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RESEARCH ARTICLE

Novel Policies are Required to Reduce Pediatric Lead Exposure from Legacy Lead (Pb) in Soil and Air

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ABSTRACT
In 1925, a U.S. conference on lead (Pb) additives tacitly approved their use in petrol. Over five-decades an exponential increase of air lead occurred from commercial marketing of leaded petrol and the sale of automobiles. The ability to measure microgram quantities of Pb was unavailable to medical researchers until the late 1960s and early 1970s. The clinical application of advanced analytical technology demonstrated that pediatric lead exposure was excessive. Beginning in the mid-1970s, actions were taken to curtail Pb additive and decreases of pediatric lead poisoning coincided with decreased air Pb from leaded petrol use. Exogenous Pb exhaust particles are absorbed through inhalation and ingestion routes of exposure. Exogenous Pb is metabolically mistaken for calcium and stored endogenously in bones, teeth, and other tissues. Endogenous Pb has intergenerational effects. All organs, most notably the nervous system, are affected. Clinical studies indicate that there is no safe level of Pb exposure. A worldwide ban on leaded petrol was achieved on August 30, 2021. Banning leaded petrol corresponded with marked decreases in lead exposure. However, exogenous Pb dust persists in soil as a legacy from the era of leaded petrol. Soil Pb is remobilized into the air. Because of traffic congestion and Pb dust emissions, population centers are of particular concern. An exceedingly strong association exists between soil Pb and blood Pb indicating that at the community-scale Pb dust mitigation is necessary to decrease pediatric Pb exposure. Urban soil Pb and blood Pb studies indicate the risk of excessive exposure from legacy Pb dust in communities is highest where the median soil Pb is ≥ 50 mg/kg. The objective of this article is to demonstrate the practical application of an advanced hand-held analytical instrument to map Pb in children's playgrounds adjacent to a major traffic corridor. We illustrate soil Pb mapping and then consider mitigation procedures for primary prevention of legacy Pb. Mapping soil Pb provides an informed basis for advising parents and encouraging community mitigation responses for reducing pediatric Pb exposure from legacy Pb dust. The soil health-plant health-animal/human health signaling nexus is compromised by legacy Pb. For the medical pediatric community, the existence of legacy lead requires new policies to address intervention of the soil-air-blood linkages of the Pb exposure pathway.

(1) Introduction

"The dialectics of experimentation…is like a quiet conversation with Nature. One asks a question and gets an answer; then one asks the next question and gets the next answer. An experiment is a device to make Nature speak intelligibly. After that one has only to listen." George Wald[1], Nobel Lecture, December 12, 1967.

Around 1 in 3 children (~800 million globally) have blood lead (Pb) levels at or above 5 µg/dL, the previous level that required action. Note that older references use the blood Pb reference established by CDC in 2012, however, the 2021 blood Pb reference value is now 3.5 mcg/dL. The CDC emphasizes that there is no known safe level of Pb exposure for children. Nearly half of these children live in South Asia[2]. Researchers found that pooled mean blood Pb concentrations in children ranged from 1.66 µg/dL (SD 3.31) in Ethiopia to 9·30 µg/dL (11.73) in Palestine, and in adults from 0.39 µg/dL (1.25) in Sudan to 11.36 µg/dL (5.20) in Pakistan. 632 million children (95% CI 394 million–780 million; 48·5%) from 34 countries were estimated to have a blood Pb level exceeding the 2012 U.S. Centers for Disease Control's reference value of 5 µg/dL. Major worldwide sources of Pb exposure were informal lead acid battery recycling and manufacture, metal mining and processing, electronic waste, and the use of lead as a food adulterant, primarily in spices[3]. This article focuses on the invisible aerosol sources of Pb resulting from its use as an additive to petrol.

The historic enabling decision on Pb additives was established in 1925 by the U.S. Public Health Service and the Department of Commerce at a meeting entitled *Conference to Determine Whether or Not There is a Public Health Question in the Manufacture, Distribution, or Use of Tetraethyl Lead Gasoline*[4]. Physiologist Yandel Henderson was a staunch opponent of using Pb additives in vehicle fuel. His comments focused on inhalation of fine particles of Pb exhaust, and he noted that "…if the material is inhaled—and its symptomology is altered when it is inhaled, because of its wider distribution in the body—it is extremely likely that…ordinary physicians…would fail to recognize the condition as lead poisoning[5]." Since research data and proof harm was lacking about the health questions concerning Pb additives in fuel, the decision was made to tacitly allow lead additive use until more definitive data was available. After the 1925 approval of lead additives in gasoline by the U.S. government, leaded petrol was effectively promoted and used throughout the world. Within decades, the distribution of leaded petrol became so widespread that the consequences of Pb contamination evolved into an international public health disaster[6].

