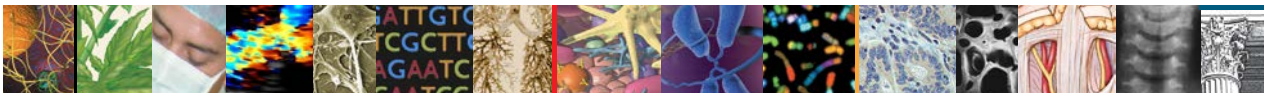

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Perspective

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Lead Contamination in Flint — An Abject Failure to Protect Public Health

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The dangers of lead exposure have been recognized for millennia. In the first century A.D., Dioscorides observed in his *De Materia Medica* that "lead makes the mind give way." The first industrial hygiene act passed in the colonies, in 1723, prohibited the use of lead in the apparatus used to distill rum, because "the strong liquors and spirits that are distilld through leaden heads or pipes are judged on good grounds to be unwholsom and hurtful." More recently, large amounts of lead were used to boost the octane rating of gasoline and improve the performance of paint. One would be challenged to design a better strategy for maximizing population exposure to a poison than to have it emitted by a ubiquitous mobile source and to line the surfaces of dwellings with it.

The dramatic reduction over the past 40 years in blood lead levels in the U.S. population is rightly regarded as one of the cardinal public health success stories. It was achieved largely by phasing out lead as a gasoline additive and restricting the amount of lead permitted in paint. At the same time, because of research opportunities created by reductions in population exposures, the consensus view on how much lead is "too much" has also evolved. It is now established that there is no safe level of lead, particularly for children. The reference blood lead concentration for children set by the Centers for Disease Control and Prevention, 5 μg per deciliter, is meaningful only for risk stratification.

Water doesn't receive as much attention as paint as a route of lead exposure, but the use of lead in water-distribution systems goes back to the Romans. Indeed, our word "plumbing" derives from the Latin for lead, and lead poisoning is often called "plumbism." The recent episode in Flint, Michigan, has brought the issue of lead in water into the public eye.

In 2014, solely as a cost-saving measure, the city began taking its water from the Flint River rather than Lake Huron. The corrosion-control treatments required by the Environmental Protection Agency's Lead and Copper Rule[1] were, for some reason, discontinued. To make matters worse, the addition of ferric chloride to reduce the formation of trihalomethanes from organic matter increased the corrosivity of the Flint River water. The water reaching consumers was therefore 19 times as corrosive

as it had been when the source was Lake Huron. The more corrosive water is, the more readily it can dissolve metals such as lead. So the lead concentration in Flint's water began to rise. In six of nine city wards, the water in 20 to 32% of the homes had a lead concentration above 15 μg per liter, a concentration that triggers remedial action under the Lead and Copper Rule. The 90th percentile was 25 μg per liter, and in some samples the concentration exceeded 1000 μg per liter (www.FlintWaterStudy.org).

This contamination had consequences. Hanna-Attisha et al. reported that among children in Flint, the incidence of blood lead concentrations above the reference value of 5 μg per deciliter rose from 2.4% to 4.9% between 2013 and 2015.[2] The increase was greatest, from 4.0% to 10.6%, among children in neighborhoods with the highest lead concentrations in water.

Children are more vulnerable to lead than adults because of their greater fractional absorption of ingested lead and greater intake on a body-weight basis and because development of the central nervous system is easily derailed in ways that result in cognitive and behavioral abnormalities. When lead concentrations in water are high, infants consuming reconstituted formula are at special risk. The European Food Safety Authority estimates that infants' dietary intake of lead ranges from 0.2 to 0.9 μg per kilogram of body weight per day, so a 5-kg infant typically takes in about 2.5 μg per day.[3] If, however, the infant consumes 1 liter of water per day with a lead concentration of 25 μg per liter, the intake of 25 μg of lead would be 10 times higher day after day.

Lead contamination of drinking water poses a particular public health challenge because it rarely originates in the source water. Rather, the problem usually lies near the point of consumption, in lead service pipes connecting the house to the water main or lead pipes, lead solder, or lead brass fixtures in the home. Large-scale contamination generally occurs when changes are made in water-treatment protocols without consideration of the effect of those changes on the amount of lead that will leach from these materials. A decade ago in Washington, D.C., a change from the use of free chlorine to chloramine to reduce disinfection by-products caused such a problem, and lead contamination of water has recently occurred in some new housing in Hong Kong because, against code, plumbers used lead solder.

