32	13	2.8	5.4	25	4.5	104
Gas Flowrate (L/min) =	55	Ethylbenzene	0.27	8.4×10^{-6}	0.077	7.3	6.3	0	0.20	13	2.9	5.3	24	4.5	99
Final Headspace Volume (L) =	104	Cyclohexane	6.0	9.0×10^{-6}	0.088	2.1	1.6	0	0.068	25	5.3	5.5	25	4.5	90
Clothes Present =	no														

3

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	fill for wash		H_c @ 19 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	3.3	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	19	Acetone	0.00089	1.1×10^{-5}	0.11	53	53	0	0.061	0.7	*	*	*	*	100
Liquid Flowrate (L/min) =	13.8	Toluene	0.23	9.1×10^{-6}	0.085	7.9	6.3	0	0.25	13	4.2	7.0	47	6.7	96
Gas Flowrate (L/min) =	55	Ethylbenzene	0.24	8.4×10^{-6}	0.077	7.3	5.7	0	0.13	16	5.0	8.1	54	6.7	87
Final Headspace Volume (L) =	104	Cyclohexane	6.0	9.0×10^{-6}	0.088	2.3	1.5	0	0.066	26	7.5	7.6	51	6.7	79
Clothes Present =	no														

4

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	fill for rinse		H_c @ 21 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	3.3	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	21	Acetone	0.0010	1.1×10^{-5}	0.11	56	54	0	0.038	3.0	0.086	*	*	*	97
Liquid Flowrate (L/min) =	13.7	Toluene	0.27	9.1×10^{-6}	0.085	8.6	7.8	0	0.14	8.2	1.5	*	*	*	102
Gas Flowrate (L/min) =	55	Ethylbenzene	0.35	8.4×10^{-6}	0.077	6.9	6.2	0	0.076	10	1.9	*	*	*	96
Final Headspace Volume (L) =	93	Cyclohexane	6.5	9.0×10^{-6}	0.088	2.0	1.9	0	0.028	6.9	1.2	*	*	*	102
Clothes Present =	yes														

5

Operating Conditions		Chemical Properties			Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	fill for rinse		H_c @ 49 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	3.3	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	49	Acetone	0.0046	1.1×10^{-5}	0.11	52	51	0	0.053	1.2	0.19	*	*	*	101
Liquid Flowrate (L/min) =	13.6	Toluene	0.54	9.1×10^{-6}	0.085	6.9	5.1	0	0.047	22	5.0	5.5	111	20	117
Gas Flowrate (L/min) =	160	Ethylbenzene	1.1	8.4×10^{-6}	0.077	6.3	4.8	0	0.032	20	4.7	4.9	101	20	103
Final Headspace Volume (L) =	104	Cyclohexane	15	9.0×10^{-6}	0.088	1.7	1.2	0	0.022	28	5.4	5.4	110	20	96
Clothes Present =	no														

6

Operating Conditions		Chemical Properties			Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	fill for rinse		H_c @ 47 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	3.3	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	47	Acetone	0.0041	1.1×10^{-5}	0.11	54	52	0	0.057	2.3	0.22	*	*	*	99
Liquid Flowrate (L/min) =	13.8	Toluene	0.51	9.1×10^{-6}	0.085	8.0	5.1	0	0.048	35	8.4	12	58	5.0	94
Gas Flowrate (L/min) =	160	Ethylbenzene	0.95	8.4×10^{-6}	0.077	6.3	4.0	0	0.028	36	8.4	10	50	5.0	84
Final Headspace Volume (L) =	104	Cyclohexane	14	9.0×10^{-6}	0.088	2.1	1.2	0	0.0073	45	11	11	57	5.0	69
Clothes Present =	no														

7

Operating Conditions		Chemical Properties			Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	fill for rinse		H_c @ 20 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	6.5	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	20	Acetone	0.00095	1.1×10^{-5}	0.11	55	54	0	0.026	1.8	0.038	*	*	*	102
Liquid Flowrate (L/min) =	13.7	Toluene	0.24	9.1×10^{-6}	0.085	6.6	5.7	0	0.21	17	2.5	4.6	24	5.1	110
Gas Flowrate (L/min) =	55	Ethylbenzene	0.26	8.4×10^{-6}	0.077	5.6	4.8	0	0.13	19	2.8	5.0	26	5.1	101
Final Headspace Volume (L) =	61	Cyclohexane	6.3	9.0×10^{-6}	0.088	1.5	1.1	0	0.048	33	4.8	4.9	25	5.1	93
Clothes Present =	no														