Beginning in 1975, the U.S. EPA required all new highway vehicles to be equipped with catalytic converters; however, Pb was incompatible with the catalyst, and unleaded petrol was required to protect the catalysts[7]. In 1980, Clair Patterson wrote a National Academy of Sciences article declaring, 'Sometime in the near future it probably will be shown that the older urban areas of the United States have been rendered more or less uninhabitable by the millions of tons of poisonous industrial lead residues that have accumulated in cities during the past century[8]." The reduction of leaded petrol was gradual up to the 1980s and then accelerated because of a Congressional mandate ordering the U.S. EPA to reduce the amount of leaded petrol[9]. The U.S. rapid phasedown of leaded petrol[10] began on January 1, 1986. The ensuing national bans of the use of leaded petrol resulted in decreases in children's blood Pb in countries around the world[11,12]. Although major advances in primary prevention have been made, data from around the world indicates that the baseline urban population-level air Pb exposures are still too high, plateauing at around 2 ug/dL[11]. The average blood lead level for people aged 1–74 years in the U.S. decreased by 78%, from 12·8 µg/dL to 2·8 µg/dL between 1976 and 1991[13]. Similar trends were noted in Sweden and Germany[11]. Phase-outs were slow to be adopted in low-income and middle-income countries (LMICs)[3], but by August 30, 2021, nearly a century after Henderson's statements, leaded petrol for highway use was finally banned worldwide[14].

For the clinical research community, a crucial issue was the lack of technical ability to affordably analyze small (µg/g) quantities of Pb. That ability developed in the late 1960s and early 1970s[15]. The advances in analytical technology were applied to clinical research, and the results indicated that common Pb exposures were excessive. The medical community was convinced that lead-based paint was the primary cause of Pb exposure, although there were objections. Studies of indoor Pb dust and hand Pb within inner city and outer city communities suggested another source of Pb dust was relevant in the exposure of children[16].

Although leaded petrol has been curtailed, its use as a fuel additive remains in the soil environment as a legacy of its previous use. The soil Pb legacy from the era of leaded petrol were demonstrated in a study of soils metals in the interior and outlying areas of the city of Baltimore[17]. The unanswered question was the effect of soil Pb on pediatric Pb exposure. This question was answered through studies in New Orleans involving collections of matched soil Pb and blood Pb samples compiled within 274 communities over 17 years[18]. The New Orleans results were transformative because first they demonstrated an inner city (high traffic congestion) and outer city (low traffic congestion) disparity for both soil Pb and blood Pb. In addition, a concurrent reduction of soil Pb and blood Pb was observed over the 17-year interval of the two surveys[18]. "In the 2001 survey, the median SPb is 99 mg/kg and the median BPb is 3.6 µg/dL. In the 2017 survey, the median SPb is 54 mg/kg and the median BPb is 1.3 µg/dL. Fisher's exact test P values are 4.0×10^{-46} for 2001 and 1.6×10^{-26} for 2017." These robust results indicate the decline in blood Pb is powerfully influenced by the reduction in soil Pb. Although traffic-generated Pb dust is now eliminated, the legacy of Pb in soil has become an increasingly significant factor in pediatric Pb exposure. It requires remedial actions to transform the Pb contaminated soil into a condition whereby Pb exposure decreases in the pediatric population.

The objectives of this article are 1) to demonstrate the practical application of an advanced handheld Pb analysis instrument (X-Ray Fluorescence or pXRF) for mapping soil Pb[19], and 2) to apply the information toward prevent pediatric Pb dust exposure. This article builds on previous studies of the spatiotemporal dynamics of pediatric Pb exposure[18]. The focus is on a well-studied urban environment. When the linkages between air Pb, soil Pb, and blood Pb are recognized, then the focus of actions shift to primary prevention mitigation and soil health interventions.

(2) Methods:

The methods section describes the aims and the scope of a field study conducted by the 2022 class at Tulane School of Medicine. The purpose was to evaluate the quality of playground soils constructed next to a major traffic corridor along the Lafitte bicycle/pedestrian greenway park in New Orleans.

