Corrosion Control with Air Stripping

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Air Stripping CO_2

- Air stripping is an effective method of corrosion control in water supplies containing significant CO2 and low to moderate alkalinity.
- Both Pb and Cu can be reduced to low levels by stripping CO2 to raise the pH, without the use of any corrosion control chemical.
- Air stripping offers several advantages to adding alkalinity and/or phosphate for Pb and Cu control in distribution systems:
  - Stable and consistent pH
  - No increase in alkalinity
  - No addition of the conjugate ion associated with the addition of a base
  - Concurrent removal of other volatile constituents such as radon
  - Lower operating cost in some cases
- Air stripping does not reduce chlorine residual
- Air stripping does not reduce alkalinity, unless scaling occurs

Typical Air Stripping Application

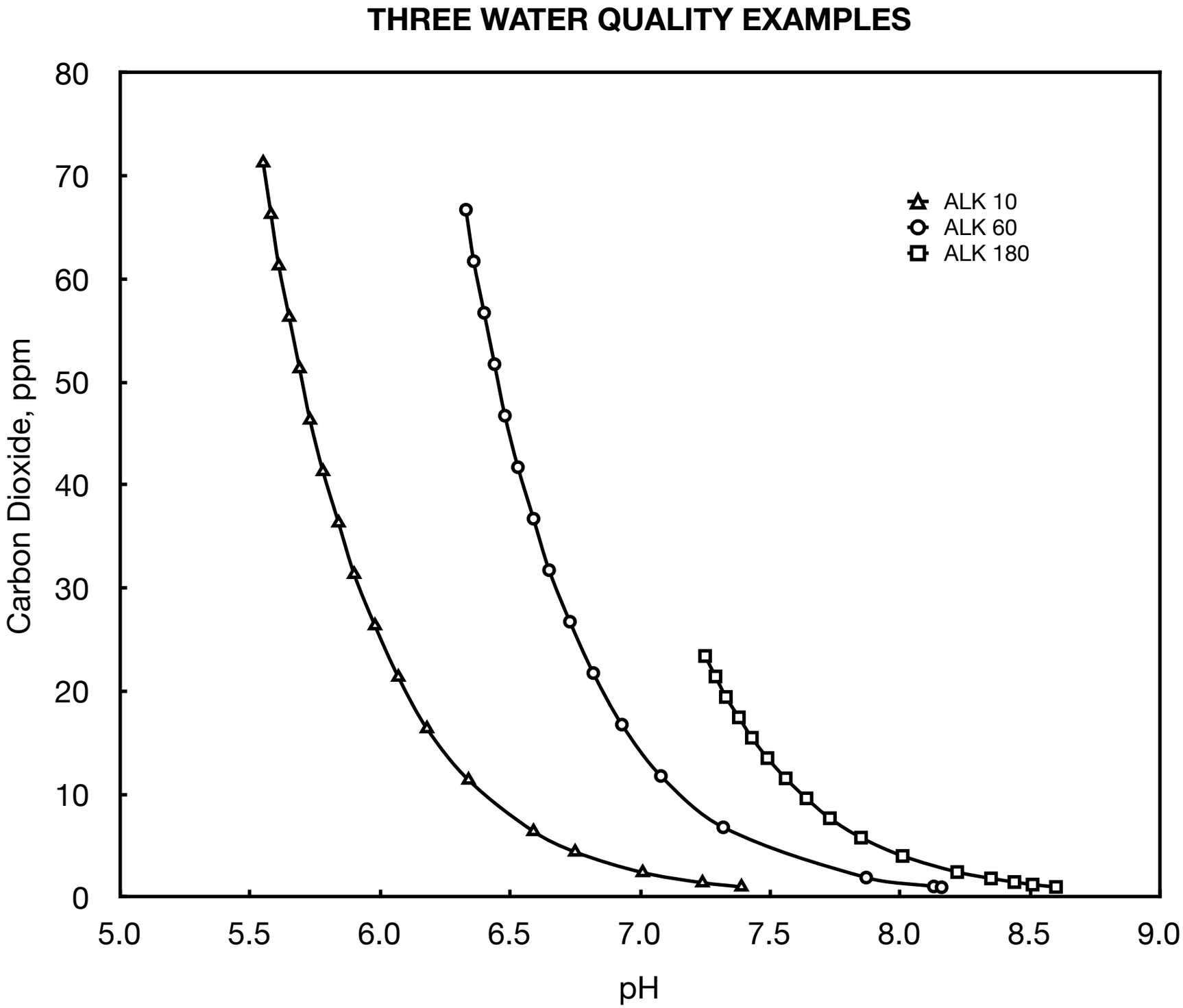
- Groundwater
- pH depressed by carbon dioxide
- Alkalinity between 8 ppm - 200+ ppm
- Low Fe & Mn
- Cu violations in distribution system - common
- Pb violations in distribution system - less common
- Utility desire to avoid chemical additions

Three Examples - Range of Alkalinity

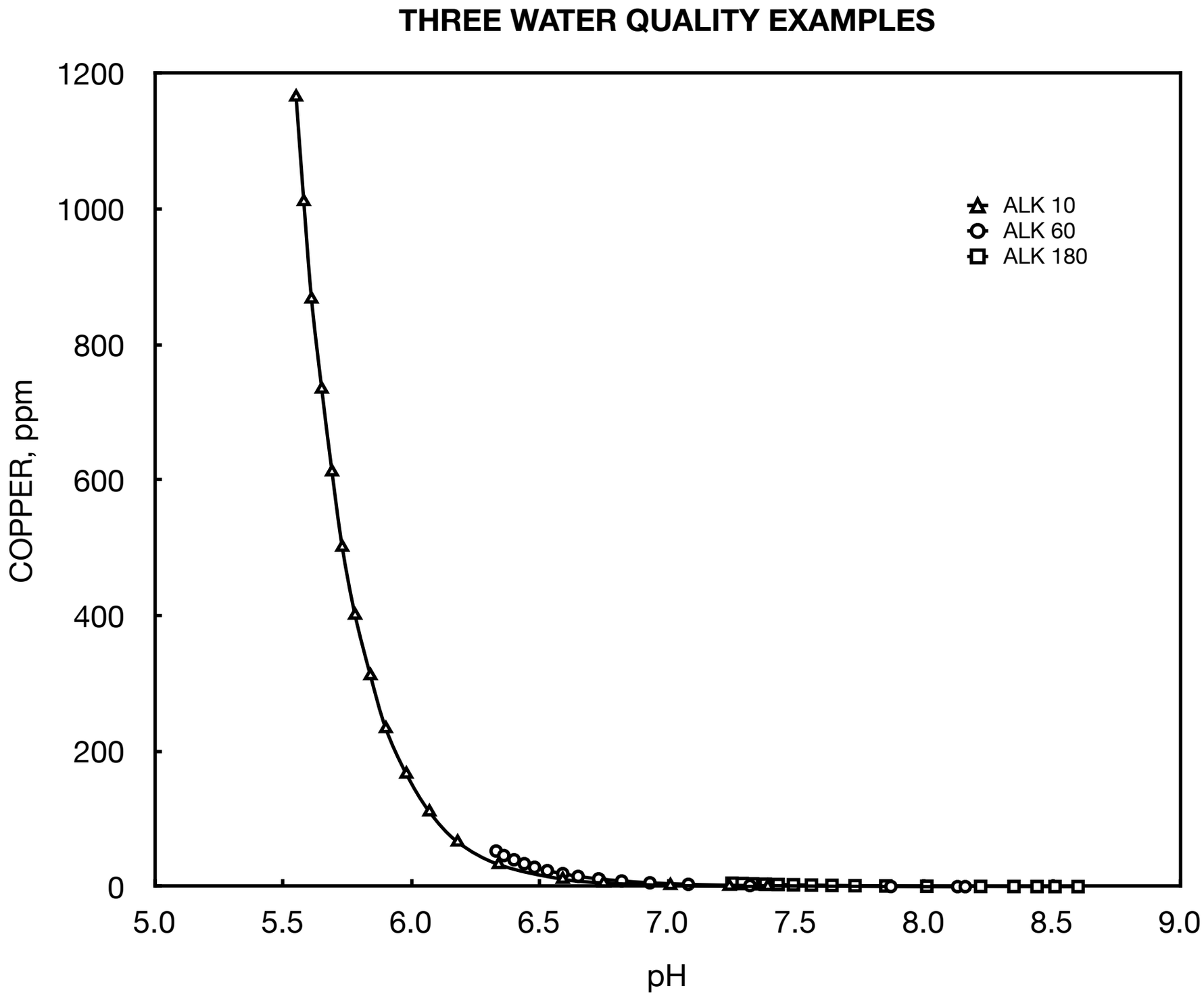
- Low Alkalinity Example: pH = 5.55; alk = 8-10 ppm; Carbon Dioxide = 71.3 ppm
    - lost copper plumbing in homes 2-3X; 90th Percentiles Cu = 5.52 ppm & Pb = 0.0040 ppm (at times Cu >80 ppm on single sample first-draw)
- Moderate Alkalinity Example: pH = 6.33; alk = 60 ppm; Carbon Dioxide = 66.7 ppm
    - lost significant fraction of copper piping
- Higher Alkalinity Example: pH = 7.25; alk = 180 ppm; Carbon Dioxide = 23.4 ppm