8

Operating Conditions		Chemical Properties			Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	fill for rinse		H_c @ 21 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	4.75	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	21	Acetone	0.0010	1.1×10^{-5}	0.11	51	50	0	0.036	1.2	0.12	*	*	*	99
Liquid Flowrate (L/min) =	8.6	Toluene	0.24	9.1×10^{-6}	0.085	6.4	4.6	0	0.11	23	4.2	6.3	54	8.5	90
Gas Flowrate (L/min) =	55	Ethylbenzene	0.26	8.4×10^{-6}	0.077	5.2	3.7	0	0.068	24	4.4	6.4	54	8.5	84
Final Headspace Volume (L) =	109	Cyclohexane	6.4	9.0×10^{-6}	0.088	1.6	0.96	0	0.022	37	6.4	6.5	55	8.5	72
Clothes Present =	no														

9

Operating Conditions		Chemical Properties			Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	fill for rinse		H_c @ 19 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	4.75	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	19	Acetone	0.00089	1.1×10^{-5}	0.11	49	47	0	0.042	3.0	1.2	*	*	*	96
Liquid Flowrate (L/min) =	8.5	Toluene	0.23	9.1×10^{-6}	0.085	7.4	5.8	0	0.18	9.7	3.5	4.3	80	19	98
Gas Flowrate (L/min) =	55	Ethylbenzene	0.23	8.4×10^{-6}	0.077	5.9	4.6	0	0.086	9.4	3.7	4.5	84	19	91
Final Headspace Volume (L) =	110	Cyclohexane	6.0	9.0×10^{-6}	0.088	1.9	1.4	0	0.043	12	4.5	4.5	84	19	86
Clothes Present =	no														

STUDY: Howard and Corsi
Study year: 1997
Solution Method: Method 4 for toluene, ethylbenzene, and cyclohexane
Method 5 for acetone and ethyl acetate
Assumptions: None
Comments:
*** = unable to be determined with available data**

10

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Rinse		H_c @ 24 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	24	Acetone	0.0012	1.1×10^{-5}	0.11	36	34	0.013	0.026	7.1	0.069	40	57	1.4	98
Liquid Volume (L) =	47	Ethyl Acetate	0.0048	9.5×10^{-6}	0.092	23	22	0.01	0.047	12	0.15	23	32	1.4	106
Gas Flowrate (L/min) =	53	Toluene	0.26	9.1×10^{-6}	0.085	5.1	1.4	0.0033	0.091	72	9.4	34	49	1.4	70
Final Headspace Volume (L) =	103	Ethylbenzene	0.31	8.4×10^{-6}	0.077	4.1	0.96	0.0024	0.056	76	10	34	49	1.4	75
Agitation Speed =	slow	Cyclohexane	7.1	9.0×10^{-6}	0.088	1.4	0.012	0.0019	0.0038	99	24	26	37	1.4	28
Clothes Present =	no														

11

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Rinse		H_c @ 22 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	22	Acetone	0.0011	1.1×10^{-5}	0.11	44	37	0.013	0.025	15	0.024	30	22	0.74	95
Liquid Volume (L) =	49	Ethyl Acetate	0.0044	9.5×10^{-6}	0.092	27	25	0.013	0.057	8.1	0.073	23	17	0.74	103
Gas Flowrate (L/min) =	53	Toluene	0.25	9.1×10^{-6}	0.085	7.1	2.5	0.0042	0.19	65	7.1	46	34	0.74	63
Final Headspace Volume (L) =	101	Ethylbenzene	0.28	8.4×10^{-6}	0.077	7.1	2.2	0.0033	0.13	69	8.1	47	35	0.74	53
Agitation Speed =	slow	Cyclohexane	6.7	9.0×10^{-6}	0.088	3.6	0.028	0.013	0.019	99	23	27	20	0.74	42
Clothes Present =	no														

12

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Rinse		H_c @ 49 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	49	Acetone	0.0046	1.1×10^{-5}	0.11	48	31	0.024	0.029	36	0.30	62	67	1.1	104
Liquid Volume (L) =	48	Ethyl Acetate	0.014	9.5×10^{-6}	0.092	28	15	0.014	0.032	48	0.61	41	45	1.1	114
Gas Flowrate (L/min) =	200	Toluene	0.53	9.1×10^{-6}	0.085	8.0	0.38	0.0035	0.0061	95	15	41	44	1.1	112
Final Headspace Volume (L) =	102	Ethylbenzene	1.0	8.4×10^{-6}	0.077	7.1	0.24	0.0024	0.0033	97	17	33	36	1.1	97
Agitation Speed =	slow	Cyclohexane	15	9.0×10^{-6}	0.088	2.3	0.003	0.0010	1.9×10^{-4}	100	46	49	53	1.1	72
Clothes Present =	no														