2.1. Site selection

This 2022 study addresses soil Pb quality of children's playgrounds in the Lafitte Greenway on both sides of the U.S. Interstate Highway 10/Claiborne Avenue traffic corridor. The New Orleans Lafitte Greenway, is a bicycle/pedestrian pathway, created five years after Hurricane Katrina flooded the city in 2005. In 2010, the land was purchased close to the French Quarter near the I-10/ Claiborne traffic corridor at the end of an unused railroad line. The Lafitte Greenway extends from the French Quarter to Mid-City and to New Orleans City Park[20]. The Freeway is elevated over Claiborne Avenue. See Figure 1, below.

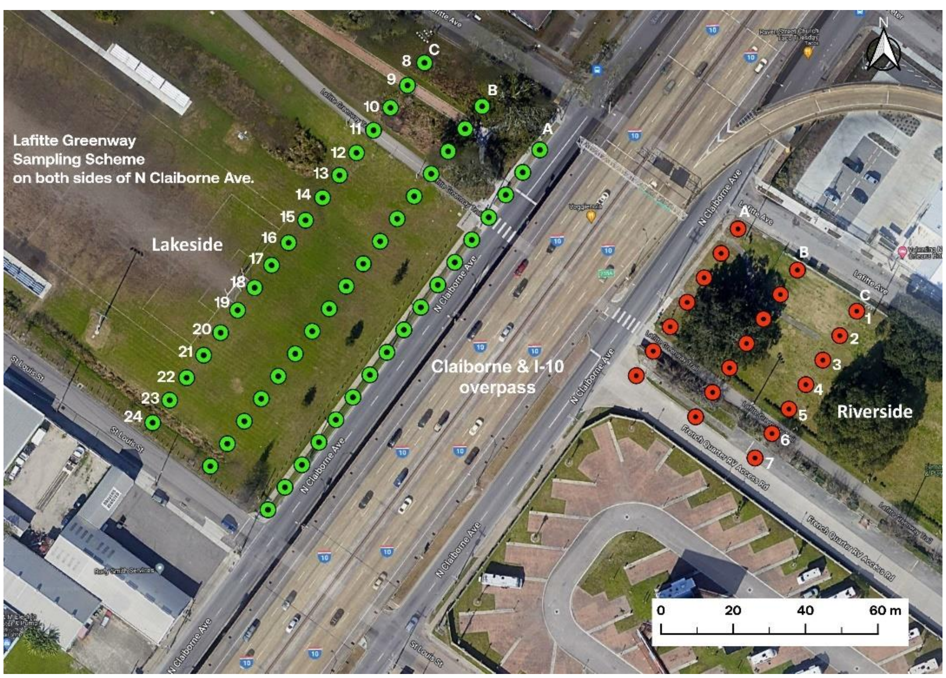

Figure 1. Map of the US I-10 Traffic Corridor and the Lafitte Greenway soil transect sampling scheme. Green circles represent samples collected on the Lakeside, while the red circles, the Riverside of the traffic corridor, respectively. Transect 8 was assigned but not conducted. assignment.

Prior to the construction of Lafitte Greenway, a 2001 survey revealed Pb-contaminated soil on the proposed path of the Greenway[21]. In 2010, the Lafitte Greenway bicycle/pedestrian path was landscaped by bulldozers and other heavy equipment, using clean, low Pb soil from outside of New Orleans to cover the Pb contaminated ground of the Lafitte Greenway[22]. The Lafitte Greenway has two play areas next to the US I-10/Claiborne traffic corridor. To the Northwest of the traffic corridor is a playground we refer to as the Lakeside playground, and Southeast is a playground referred to as the Riverside playground (Figure. 1).

2.2. Soil sampling

Students (n=24) were assigned to collect soil samples from the Lafitte Greenway playgrounds. Each class member was provided numbered soil collection kits (n=24). Each kit included a collection spatula, three labeled collection bags, and Figure 1, with tagged numbered transects (1-24) as a guide for soil collection. Each student signed up for a numbered collection kit and was responsible for collecting soil from a specific transect, as shown on Figure 1. Using the map for guidance, students were instructed to find the approximate location of each collection transect listed on Fig. 1. The assigned transect 8 was not collected, thereby reducing the number of soil collectors (n=23)

The following instructions were provided with each kit. First, a soil sample was defined as the topsoil from 2.5 cm depth from the soil surface and having a volume 100 cm^3 – 120 cm^3 at each collection site along each respective numbered transects. Soil sample "A" was collected nearest the I-10/Claiborne Avenue traffic corridor. After sample "A" was collected, the students were instructed to take ten long strides (~8-10 m) following the transect line away from the I-10 Claiborne traffic corridor, and collect samples "B", and after collecting sample "B", each student was instructed to pace out ten long strides further away from the traffic corridor on the transect line to collect sample "C".

