Effects of Phosphate on Lead Leaching in the Presence of Chlorine and Chloramine

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Outline of the presentation

- Goals
- Methods
- Metal release data
- Chlorine demand data
- Morphological data
- Conclusions and recommendations

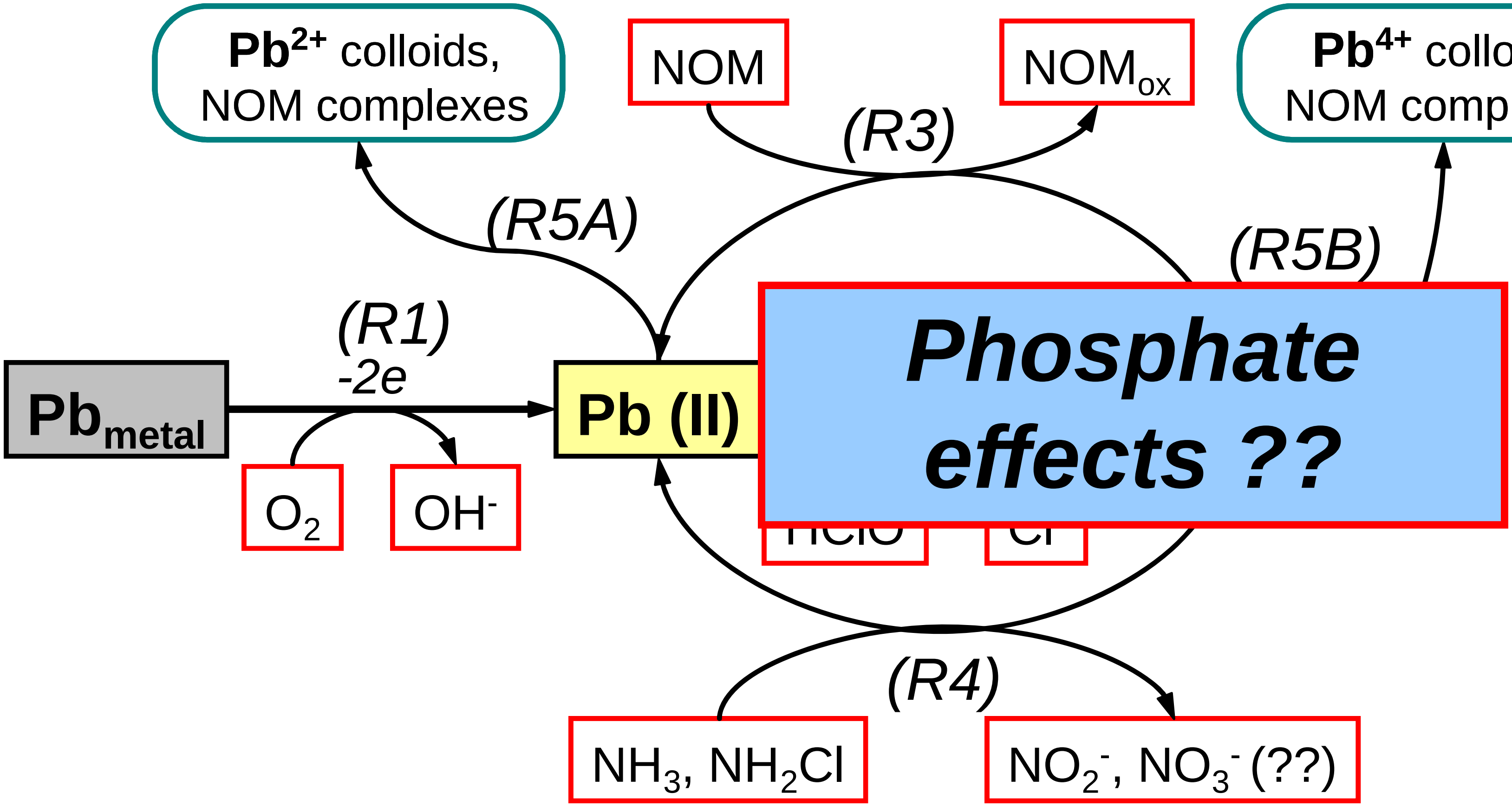
Goals

- Examine the effectiveness of phosphate in suppressing lead release in the presence of chlorine and chloramine
- Compare release of total and colloidal lead in the absence and presence of phosphate
- Examine morphological changes of corroding lead surfaces in the presence of phosphate

Background information

- There was a well-known lead release episode in Washington DC (2002-2003) associated with the introduction of chloramine as the secondary disinfectant
- Major mechanism involved in release of lead in the presence of chloramine is the reduction of lead dioxide PbO_2 that is formed only in the presence of chlorine
- The introduction of phosphate by WASA has helped to suppress lead release to below the action level (15 μg/L, 90th percentile) but the transition was relatively slow
- What features of the action phosphate in the presence of chlorine or chloramine can be expected?

Reaction of chlorine species with Pb(II)