13

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Wash		H_c @ 23 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	9.75	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	23	Acetone	0.0011	1.1×10^{-5}	0.11	31	29	0.0093	0.0073	7.0	0.011	13	10	0.74	95
Liquid Volume (L) =	49	Toluene	0.26	9.1×10^{-6}	0.085	5.6	3.7	0.0089	0.032	33	1.5	9.6	7.1	0.74	93
Gas Flowrate (L/min) =	53	Ethylbenzene	0.29	8.4×10^{-6}	0.077	4.9	3.0	0.0062	0.023	36	2.2	12	9.2	0.74	91
Final Headspace Volume (L) =	101	Cyclohexane	6.7	9.0×10^{-6}	0.088	2.0	0.36	0.0061	0.025	82	9.4	11	8.4	0.74	61
Agitation Speed =	slow														
Clothes Present =	no														

14

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Wash		H_c @ 22 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	22	Acetone	0.0011	1.1×10^{-5}	0.11	35	33	0.0023	0.0042	5.1	0.0084	9.3	7.5	0.81	99
Liquid Volume (L) =	47	Toluene	0.24	9.1×10^{-6}	0.085	5.7	3.7	0.0019	0.016	34	2.5	15	12	0.81	79
Gas Flowrate (L/min) =	53	Ethylbenzene	0.27	8.4×10^{-6}	0.077	4.8	3.1	0.0012	0.011	37	2.6	15	12	0.81	77
Final Headspace Volume (L) =	103	Cyclohexane	6.5	9.0×10^{-6}	0.088	3.3	0.78	9.4×10^{-4}	0.0094	76	9.2	11	8.8	0.81	30
Agitation Speed =	slow														
Clothes Present =	no														

15

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Wash		H_c @ 51 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	51	Acetone	0.0050	1.1×10^{-5}	0.11	45	31	0.012	0.0028	30	0.022	32	4.3	0.13	99
Liquid Volume (L) =	49	Toluene	0.57	9.1×10^{-6}	0.085	8.0	2.7	0.0022	0.0096	67	3.5	49	6.6	0.13	73
Gas Flowrate (L/min) =	200	Ethylbenzene	1.2	8.4×10^{-6}	0.077	7.3	2.1	0.0014	0.0067	72	4.3	31	4.2	0.13	75
Final Headspace Volume (L) =	101	Cyclohexane	16	9.0×10^{-6}	0.088	2.8	0.045	6.7×10^{-4}	0.0026	98	24	34	4.6	0.13	47
Agitation Speed =	slow														
Clothes Present =	no														

16

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Rinse		H_c @ 21 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	21	Acetone	0.0010	1.1×10^{-5}	0.11	41	33	0.011	0.021	19	0.024	2.9	24	8.6	101
Liquid Volume (L) =	50	Toluene	0.24	9.1×10^{-6}	0.085	6.6	3.7	0.0089	0.036	45	0.84	1.3	11.0	8.6	92
Gas Flowrate (L/min) =	53	Ethylbenzene	0.26	8.4×10^{-6}	0.077	6.1	2.6	0.0042	0.018	57	1.1	1.6	13	8.6	88
Final Headspace Volume (L) =	88	Cyclohexane	6.3	9.0×10^{-6}	0.088	2.5	0.52	0.0056	0.012	79	2.9	3.0	25	8.6	74
Agitation Speed =	slow														
Clothes Present =	yes														

17

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Rinse		H_c @ 50 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	50	Acetone	0.0048	1.1×10^{-5}	0.11	32	28	0.015	0.017	9.4	0.099	7.7	21	2.8	99
Liquid Volume (L) =	47	Toluene	0.56	9.1×10^{-6}	0.085	5.9	2.6	0.0037	0.078	56	3.9	6.5	18	2.8	135
Gas Flowrate (L/min) =	200	Ethylbenzene	1.1	8.4×10^{-6}	0.077	5.3	1.9	0.0035	0.051	65	4.0	5.4	15	2.8	132
Final Headspace Volume (L) =	92	Cyclohexane	16	9.0×10^{-6}	0.088	2.2	0.35	0.0058	0.0028	84	6.8	6.9	19	2.8	137
Agitation Speed =	slow														
Clothes Present =	yes														

18

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Wash		H_c @ 18 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10.5	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	18	Acetone	0.00085	1.1×10^{-5}	0.11	45	36	0.0038	0.0051	20	0.0075	5.6	9.0	1.6	104
Liquid Volume (L) =	49	Toluene	0.22	9.1×10^{-6}	0.085	7.0	4.1	0.0056	0.021	42	0.58	2.2	3.6	1.6	103
Gas Flowrate (L/min) =	53	Ethylbenzene	0.22	8.4×10^{-6}	0.077	5.8	2.6	0.0024	0.011	54	0.93	3.6	5.7	1.6	95
Final Headspace Volume (L) =	90	Cyclohexane	5.8	9.0×10^{-6}	0.088	2.1	0.45	0.0019	0.0099	79	3.6	4.0	6.4	1.6	78
Agitation Speed =	slow														
Clothes Present =	yes														

