Using Aeration for Corrosion Control

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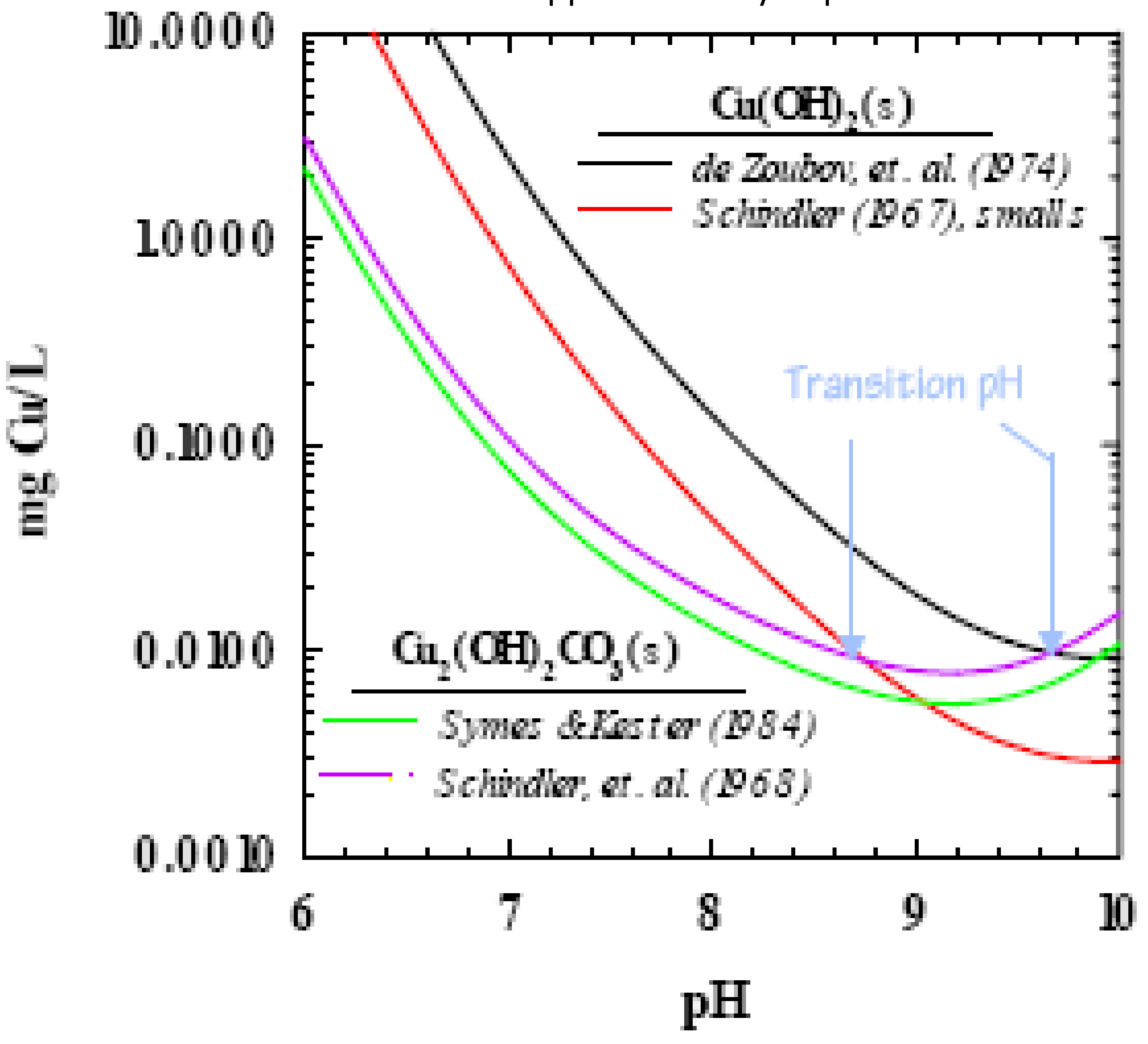
murraysmith