NOTE: THE FOLLOWING SIX (6) GRAPHS ARE FROM A THEORETICAL SOLUBILITY MODEL WITH NEW PIPE SURFACES - Pb & Cu ARE NOT ACTUAL LEVELS THAT WOULD RESULT IN THE FIELD WITH ACTUAL PIPING SURFACES.

Carbon Dioxide/pH/Alkalinty



Carbon Dioxide/Copper



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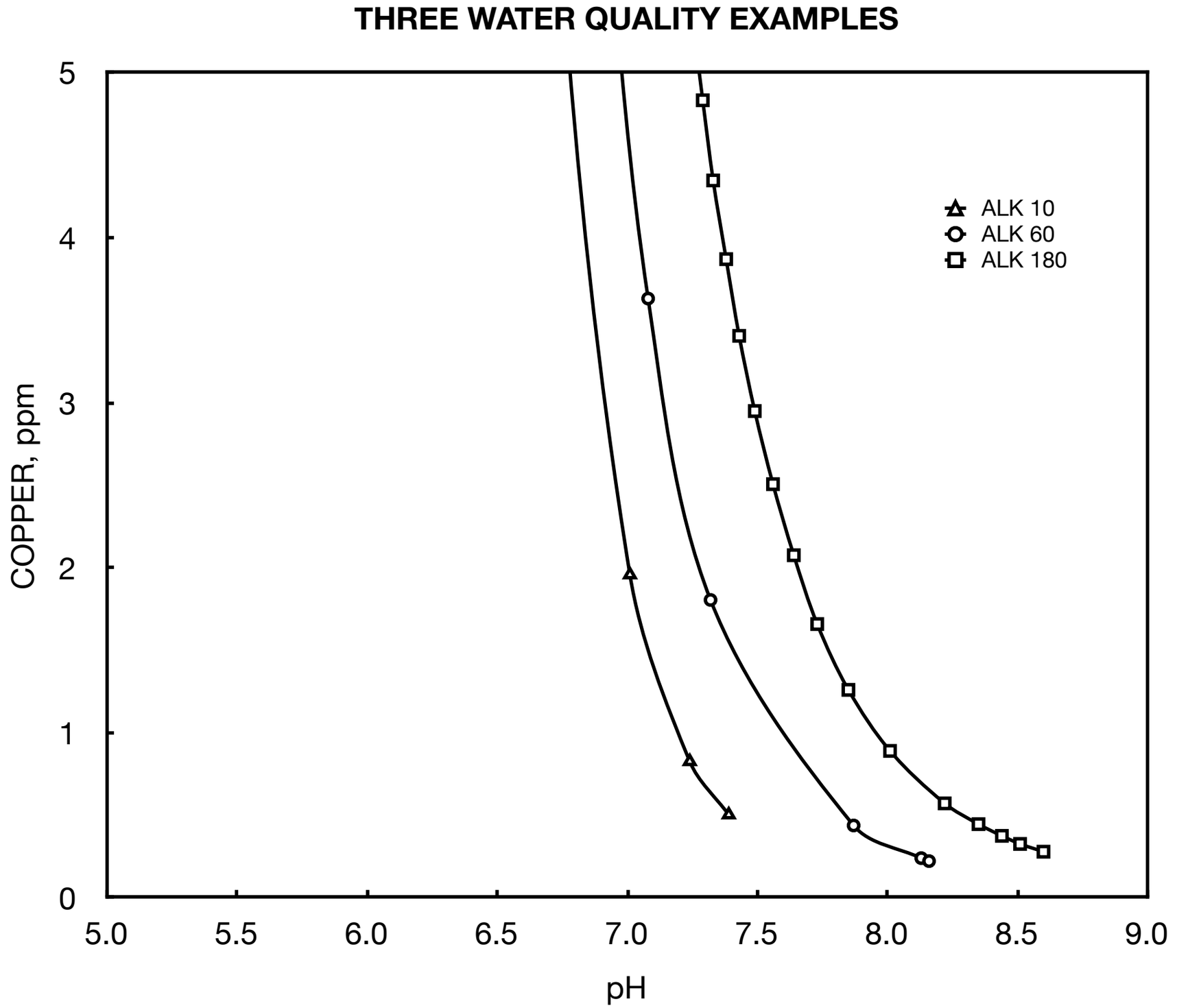
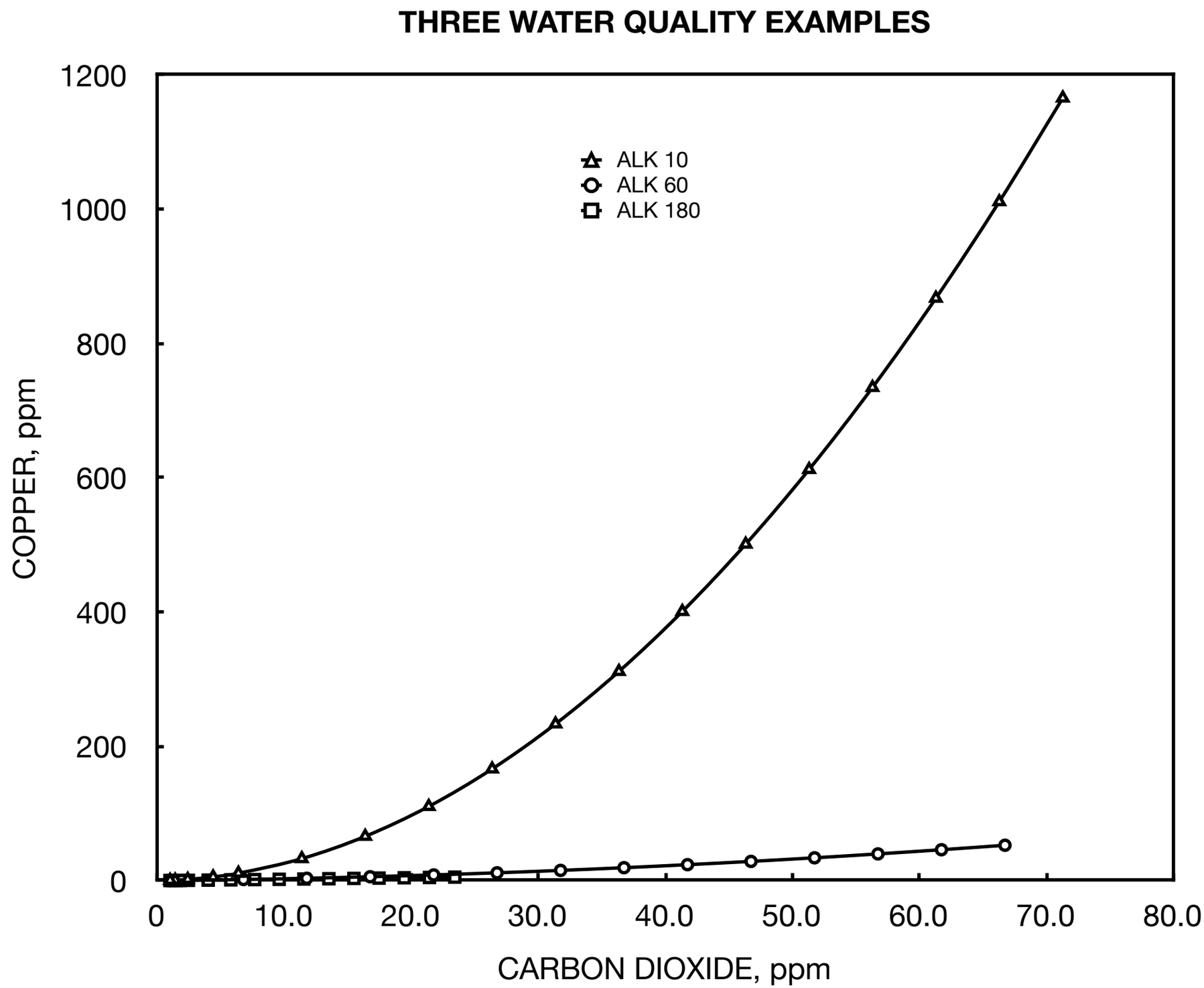
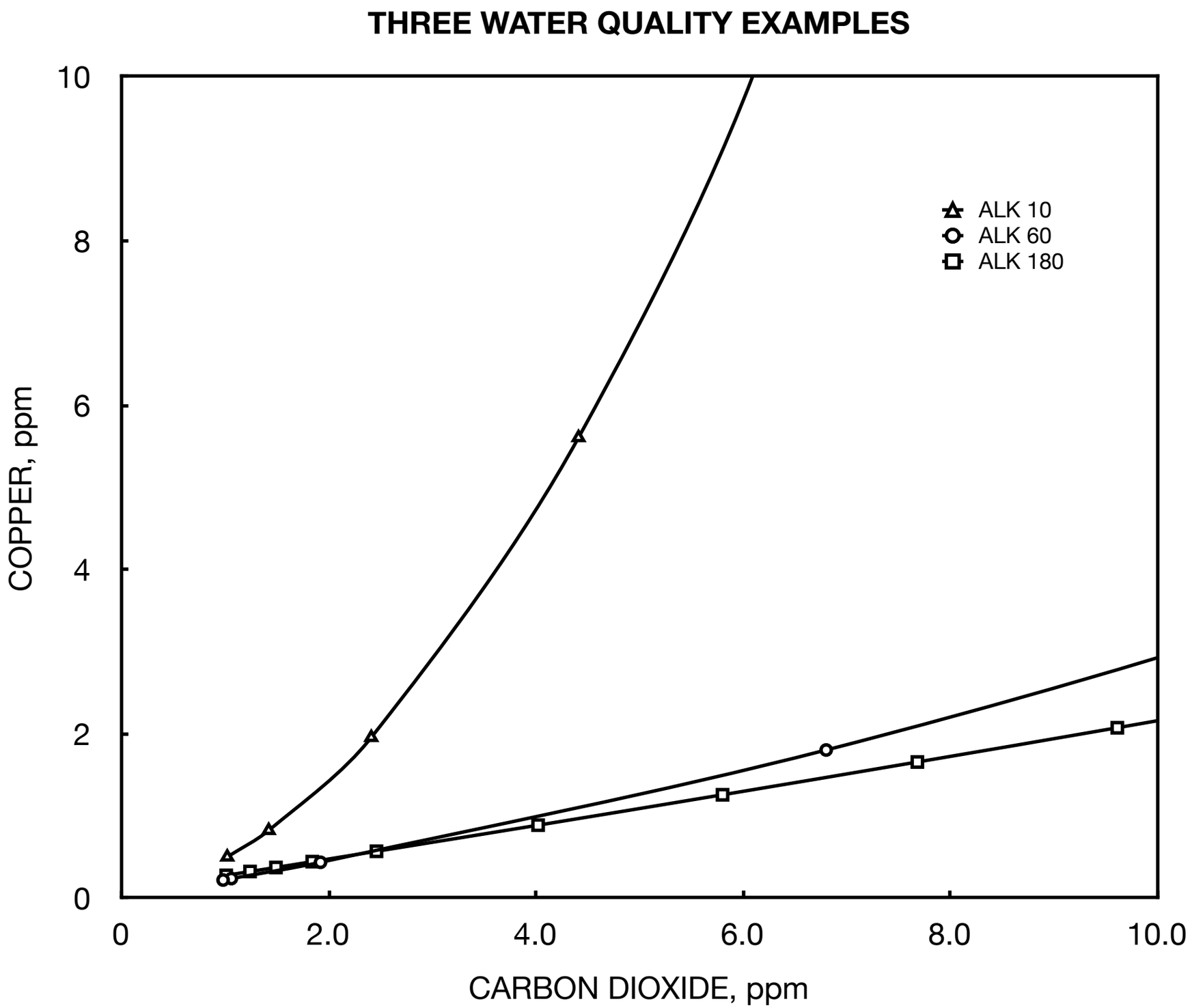