In summary, soil samples along 23 transects from three different sites "A", "B", and "C" distances (n=69) were collected from two Lafitte Greenway playgrounds on both sides of the I-10/Claiborne Avenue traffic corridor. Note that as shown in Fig. 1, the two playgrounds had differing numbers of transects and soil samples. From the Lakeside playground, 16 transects (48 samples) were collected, and on the Riverside playground, 7 transects (21 soil samples) were collected.

2.3. Soil Pb analysis and data evaluation.

Analysis of the soils were conducted on in-the-bag samples using Portable Energy Dispersive X-Ray Fluorescence Spectrometry (pXRF)[23]. A Niton XL2 handheld pXRF was used to analyze each sample for 30 seconds. The Limit of Detection (LOD) was estimated for each sample. For samples < LOD the error/precision of the measurement[23,24] was multiplied by 1.5. The resulting LODs were divided by $\sqrt{2}$ and used as an estimate of soil Pb concentration in mg/kg. The median (95% Confidence Interval) LOD for these samples was 17.7 (16.9 – 18.4) and the Median Absolute Deviation (MAD) was 1.2. The number of samples <LOD was 36/69 (52%).

To visualize results, "violin" plots were created[25,26]. In addition, to evaluate the effect of distance on the soil Pb results in the playgrounds, the median Pb concentration of soils were graphed as a function of the three collection distances from the I-10 traffic corridor.

(3) Results

This study addresses the quality of soil Pb on two Lafitte Greenway children's playgrounds located next to a major traffic corridor through New Orleans. The traffic corridor is U.S. Highway I-10 and elevated above Claiborne Avenue which is located at ground level. Previous studies in New Orleans indicate that in communities where a median soil Pb is less than 50 mg/kg, children had a relatively safe, but still some exposure, presenting with a median blood Pb of < 1 µg/dL[18].

3.1 Comparison of the soil Pb datasets for the two playgrounds

Figure 2 illustrates the violin soil Pb datasets collected from the Lakeside and Riverside playground soil samples. The black bars show the 95% confidence interval of the median[25,26]. Note that the Lakeside playground's median soil Pb (13 mg/kg) is tightly bound within the 95% confidence interval for soil Pb. The Riverside playground median soil Pb (149 mg/kg) has a wide 95% confidence interval range.

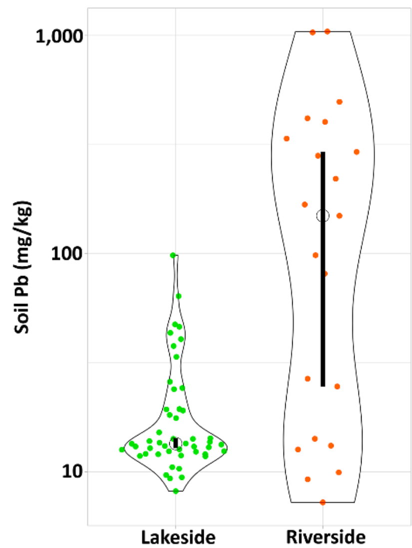

Figure 2. Violin plots of soil Pb for the Lakeside (48 samples) and Riverside (21 samples) in New Orleans

One possible reason for the large 95% interval is that too few samples were collected in the Riverside playground. However, the best explanation for the wide interval is the extreme variability of soil Pb on the Riverside playground soils. Figure 2 shows the composite sample results for the Lakeside and Riverside playground soils. The width of the results indicates the variation of the soil Pb on each playground. Note the narrow distribution of soil Pb on the Lakeside playground compared to the large width of the distribution of soil Pb in the Riverside playground,

3.2 Distance of the soil sample from the traffic flow

The pattern of soil Pb distribution as a function of distance differed between the two playgrounds. Figure 3 illustrates the median distribution of soil lead as a function of distance from the I-10/Clayborne traffic corridor for the Lakeside playground compared to the Riverside playground of the Lafitte Greenway. In the Lakeside playground median soil Pb results were compiled from 17 soil samples for each distance, whereas the median of 7 soil sample results was compiled for each distance on the Riverside playground. One unexpected result for the Riverside playground is the increase of soil Pb with distance from the traffic corridor.

