Water Quality Research Foundation

Differing Mechanisms for Lead Phosphate Particle Removal By Point-of-Use Media Depend on Particle Size and Lability

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Introduction

- Orthophosphate corrosion-control treatment can create lead phosphate solids that protect pipes and sometimes detach to contaminate water
- Orthophosphate tends to produce lead nanoparticles in the short-term and larger recalcitrant particles in the long-term
- Both types of lead orthophosphate particles have been implicated in instances of poor POU filter performance [1-4]
- Each type of POU ion-exchange media affect water chemistry differently, which can affect lead phosphate particle removal [3]
- OH^- or H^+ form resins will change pH near the media, which could potentially dissolve lead phosphates. Removal of phosphate by anion exchange media could also dissolve phosphates

Objectives

- Examine physicochemistry (particle size, surface charge) of representative lead phosphate particles and their propensity to dissolve in acid or base (i.e., lability)
- Reveal differing mechanisms of removal by different types of media that affect performance in removing lead phosphate particles

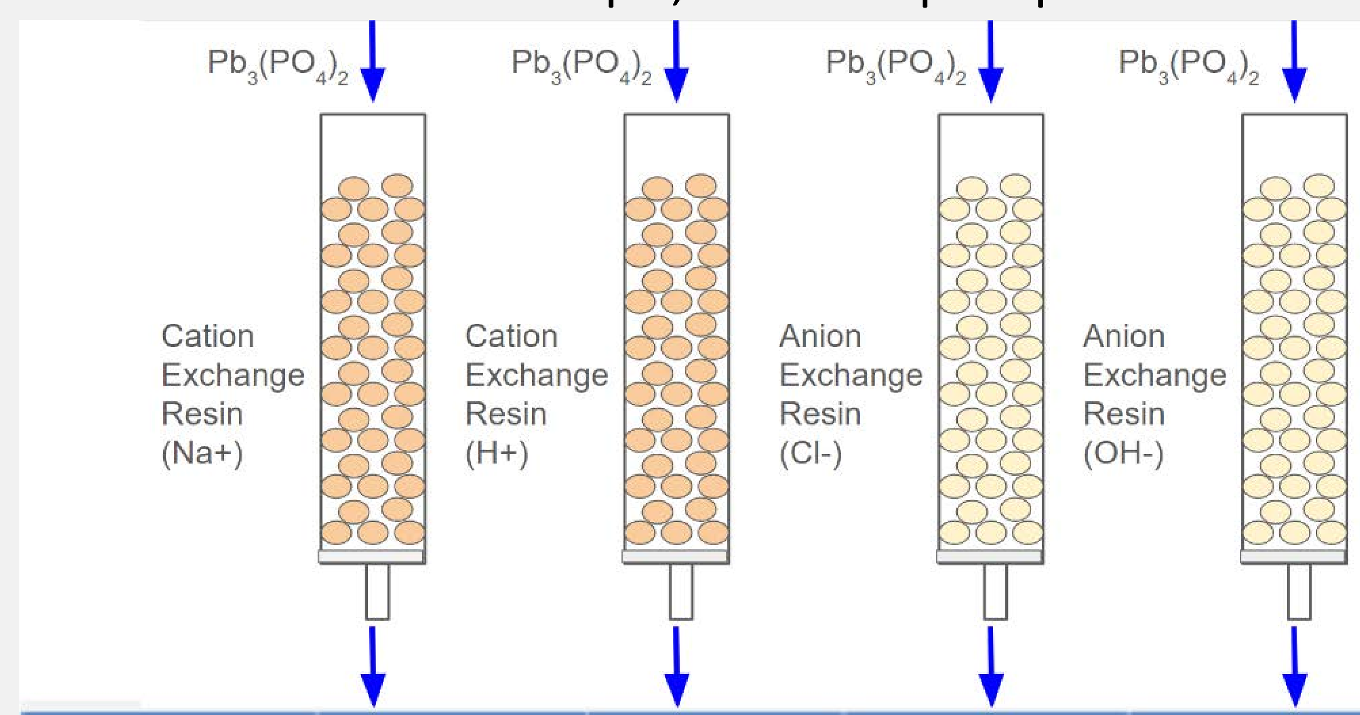
Methods

Synthesize Challenge Suspensions

- Prepare fresh soluble lead phosphate nanoparticles according to Lytle recipe [4] and large lead phosphate particle suspensions aged > 3 years at pH 7.0

Ion-Exchange Media Performance

- Pass lead phosphate particle suspensions through cation (Na^+ & H^+) and anion (Cl^- & OH^-) exchange resin. Monitor influent and effluent for pH, lead and phosphate.



pH	7.7	4.1	5.7	10.9
PO_4 (%)	8	13	99	99

Figure 1. Ion-Exchange Treatment of Challenge Waters with 0.13 mg/L Pb, 1.38 mg/L PO4 as P, and pH 7.4. Typical effluent pH and percentage removal of phosphate.