19

Operating Conditions	
Cycle Type =	Wash
Duration (min) =	10.5
Liquid Temperature (C) =	49
Liquid Volume (L) =	49
Gas Flowrate (L/min) =	200
Final Headspace Volume (L) =	90
Agitation Speed =	slow
Clothes Present =	yes

Chemical Properties			
	H_c @ 49 C	D_l @ 24 C	D_g @ 24 C
Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)
Acetone	0.0046	1.1×10^{-5}	0.11
Toluene	0.54	9.1×10^{-6}	0.085
Ethylbenzene	1.1	8.4×10^{-6}	0.077
Cyclohexane	15	9.0×10^{-6}	0.088

Chemical Concentrations			
$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$
(mg/L)	(mg/L)	(mg/L)	(mg/L)
47	37	0.020	0.012
6.7	2.6	0.0078	0.023
5.5	1.7	0.0043	0.015
1.8	0.12	0.0020	0.0094

Mass Transfer Parameters					
η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
(%)	(L/min)	(L/min)	(L/min)		(%)
22	0.082	5.9	18	3.1	99
62	2.1	3.4	11	3.1	100
69	2.2	2.9	8.9	3.1	96
94	6.0	6.2	19	3.1	131

20

Operating Conditions	
Cycle Type =	Rinse
Duration (min) =	9.75
Liquid Temperature (C) =	21
Liquid Volume (L) =	82
Gas Flowrate (L/min) =	53
Final Headspace Volume (L) =	58
Agitation Speed =	slow
Clothes Present =	no

Chemical Properties			
	H_c @ 21 C	D_l @ 24 C	D_g @ 24 C
Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)
Acetone	0.0010	1.1×10^{-5}	0.11
Ethyl Acetate	0.0042	9.5×10^{-6}	0.092
Toluene	0.24	9.1×10^{-6}	0.085
Ethylbenzene	0.3	8.4×10^{-6}	0.077
Cyclohexane	6.5	9.0×10^{-6}	0.088

Chemical Concentrations			
$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$
(mg/L)	(mg/L)	(mg/L)	(mg/L)
19	18	0.0087	0.0063
13	13	0.0056	0.010
3.2	2.4	0.0022	0.014
3.0	2.1	0.0016	0.0091
1.5	1.0	6.6×10^{-4}	0.0053

Mass Transfer Parameters					
η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
(%)	(L/min)	(L/min)	(L/min)		(%)
3.4	0.024	6.4	24	3.7	100
5.2	0.053	3.4	12	3.7	102
26	2.7	5.6	21	3.7	88
28	3.0	6.1	23	3.7	85
36	3.4	3.6	13	3.7	81

21

Operating Conditions	
Cycle Type =	Rinse
Duration (min) =	10
Liquid Temperature (C) =	21
Liquid Volume (L) =	95
Gas Flowrate (L/min) =	53
Final Headspace Volume (L) =	55
Agitation Speed =	slow
Clothes Present =	no

Chemical Properties			
	H_c @ 21 C	D_l @ 24 C	D_g @ 24 C
Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)
Acetone	0.0010	1.1×10^{-5}	0.11
Ethyl Acetate	0.0042	9.5×10^{-6}	0.092
Toluene	0.24	9.1×10^{-6}	0.085
Ethylbenzene	0.3	8.4×10^{-6}	0.077
Cyclohexane	6.4	9.0×10^{-6}	0.088

Chemical Concentrations			
$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$
(mg/L)	(mg/L)	(mg/L)	(mg/L)
38	36	0.010	0.010
27	25	0.0072	0.016
6.5	4.8	0.0031	0.027
6.2	4.8	0.0022	0.019
2.6	1.4	0.0014	0.0096

Mass Transfer Parameters					
η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
(%)	(L/min)	(L/min)	(L/min)		(%)
4.8	0.020	9.7	20	2.1	98
5.2	0.039	4.6	9.5	2.1	100
28	2.9	8.8	18	2.1	82
31	3.2	9.1	19	2.1	83
44	5.2	5.6	12	2.1	73

22

Operating Conditions	
Cycle Type =	Rinse
Duration (min) =	10
Liquid Temperature (C) =	51
Liquid Volume (L) =	96
Gas Flowrate (L/min) =	200
Final Headspace Volume (L) =	54
Agitation Speed =	slow
Clothes Present =	no

Chemical Properties			
	H_c @ 51 C	D_l @ 24 C	D_g @ 24 C
Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)
Acetone	0.0050	1.1×10^{-5}	0.11
Ethyl Acetate	0.015	9.5×10^{-6}	0.092
Toluene	0.56	9.1×10^{-6}	0.085
Ethylbenzene	1.1	8.4×10^{-6}	0.077
Cyclohexane	16	9.0×10^{-6}	0.088