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The burden of childhood lead poisoning has always weighed most heavily on populations that are politically and economically disenfranchised. In Flint, 4 in 10 families live below the poverty line, unemployment is high, and the majority of the population is black. In general, disadvantaged children are exposed to more lead than their wealthier counterparts because they are more likely to live in houses in poor repair that still harbor deteriorating lead paint, to live in urban neighborhoods with greater soil and dust lead concentrations from traffic and industrial activities, and to have nutritional deficiencies that increase lead absorption. An elevated water lead concentration therefore adds to a background exposure that is already high. Indeed, Hanna-Attisha et al. showed that even before the water contamination began, the incidence of blood lead concentrations above 5 μg per deciliter was more than three times as high among children in Flint as among children in neighboring municipalities.[2] Were Flint more affluent, it's unlikely that the contamination would have continued for 18 months after citizens first voiced complaints about water quality.

An institutional factor that probably contributed to the crisis is that Flint was in receivership because of severe financial difficulties. The decision to switch water suppliers was made by a state-appointed emergency manager rather than local officials, who might have been better positioned to make a decision reflecting concern for public health as well as the bottom line. Although the cost of repairing Flint's water infrastructure is uncertain, estimates range as high as $1.5 billion. The cost of reducing the corrosivity of the Flint River water at the time of the change would have been minimal, perhaps $100 per day[4] — proving again that prevention is generally cheaper

than remediation and treatment. More money will be spent in the courts, since multiple lawsuits have already been filed. Imagine what could have been achieved for the people of Flint if the funds that will now be needed to repair the damage and litigate lawsuits could instead have been used to pursue goals such as improving the schools, de-leading homes, or funding programs providing job training, early education, or treatment and prevention for substance abuse or domestic abuse.

An audio interview with Dr. Bellinger is available at NEJM.org

Other costs that can be anticipated include developmental surveillance and treatment of the thousands of affected children. In coming years, parents will undoubtedly wonder, with anxiety and even guilt, whether their children's every developmental stumble stems from this episode.

It is notable that the Flint contamination might never have been brought to light had citizens not persisted in efforts to force local, state, and federal officials to take action. This is not the way public health protection should work, and the crisis appears to reflect failures at every level of government. In 1969, environmentalist René Dubos warned that the problem of childhood lead poisoning "is so well-defined, so neatly packaged, with both causes and cures known, that if we don't eliminate this social crime, our society deserves all the disasters that have been forecast for it."[5] We have yet to fully respond to Dubos's admonition.

We have the knowledge required to redress this social crime. We know where the lead is, how people are exposed, and how it damages health. What we lack is the political will to do what should be done.

Disclosure forms provided by the author are available with the full text of this article at NEJM.org.

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1. National primary drinking water regulations for lead and copper: short-term regulatory revisions and clarifications. Federal Register. October 10, 2007 (https://www.federalregister.gov/articles/2007/10/10/E7-19432/national-primary-drinking-water-regulations-for-lead-and-copper-short-term-regulatory-revisions-and-clarifications).
2. Hanna-Attisha M, LaChance J, Sadler RC, Champney Schnepp A. Elevated blood lead levels in children associated with the Flint drinking water crisis: a spatial analysis of risk and public health response. Am J Public Health 2016;106:283-90.
3. European Food Safety Authority. Scientific opinion on lead in food. EFSA 2010;8:1570 (http://www.efsa.europa.eu/sites/default/files/scientific_output/files/main_documents/1570.pdf).
4. Poisoned water. That Flinty taste. Economist 2016;418(8973):23.
5. Oberle MW. Lead poisoning: a preventable childhood disease of the slums. Science 1969;165:991-2.

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Mitochondrial Replacement Techniques — Implications for the Clinical Community

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Mitochondrial DNA (mtDNA) diseases may be the poster child for highly targeted, "personalized" medicine. These heterogeneous disorders, although rare individually, have well-defined genetic causes — more than 400 known pathogenic mutations or deletions in the 16,569-base-pair mitochondrial chromosome that contains only 37 genes. Affected persons may present at any age with some combination of severe, often progressive, and sometimes fatal neurologic, musculoskeletal, cardiac, gastrointestinal, renal, ophthalmologic, and audiologic involvement. No cures or therapies have been approved by the Food and Drug Administration (FDA) for any mtDNA disease, although symptom-based clinical management can be beneficial.

Despite their precisely defined causes, it's often difficult to predict the onset or severity of these diseases because of heteroplasmy: the culprit mtDNA mutation is commonly present in only a fraction of the body's mitochondria. Building on the principle that less is better, reducing mutant heteroplasmy loads below an often tissue-specific and difficult-to-define threshold presents a potential opportunity to improve health that is unique to these diseases. Research in animal and somatic cellular models has focused on this potential, using endonuclease, TALEN (transcription activator–like effector nuclease), or