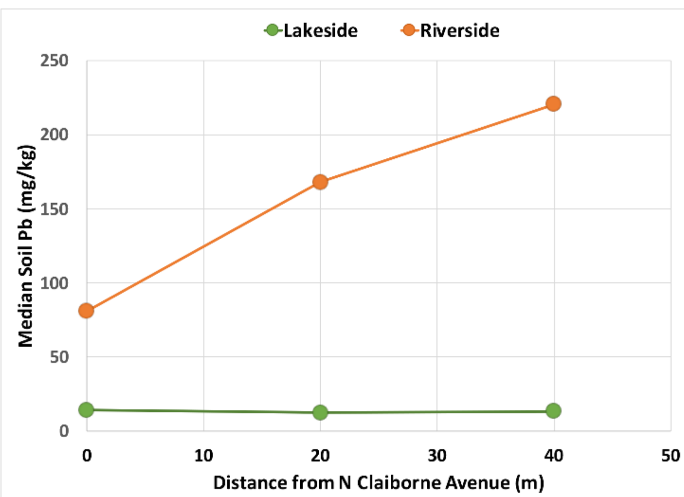

Figure 3. Soil Pb as a function of distance from US I-10

(4) Discussion

4.1 Exogenous and Endogenous Pb Sources and Exposure

The Pb observed and experienced in urban settings requires further discussion. Two lead containing consumer products, lead-based paint, and leaded gasoline have left residual (or legacy) Pb in the environment and have major impacts on pediatric exposure. Because of their visibility and high Pb content, lead-based paints have been assumed to be the major source of pediatric Pb exposure for all children. In 1969 on April 14, the Lead Industry Association (L.I.A.) actively reinforced paint as the only source involved in Pb poisoning. The L.I.A. board of directors stated, "It should be a primary objective of any L.I.A. program, or L.I.A. participation in other programs, aimed at resolving the childhood lead poisoning problem to keep attention focused on old, leaded paint as its primary source and to make clear that other sources of lead are not significantly involved[27]." Measuring blood Pb and ascribing the exposure to lead-based paint fails ethical and medical standards because children are being used as secondary sensors of primary sources of Pb exposure, and this is to the detriment of children and society. Of course, careful attention must be paid to old lead-based paint to assure it is intact, coated with non-leaded paint, and not in the exposure pathway by weathering or improper removal or disturbance that contaminates the environment[28]. Extreme individual clinical cases of Pb exposure are still being observed from lead-based paint. Still, the outcome of invisible Pb exposure in the urban pediatric population needs a more comprehensive explanation.

Leaded gasoline is an exogenous source of lead. The amount of Pb used in the U.S. as additives in petrol was about equal to the amount of Pb added to lead-based paint[29]. Most European nations banned lead-based paint in the late 1910s-1920s. The promotion of highway building, vehicle sales, and high petrol prices have an immense bearing on per capita vehicle use, many European urban areas were spared the massive amounts of Pb dust compared to the U.S., where the nexus of automobile-highway-petroleum use were strongly promoted[29]. The critical issue is to fully grasp Yandel Henderson's 1925 concerns[5], eliminate invisible Pb aerosols exhausted from the combustion of leaded petrol, and locate the Pb deposited in the environment to prevent Pb exposure in the pediatric population.

The use of leaded petrol, now banned worldwide, left a legacy of ingestible Pb dust in urban soil and remobilized Pb dust into the air contributing to inhalation and ingestion pathways of pediatric Pb exposure, subject to seasonal conditions[30,31,32]. Remobilized soil Pb and dust is being observed as contributing to the elevated blood Pb of urban populations worldwide. Atmospheric and soil Pb demonstrate near-identical seasonal properties that match seasonal variation in children's blood Pb levels. Resuspended soil is a significant source of atmospheric Pb that becomes settled Pb dust in the environment[33,34].

Endogenous Pb is sourced from exogenous sources of Pb which are transferred to bones. Lead interferes with calcium metabolism, and the cellular substitution of Pb in place of Ca affects all organs, especially the nervous system. Lead blocks signaling between neuron synapses, and the lack of signaling functions causes the brain cells to die. The frontal cortex is particularly vulnerable, and the resulting damage to that part of the brain is the loss of executive functions and adverse effects on lifetime judgment and behavior of lead-exposed individuals. The consequences of children's continuing Pb exposure include damaging effects to intelligence and behavior and adverse effects on personality traits of the adult population[29,30]. Both exogenous and endogenous sources of Pb become a lifelong supply of Pb exposure, and together appear to influence the decreases of blood Pb[31.32]. For children, especially during their prenatal and early physiological development, no level of Pb exposure is safe[39]. The continuing worldwide health implications of former leaded petrol and its environmental legacy of accumulation cannot be ignored[6].