Chemical Concentrations			
$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$
(mg/L)	(mg/L)	(mg/L)	(mg/L)
39	37	0.021	0.020
19	18	0.014	0.018
6.5	4.8	0.0039	0.0068
5.7	4.0	0.0027	0.0053
2.0	1.1	8.6×10^{-4}	0.0026

Mass Transfer Parameters					
η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
(%)	(L/min)	(L/min)	(L/min)		(%)
3.1	0.15	6.0	30	5.1	99
5.1	0.25	3.5	18	5.1	101
33	3.3	4.4	23	5.1	86
32	2.9	3.4	17	5.1	87
44	4.5	4.5	23	5.1	79

23

Operating Conditions	
Cycle Type =	Rinse
Duration (min) =	10
Liquid Temperature (C) =	20
Liquid Volume (L) =	48
Gas Flowrate (L/min) =	53
Final Headspace Volume (L) =	102
Agitation Speed =	fast
Clothes Present =	no

Chemical Properties			
	H_c @ 48 C	D_l @ 24 C	D_g @ 24 C
Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)
Acetone	0.00095	1.1×10^{-5}	0.11
Ethyl Acetate	0.0040	9.5×10^{-6}	0.092
Toluene	0.24	9.1×10^{-6}	0.085
Ethylbenzene	0.3	8.4×10^{-6}	0.077
Cyclohexane	6.3	9.0×10^{-6}	0.088

Chemical Concentrations			
$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$
(mg/L)	(mg/L)	(mg/L)	(mg/L)
39	33	0.014	0.018
27	23	0.011	0.033
6.7	2.0	0.0034	0.079
5.9	1.5	0.0033	0.052
2.0	0.0	0.0055	0.0029

Mass Transfer Parameters					
η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
(%)	(L/min)	(L/min)	(L/min)		(%)
16	0.048	99	49	0.50	101
16	0.091	45	22	0.50	98
70	11	103	51	0.50	66
74	12	110	55	0.50	62
100	52	68	34	0.50	58

24

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Rinse		H_c @ 49 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10.25	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	49	Acetone	0.0046	1.1×10^{-5}	0.11	42	29	0.014	0.030	31	0.31	120	69	0.58	97
Liquid Volume (L) =	49	Ethyl Acetate	0.014	9.5×10^{-6}	0.092	18	12	0.0081	0.032	34	0.82	103	59	0.58	112
Gas Flowrate (L/min) =	200	Toluene	0.53	9.1×10^{-6}	0.085	7.4	0.070	0.0017	0.0018	99	38	161	92	0.58	68
Final Headspace Volume (L) =	101	Ethylbenzene	1.0	8.4×10^{-6}	0.077	6.8	0.054	0.0013	0.0010	99	38	101	58	0.58	57
Agitation Speed =	fast	Cyclohexane	15	9.0×10^{-6}	0.088	2.7	0.0038	7.6×10^{-4}	1.8×10^{-4}	100	94	105	61	0.58	92
Clothes Present =	no														

25

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Rinse		H_c @ 18 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	18	Acetone	0.00085	1.1×10^{-5}	0.11	42	37	0.0036	0.011	10	0.023	3.9	11	2.8	99
Liquid Volume (L) =	95	Ethyl Acetate	0.0037	9.5×10^{-6}	0.092	26	24	0.0044	0.019	7.8	0.055	3.2	8.9	2.8	103
Gas Flowrate (L/min) =	53	Toluene	0.22	9.1×10^{-6}	0.085	6.1	4.7	0.0057	0.047	24	1.5	3.8	11	2.8	93
Final Headspace Volume (L) =	55	Ethylbenzene	0.2	8.4×10^{-6}	0.077	5.0	3.8	0.0039	0.0230	24	1.5	4.0	11	2.8	92
Agitation Speed =	fast	Cyclohexane	5.8	9.0×10^{-6}	0.088	1.9	1.2	0.0032	0.018	48	2.9	3.1	8.7	2.8	85
Clothes Present =	no														

26

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Rinse		H_c @ 50 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	50	Acetone	0.0048	1.1×10^{-5}	0.11	45	39	0.015	0.013	15	0.086	9.0	9.0	1.0	102
Liquid Volume (L) =	94	Ethyl Acetate	0.015	9.5×10^{-6}	0.092	23	18	0.011	0.010	22	0.13	3.8	3.8	1.0	98
Gas Flowrate (L/min) =	200	Toluene	0.56	9.1×10^{-6}	0.085	6.4	4.3	0.0026	0.0042	33	1.5	4.3	4.3	1.0	105
Final Headspace Volume (L) =	56	Ethylbenzene	1.1	8.4×10^{-6}	0.077	5.1	3.3	0.0017	0.0028	34	1.7	3.2	3.2	1.0	101
Agitation Speed =	fast	Cyclohexane	16	9.0×10^{-6}	0.088	1.7	0.64	5.4×10^{-4}	0.0021	62	5.9	6.3	6.3	1.0	90
Clothes Present =	no														