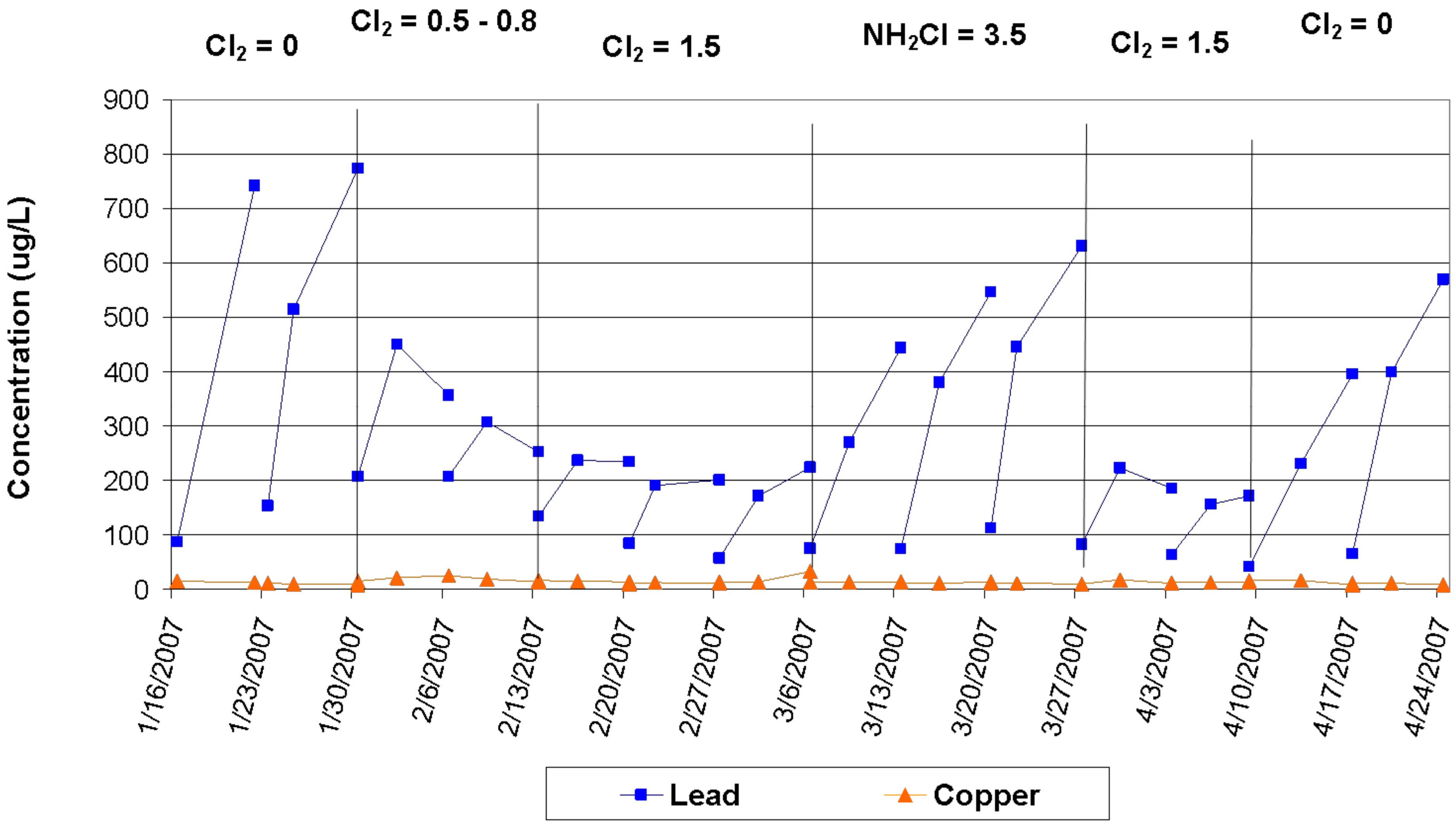


Pb^{2+} colloids, NOM complexes
NOM
NOM_{ox}
Pb^{4+} colloids, NOM complexes
(R3)
(R5A)
(R5B)
(R1)
-2e
Pb_{metal}
Pb (II)
O_2
OH^-
Phosphate effects ??
(R4)
NH_3, NH_2Cl
NO_2^-, NO_3^- (??)

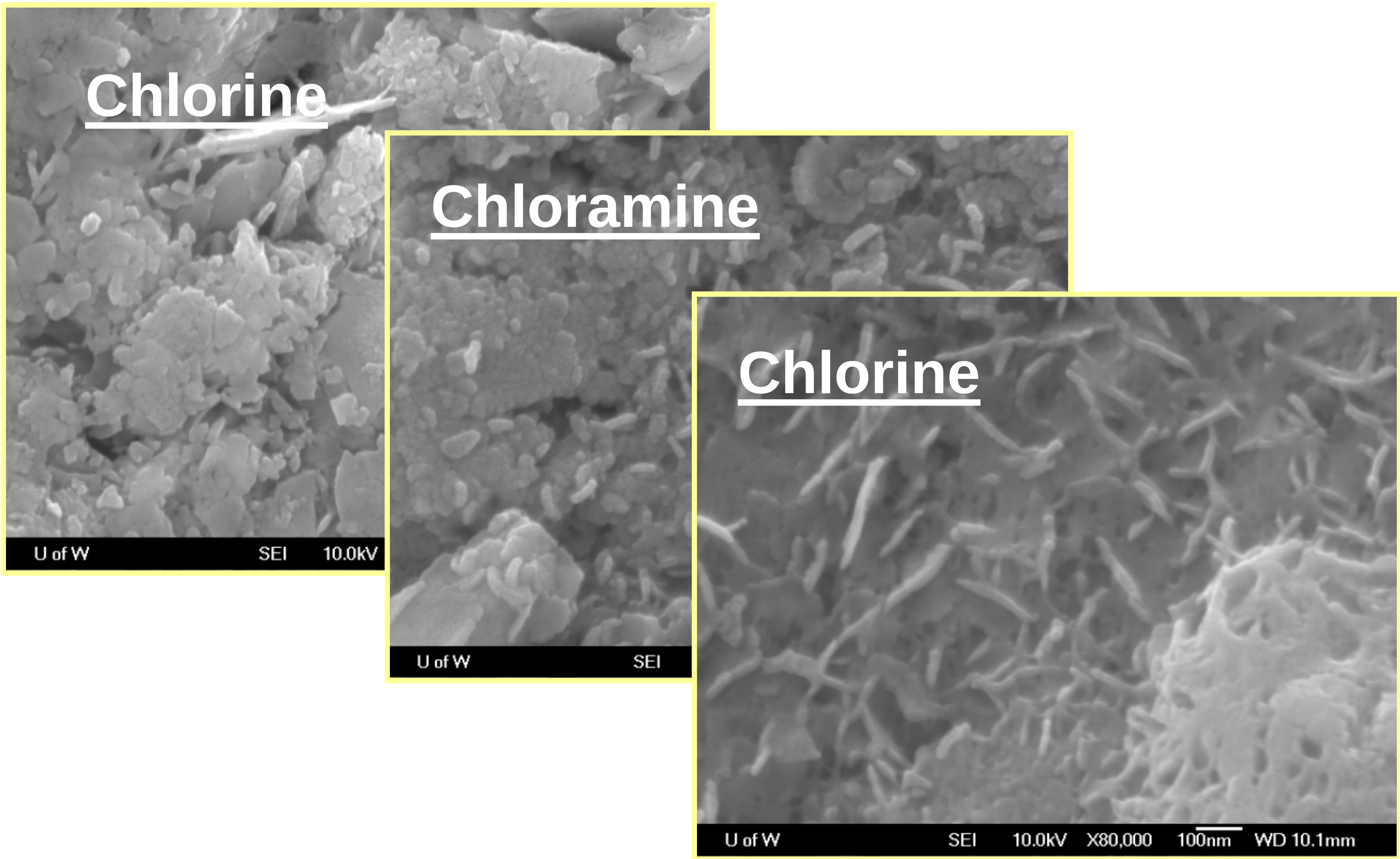
Analytical methods

- Experiments with model phases
  - Hydrocerrussite $Pb_3(OH)_2(CO_3)_2$, cerussite $PbCO_3$
  - Hydroxypyromorphite $Pb_5(OH)(PO_4)_3$, chloropyromorphite $Pb_5(Cl)(PO_4)_3$
- Recirculation corrosion rig
  - Exposures at HDR lab in Bellevue
- Perkin-Elmer DRC-e Elan ICP/MS instrument to measure metal concentrations
  - Some measurements done by Seattle Public Utilities
- SEM/EDX analyses with a JEOL 7000F high-resolution microscope
- XRD analyses with a Philips PW1830 and Siemens D5000 diffractometers
- Particle size and surface change measurements (Brookhaven Instruments ZetaPlus and Shimadzu SALD)

