The U.S. has a Clean Air Act and Clean Water Act. The missing environmental component, soil, results in a knowledge gap that has a profound influence on the lives of children. The national issue of children's lead exposure illustrates the effect of the soil knowledge gap. Clinicians have evaluated low lead exposure impacts on children and throughout one's lifespan. The medical impacts range from learning and behavioral problems to some of the most difficult and expensive chronic health conditions known to medicine, including kidney failure requiring dialysis, hypertension and heart disease, diabetes, and many nervous system dysfunctions including Alzheimer's disease. In response to clinical findings, the Centers for Disease Control and Prevention recognize that there is no known safe level of lead exposure for humans (USCDC, 2012). To complicate the problem, the ordinary medical method for intervention, which focuses on lead-based paint, is deemed ineffective. Moving forward with primary prevention of children's exposure to lead requires essential knowledge about human biology, urban contamination, and soil.

Hand-to-Mouth Behavior Is an Innate Human Trait

Children's behavior is controlled by a specific DNA-directed hand-to-mouth behavior (Fig. 1). The behavior begins in the womb during early gestation and continues after birth (Desmurget et al., 2014). Simply stated, hand-to-mouth behavior is hard-wired into the human brain, and the exposure vulnerability to lead dust of infants, toddlers, and young children is tied to that fact. "The motor repertoire of infants is narrow. Yet newborns can accurately bring their hands toward their mouth for self-feeding, thumb-sucking, or perioral exploration, thus showing fine coordinated movement synergies between the hand and mouth…these gestures of high ethological value are selectively encoded in the human brain and represented as integrated primitives within the precentral gyrus, a key region for sensorimotor processing" (Desmurget et al., 2014). An essential requirement for preventing children's exposure to lead is the need for clean air, water, and soil.

Ordinary Medical Intervention Is Ineffective

The usual medical strategy for intervention focuses on education and household dust cleanup. Cochrane Collaboration provides critical reviews for evaluating the effectiveness of medical interventions. A recent Cochrane evaluation was performed on education and household interventions for preventing children's lead exposure. The Cochrane report unequivocally states that the existing intervention method is ineffective at reducing children's blood lead levels (Yeoh et al., 2012). The corollary is that there is no known intervention for primary prevention of lead dust. The lack of effective intervention means that even when diagnosed, children endure continuing lead poisoning. The lifelong medical and societal consequences are enormous (Bellinger, 2011).

The situation is even more alarming because lead intervention is triggered by blood lead findings, and children are being used for testing lead residues in the environment. This violates national and international standards for the treatment of human subjects. According to World Medical Association (2013) criteria, if a method is shown to be ineffective, then the medical community must revise...
the intervention to prevent harm. The U.S. treatment protocols are thus doubly culpable because not only do they employ children’s blood lead as an indicator of lead contamination, but they also use an ineffective intervention method to prevent children from further harm.

**Soil Is a Potent Reservoir of Lead Dust**

While lead-based paint is believed to be the major source of interior dust, seasonal changes in children’s blood lead do not support that perception. In Detroit and other cities, blood lead is lowest toward the end of winter after children have been cooped up inside (and presumably exposed to household paint) and highest during the late summer and early fall when the children are outside and in contact with soil (Zahran et al. 2013). Urban soil has become severely lead contaminated, especially in inner cities (Filippelli and Laidlaw 2009; Mielke et al. 2013).

Soil ingestion is recognized as common among humans (Starks and Slabach, 2012). When ingestion is involved, a factor of 10 is normally used for a margin of safety (USEPA, 2002; USDHHS, 2005). Assuming ingestion and adding the margin of safety, the USEPA soil lead standard should be reduced from 400 mg/kg to 40 mg/kg. Some states and many nations have promulgated soil lead standards at or below 100 mg/kg (Jennings, 2013).

Accumulated lead residues in soil are a source of lead aerosols. During seasonally drier periods such as late summer and fall, lead dust resuspension from contaminated soil is directly associated with fluctuations in blood Pb (Laidlaw et al., 2005, 2012). Empirical research shows that if the goal is to prevent Pb exposure ≥10 μg/dL for children living in a community, then the median soil lead must be <80 mg/kg (Mielke et al., 1999). Given the current CDC 5 μg/dL blood lead reference value, the soil Pb standard must be revised sufficiently downward to ensure a margin of safety that protects most children from the risks of inadvertent exposure to soil reservoirs of lead dust.

One major issue is that outdoor lead is being measured in units of lead content per weight of soil whereas interior dust is measured in units of lead per surface area. The interior standard is 40 micrograms per square foot. When measured outdoors in units of lead per surface area it is daunting to discover that the U.S. soil standard of 400 mg/kg (ppm) is equivalent to surface loading of about 1,500 μg/ft² (Mielke et al., 2007). The standard measurement used to describe outdoor soil is ineffective as a guideline for safety because it fails to clearly communicate how much lead children can obtain on their hands from the soil surface (see Fig. 2).

**Fig. 2.** Three-dimensional map of New Orleans showing both soil lead in µg/g and µg/ft². Note the large difference between the usual soil measurement and the lead loading in µg/ft² of the soil surface. The U.S. lead loading standard of the interior floor is 40 μg/ft², and this compares with the lead loading of 1,500 μg/ft² when the soil lead meets the U.S. soil standard of 400 μg/g or ppm (Mielke et al., 2007).

**Conclusions**

The soil knowledge gap among health practitioners is related to the failure to understand essential characteristics about human biology in the context of the air–water–soil nexus of children’s environmental health. In the case of the lead exposure issue, closing the soil knowledge gap at least requires: Acknowledging the innate vulnerability of less than three-year-old children to lead residues in their environment including, air, water, and soil; conceding the failure of current lead-based paint intensive interventions for preventing exposure of children; underscoring soil loading vs. lead content as part of risk analysis; upgrading standards to use at least a factor of 10 to protect children;
exploiting federal resources such as the USDA and the U.S. Geological Survey to map urban soils; recognizing the value of low lead soils that exist outside of every city as an essential resource for revitalizing urban lands to create safe areas for the youngest citizens; and accepting clean soil along with air and water as critical components of the long-term goal of resolving national health issues.

References