Agenda

Corrosion Control

Copper Solubility & Corrosion Rate General Decrease with Increasing pH

Copper Solubility vs pH



Dortwegt, R. Et Al 2001

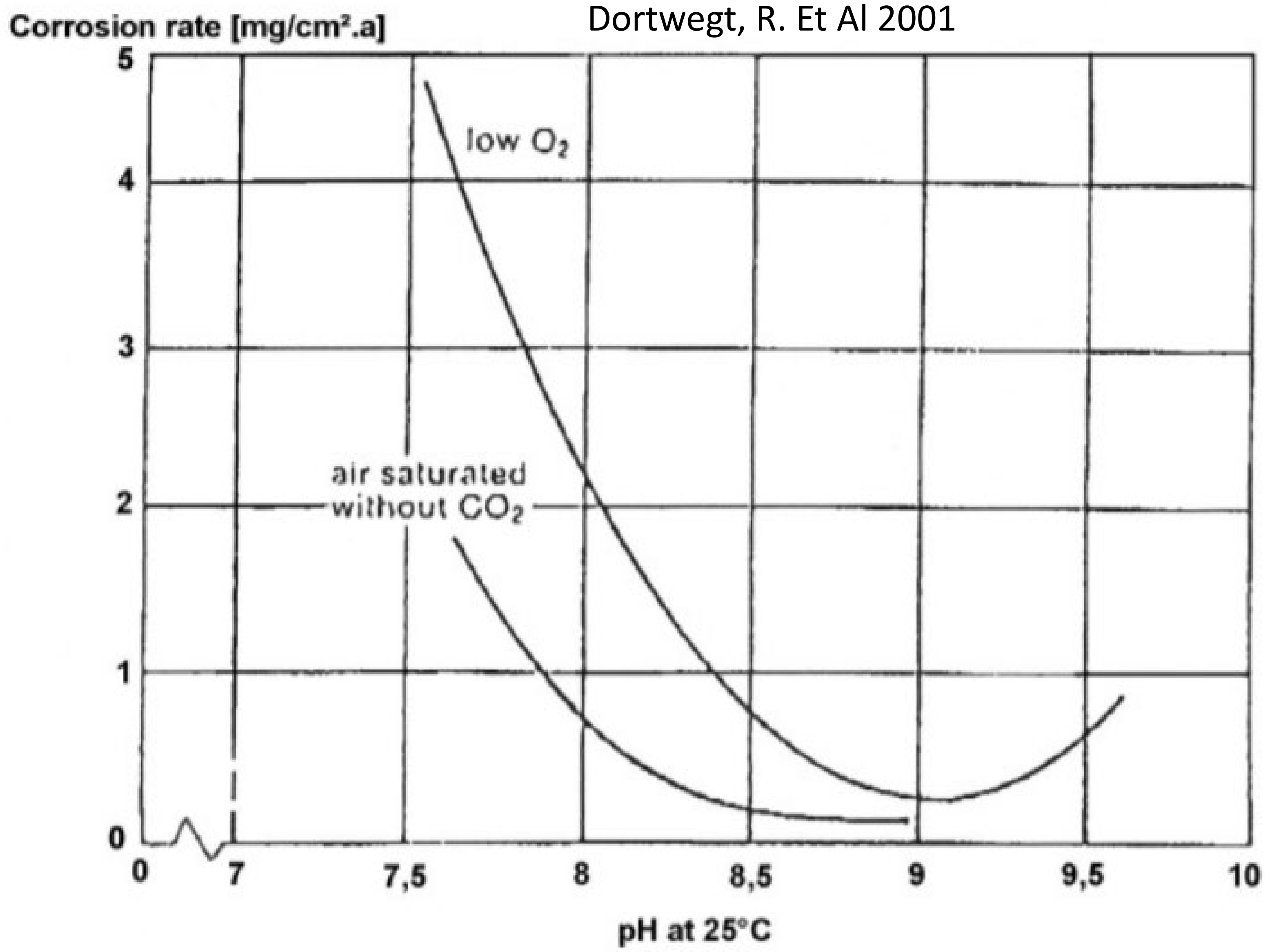
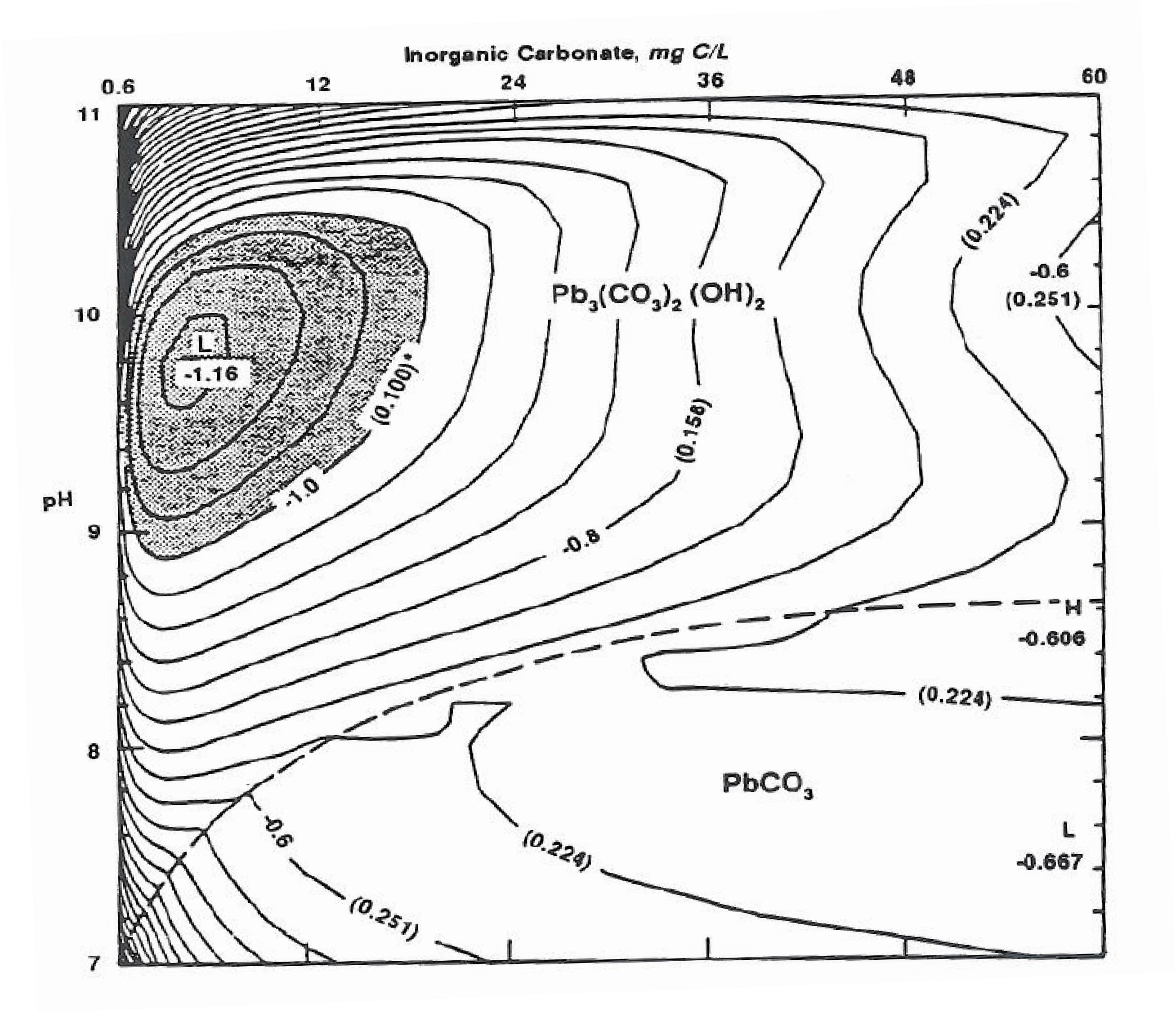


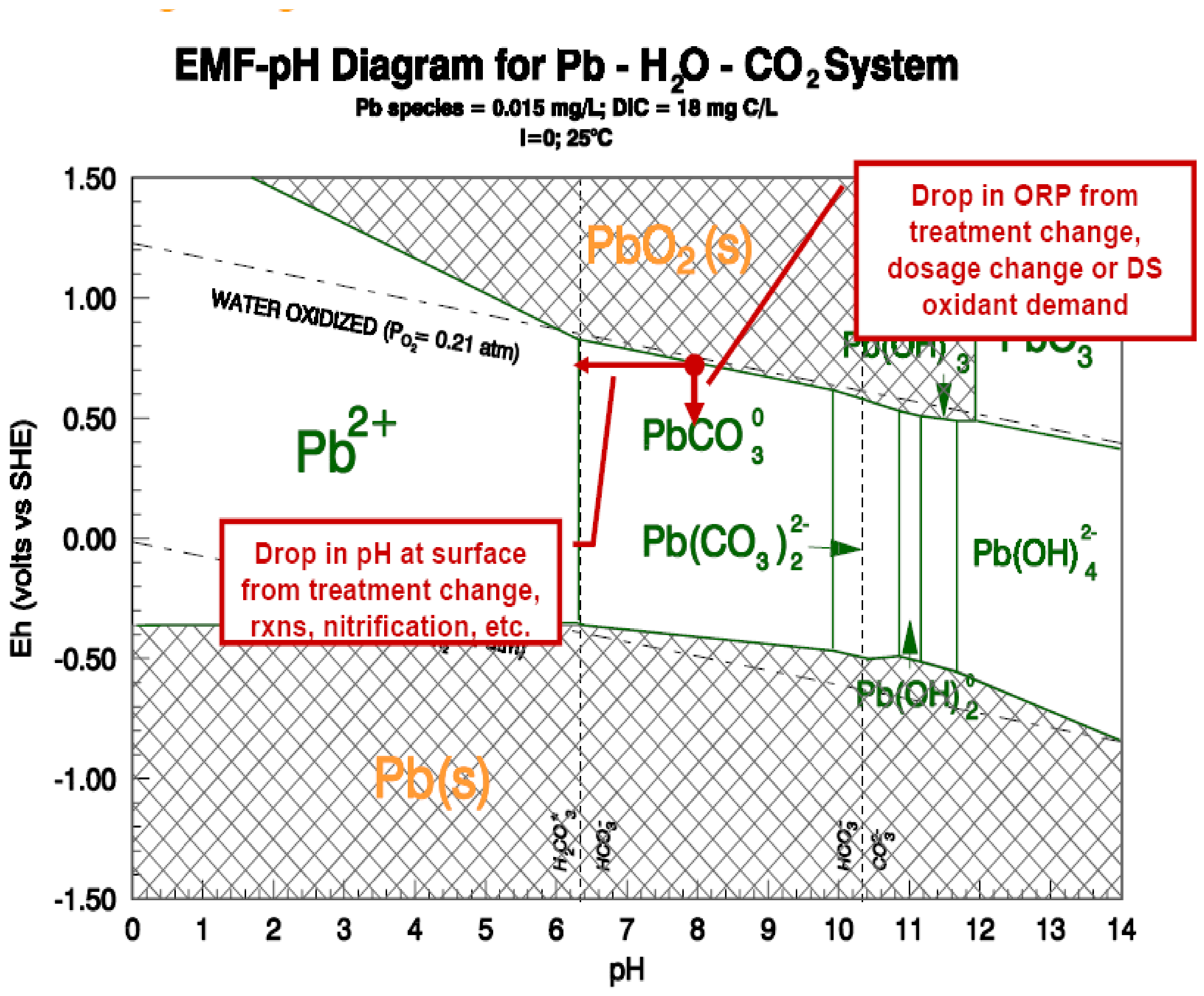
Figure 2: Corrosion rate vs .pH.