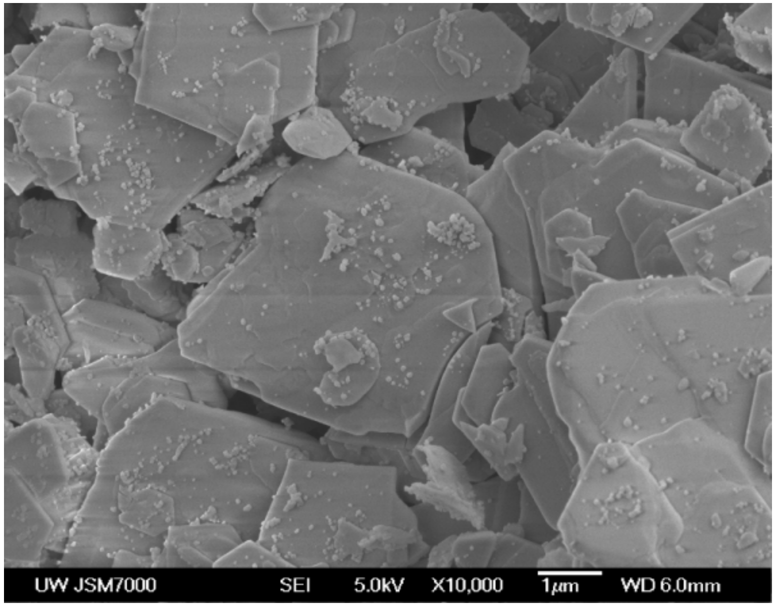
Lead release profile for recirculation loops in the absence of phosphate (old lead pipe)



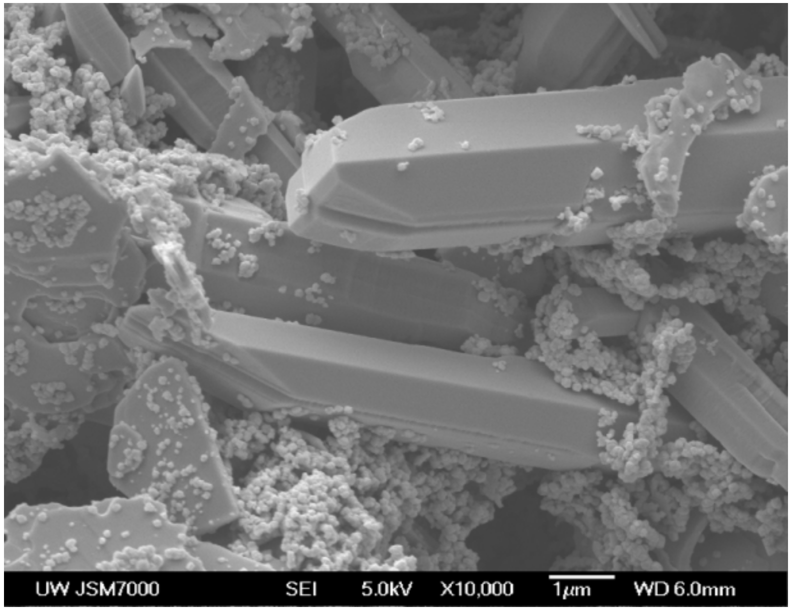
SEM morphology of new lead pipe in the absence of phosphate



