A better informed society can prevent lead poisoning disasters

September 18 2020, by Karen Walker

Credit: Pixabay/CC0 Public Domain

Six years after it began, the Flint, Michigan, water crisis remains among the highest-profile emergencies in the United States.

Extensive iron and lead corrosion of the water distribution system in Flint, coupled with lead release, created "red water" complaints, rapid loss of chlorine disinfectant and an outbreak of Legionnaires Disease that killed 12 people. State and federal agencies have disbursed $450 million in aid so far. In August, the state of Michigan reached a mediated settlement in a civil suit and is expected to pay about $600 million to victims, many of whom are children.

"The Flint story is a cautionary tale of poor anticipation of risks, actions that were too little too late, reactionary and not driven by scientific data," John R. Scully, University of Virginia Charles Henderson Chaired Professor of Materials Science and Engineering, said. Scully also serves as technical editor in chief of CORROSION Journal.

In a paper published Sept. 8 in the *Proceedings of the National Academy of Sciences*, Scully and Raymond J. Santucci, who earned his Ph.D. from UVA's Department of Materials Science and Engineering in 2019, address unresolved scientific questions that can help avert future lead poisoning disasters. Lead poisoning from degrading lead pipes is a pervasive threat, and future incidents are likely.

"This requires a fresh perspective, to avoid just looking in the rearview mirror and instead focus on what lies around the curve ahead," Scully said.

Commonly proposed strategies offer false comfort based on sparse water testing, rules of thumb, and traditional mitigation strategies rather than by rigorously challenged sound scientific principles, according to the paper's authors.

"We need to better understand the scientific factors that govern lead release, and that starts with a better testing strategy and understanding of some fundamental truths," Scully said.

Scully and Santucci argue that the people who manage and regulate public water systems should be using scientific data to predict the risks of lead release. Risk assessments based on scientific data should replace current reliance on water sampling, which is imprecise and often too late to prevent a disaster.

A predictive framework for lead corrosion would allow regulators and infrastructure managers to anticipate problems and manage the risk of water conditions associated with unacceptable lead release.

Santucci and Scully recommend better thermodynamic and kinetic calculations and models that can predict lead release and accumulation. The models proposed could generate risk assessments based on dynamic data such as water chemistry, reaction rates, scale formation and inhibitor corrosion mechanisms, as well as water stagnation and flow.

Citizen scientists can help meet the data-gathering challenge. "Rapid accurate testing, perhaps via mobile phone test kits, could provide more real-time data. Hand-held, mobile tech that enables citizens to monitor their own drinking water should have advanced already," Scully said.

Santucci and Scully illustrate how chemical thermodynamics can predict the formation of thermodynamically stable lead-based compounds on lead pipe surfaces. Certain compounds form advantageous films that might act as kinetic barriers to hinder corrosion and function to sequester otherwise soluble lead.

"Stable film development depends on a certain equilibrium chemistry, with consequences for phosphate treatment," Santucci said. "Add more phosphate and you can remove more soluble lead to form a protective lead phosphate film. Remove phosphate completely, and you then rely on hoping that other lead compounds (lead -carbonate, -sulfate, -oxide, etc.) can remove the levels of lead you need," which is usually not the case.

In phosphate-treated water, a lead-phosphate film will form. "From our data, it is thermodynamically impossible to stay within the acceptable range of the EPA's Lead and Copper rule without an inhibitor like phosphate. But it takes time for the scale to form. We need to explore new inhibitor chemicals and surface-altering agents that optimize the protective scale coverage on a pipe wall," Santucci said.

The authors also suggest altogether new ideas to anticipate, monitor and prevent future lead in water crises. Artificial intelligence and machine learning could help identify relationships between water and pipe conditions and lead levels in drinking water. Santucci and Scully also propose a promising strategy of using isotope analysis to trace the sources of lead. "This strategy would enhance our understanding of how lead is released from lead pipes and other not so obvious sources, which is dearly lacking," their paper states.

Public officials may argue that the investment in scientific research and modeling is unnecessary because lead-based pipes are being replaced, albeit at homeowners' expense. Scully and Santucci disagree with that perspective. "Total replacement of lead service lines is a wonderful goal, but finding all sources of lead can be difficult," Scully said.

Replacing lead in public water systems does not simply mean replacing lead pipes. Additional sources include lead-based solder used to join pipes together and commercial brass that commonly contains small amounts of lead, and lead ions that soak into the corrosion film of steel pipes over time. Partial replacement of lead pipes with other pipes such as steel or copper can actually increase lead release due to galvanic corrosion, a process where contact between two dissimilar metals causes protection of one and accelerated degradation of the other.

Santucci and Scully argue for holistic, kinetic models that incorporate the rate of lead release from all possible sources, under many real-world operating conditions.

"The root cause of the Flint water crisis can be found at the intersection of materials science, surface science, water chemistry and electrochemistry," Scully said. "A better-informed society can prevent such disasters from happening in the future through improved risk assessment, anticipation and management of factors affecting lead release. We all have a part to play in averting future lead poisoning disasters."

More information: Raymond J. Santucci et al, The pervasive threat of lead (Pb) in drinking water: Unmasking and pursuing scientific factors that govern lead release, *Proceedings of the National Academy of Sciences* (2020). DOI: 10.1073/pnas.1913749117

Provided by University of Virginia