Corrosion Control

Lead corrosion is more complex, but pH plays a role in lead carbonate solubility, lead species, orthophosphate effectiveness and pipe scale stability

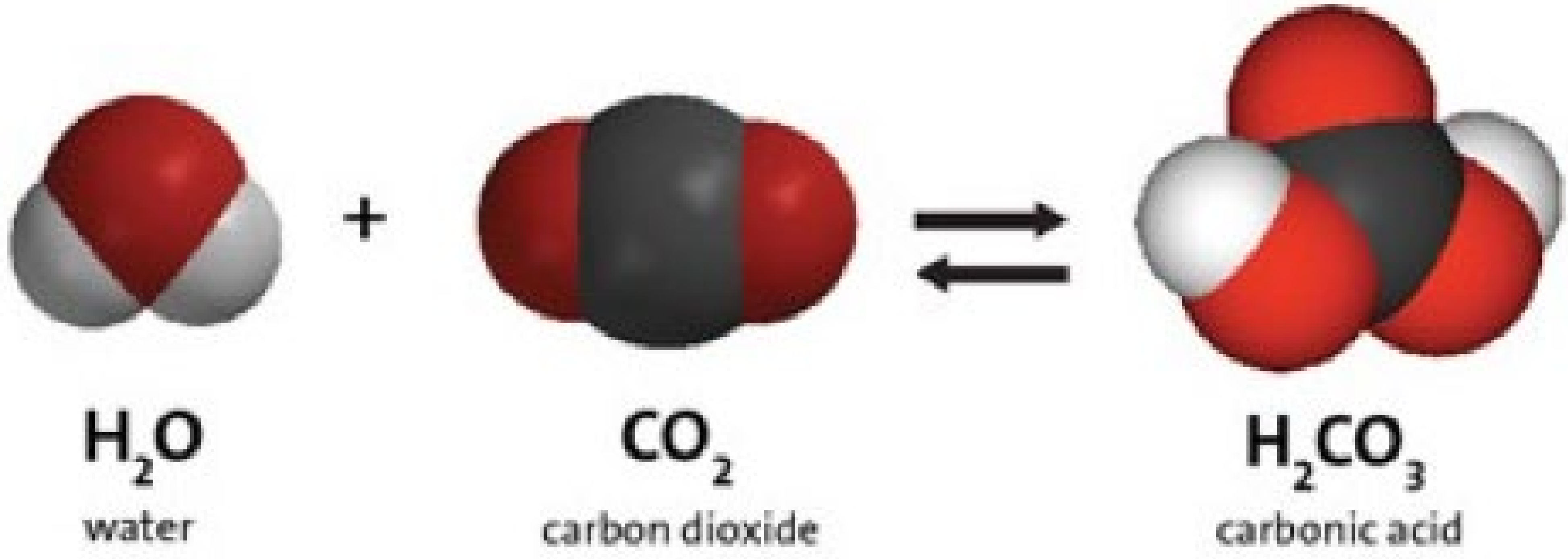


Lead Solubility Contour Diagram, pH vs DIC, I=0.01, Source, Lead Control Strategies, AWWARF



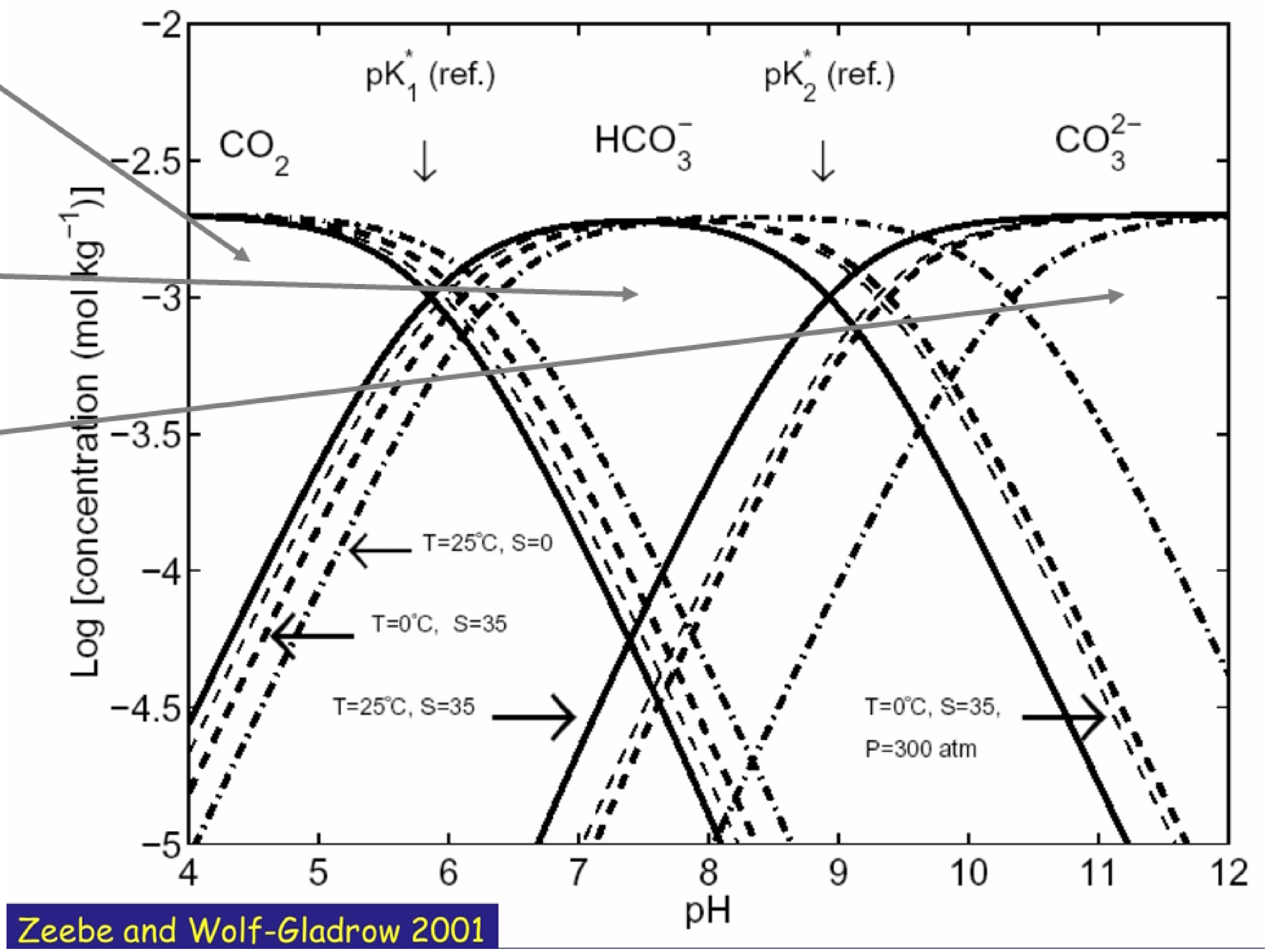
Source: New Insights into Lead and Copper Corrosion Control and Treatment Change Impacts, Michael Schock, USEPA, ORD, NRMRL, WSWRD