STUDY: Shepherd, Kemp, and Corsi
Study year: 1996
Reference: *Journal of the Air & Waste Management Association, Vol. 46, No. 7*, 1996, pp.631-642.
Solution Method: Method 8. Stripping efficiencies based on predicted $C_{l,end}$ values using K_LA values.
Assumptions: $C_{g,in} = C_g = 0$.
Comments: K_LA values are equal to the total liquid volume multiplied by the K_La values reported in the paper, where a equals A/V_l.
*** = unable to be determined with available data**

27

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	rinse		H_c @ 31 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	31	Chloroform	0.24	9.7×10^{-6}	0.10	1.0	0.50	0	0	50	5.2	*	*	*	*
Liquid Volume (L) =	74														
Gas Flowrate (L/min) =	180														
Final Headspace Volume (L) =	55														
Mass of Clothes Present (kg) =	0														

28

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	rinse		H_c @ 31 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	31	Chloroform	0.24	9.7×10^{-6}	0.10	1.0	0.82	0	0	18	1.5	*	*	*	*
Liquid Volume (L) =	74														
Gas Flowrate (L/min) =	180														
Final Headspace Volume (L) =	55														
Mass of Clothes Present (kg) =	4.5														

29

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	wash		H_c @ 32 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	32	Chloroform	0.25	9.7×10^{-6}	0.10	1.0	0.76	0	0	24	2.1	*	*	*	*
Liquid Volume (L) =	74														
Gas Flowrate (L/min) =	180														
Final Headspace Volume (L) =	55														
Mass of Clothes Present (kg) =	0														

30

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	wash		H_c @ 33 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	33	Chloroform	0.26	9.7×10^{-6}	0.10	1.0	0.88	0	0	12	2.1	*	*	*	*
Liquid Volume (L) =	74														
Gas Flowrate (L/min) =	180														
Final Headspace Volume (L) =	55														
Mass of Clothes Present (kg) =	0														

31

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	wash		H_c @ 31 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	31	Chloroform	0.24	9.7×10^{-6}	0.10	1.0	0.90	0	0	9.5	0.96	*	*	*	*
Liquid Volume (L) =	74														
Gas Flowrate (L/min) =	180														
Final Headspace Volume (L) =	55														
Mass of Clothes Present (kg) =	2.3														

32

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	wash		H_c @ 31 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	31	Chloroform	0.24	9.7×10^{-6}	0.10	1.0	0.75	0	0	25	1.5	*	*	*	*
Liquid Volume (L) =	74														
Gas Flowrate (L/min) =	180														
Final Headspace Volume (L) =	55														
Mass of Clothes Present (kg) =	2.3														

33

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	wash		H_c @ 29 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	29	Chloroform	0.21	9.7×10^{-6}	0.10	1.0	0.82	0	0	18	0.74	*	*	*	*
Liquid Volume (L) =	74														
Gas Flowrate (L/min) =	180														
Final Headspace Volume (L) =	55														
Mass of Clothes Present (kg) =	4.5														

34

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	wash		H_c @ 30 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	30	Chloroform	0.22	9.7×10^{-6}	0.10	1.0	0.83	0	0	17	1.4	*	*	*	*
Liquid Volume (L) =	74														
Gas Flowrate (L/min) =	180														
Final Headspace Volume (L) =	55														
Mass of Clothes Present (kg) =	4.5														

STUDY: Wooley and Nazaroff
Study year: 1990
Reference: *Journal of the Air and Waste Management Association, Vol. 40* , 1990, pp.1114-1120
Solution Method: Not enough information given to solve K_LA.
Stripping efficiency values based on mass of ethanol added to wash water and mass of ethanol remaining after operation.
Assumptions: $C_{g,in} = 0$.
Comments: Mass closure values from paper.
*** = unable to be determined with available data**

35

Operating Conditions		Chemical Properties				Chemical Concentrations		Mass Transfer Parameters					
Cycle Type =	wash		H_c @ 35 C	D_l @ 24 C	D_g @ 24 C	Initial Mass	Final Mass	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	9	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(g)	(g)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	35	Ethanol	7.3×10^{-4}	1.3×10^{-5}	0.12	9.7	8.7	10	*	*	*	*	90
Liquid Volume (L) =	*	Ethanol	7.3×10^{-4}	1.3×10^{-5}	0.12	9.6	8.6	10	*	*	*	*	90
Gas Flowrate (L/min) =	*	Ethanol	7.3×10^{-4}	1.3×10^{-5}	0.12	9.7	9.1	6.2	*	*	*	*	93
Final Headspace Volume (L) =	*												
Mass of Clothes Present (kg) =	3.1												