Conduct Pitcher Filter Performance Study

Use challenge waters and New York City water recently proven to have very poor POU removal performance [2]

Results

- H^+ form resin lowered effluent water pH to 4, OH^- form resin raised pH to 10.9, other resins had little effect **(Fig. 1)**
- Na^+ and H^+ cation exchange resin both had very good removal for soluble Pb, but H^+ form had far superior performance for fresh nanoparticles **(Fig. 2)**

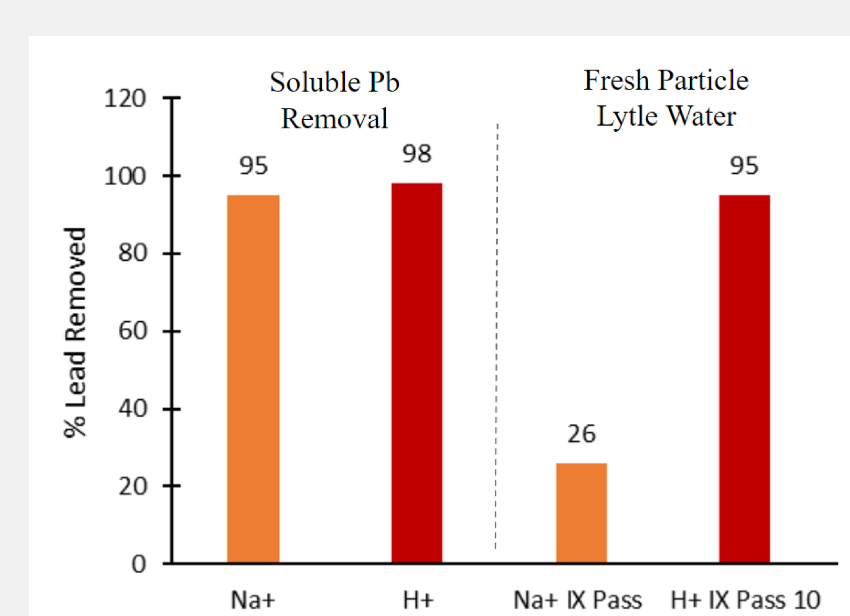


Figure 2. Soluble Lead Removal by Cation Form Resins (left) and Treatment of Nanoparticles (right)

- Tested without any filter media, nanoparticulate lead dissolved immediately at a pH 4 (98-100% soluble lead) **(Fig. 3)**, but larger older particles made in the lab or in NYC water did not, suggesting better removal for H+ resin was due to dissolution of nanoparticles
- To confirm this hypothesis, after reducing the lead phosphate nanoparticle influent pH to 4, Na^+ form resin lead removal increased from 6% to 95% (data not shown)
- NYC pipe loop lead particles and lab synthesized large old particles did not dissolve readily even at pH 4 **(Fig. 3)**, and had much lower lead removal rates in H^+ form resin compared to lead nanoparticles **(Fig. 4)**
- All these results explain why mixed H^+ and OH^- form resin filters, outperformed Na^+ form resins for fresh lead phosphate in NYC water, but the opposite trend was observed for old lead particles [2]

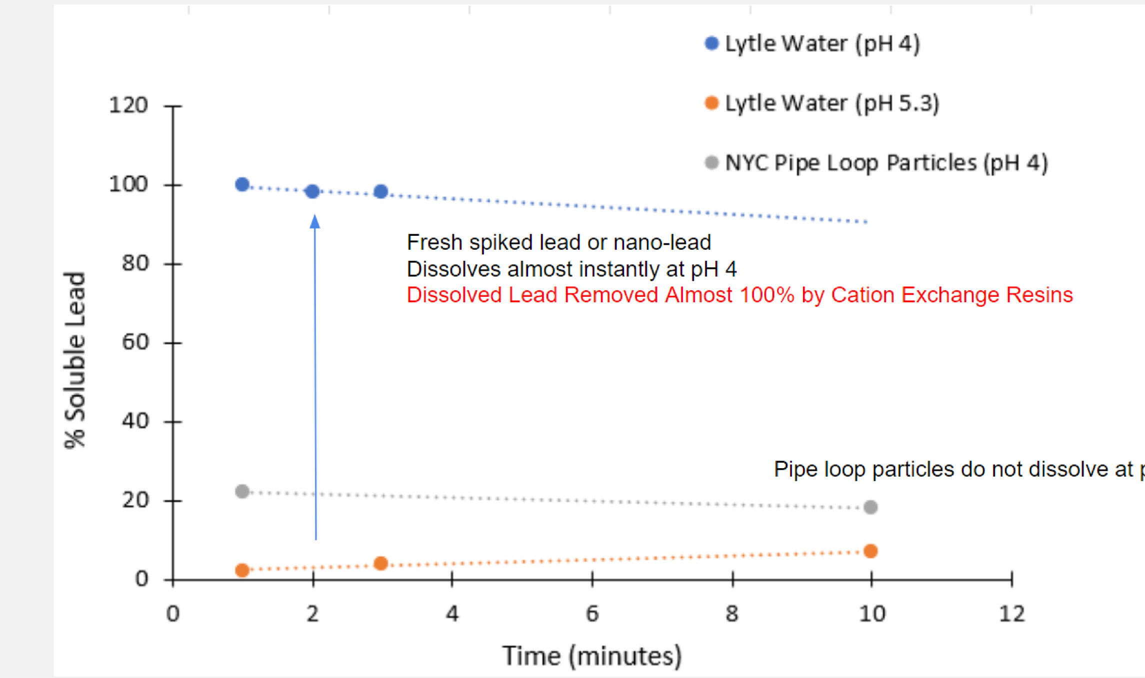


Figure 3. Lead Dissolution at pH 4 for Lead Phosphate and NYC Pipe Loop Particles

