The Effects of Calcium on the Particle Structure and Solubility of Hydroxypyromorphite

An Executive Summary

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Due to recent events, there is increased awareness of problems related to the presence of lead in drinking water. Incidents of elevated lead events that took place in Flint, Michigan, University Park, Illinois, and Newark, New Jersey are just a few well-known examples of what is likely happening all across the country as failing drinking water infrastructure exposes families to this dangerous neurotoxin. The effects of prolonged exposure to lead have been well documented for decades. Though the U.S. Environmental Protection Agency (EPA), advised by the Centers for Disease Control and Prevention (CDC), has long taken the stance that no amount of lead consumption is considered safe, the Lead Copper Rule (LCR) of 1991 establishes an action level for total lead at 15 μg/L in drinking water (U.S. EPA, 40 C.F.R. Part 141 Subpart I). Should a certain proportion of sampled homes contain water in exceedance of this threshold, the city or local private utility responsible for providing safe and clean drinking water must act immediately to mitigate the issue, advise the public as to how to protect their health, and usually provide bottled water and point-of-use filters to residents until the water is back within compliance. The point-of-use (POU) filters typically provided by state and local authorities are either a faucet-mount style or pitcher filter that is NSF/ANSI certified to reduce lead to a maximum concentration of 10 μg/L. However, recent analyses conducted by the City of Newark (Figure 1) indicate that lead is still able to pass through these POU filters in some cases even when the device is properly installed and used (CDM Smith, 2019).

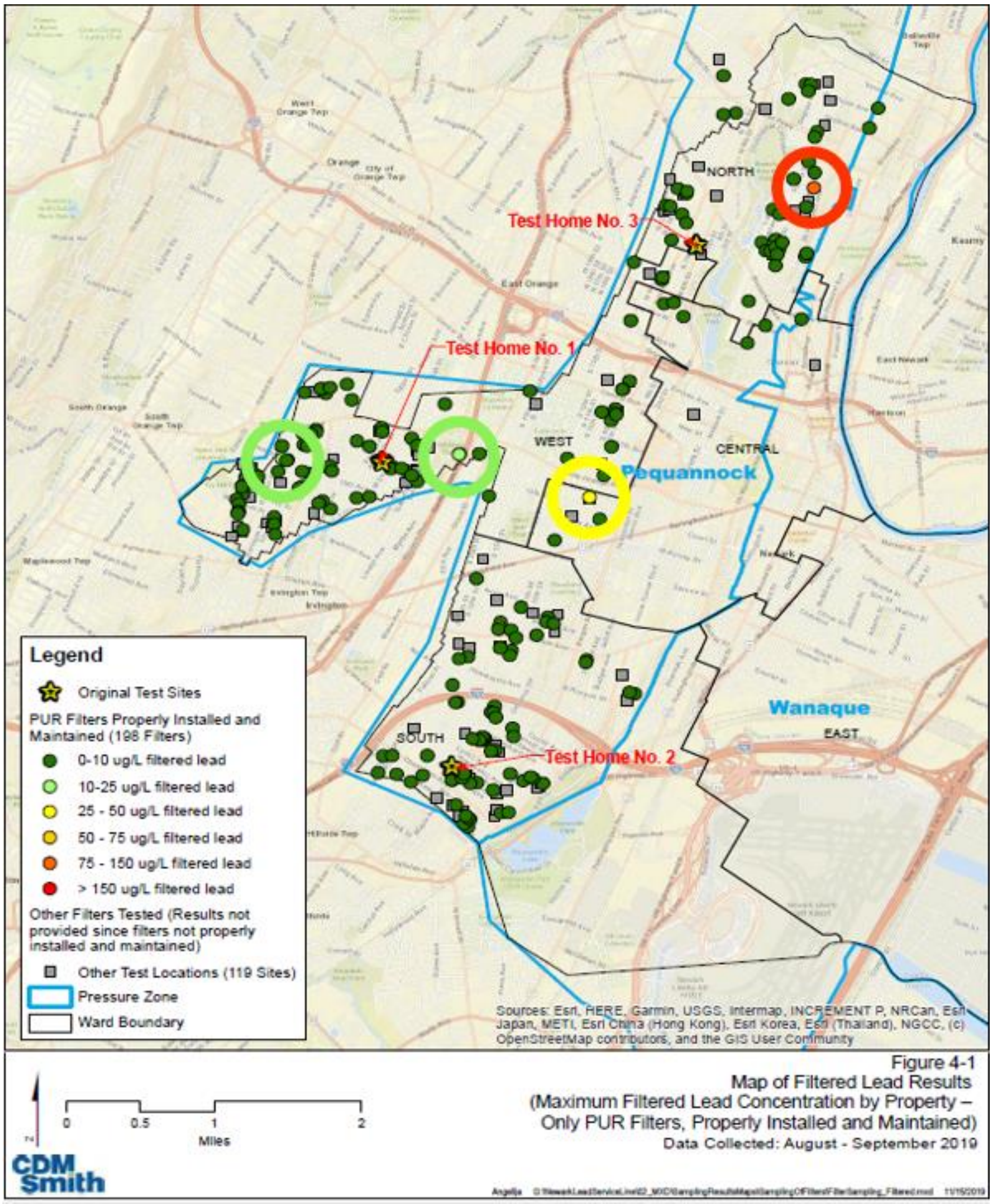

Figure 1. Map of homes where POU filters were properly installed and maintained in Newark, NJ and the concentration of lead detected in their water after filtering. Four residences of the homes sampled were found to exceed 10 ug/L of lead (CDM Smith, 2019).