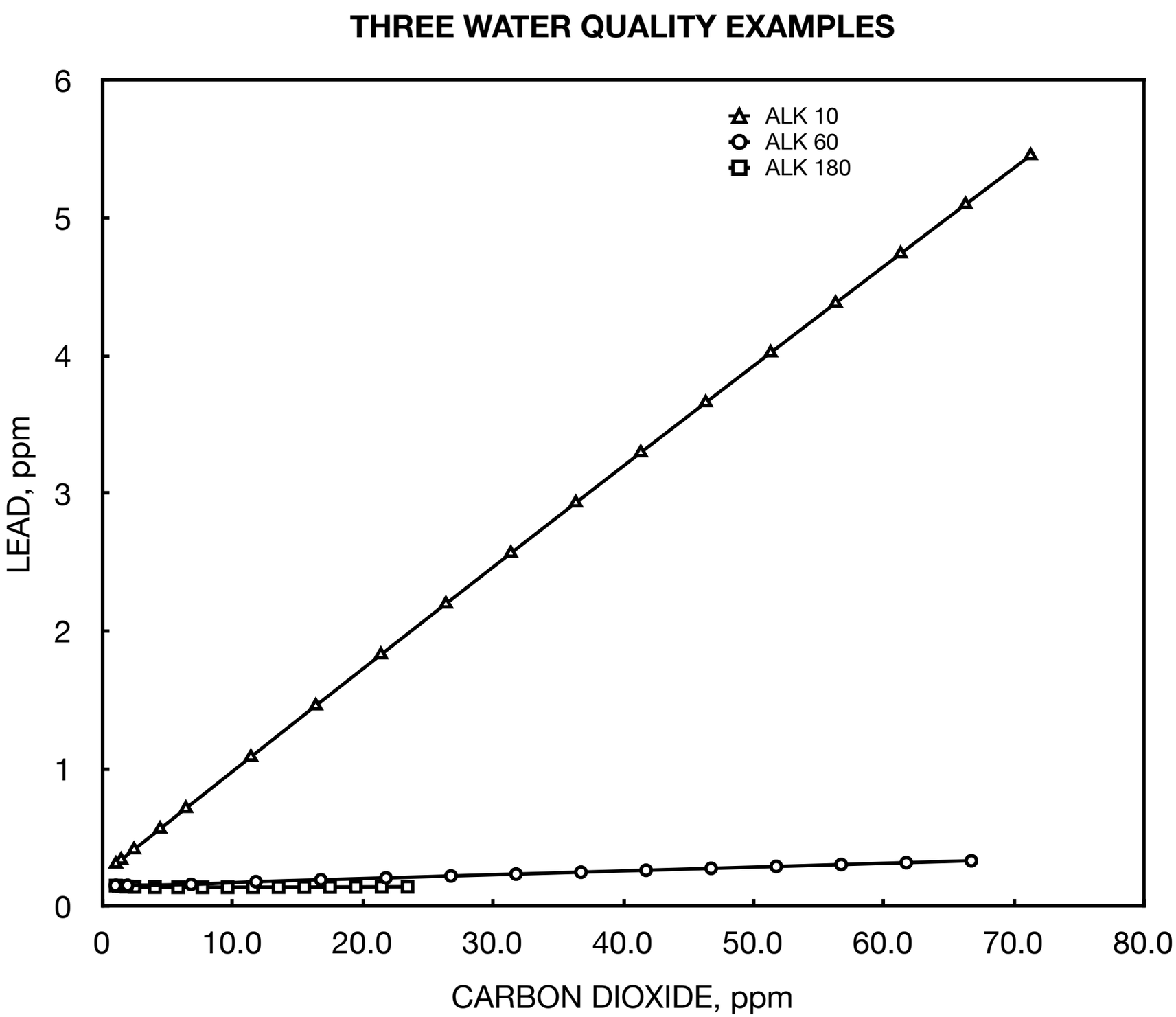
Carbon Dioxide/Copper



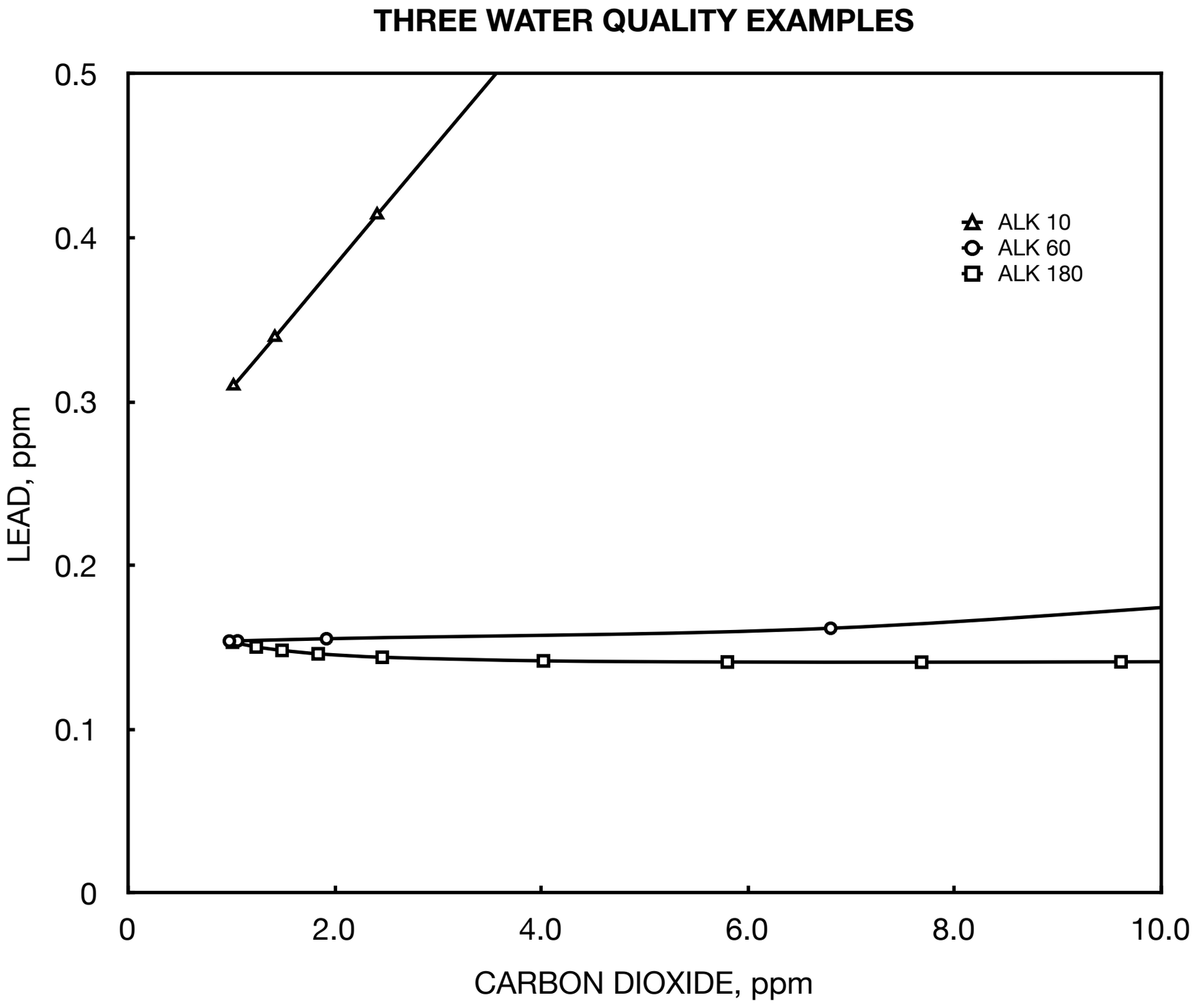
Carbon Dioxide/Copper



Carbon Dioxide/Lead



Carbon Dioxide/Lead

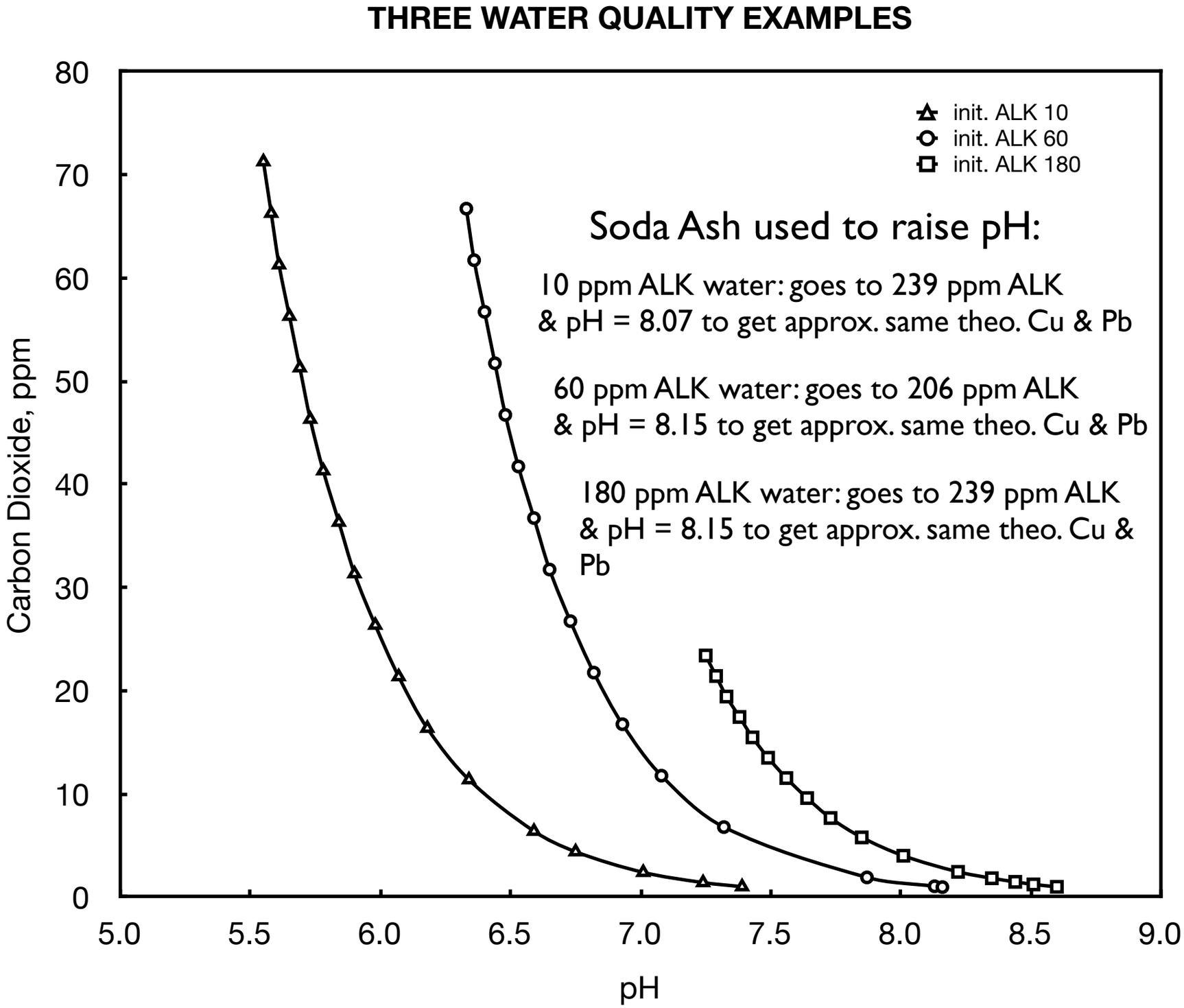


Important Points

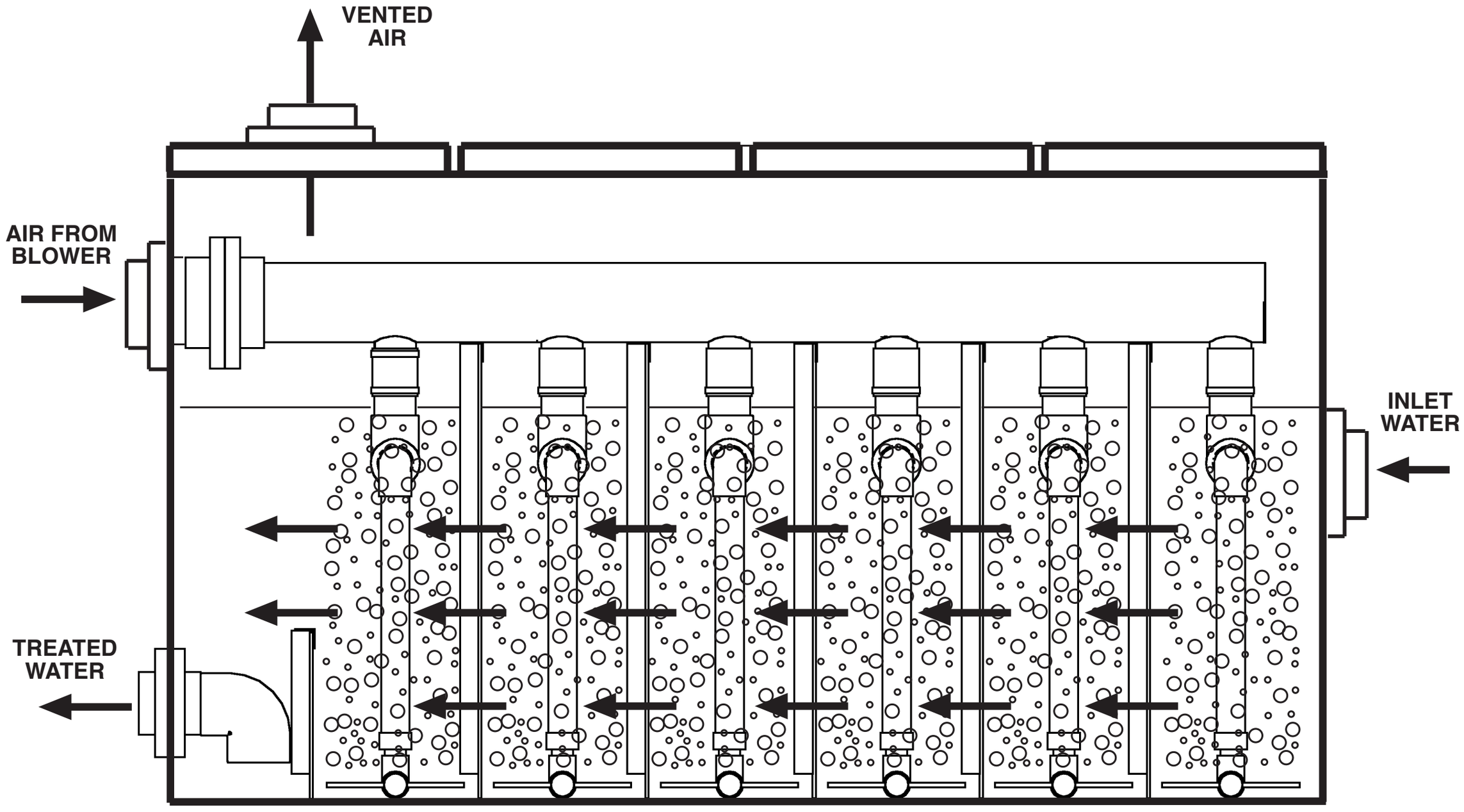
- low Cu levels achieved at pH 7.2 - 7.8, as a function of alkalinity and CO_2
- this pH range corresponds to removal of CO_2 to below 2 - 4 ppm for low copper, as a function of alkalinity
- higher Cu and Pb with lower alkalinity (lower pH) for a given level of carbon dioxide
- Pb level relatively insensitive to carbon dioxide level at higher alkalinity ($\geq$50)
- Pb level very sensitive to carbon dioxide level at very low alkalinity ($\leq$20)
- a significant fraction of Pb can be particulate and not predicted by theoretical solubility models
- recall that previous graphs show theoretical Cu & Pb & actual levels will be much lower in field

How About Chemical Treatment?