Carbon Dioxide



Carbonate System Components

- Carbonic Acid (H_2CO_3) or Carbon dioxide (CO_2)
  - Can donate two protons (a weak acid)
- Bicarbonate (HCO_3^-)
  - Can donate or accept one proton (can be either an acid or a base
- Carbonate (CO_3^{2-})
  - Can accept two protons (a base)

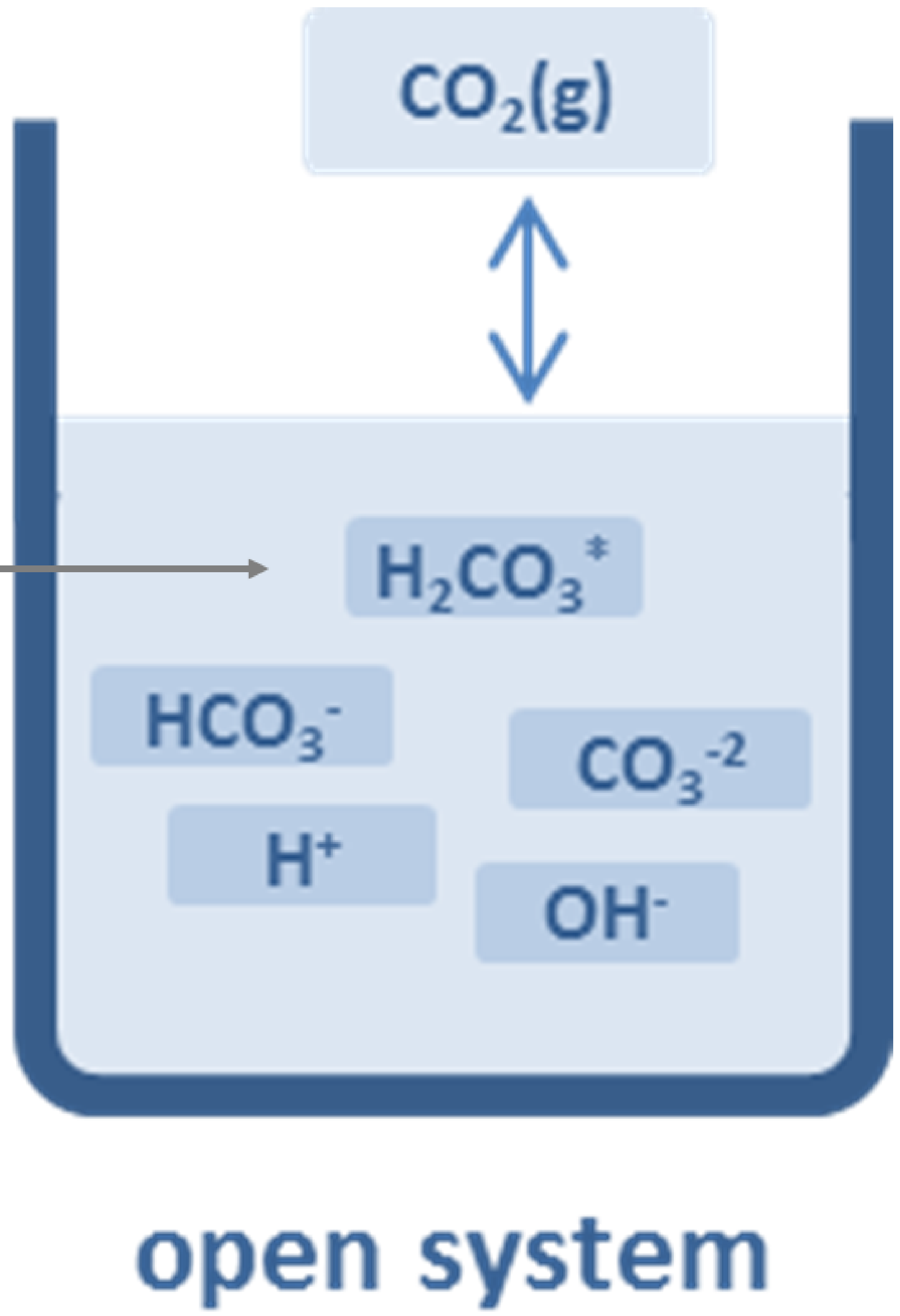


Open Systems

Henry's Law: $K_H = 10^{-1.47}$ Matm^{-1}

$\{H_2CO_3^*\} = K_H * P_{CO2}$

CO_2 Partial Pressure



$\{H_2CO_3^*\} = K_H * 10^{-pCO2}$

$P_{CO2} = 10^{-pCO2} = 0.0039$ atm (25 C)

Henry’s law

- At a constant temperature, the amount of a given gas dissolved in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid.

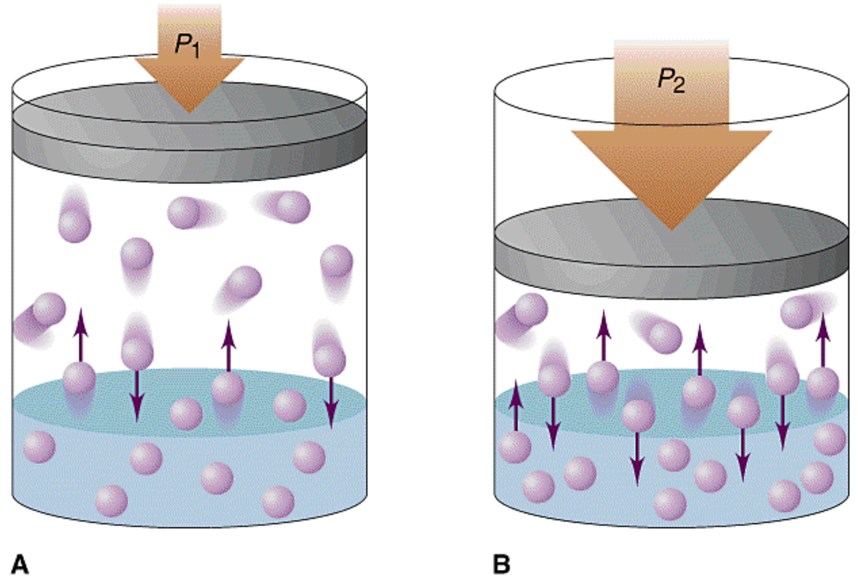
$p = k_H \cdot c$

•where:

•***p*** is the partial pressure of the solute above the solution

•***c*** is the concentration of the solute in the solution (in one of its many units)

•$\boldsymbol{k_H}$ is the Henry's Law constant, which has units such as L··atm/mol *or* atm/(mole fraction) *or* Pa · m^3/mol



Henry's Constant

Compound	$\Delta H \times 10^{-3}$
Oxygen	1.45
Methane	1.54
Hydrogen sulfide	1.85
Carbon dioxide	2.07
Carbon tetrachloride	4.05
Trichloroethylene	3.41
Bezene	3.68
Chloroform	4.00