A follow-up fractionation study conducted by the EPA confirmed that lead was, in fact, passing through the filters as lead nanoparticles identified as hydroxypyromorphite [$Pb_5(PO_4)_3OH$] ([b]Lytle, et al. 2020). In an attempt to increase the filterability of these nanoparticles by promoting coagulation within the water matrix, this research project experiments with introducing calcium to the particle solution and observes any impacts on the physical characteristics of the hydroxypyromorphite particles, as well as changes in solubility.

This research project took place at U.S. EPA's Office of Research and Development (ORD) in Cincinnati, Ohio during the period of March through September of 2021. Three sets of comparative studies were conducted over the course of several weeks. All experimental particle solutions were created using a method established by prior research – see [a]Lytle, et al. 2020. The basic sequence of steps used in creating the lead phosphate hydroxide solution with calcium added is illustrated in Figure 2.

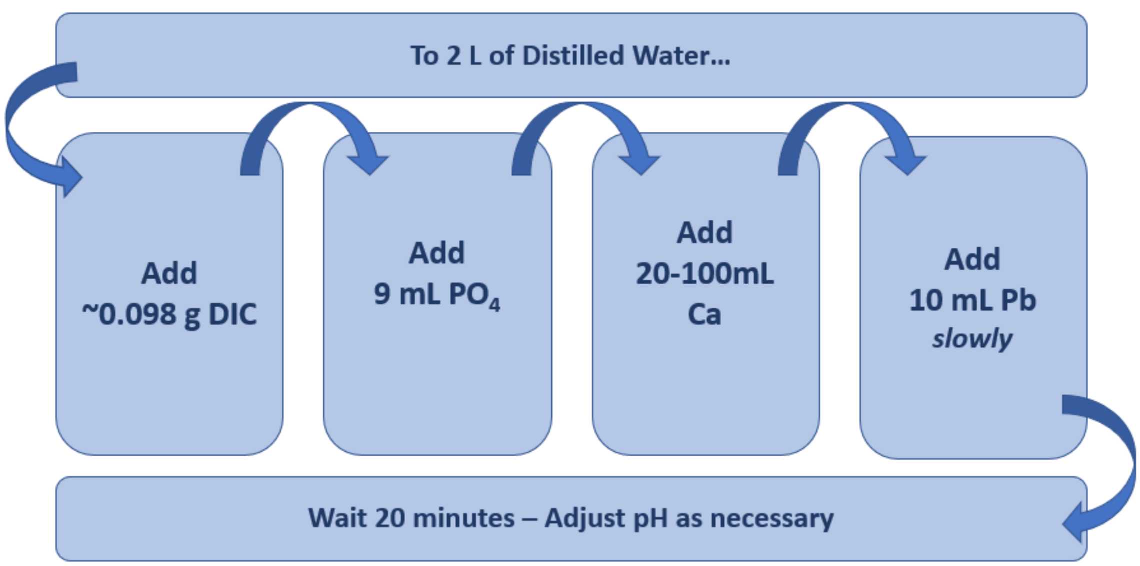

Figure 2. Sequence of steps used to create lead particle solution with calcium.

An aliquot of unfiltered solution was run on a Zetasizer to obtain particle charge, size, and mobility data. A portion of the particle solution was then filtered through a 30 kDa ultrafilter using a pressurized Ultracel apparatus. Two samples of the ultrafiltered solution were collected, one analyzed for lead using an ICP-MS and one analyzed for phosphate using a SmartChem discrete analyzer. The ultrafilter itself was collected for x-ray diffraction (XRD) analysis, and a carbon stub was dabbed on the filter to collect particles for scanning electron microscopy (SEM) analysis to confirm the crystal structure of the minerals being precipitated. Two sets of experiments were conducted as aging studies, meaning the original 2 L of particle solution was divided up into 5 sample bottles and samples were collected as described above once per week for 5 subsequent weeks.

Ultimately, it was determined that the presence of calcium had no noticeable impact on the hydroxypyromorphite structure, nor did it impact the solubility of the nanoparticles. More experimentation is necessary to determine if calcium dosing is a viable option for mitigating or even removing lead completely from drinking water systems. Other water chemistry conditions should also be considered in any future experimentation involving the nanoparticle, hydroxypyromorphite. These experiments were part of a larger initiative investigating the efficacy of point-of-use (POU) filters at removing lead from residential drinking water. In turn, this research initiative is one of many within ORD that works toward ensuring that everyone in the U.S. has access to safe and sustainable drinking water resources.

Literature Cited

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[a]Lytle, D. A., Formal, C., Dorè, E., Muhlen, C., Harmon, S., Williams, D., Triantafyllidou, S., Pham, M. Synthesis and Characterization of Stable Lead (II) Orthophosphate Nanoparticle Suspensions. *Journal of Environmental Science and Health, Part A*, 2020. DOI: 10.1080/10934529.2020.1810498

[b]Lytle, D. A., Schock, M. R., Formal, C., Bennett-Stamper, C., Harmon, S., Nadagouda, M. N., Williams, D., DeSantis, M. K., Tully, J., & Pham, M. Lead Particle Size Fractionation and Identification in Newark, New Jersey's Drinking Water. *Environmental science & technology, 54(21), 13672–13679, 2020*. https://doi.org/10.1021/acs.est.0c03797