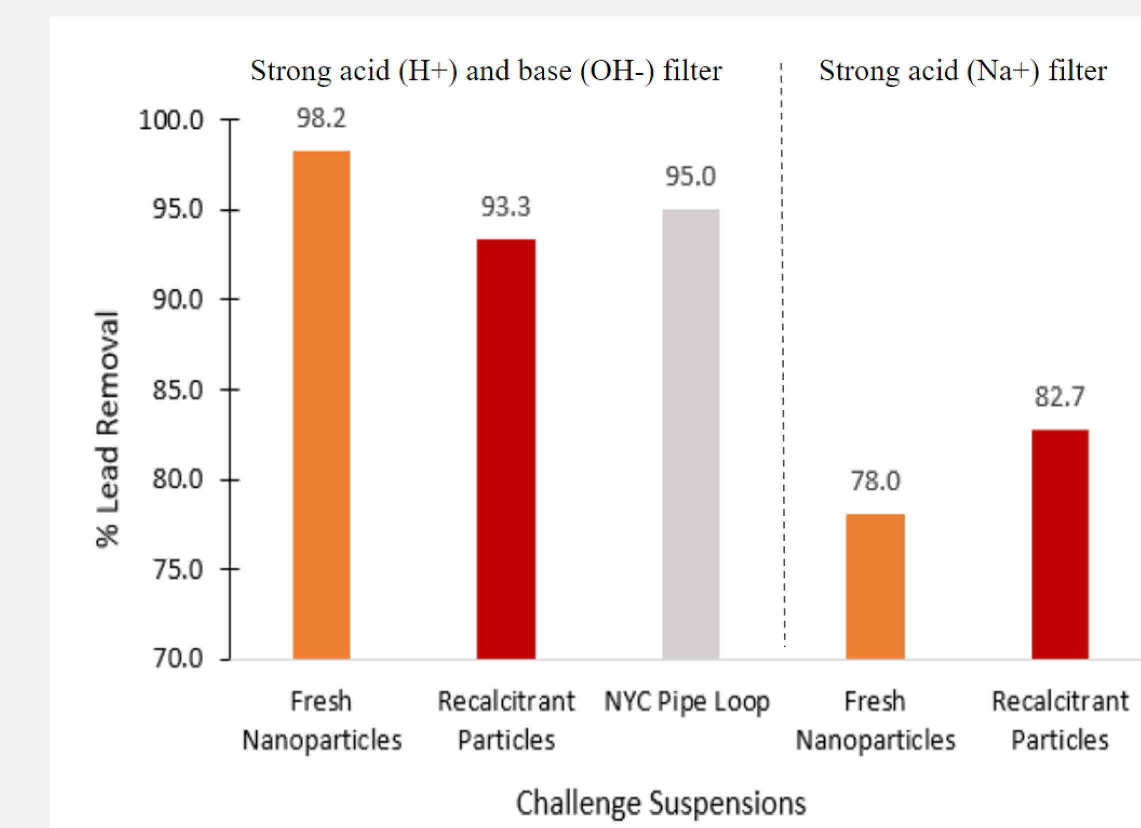


Figure 4. Lead Removal Performance for Different Off the Shelf Filters

Conclusions

- Strong acid H^+ form resin, has superior ability to remove lead nanoparticles, because they can dissolve the lead to enhance removal
- Strong acid Na^+ form resins, were slightly better than H^+ form resins, at filtering larger and solder lead phosphate particles synthesized in the laboratory and present in NYC pipe loop water **(Fig. 4)**
- Strong base resin in OH^- or Cl^- form did remove soluble PO_4^{-3}, but otherwise had little effect on lead removal (data not shown)

Future Directions

- In conjunction with prior research showing that anionic soluble lead polyphosphates are poorly removed by cation exchange resin [5], we will proactively identify resin types most likely to show poor performance dependent on the type of lead present.

References: [1] Purchase J., Edwards M. (2020) "Understanding Failure Modes of NSF/ANSI 53 Lead-Certified Point-of-Use Pitcher and Faucet Filters" [2] Sapienza V. (2020) "Evaluation of Water Pitcher Filter Performance for Lead Removal" [3] Dore E., Lytle D. (2022) "Effectiveness of point-of-use and pitcher filters at removing lead phosphate nanoparticles from drinking water" [4] Lytle D. (2020) "Synthesis and Characterization of stable lead (II) orthophosphate nanoparticle suspensions" [5] Mazzola F. (2022) "Quantifying Lead Complexation by Polyphosphate"