Henry's Law – Different Forms

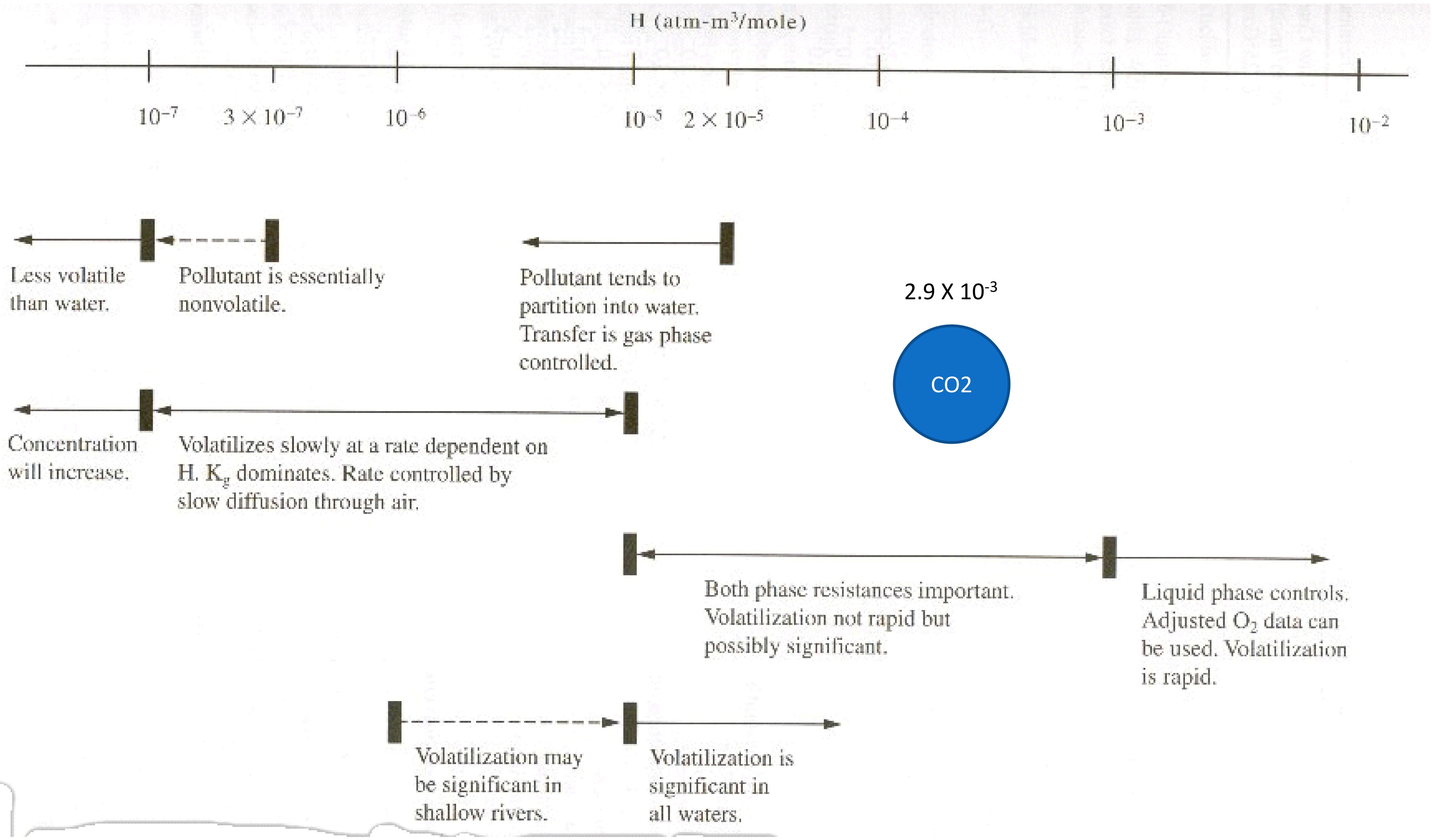
https://chemengineering.wikispaces.com/Henry%27s+Law

Table 1: Some forms of Henry's law and constants (gases in water at 298 K)[7]

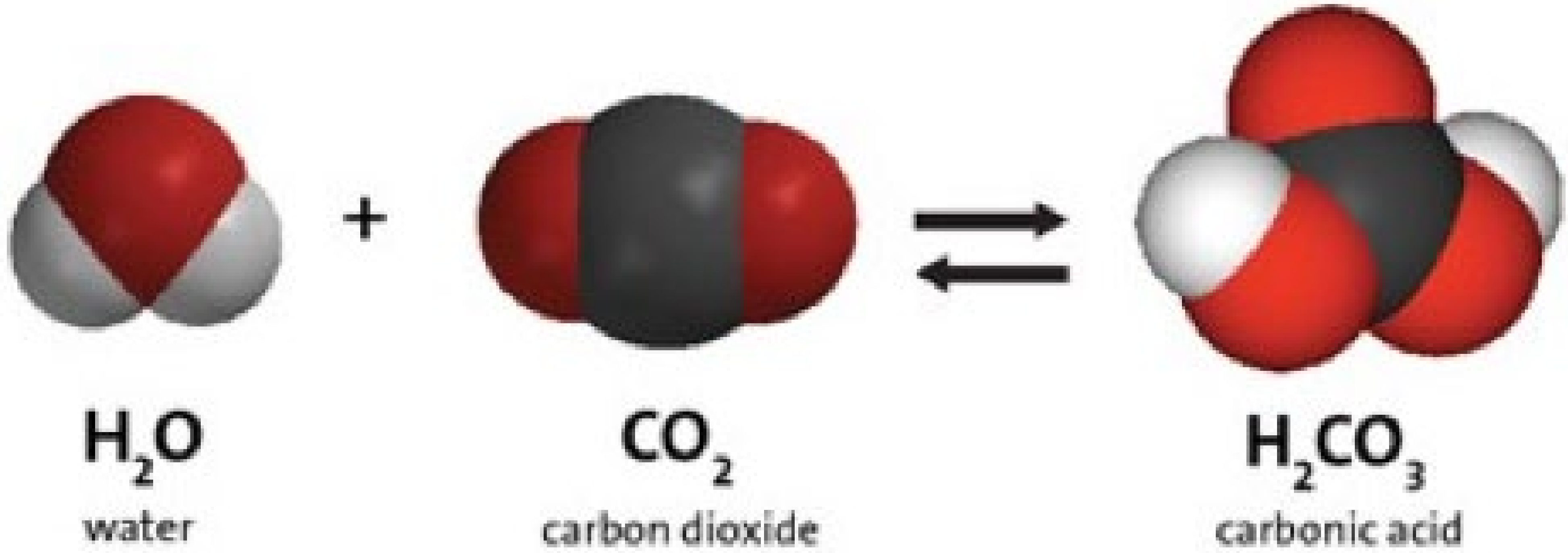
equation:	$k_{\mathrm{H,pc}} = \frac{p_{\mathrm{gas}}}{c_{\mathrm{aq}}}$	$k_{\mathrm{H,cp}} = \frac{c_{\mathrm{aq}}}{p_{\mathrm{gas}}}$	$k_{\mathrm{H,px}} = \frac{p_{\mathrm{gas}}}{x_{\mathrm{aq}}}$	$k_{\mathrm{H,cc}} = \frac{c_{\mathrm{aq}}}{c_{\mathrm{gas}}}$
dimension:	$\left[\frac{\mathrm{L_{soln}} \cdot \mathrm{atm}}{\mathrm{mol_{gas}}}\right]$	$\left[\frac{\mathrm{mol_{gas}}}{\mathrm{L_{soln}} \cdot \mathrm{atm}}\right]$	$\left[\frac{\mathrm{atm} \cdot \mathrm{mol_{soln}}}{\mathrm{mol_{gas}}}\right]$	**dimensionless**
O_2	769.23	1.3 E-3	4.259 E4	3.180 E-2
H_2	1282.05	7.8 E-4	7.099 E4	1.907 E-2
CO_2	29.41	3.4 E-2	0.163 E4	0.8317
N_2	1639.34	6.1 E-4	9.077 E4	1.492 E-2
He	2702.7	3.7 E-4	14.97 E4	9.051 E-3
Ne	2222.22	4.5 E-4	12.30 E4	1.101 E-2
Ar	714.28	1.4 E-3	3.955 E4	3.425 E-2
CO	1052.63	9.5 E-4	5.828 E4	2.324 E-2