Lead solid phases: Transformation of $Pb_3(OH)_2(CO_3)_2$ to $PbCO_3$ and PbO_2



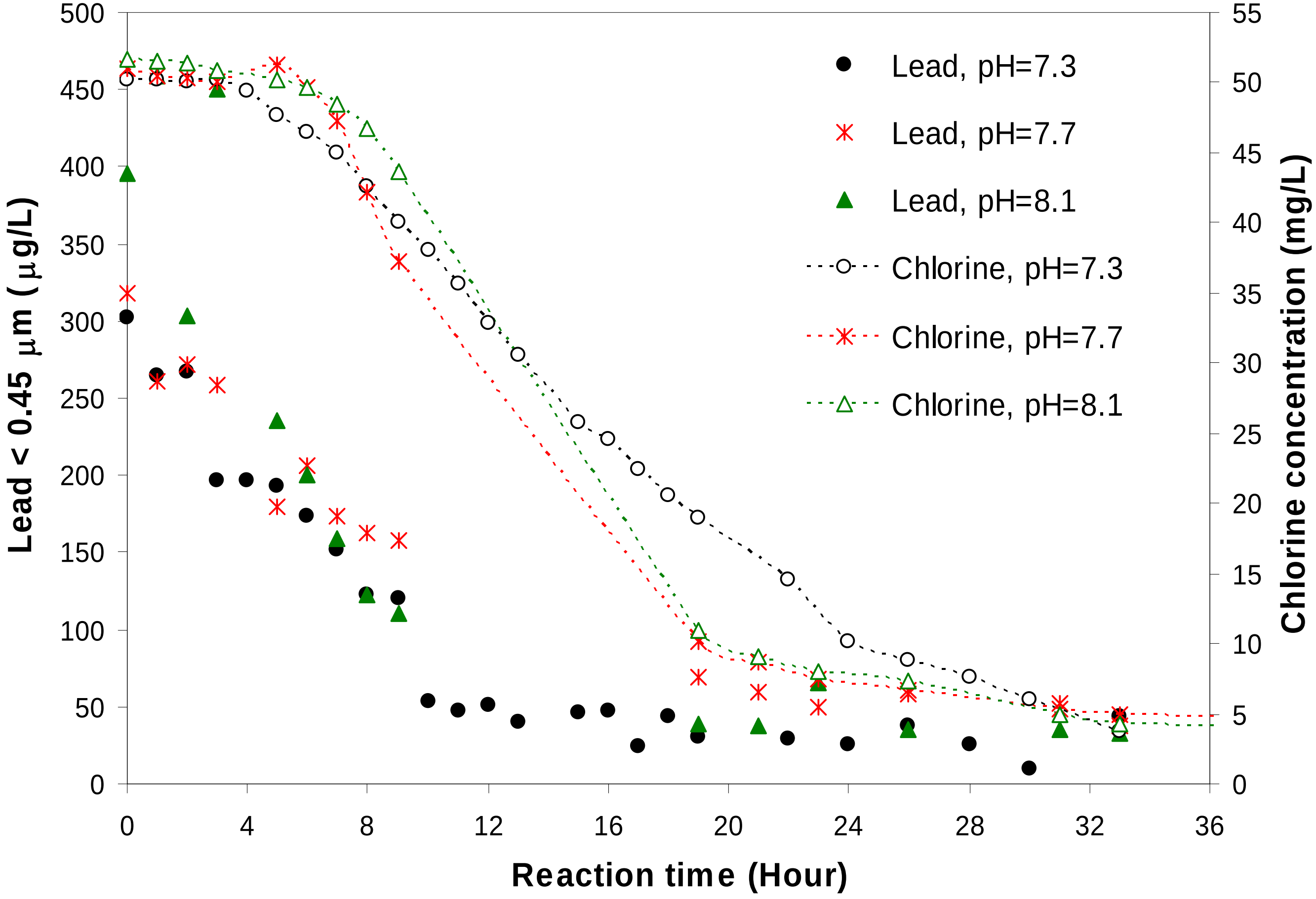
4 hours



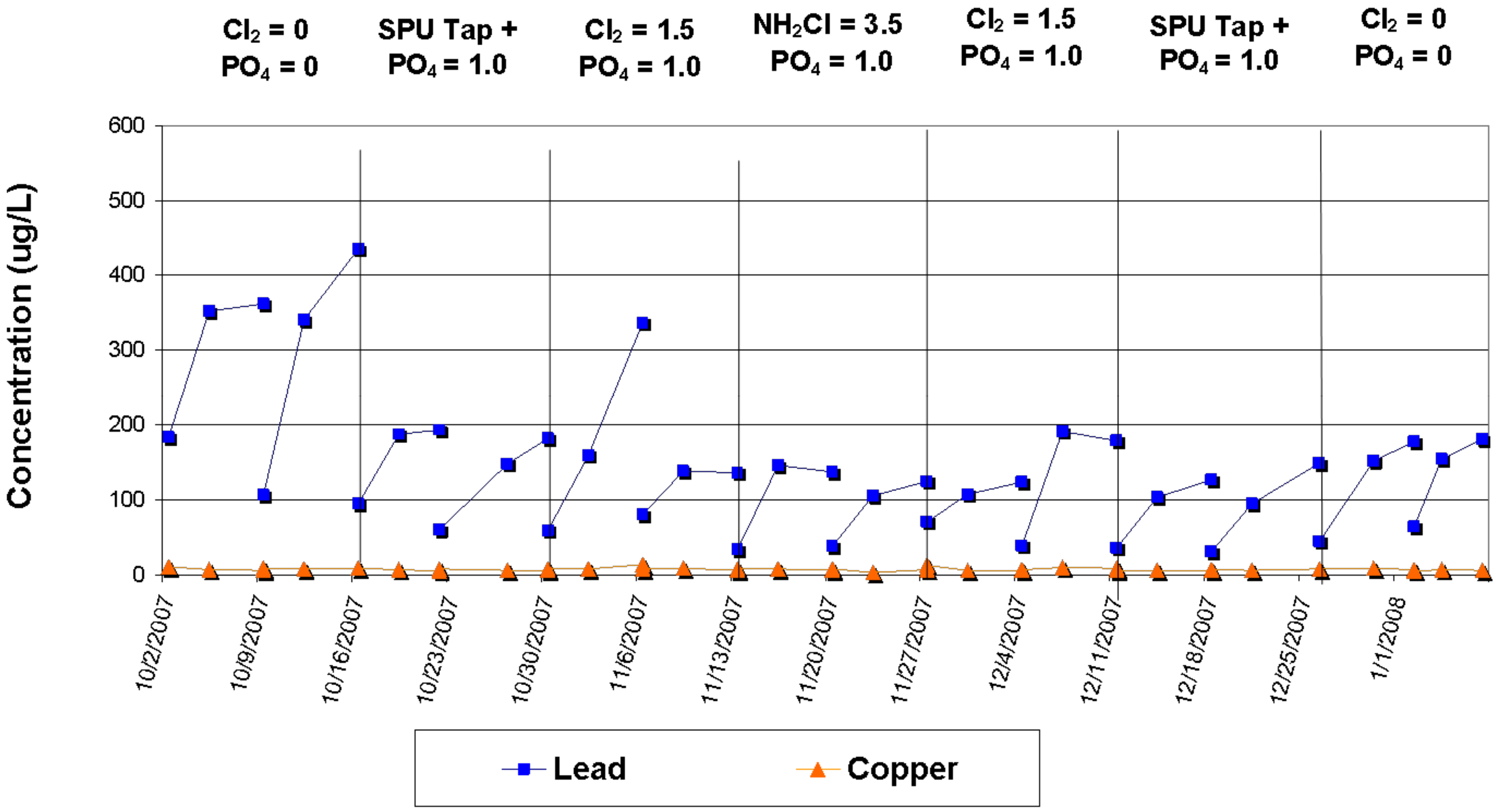
8 hours

Initial pH=7.0, $Pb_3(CO_3)_2(OH)_2$=0.5 g/L, HOCl=55 mg Cl_2/L, DIC=12 mg C/L

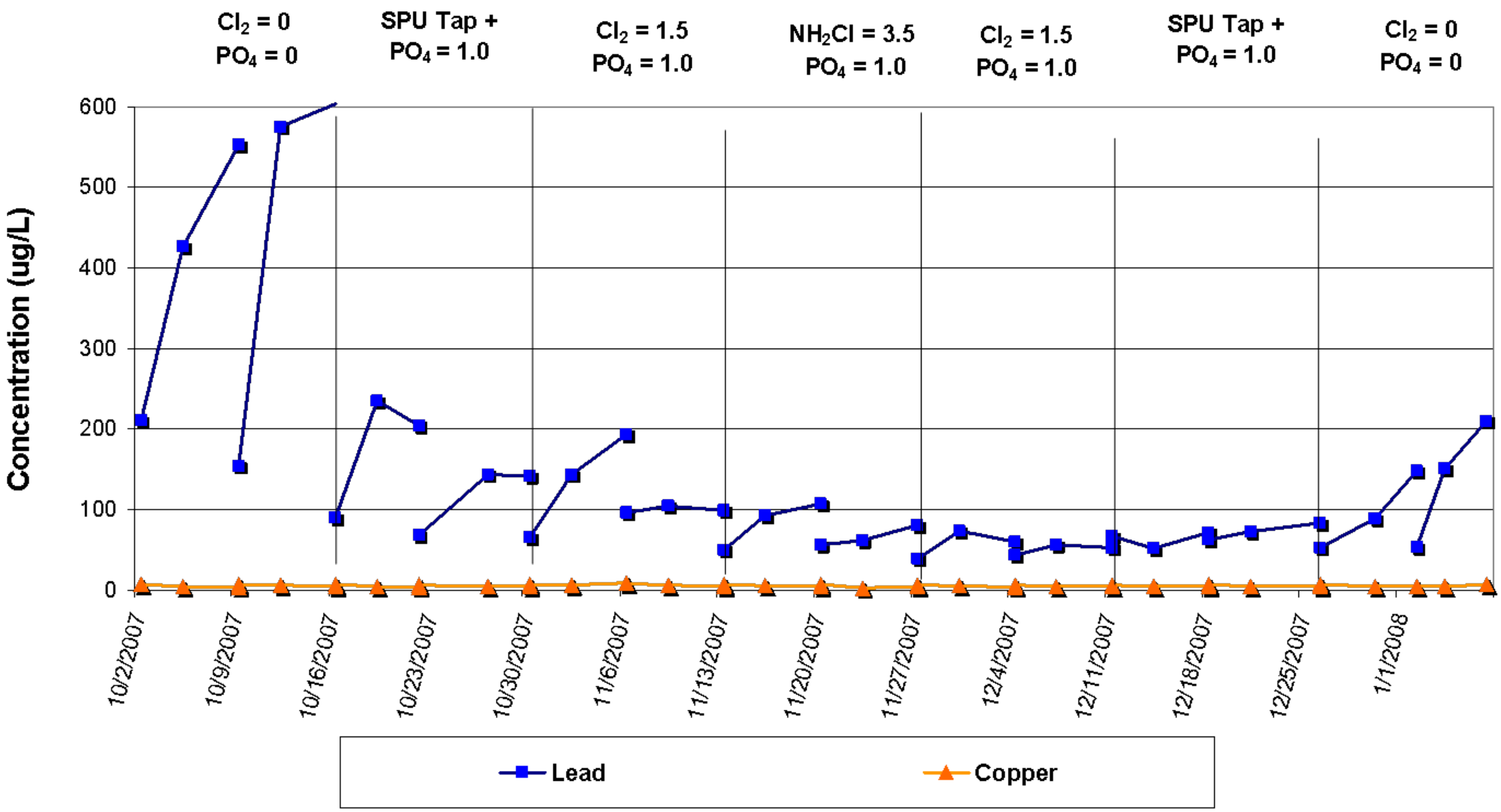