36

Operating Conditions		Chemical Properties				Chemical Concentrations		Mass Transfer Parameters					
Cycle Type =	wash		H_c @ 55 C	D_l @ 24 C	D_g @ 24 C	Initial Mass	Final Mass	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	9	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(g)	(g)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	55	Ethanol	*	1.3×10^{-5}	0.12	10	8.7	13	*	*	*	*	89
Liquid Volume (L) =	*	Ethanol	*	1.3×10^{-5}	0.12	9.8	9.4	4.1	*	*	*	*	97
Gas Flowrate (L/min) =	*	Ethanol	*	1.3×10^{-5}	0.12	9.7	9.1	6.2	*	*	*	*	95
Final Headspace Volume (L) =	*												
Mass of Clothes Present (kg) =	3.1												

DISHWASHER DATABASE

STUDY: Howard and Corsi
Study year: 1997
Solution Method: Method 4
Assumptions: $C_{g,in}$ = 0, unless otherwise given
Comments: # = initial liquid-phase concentration based on average of duplicate samples with a relative difference greater than 20%, but no more than 36%. Mass closure is average over four time periods within experiment.
*** = unable to be determined with available data**

Entry # 1

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Rinse		H_c @ 43 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	43	Acetone	0.0034	1.1×10^{-5}	0.11	89	45	0	0.25	50#	7.0	*	*	*	95
Liquid Volume (L) =	7.4	Toluene	0.46	9.1×10^{-6}	0.085	16	0.55	0	0.26	97#	33	*	*	*	90
Headspace Volume (L) =	181	Ethylbenzene	0.80	8.4×10^{-6}	0.077	11	0.36	0	0.18	97#	31	*	*	*	84
Ventilation Rate (L/min) =	5.7	Cyclohexane	13	9.0×10^{-6}	0.088	5.5	0.016	0	0.075	100#	45	48	*	*	95
Dishes Present =	No														

2

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Rinse		H_c @ 42 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	42	Acetone	0.0032	1.1×10^{-5}	0.11	74	49	0	0.22	34	4.2	*	*	*	94
Liquid Volume (L) =	7.4	Toluene	0.44	9.1×10^{-6}	0.085	14	0.63	0	0.27	96	30	*	*	*	91
Headspace Volume (L) =	181	Ethylbenzene	0.75	8.4×10^{-6}	0.077	12	0.41	0	0.18	97	32	*	*	*	86
Ventilation Rate (L/min) =	5.7	Cyclohexane	12	9.0×10^{-6}	0.088	7.1	0.018	0	0.070	100	49	49	*	*	82
Dishes Present =	Yes														

3

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Rinse		H_c @ 39 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	39	Acetone	0.0028	1.1×10^{-5}	0.11	66	36	0	0.20	43	5.8	*	*	*	93
Liquid Volume (L) =	7.4	Toluene	0.42	9.1×10^{-6}	0.085	8.9	0.27	0	0.17	97	32	*	*	*	91
Headspace Volume (L) =	181	Ethylbenzene	0.68	8.4×10^{-6}	0.077	8.7	0.19	0	0.13	98	35	*	*	*	87
Ventilation Rate (L/min) =	5.7	Cyclohexane	12	9.0×10^{-6}	0.088	3.9	0.004	0	0.043	100	58	58	*	*	83
Dishes Present =	Yes														

4

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Wash		H_c @ 43 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	43	Acetone	0.0034	1.1×10^{-5}	0.11	53	33	0	0.30	37	5.1	*	*	*	92
Liquid Volume (L) =	7.4	Toluene	0.46	9.1×10^{-6}	0.085	10	0.46	0	0.33	96	30	*	*	*	99
Headspace Volume (L) =	181	Ethylbenzene	0.81	8.4×10^{-6}	0.077	10	0.81	0	0.27	97	33	*	*	*	93
Ventilation Rate (L/min) =	5.7	Cyclohexane	13	9.0×10^{-6}	0.088	5.1	13	0	0.11	100#	51	51	*	*	87
Dishes Present =	No														

5

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Wash		H_c @ 45 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	45	Acetone	0.0037	1.1×10^{-5}	0.11	61	32	0.014	0.34	47	6.8	*	*	*	93
Liquid Volume (L) =	7.4	Toluene	0.49	9.1×10^{-6}	0.085	12	0.41	0.005	0.31	98	33	*	*	*	95
Headspace Volume (L) =	181	Ethylbenzene	0.90	8.4×10^{-6}	0.077	12	0.29	0.004	0.23	98	35	*	*	*	90
Ventilation Rate (L/min) =	5.7	Cyclohexane	14	9.0×10^{-6}	0.088	6.4	0.016	0.002	0.10	100	50	50	*	*	88
Dishes Present =	Yes														