Lead exposure contributes to the loss of children's intellectual ability with the economic impact of lead exposure in High Income Countries of an estimated economic cost in the U.S. and Europe of $51 and $55 billion, respectively[40]. In contrast, Low to Middle Income Countries (LMICs), have economic losses costing approximately $977 billion (range $728.6–1162.5 billion) of international dollars, with losses estimated at $134.7 billion in Africa (4.03% of gross domestic product (GDP) in that region), $142.3 billion in Latin America and the Caribbean (2.04% of GDP in that region), and $699.9 billion in Asia (1.88% of GDP in that region)[34]. The burden associated with childhood lead exposure in these countries is about 1.20% of world GDP in 2011. Given the toxicity of lead, even low amounts of exposure require urgent attention to control exposures and expand the sampling of legacy Pb sources in countries with little or scant data[3,40].

4.2 The Soil-Health-Plant-Health-Human-Health-Signaling Nexus.

Soil health relates to the signaling nexus between soil microorganisms (i.e., bacteria and fungi) plants, animals, and humans. The evolution of plants involved defensive mechanisms including an exceptional array of biochemically active compounds. "From an environmental stewardship perspective, the evolving concept of environment signals can provide insights with which to address the impact of hormonally active chemicals on humans and the ecosystems which they share with other species. Disruption of the apparently broad communication system has the potential for global change that transcends the endocrine system[41]."

Healthy soils support a broad communication system among an array of microorganisms that results in phytochemical systems rich in high quality nutrients and compounds that are beneficial for plant health and the health of animals and humans alike[42]. Modern industrial agricultural emphasizes quantity of food over the quality of food[43]. Fruits, vegetables, cereals, and nuts are bred to increase quantity and the result of the agricultural system is a decrease of the quality nutrients. "Once you understand the connections, it becomes clear that for plants, animals, and people alike, the roots of health grow from healthy soils[42]."

Likewise, soil health, especially in urban environments and population centers, has undergone a different type of degradation. In the case of Pb, industrial transformation of transportation into automobiles fueled by leaded petrol resulted in uneven soil Pb legacy. There is a marked inequality of Pb dust amongst interior communities' traffic-congested areas and outlying communities with low traffic congestion areas. A study of soils in metropolitan Baltimore observed a striking difference of Pb in garden soils of inner-city compared to the outer-city soils of outlying communities[17]. The authors raised the possibility that soil Pb affects pediatric lead exposure, but there was no supporting data[17]. The New Orleans two-decade long studies of soil Pb and pediatric blood Pb within inner city and outer city communities illustrates the discrepancy of Pb toxicants in surface soils and their effect on pediatric Pb[44]. Lead is one example of environmental toxicants that are detrimental to the health of children and human communities[45]. Toxicant contaminated urban-industrial cities can benefit from policy measures that improve soil health.

4.3 Novel ways to transform Pb contaminated into healthy soil and reducing pediatric Pb exposure

As described in the introduction the research community lacked technical ability to affordably analyze small (µg/g) quantities of Pb from the beginning of the introduction of Pb additives to petrol. However, in the late 1960s and early 1970s, decades after additive use, that limitation was overcome[15]. The advances in analytical technology were applied to clinical research, and the results indicated that common Pb exposures were excessive. The medical and public health community became convinced that lead-based paint was the primary cause of Pb exposure, however, there were objections to lead-based paints as the driver of pediatric Pb exposure. Studies of indoor Pb dust and hand Pb within inner city and outer city communities of Rochester, NY indicated an unknown alternative source of Pb dust that was responsible for pediatric exposure[16].

Recent advances in soil Pb analysis has been boosted with the development during the 1990s and 2000s of the portable (specifically, handheld) X-Ray Fluorescence analytical instrument (pXRF)[19]. Soil analysis with pXRF requires minimal preparation. Four soil Pb extraction methods were compared on the same sample set and the agreement R between them were excellent[19]. This means that soil analysis can be conducted on-site as a point-of-care soil testing activity. The pXRF provides test results within minutes, however, pXRF has limitations on individual samples that affect readings such as high detection limit, interference with plastic, exposure time, inconsistency of a sample, moisture content, and porosity. However, with the pXRF large numbers of samples can measured and the size of the sample set overcome the limitations associated with results of an individual soil sample.