Hydrocerussite oxidation



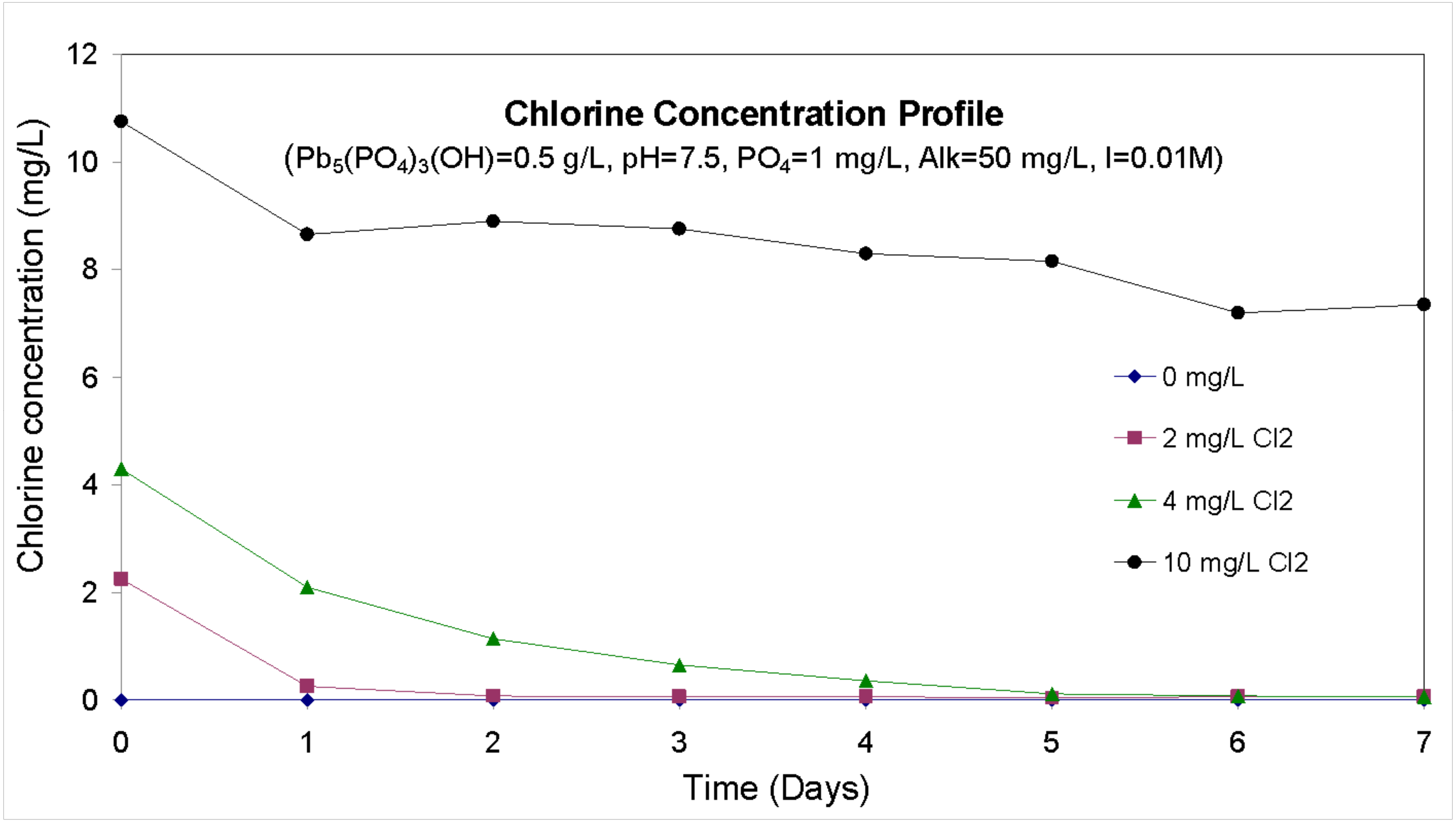
Lead release profile for recirculation loops in the presence of phosphate (new lead pipe)



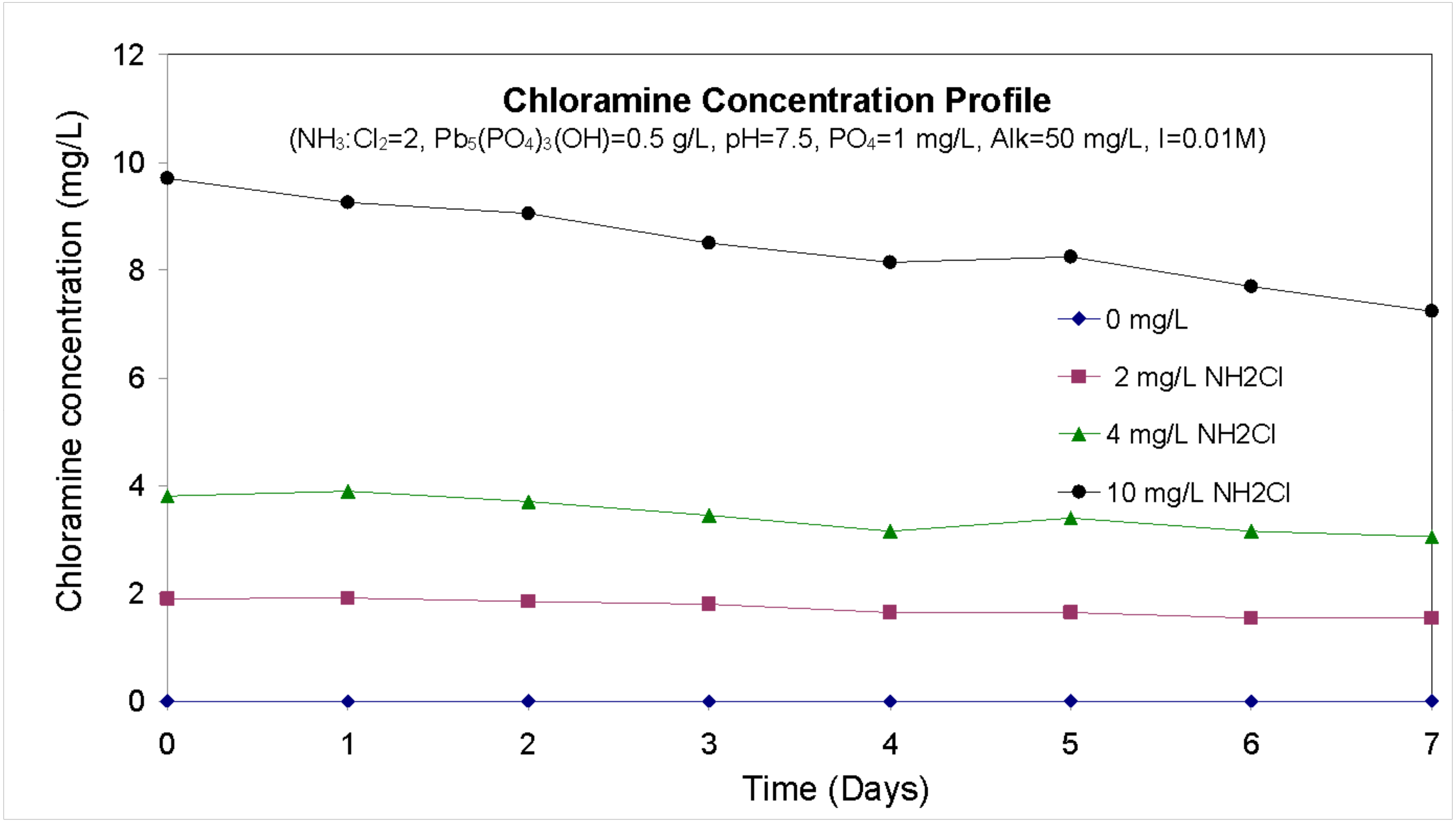
Lead release profile for recirculation loops in the presence of phosphate (old lead pipe)