6

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Wash		H_c @ 38 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	10	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	38	Acetone	0.0026	1.1×10^{-5}	0.11	61	36	0	0.23	42	9.4	*	*	*	94
Liquid Volume (L) =	7.4	Toluene	0.40	9.1×10^{-6}	0.085	14	0.58	0	0.29	96	34	*	*	*	92
Headspace Volume (L) =	181	Ethylbenzene	0.64	8.4×10^{-6}	0.077	14	0.41	0	0.21	97	36	*	*	*	87
Ventilation Rate (L/min) =	5.7	Cyclohexane	11	9.0×10^{-6}	0.088	9.2	0.022	0	0.088	100#	62	62	*	*	83
Dishes Present =	Yes														

7

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Rinse		H_c @ 55 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	7	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	55	Acetone	0.0061	1.1×10^{-5}	0.11	97	44	0	0.47	55#	8.2	*	*	*	90
Liquid Volume (L) =	7.4	Toluene	0.62	9.1×10^{-6}	0.085	16	0.36	0	0.33	98	39	*	*	*	92
Headspace Volume (L) =	181	Ethylbenzene	1.3	8.4×10^{-6}	0.077	15	0.24	0	0.24	98	42	*	*	*	87
Ventilation Rate (L/min) =	5.7	Cyclohexane	18	9.0×10^{-6}	0.088	7.0	0.011	0	0.094	100	57	56	*	*	86
Dishes Present =	No														

8

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Rinse		H_c @ 55 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	6.75	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	55	Acetone	0.0061	1.1×10^{-5}	0.11	58	48	0	0.33	18	1.7	*	*	*	100
Liquid Volume (L) =	7.4	Toluene	0.62	9.1×10^{-6}	0.085	13	0.46	0	0.24	96	33	*	*	*	91
Headspace Volume (L) =	181	Ethylbenzene	1.4	8.4×10^{-6}	0.077	15	0.37	0	0.18	97	36	*	*	*	83
Ventilation Rate (L/min) =	5.7	Cyclohexane	18	9.0×10^{-6}	0.088	9.2	0.019	0	0.080	100#	56	50	*	*	81
Dishes Present =	Yes														

9

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Wash		H_c @ 54 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	7	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	54	Acetone	0.0058	1.1×10^{-5}	0.11	62	30	0	0.44	51	7.6	*	*	*	94
Liquid Volume (L) =	7.4	Toluene	0.61	9.1×10^{-6}	0.085	16	0.38	0	0.30	98	38	*	*	*	97
Headspace Volume (L) =	181	Ethylbenzene	1.3	8.4×10^{-6}	0.077	17	0.28	0	0.22	98	41	*	*	*	92
Ventilation Rate (L/min) =	5.7	Cyclohexane	18	9.0×10^{-6}	0.088	7.9	0.015	0	0.083	100	50	50	*	*	92
Dishes Present =	No														

10

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Wash		H_c @ 55 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	6.67	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	55	Acetone	0.0061	1.1×10^{-5}	0.11	44	28	0.052	0.48	37	4.9	*	*	*	100
Liquid Volume (L) =	7.4	Toluene	0.62	9.1×10^{-6}	0.085	9.9	0.34	0.010	0.29	97	31	*	*	*	98
Headspace Volume (L) =	181	Ethylbenzene	1.4	8.4×10^{-6}	0.077	10	0.25	0.008	0.21	97	34	*	*	*	90
Ventilation Rate (L/min) =	5.7	Cyclohexane	18	9.0×10^{-6}	0.088	5.1	0.014	0.004	0.080	100	47	46	*	*	85
Dishes Present =	Yes														

11

Operating Conditions		Chemical Properties				Chemical Concentrations				Mass Transfer Parameters					
Cycle Type =	Wash		H_c @ 53 C	D_l @ 24 C	D_g @ 24 C	$C_{l,in}$	$C_{l,out}$	$C_{g,in}$	$C_{g,end}$	η	K_LA	k_lA	k_gA	k_g/k_l	Mass Closure
Duration (min) =	6.67	Chemical	(m^3_{liq}/m^3_{gas})	(cm^2/sec)	(cm^2/sec)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(L/min)	(L/min)	(L/min)		(%)
Liquid Temperature (C) =	53	Acetone	0.0056	1.1×10^{-5}	0.11	60	36	0.008	0.48	40#	5.2	*	*	*	97
Liquid Volume (L) =	7.4	Toluene	0.6	9.1×10^{-6}	0.085	15	0.48	0.003	0.26	97#	35	*	*	*	88
Headspace Volume (L) =	181	Ethylbenzene	1.3	8.4×10^{-6}	0.077	17	0.41	0.0020	0.19	98#	37	*	*	*	82
Ventilation Rate (L/min) =	5.7	Cyclohexane	17	9.0×10^{-6}	0.088	8.5	0.026	0	0.092	100#	55	54	*	*	84
Dishes Present =	Yes														