As illustrated in Figs. 2 and 3, in the case of the Lakeside playground of the Lafitte Greenway, the median soil Pb of 13 mg/kg is consistently below 50 mg/kg. The Lafitte Greenway Lakeside playground has soil that offers excellent primary Pb prevention for children. On the other hand, the overall median soil Pb of 149 mg/kg on the Riverside playground at the I-10 freeway/Claiborne traffic corridor exceeds the median amount of 50 mg/kg over the entire playground[18]. The Riverside playground soil is exceedingly Pb contaminated. It is not protective for children playing there nor, because of remobilization of Pb dust, the community surrounding the playground. The increase of soil Pb with distance on the Riverside playground was unexpected. We speculate that this outcome is due to spreading clean soil on the playground closest to the traffic corridor.

The method of adding clean soil to Pb contaminated properties used in the Lafitte Greenway have been evaluated on over thirty playgrounds at childcare centers in New Orleans[46]. The same method of adding clean soil was also used to decrease extremely Pb contaminated soil from a former smelter site at a craft village, Dong Mai, Vietnam[47]. The median blood Pb of children in Dong Mai underwent a substantial 67% decrease from 40.4 µg/dL to 13.3 µg/dL after the cleanup involving the elimination of dust inside of home interiors, play areas, and repaving the road through the village[47]. The Lafitte Greenway playground and other projects recall George Wald's quote, "The dialectics of experimentation…is like a quiet conversation with Nature. One asks a question and gets an answer; then one asks the next question and gets the next answer. An experiment is a device to make Nature speak intelligibly. After that one has only to listen[1]." Regarding a remedy, the question about transforming the high soil Pb on the Riverside playground into a Pb-safe playground is clearly demonstrated by the soil Pb results on the Lakeside playground. Applying the same low-lead landscaping treatment used on the Lakeside playground to the Riverside playground is the remedy for the soil Pb contamination issue. Also, due to Pb dust mobilization the Pb contaminated playground is a source of Pb dust in the surrounding community. Thus, the remedy of the playgrounds extends into the surrounding communities.

4.4 Strategies and technics to mitigate soil contamination

To achieve the best results, it may be necessary to combine soil remediation strategies and sustainable conservation practices to decrease contamination risk and prevent recontamination. Such strategies and techniques are summarized in Figure 4 for remediation of contaminated urban soils contaminated by legacy Pb[48]. The easiest and least costly strategy for the studied playgrounds would be to apply clean local soil, compost, or mulch to cover the contaminated layer of soil that not only will create a barrier for children playing on the ground, but also provide soil nutrients, biodiversity, and better water infiltration. Compost additions to contaminated sites showed reduction in environmental Pb concentrations due to organo-mineral complexes with organic matter and dilution effects[49-52].