Chlorine consumption profiles for hydroxypyromorphite

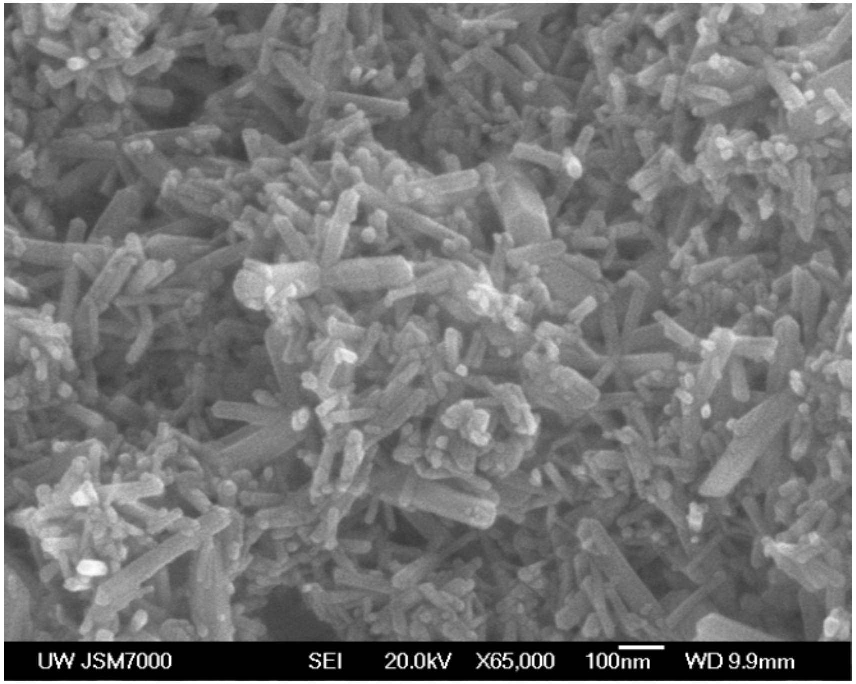


Chloramine consumption profiles for hydroxypyromorphite

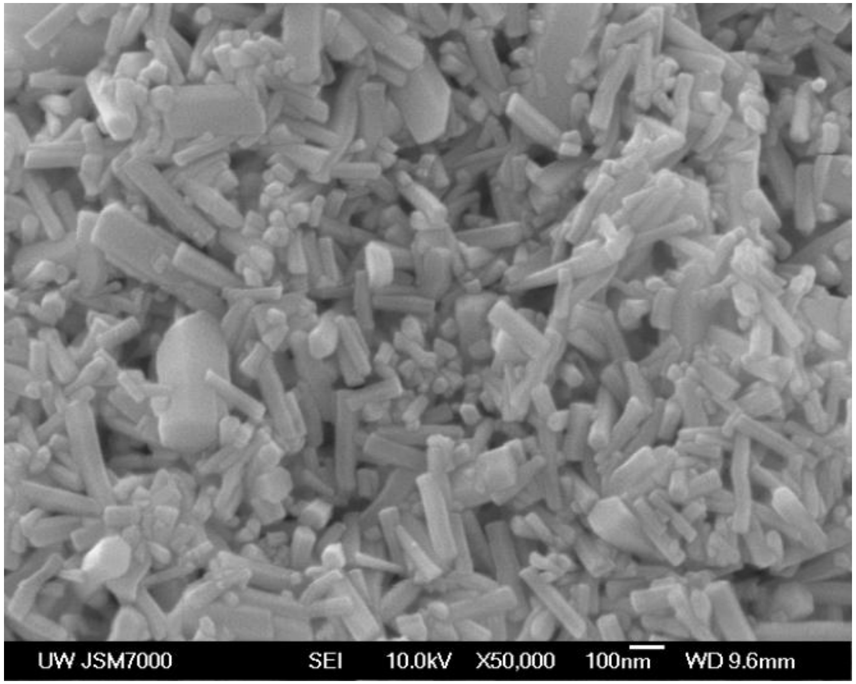


Morphology of hydroxypyromorphite at 186 hours of oxidation by chlorine

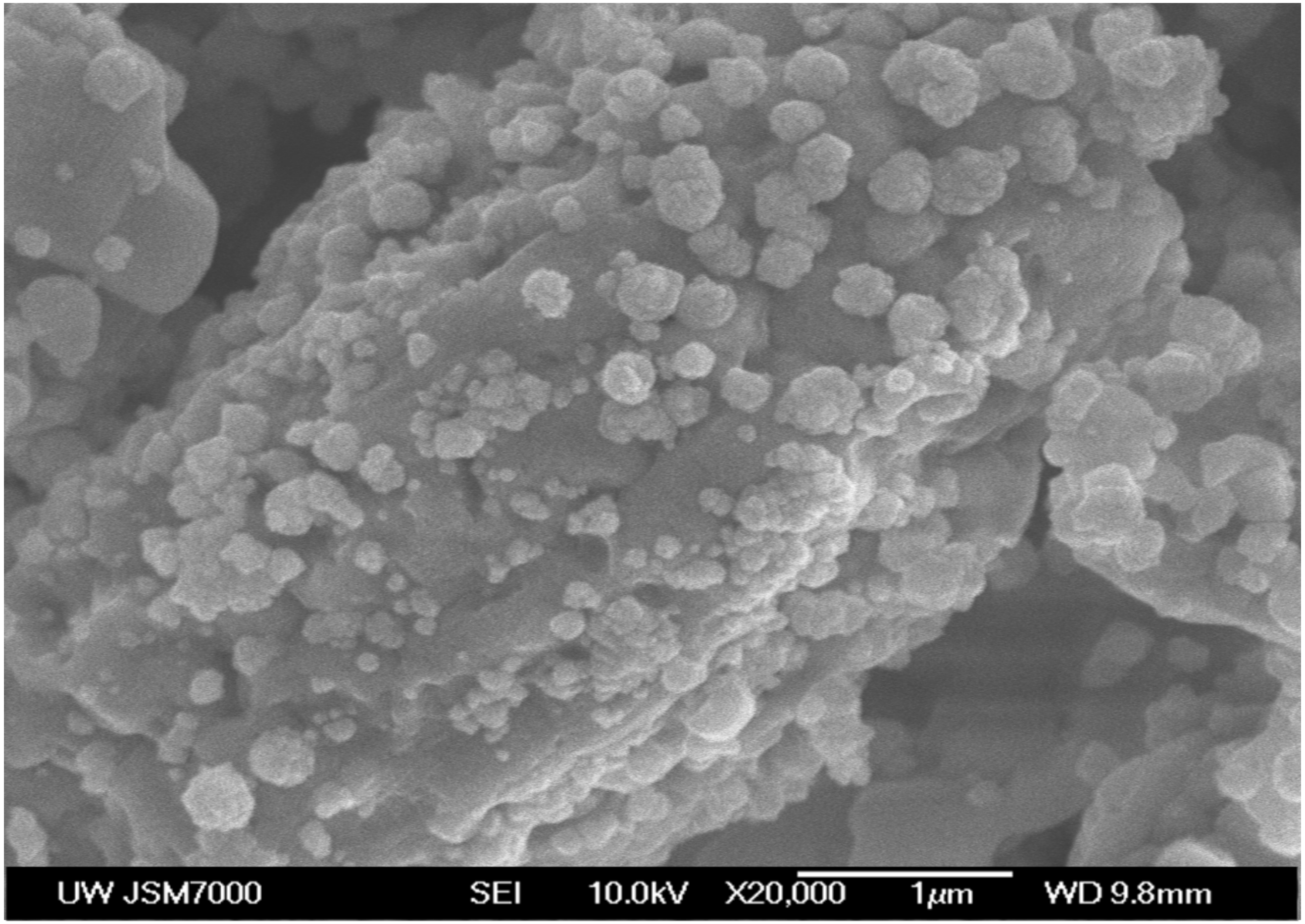
Before acid treatment



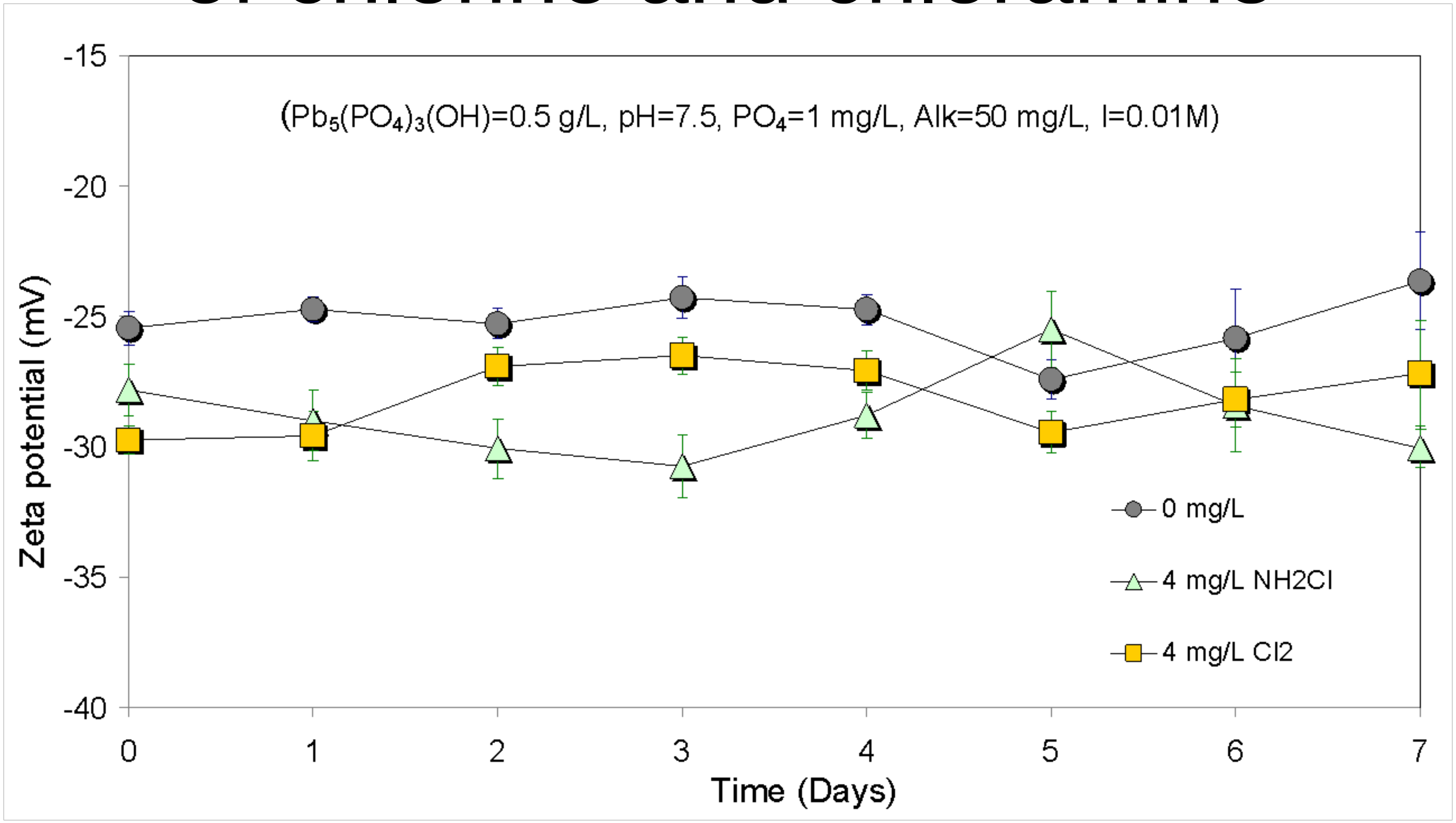
After acid treatment



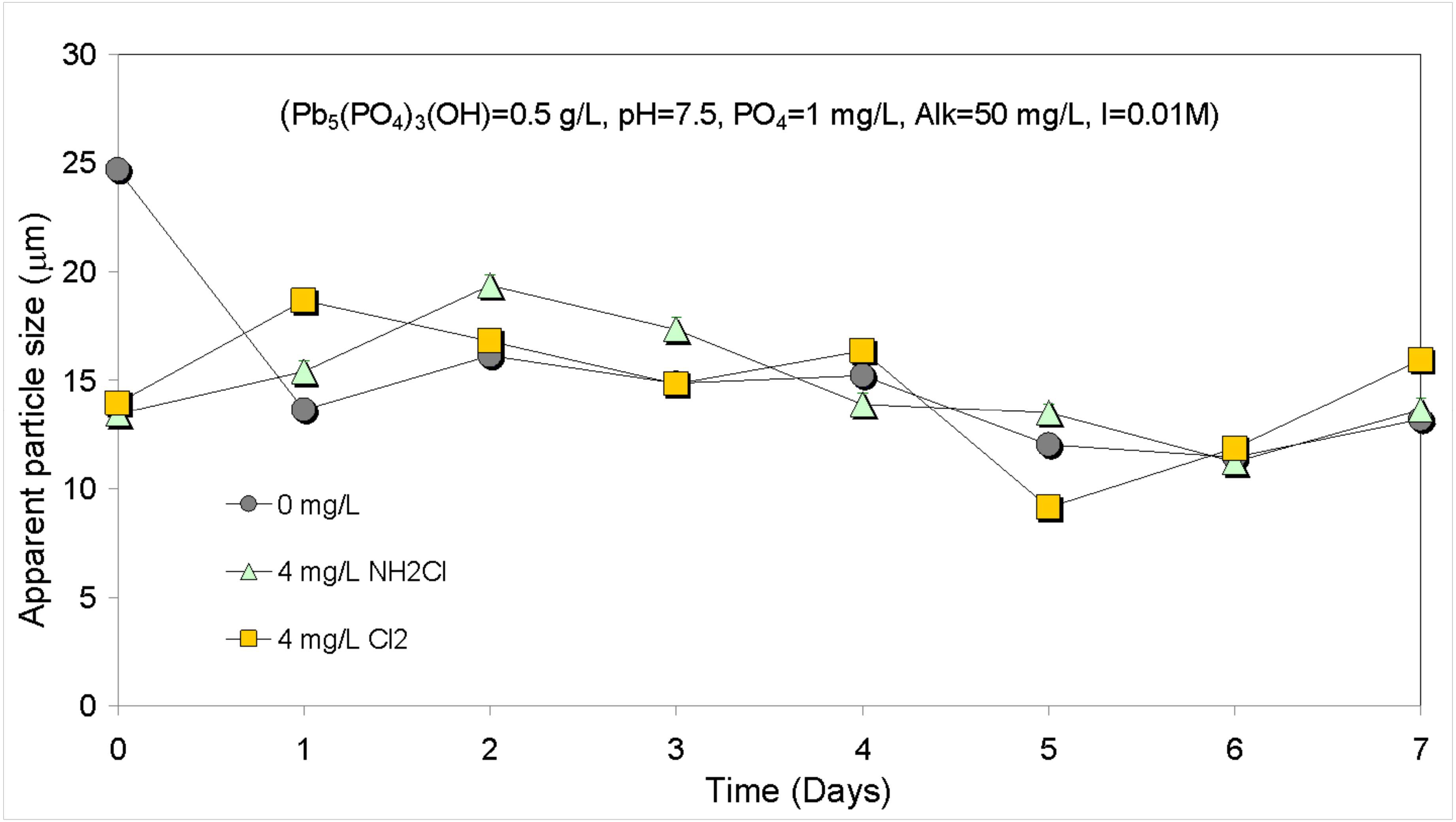
Lead dioxide formed as a result of cerussite oxidation