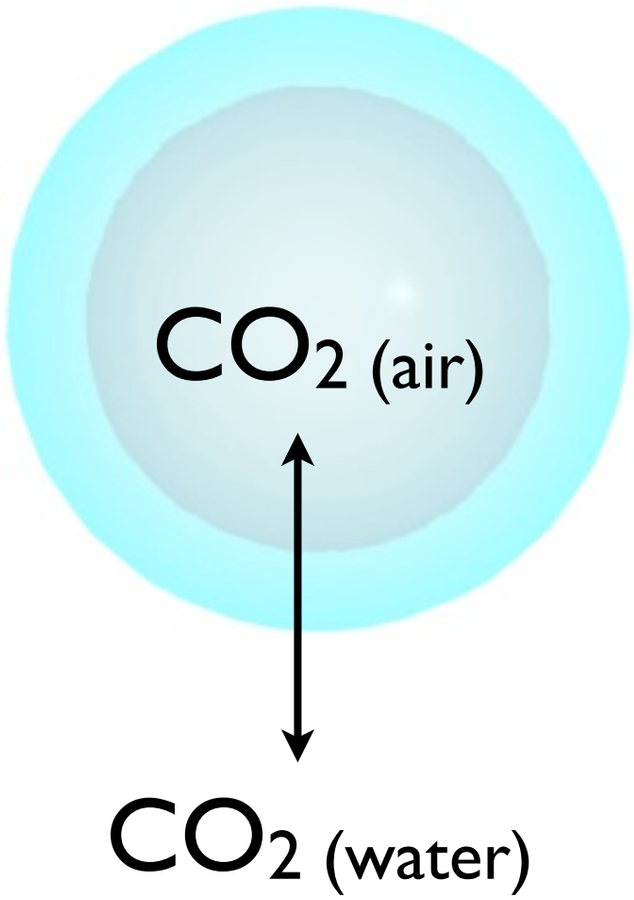
Carbon Dioxide/pH/Alkanlinty



Multi-Stage Bubble Air Stripping



Equilibrium



Henry's Constant

Contaminant	k_H, M/atm
Isopentane	7.30E-04
H_2S	1.00E-03
Methane	1.30E-03
Radon	9.30E-03
CO_2	3.40E-02
PCE	5.50E-02
TCE	1.20E-01
Benzene	1.80E-01
Chloroform	2.50E-01
MTBE	1.7
Ethanol	190

more strippable

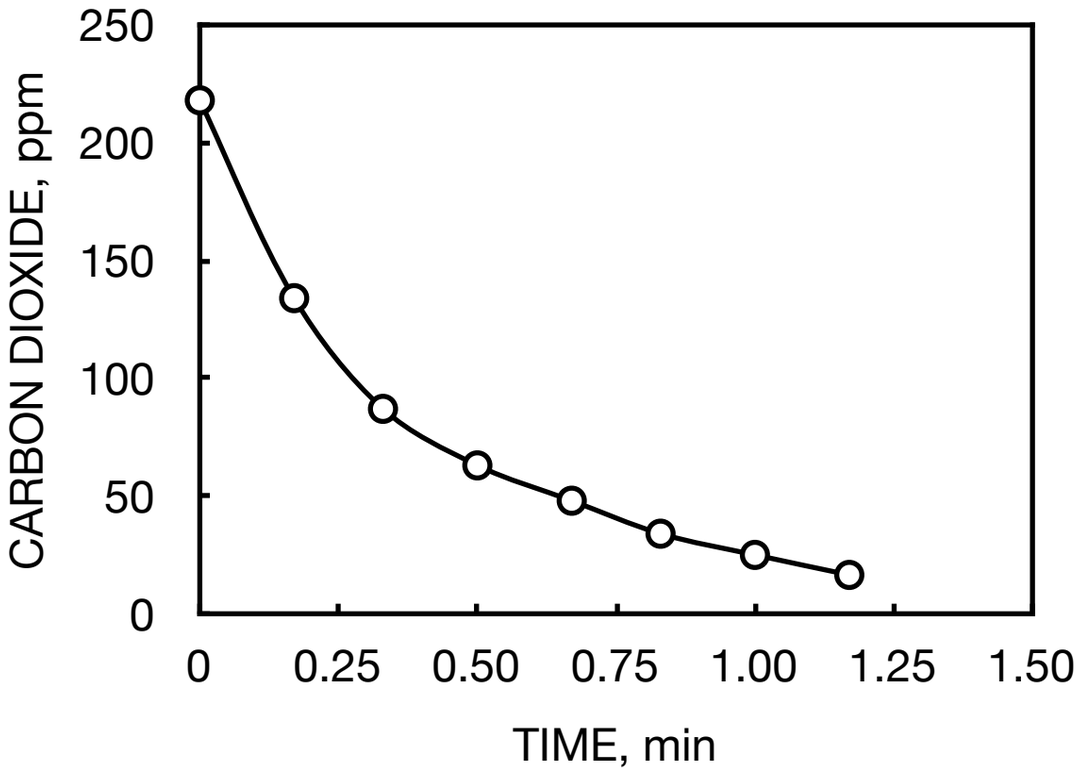
less strippable

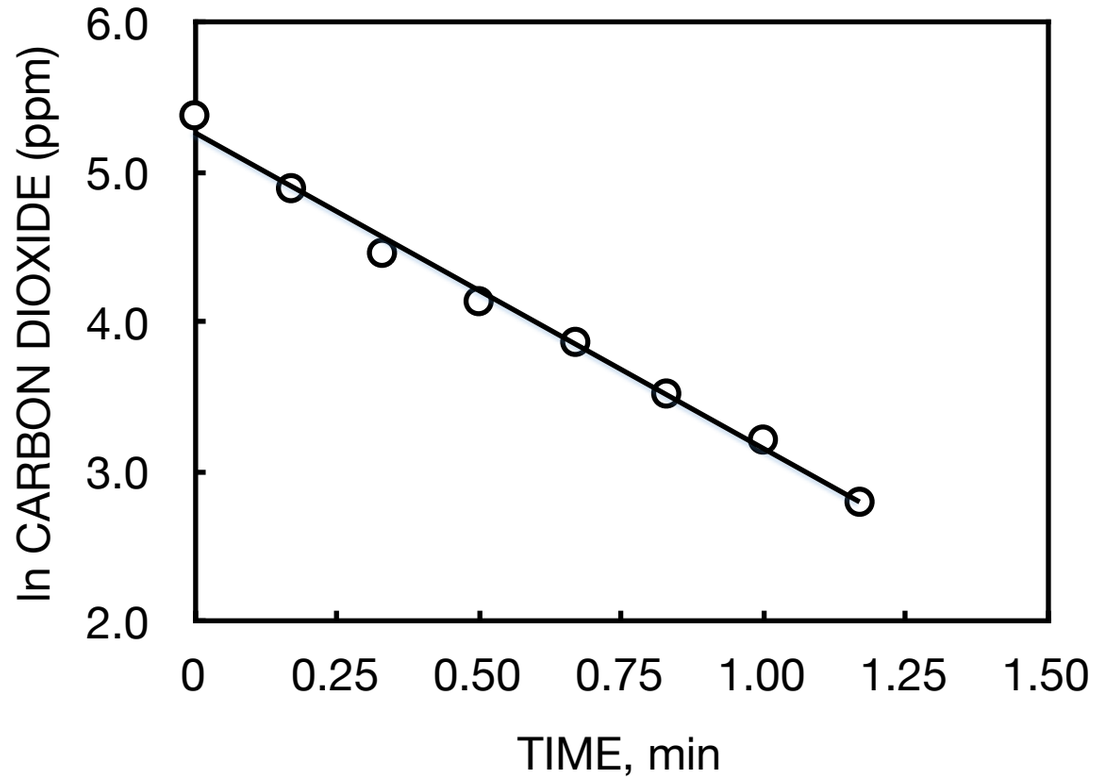
$$CO_{2\,(water)} + H_2O \longleftrightarrow H^+ + HCO_3^-$$