- c_{aq} = moles of gas per liter of solution
- L_{soln} = liters of solution
- p_{gas} = partial pressure above the solution, in atmospheres of absolute pressure
- x_{aq} = mole fraction of gas in solution ≈ moles of gas per mole of water
- **atm** = atmospheres of absolute pressure

Henry's Law Constants



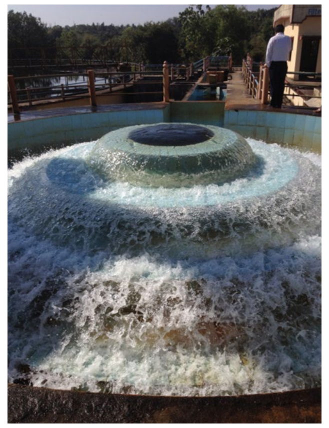
Carbon Dioxide



CO_2 Removal

20-30% → **99.9%**

Spray



Cascade/Tray

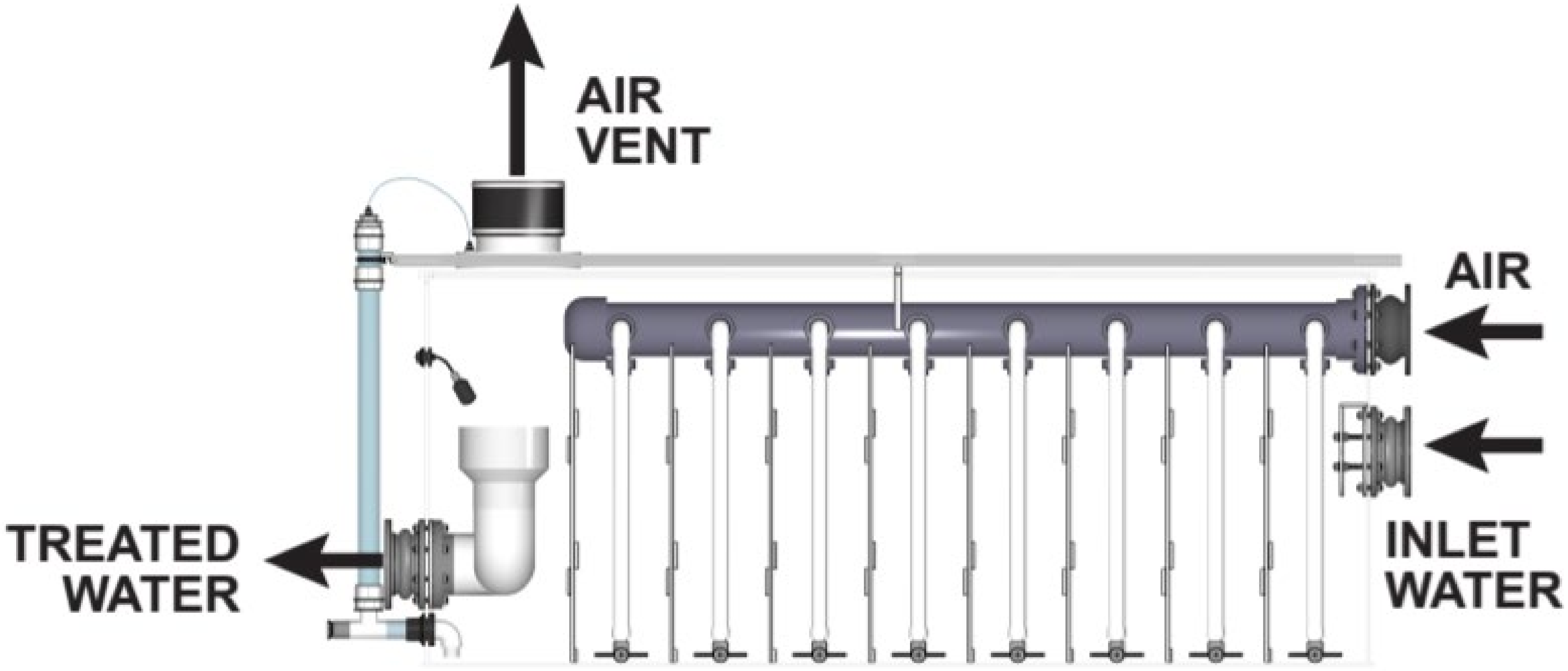
Degasser/Diffuser

Multi-Stage Bubble Diffuse

Packed Tower

Multistage Bubble Aeration

Multi-Stage Bubble Diffusers



Multi-Stage Bubble Diffuser

MSBD

Commercial Multi-Stage Air Stripper

MODEL DB86

DEEPBUBBLE™

Multi-Stage Air Stripper

- HDPE VESSEL & MODULAR ALUMINUM FRAME
- INSULATED NO-SWEAT TANK
- HIGH-EFFICIENCY
- LOW MAINTENANCE

Number of Stages	8
Max Flow, gpm	2,200 PUMPED 1,500 GRAVITY
Max Air, scfm	2,000
Inlet & Outlet Size	2” to 12” exp flange
Vent	8“ to 12”
Empty (shipping) Weight, lb	3,125 (vessel only)
Operating Weight, lb	16,600 (vessel operating)
Blower, Filter, and Skid, lb	1,000

NOTE: specifications subject to change without notice

Lowry Installations for CO_2 Stripping

Partial List of Completed CO_2 Air Strippers
for pH Adjustment/Corrosion Control

Tucuman, Argentina
Buenos Aires, Argentina
Mammoth Lakes, CA WTP 1
Mammoth Lakes, CA WTP 2
Mammoth Lakes, CA Well 1
St. Cloud, FL
Grand Forks, ND
Spanaway, WA Well 5
Ashland, ME
Ashford, CT
Moyie Springs, ID
New Milford, CT
Westminster, MD
South Lake Tahoe, CA
Chico, CA
McKenzie Bridge, OR
Scottsdale, AZ

Dayton, OR
Minden, NV
Killington, VT
Castine, ME
Harrison, ME
Lakeville, CT
Searsport, ME
Hollis, NH
Pine Cove, CA
Bow, NH
Sutton, MA
Hawthorne, CA
Coventry, RI
Mexico, ME
Reading, PA
Berry Creek, CA
Scottsdale, AZ

Idyllwild, CA
Manchester, ME
Swansea, MA
Divide, CO
Madawaska, ME
Poland Spring, ME
Nevada City, CA
Shrewsbury, MA
Hollis, ME
Bethel, ME
Tijeras, NM
Missoula, MT
Rochester, NH
Brownville, ME
Bonners Ferry, ID
Mariposa, CA
Whitehorse, Yukon Territory, CN
Dixfield, ME