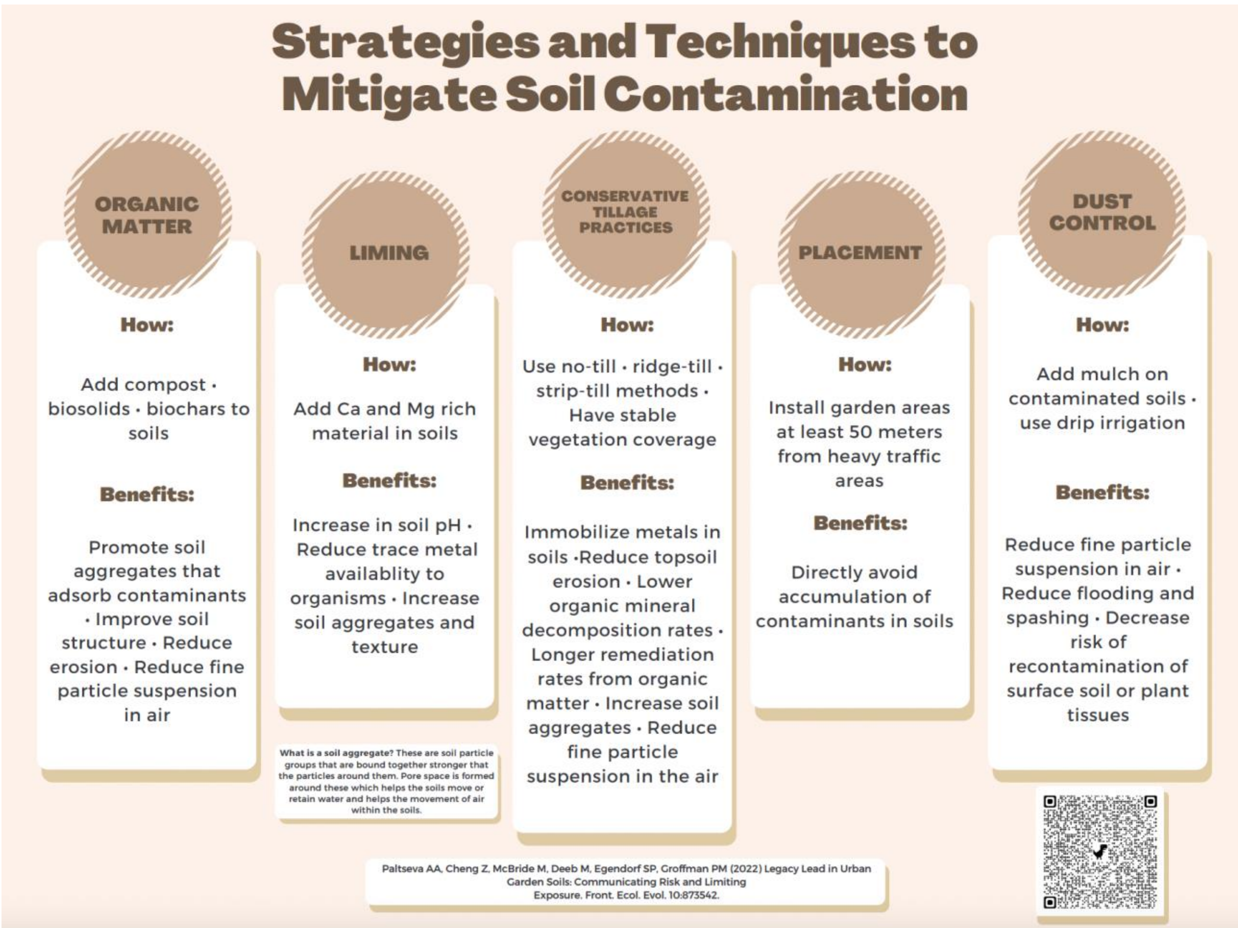

Fig. 4. Strategies and techniques for mitigating urban soil contamination[48]. Neva Powers prepared the infographic.

A Norwegian national action plan for mapping and remediation of playground soils sets precedence for the world[53]. An example of a review of multiple approaches for addressing urban soil Pb contamination is available for anyone interested in pursuing this topic[54]. Creating cleanup projects in areas of rundown communities has been reported as beneficial to mental health[55]. The materials removed from deep foundation construction projects in New York City are mixed with composts to serve beneficially for improving the soil quality of gardens and playgrounds[56].

(5) Conclusions:

Lead contaminated soil is unhealthy for communities and pediatric populations. Exogenous Pb sources, such as lead-based paint are notoriously toxic. Invisible dust originating from the use of Pb additives in petrol is inhalable toxicant, settles as

Pb dust in soil, is easily picked up by hands and toys, is readily tracked into homes, remobilize into the air as inhalable Pb dust, wafts into houses, and thus poses continuing multi-media exposure risks for the pediatric population. Exogenous sources of Pb are absorbed and stored in the bones and teeth and become an endogenous source. The legacy of Pb dust in soil and its remobilization into the air, combined with endogenous Pb sources from bone, establishes the baseline exposure of children and adults. In New Orleans, studies on the association between soil Pb and children's blood Pb reveal that a median soil Pb greater than 50 mg/kg is unsafe for children at the community scale. Mitigation of soil Pb requires novel policies to decrease contact with the exogenous legacy reservoirs of Pb in soil and curtail remobilization of soil Pb. This article illustrates how mapping soil Pb of two playgrounds along the Lafitte Greenway and adjacent to a major traffic corridor provides information to evaluate the conditions of playgrounds. One playground, the Lakeside playground is lead-safe for children, and the other playground, the Riverside Playground, is unsafe because of high soil Pb results. If a playground is unsafe for children, then in the context of the larger community, the playground is unsafe for everyone. Healthy soils play a vital role in community-scale pediatric Pb exposure. The inextricable links between community scale air Pb, soil Pb, and blood Pb must be understood in the context of advancing the primary prevention of pediatric Pb exposure.

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Author Contributions: H.W.M. conceived the class project, recruited class participation, obtained assistance to analyze soil samples of the Lafitte Greenway playgrounds, and wrote the first draft of the manuscript. C.R.G. analyzed, organized, and mapped the Lafitte Greenway soil (Figures 1-3). A.P. provided editorial assistance and contributed to the soil remediation section of the manuscript.

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Conflicts of Interest: The authors declare they have no conflicts of interest.

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