$$HCO_3^- \longleftrightarrow H^+ + CO_3^{2-}$$

Multi-Stage Bubble Air Stripping

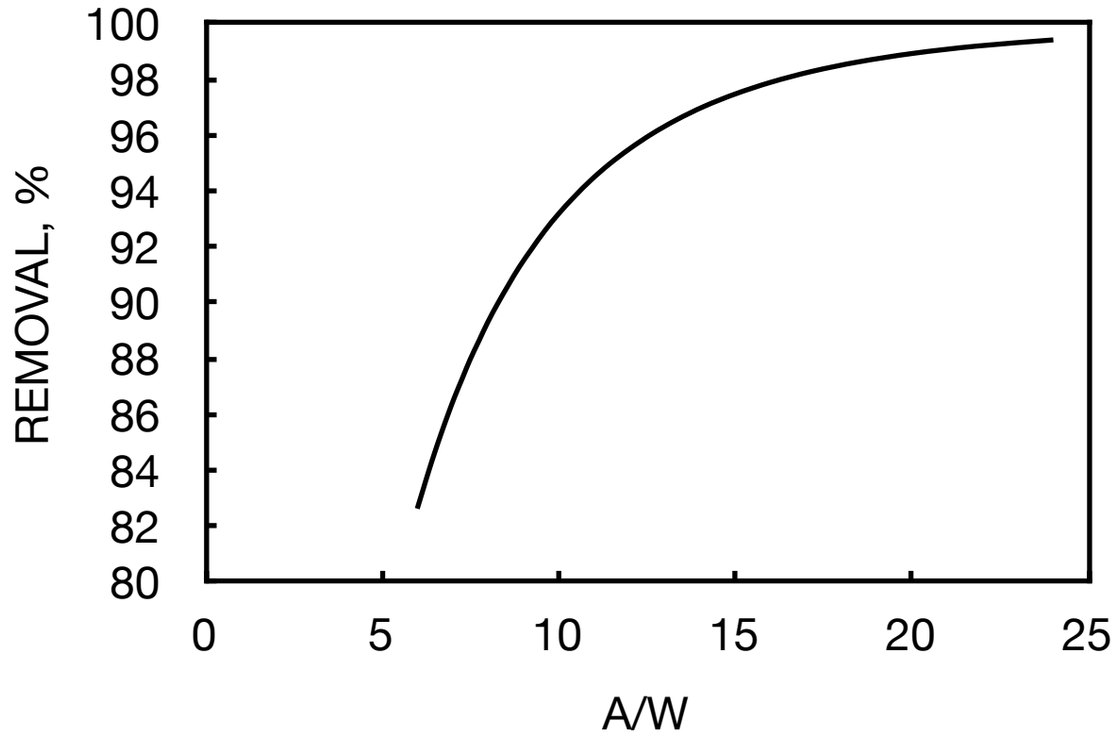
$$-dC/dt = kC$$





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

- HENRY'S CONST. & STAGES
- DEPTH
- BUBBLE SIZE
- TEMPERATURE



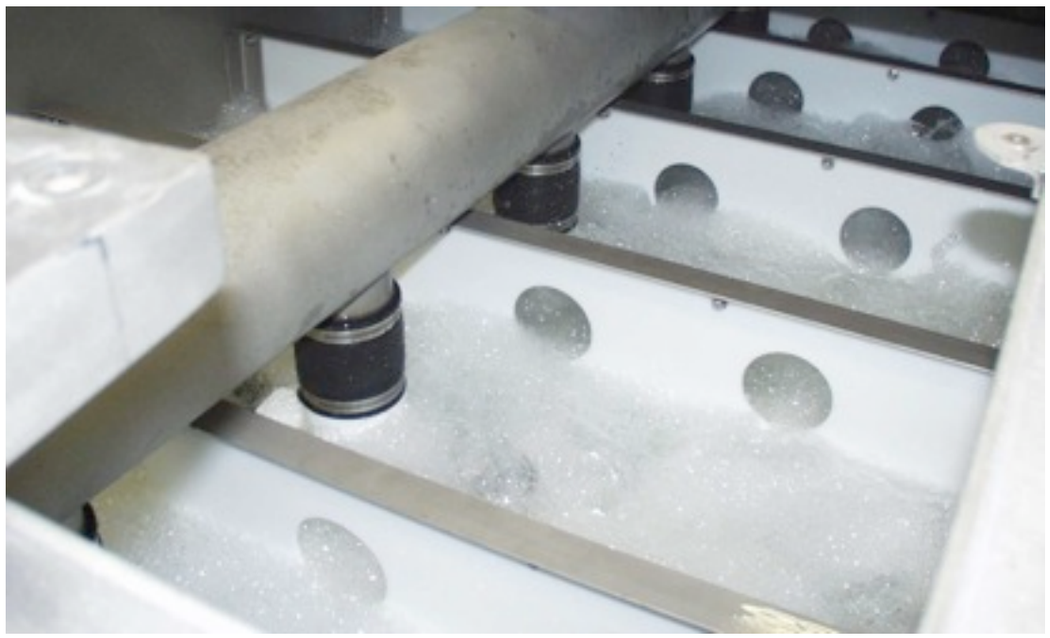
Two CA Utilities with Pb & Cu

"California's First Aeration Plants for Corrosion Control" by M.R. Schock, J. Holldber, T.R. Lovejoy, and J.D. Lowry, JWWA, Mar 2002

- High Cu and Pb in distribution
- Struggled with phosphate addition to control
- Did not want chemical additions
- Air stripping solved both Pb and Cu without chemicals
- pH raised from 6.1-6.3 to 7.6-7.8
- Started in Oct. 1998 and met Pb & Cu action levels by Jan. 1999.

CA - Three Wells/Air Strippers

High Copper Levels - Staining
Started Systems, Dumped Storage
Customers Reported Stains Gone in 24-hr



Harrison & Farmington, ME

Harrison - 350 gpm Well pH = 6.2

High Cu & Pb Levels: 90th-Percentile levels were 6.8 ppm Cu and 39 ppb Pb

Air stripping solved problems w/o chemicals, with Pb reduction occurring gradually over several months with treated pH ≈7.3, Radon removal = >90%

NOTE: Operator has increased flow rate in summer months above design flow, and observes rising Pb & Cu levels. Lowering flow rate corrects this problem.

Farmington - 750 gpm Well

High Cu & Pb Levels: were adding silicates

Air Stripping Solved Problems w/o Chemcials, with treated pH ≈7.3-7.5; CO_2 & Radon removal = >95%

NOTE: State wanted chemicals to be added for 18 months after startup, but the pH was 8 and we wanted to see results without chemicals, so it was terminated. This saved the utility $27,000 and there were no problems.

Other Examples

CA Utility - 1400 gpm

pH: 6.2 Raised to 7.6-7.8

NV Supply - 150 gpm

pH: 6.4 Raised to 7.8

Lakehurst Acres (Pond Village)