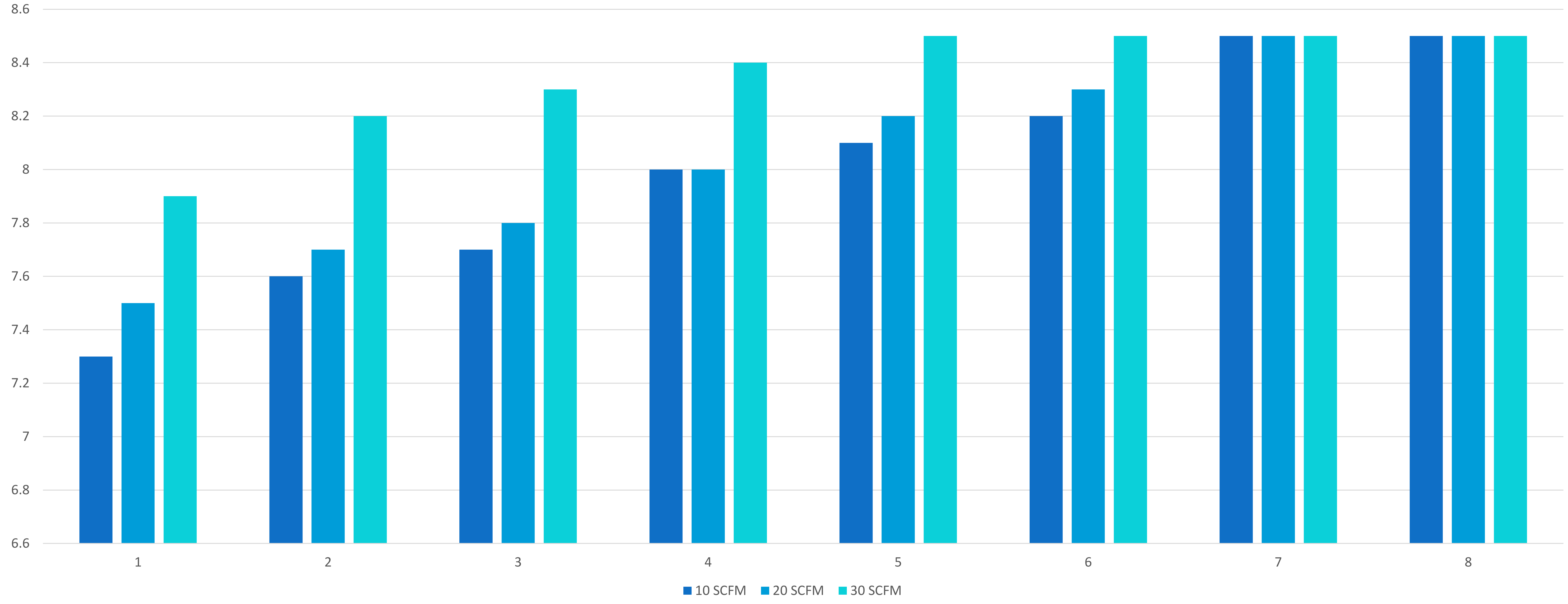
Oxford, ME
Dayton, OR
Rockville, CT
Shelton, CT
Farmington, ME
Danbury, CT
Charlton, MA
Watertown, CT
South Paris, ME
Forest Ranch, CA
Rumford, ME
Steamboat Springs, CO
Fallen Leaf, CA
Bowdoinham, ME
Spanaway, WA Well 9
Hamilton, ON, CN
Stonington, CT

Pilot Testing

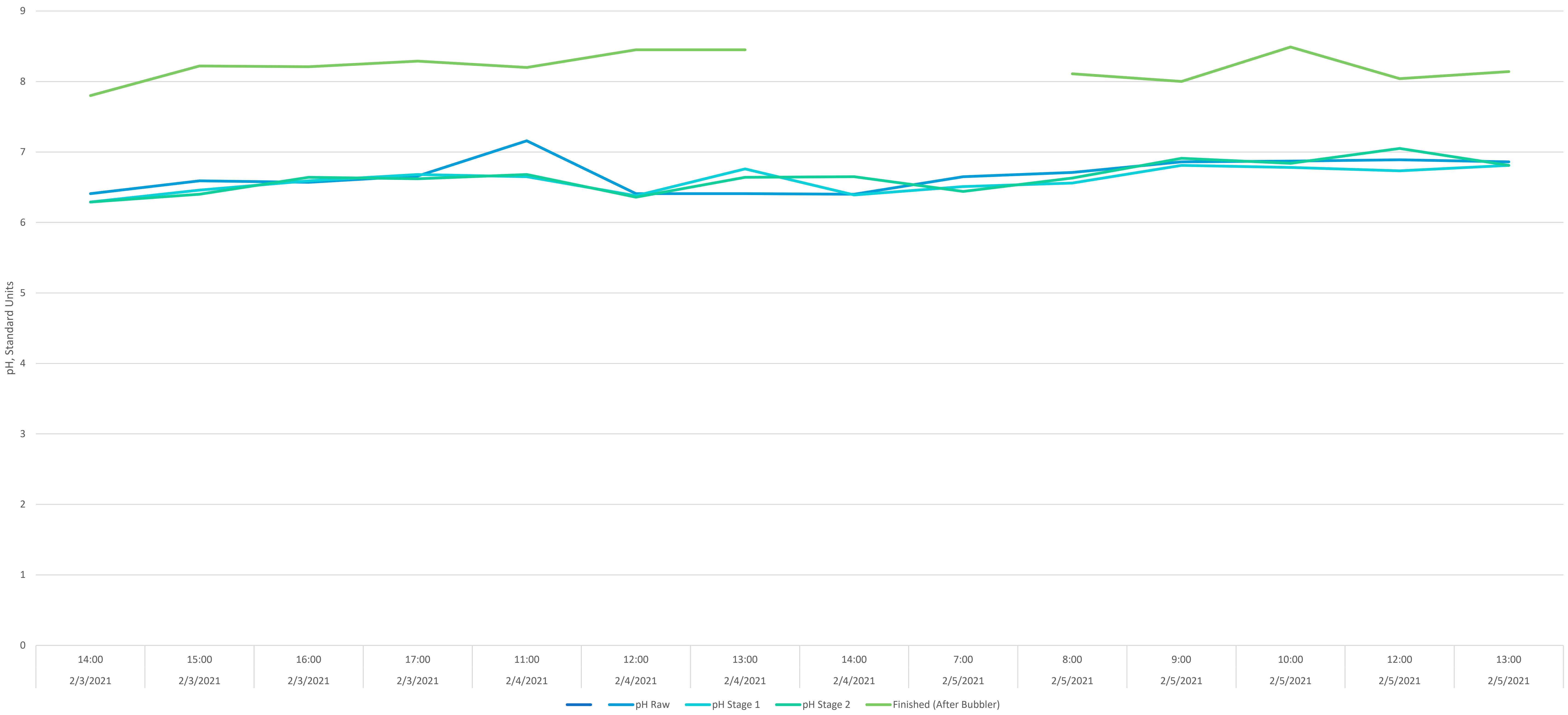
Pilot Testing

Pilot Testing

Pilot Testing



Pilot Testing



Pilot Testing

Parameter	Average	Minimum	Maximum	Removal %
pH (Raw)	6.4	6.2	7.7	
pH (Stage 2)	6.3	6.2	6.5	
pH(Post DB)	8.2	7.8	8.5	
T (Raw)	17.2	15.0	18.1	
T (Stage 2)	17.4	16.9	18.0	
CO_2 (Raw)	121	76	152	
CO_2 (Post DB)	1.5	0.7	3.8	99%

Design Procedure

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Given a specific contaminant (Henry's Constant) and water temperature, the basic design parameters for the process are:

- Air/Water (A/W) Ratio
- Depth of Bubble Rise
- Size of Bubbles
- Number of Stages

The stages in the process are what create an efficiency far beyond what a single completely-mixed vessel would produce. As the number of stages increases, the process efficiency approaches that of a theoretical plug-flow process. The two processes are shown below in equations 1 and 2.