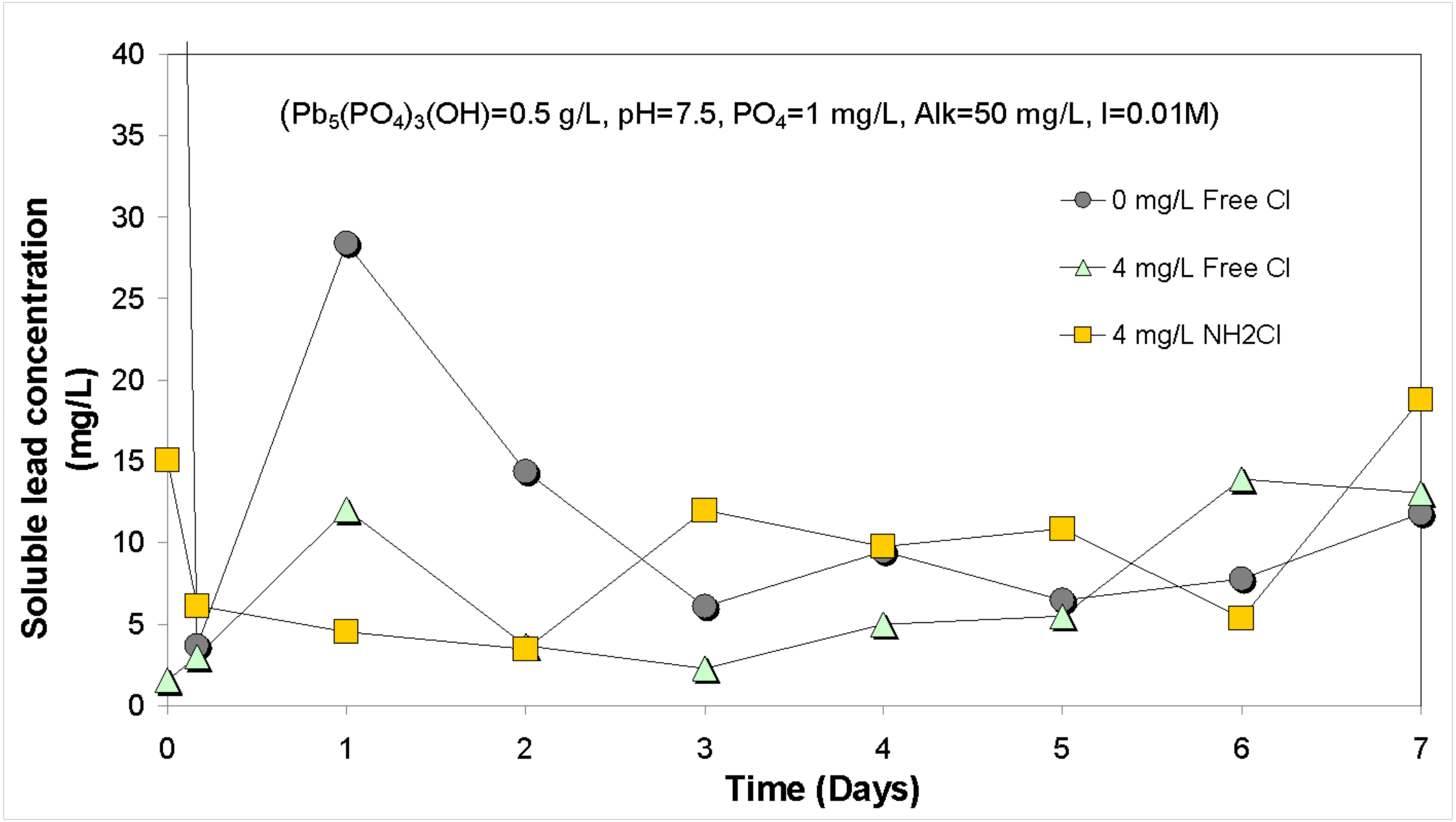
Zeta-potential profiles for hydroxypyromorphite in the presence of chlorine and chloramine



Apparent size profiles for hydroxypyromorphite in the presence of chlorine and chloramine



Soluble lead profiles for hydroxypyromorphite in the presence of chlorine and chloramine



Conclusions

- Phosphate is effective in suppressing lead release both from corroding lead and representative lead phases
- Lead dioxide phase is a characteristic products of the oxidation of lead (II) carbonate phases by chlorine
- Phosphate interferes with and largely prevents the formation of lead dioxide phase in the presence of chlorine
- Chlorine and chloramine do not seem to affect colloidal properties of lead phosphate phases
- The kinetic aspects of phosphate effects of the formation of phosphate minerals and prevention of lead dioxide formation are to be determined in more detail

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