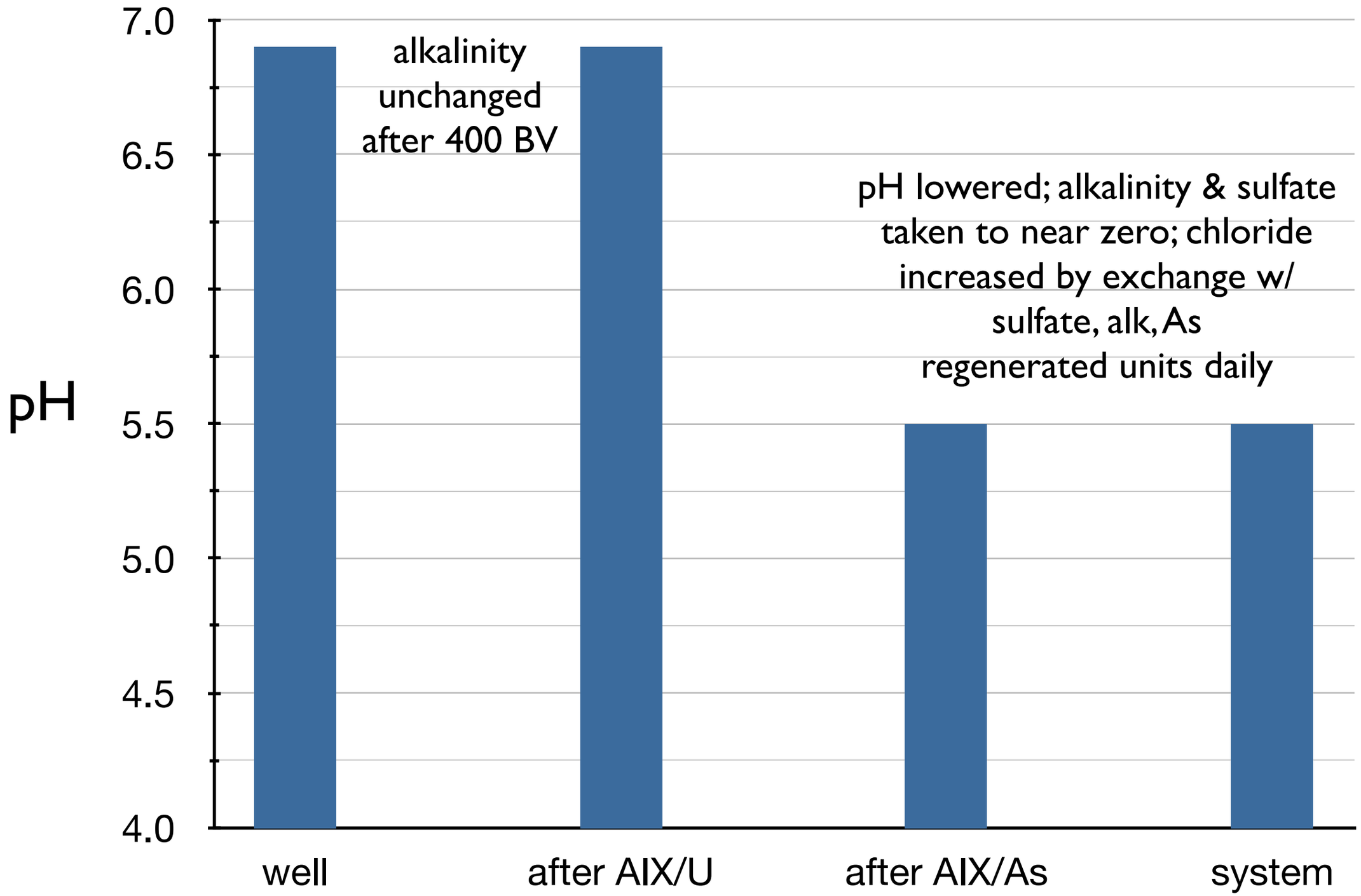
Water Treatment & Corrosion Control

- U Removal
- As Removal
- Radon Removal
- pH Control
- Pb & Cu Reduction

Timeline - 2004 to 2009

- Anion Exchange (AIX) Designed for U & As
- U & As Removal Implemented & Operated for 4-5 months
- High Pb & Cu Detected
- Alkalinity Added
- Treatment Changed to AIX for U & Adsorption for As, AIX regenerated to sewer every 2-3 yrs
- Unstable pH Control
- Air Stripper Designed/Installed
- Pb & Cu in Compliance

Misapplication - AIX w/Frequent Regen.



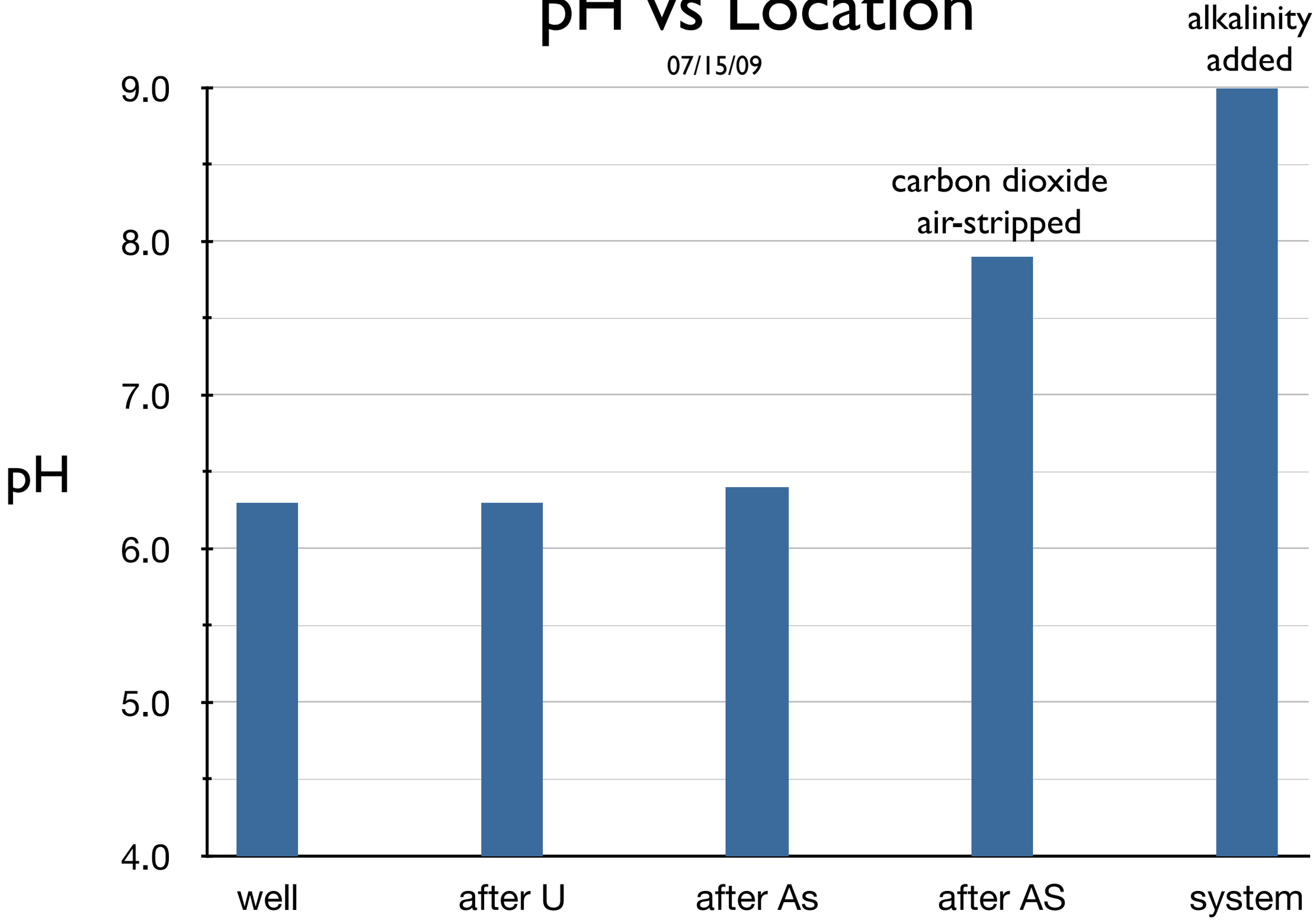
Alkalinity (Potash) Added

Pb in Piping System

Air Stripper Added

pH vs Location

07/15/09



Conclusions

- Air stripping is an ideal solution to corrosion control problems caused by high carbon dioxide in groundwaters with low to moderately high alkalinity
- Corrosion control chemicals can be eliminated or avoided by using air stripping, resulting in a superior water quality following treatment
- Air stripping carbon dioxide to low levels produces a treated water with a more stable pH and water quality compared to a chemically-treated water