Completely-mixed stages in series:

(1) $C/C_o = [\ 1/(1+kt)]^m$

Where:

- C = concentration at steady state
- C_o = inlet concentration
- k = the first-order rate constant for a single stage, time-1 (directly proportional to air intensity, AI)
- t = detention time, volume/flow, of a single stage
- m = number of stages in series

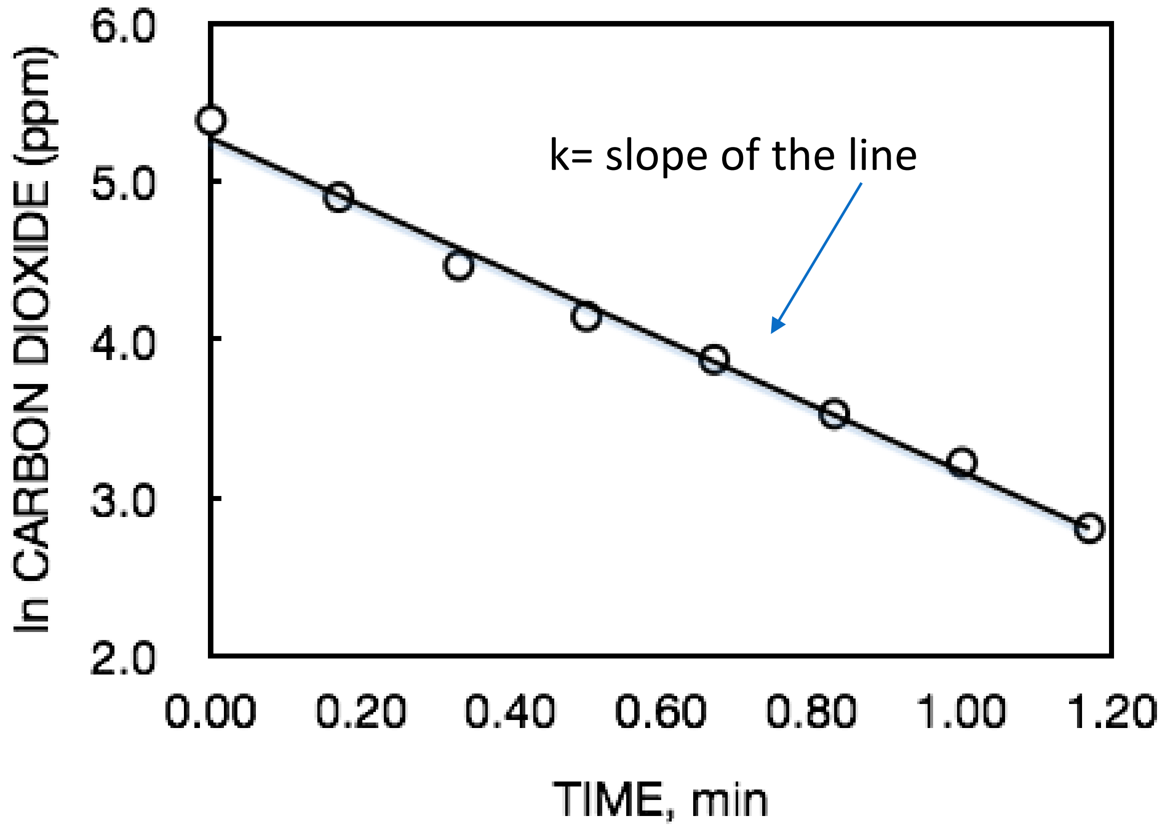
Plug-flow:

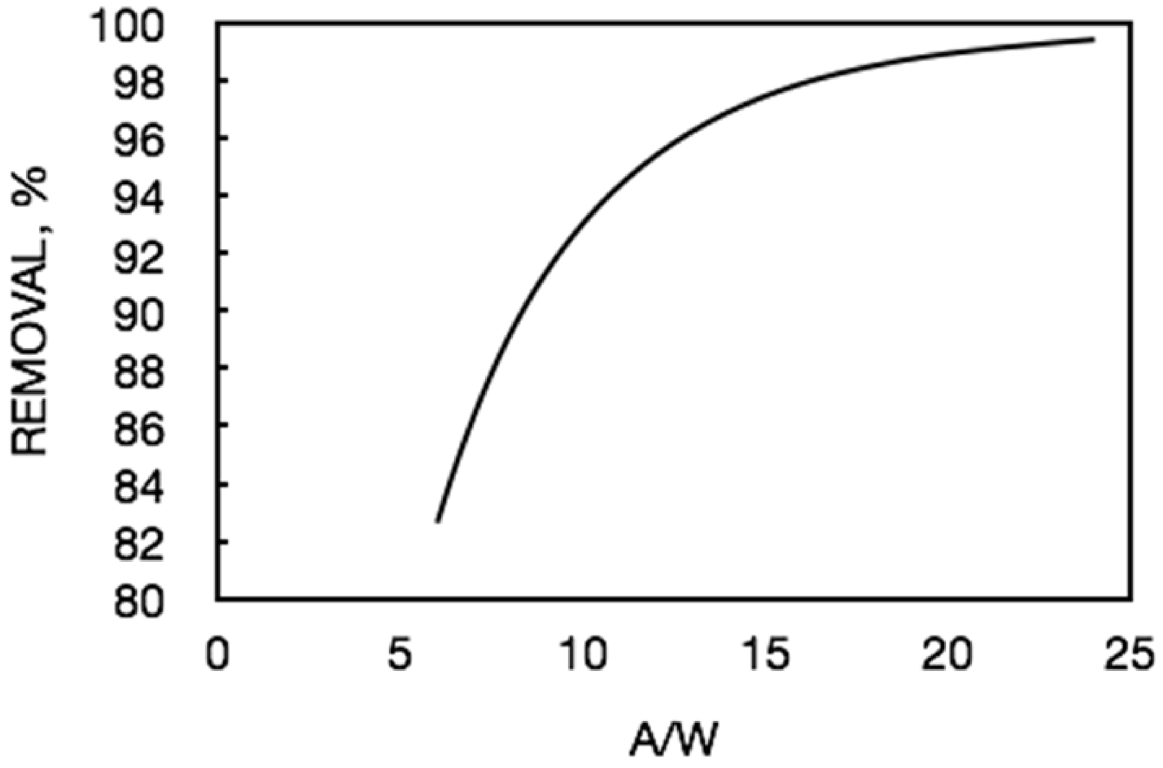
(2) $C_t / C_o = e^{-kt}$

Where:

- C_t = concentration at time t

Design Procedure





Removal of carbon dioxide through six stage system
At varying A:W ratios

Size Appropriate Unit and Blower

	Model DB32	Model DB63	Model DB84	Model DB86
Number of Stages	3	6	8	8
Max Flow, gpm	150	500	1,200	1,800
Max Air, scfm	200	600	1,350	2,000

Q&A

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Thank you!