Research Article

Pharmacology Research in Environmental Signaling: Life Expectancy, Invisible Lead Dust, and Proactive Intervention to Reduce Children's Pb Exposure in New Orleans, LA (USA)

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Abstract

Pharmacology is the study and research into the chemistry of life. This paper discusses the environmental signaling and external chemicals utilizing internal signals. There is no known safe level of lead exposure. Lead contact is determined clinically by measuring blood as a biomarker to determine exposure. The standard follow-up to excessive lead exposure is a reactive intervention of the individual's residential house. The intervention method has been deemed ineffective at reducing children's lead exposure. Measuring lead in the environment of communities along with the blood lead biomarker serves an alternative environmental signaling approach for assessing the source and inform a proactive method for curtailing exposure. The goals of this paper are: to describe environmental signaling for unearthing New Orleans's lead problem, to explore the influence of a large natural flooding event on the environment and children's lead exposure in the city, and to apply the knowledge acquired to reduce children's lead exposure in lead contaminated communities of the city.

1. Introduction

1.1 Disparities in Life Expectancy

A "place matters" report describes the life expectancy disparity between people living in outer communities compared with inner city communities of New Orleans [1]. Depending on community location, life expectancy

varies from 55-58 years to 77-80 years. The disparity is illustrated by a map published in the New Orleans Times-Picayune [2].
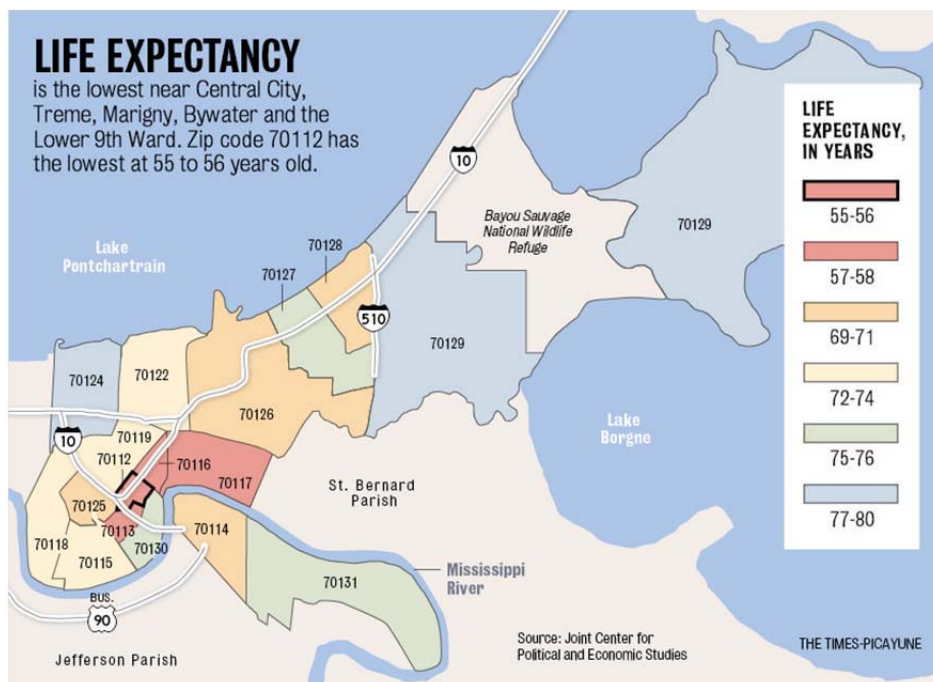
Figure 1: Map of life expectancy within various communities of New Orleans. Note that communities located in the outer areas of the city list life expectancy as 77-80 years while the life expectancy is 55-58 years in communities of the inner-city. Source: Somosot, M. 6/21/2012 The Time Picayune [2].

Pharmacology is the study of the chemistry of life. This paper focuses on lead in the exterior environment and its influence on morbidity. Environmental signaling is novel in pharmacology because it addresses external chemicals and their associations with internal signaling and wellness. Instead of emphasizing the treatment of disease, wellness emphasizes preventing illness and prolonging life as the principle healthcare objective. Environment signaling seeks to unravel fundamental obstructions that thwart wellness by seeking to improve the chemistry of life and treat common health issues.

While health disparities have been long acknowledged, the lack of progress in reducing disparities is disquieting [3]. Urban lead residues are the focus of this paper. A unique natural experiment emerged in New Orleans after Hurricane Katrina which provided the opportunity to evaluate the spatiotemporal dynamics of urban soil lead-dust and children's lead exposure outcomes.

Lead dust (i.e., particles) in air, water and soil are important sources of lead. Lead particles are invisible. The invisibility of lead dust contributes to a prevention conundrum. Urban air lead dust is derived from numerous

commercial sources, especially lead-based paints and lead additives to gasoline. Dust from sanding or weathering of lead-based paint is extremely concentrated and thereby connected with acute lead poisoning [4]. The invisible lead particles emitted by vehicles fueled with lead containing petrol over several decades resulted in a massive quantity of lead dust that accumulated in proportion to patterns of traffic flows through cities [5]. Lead from vehicle emissions contribute to chronic lead exposure. Lead additives in petrol created a worldwide aerosol contamination problem [6]. The dust from lead-based paint and petrol settles on the ground thereby making soils both a sink and a potential source of lead dust [7]. One consequence is that lead dust from contaminated soil is re-suspended into the air in late summer and early fall becoming a lead exposure source manifesting as "children's summer disease" [8]. The discussion section describes additional details about numerous clinical consequences that support the reality of lead exposure as an ongoing detriment to wellness, especially to very young children.

There is a critical need for effective interventions to prevent lead exposure. The common approach to intervention is to treat lead exposure at an individual residential house-by-house basis but this approach for reducing exposure has been judged ineffective [9,10]. Effective primary lead prevention of children's exposure requires new concepts and actions. The goal of this paper is to describe environmental signaling as a process to unearth the lead problem in New Orleans, to explore the influence of a large natural Hurricane event on environmental signaling in the city, and to apply that knowledge toward reducing children's exposure in lead contaminated communities of the city.

2. Methods

2.1 Environmental Measurement and Lead Exposure Signaling

This study builds on a unique opportunity to learn from an urban scale natural experiment. The flooding of 80% of its residential communities by Hurricane Katrina in late August 2005, New Orleans underwent soil changes, housing renovation, and cleanup. The datasets obtained before and ten years after the catastrophic flooding provide the basis for a rare chance to study lead dust and associated health outcomes at the scale of communities of an entire metropolitan area. Along with environmental samples the surveys include children's blood lead results. Biomonitoring data for children's exposure results used in this study were collected (per protocols established by the CDC) by Louisiana Healthy Homes and Childhood Lead Poisoning Prevention (LHHCLPP).

2.2 Environmental sample collection and preparation

Pre-Katrina, the research team collected soil at the rate of 19 samples per census tract from the entire New Orleans metropolitan area, south of Lake Pontchartrain. By 2000 a soil lead map was completed for the city [11]. All samples were collected from the top 2.5 cm and systematically collected from four locations; busy roads (no samples from intersections), residential roads (no samples from intersections), mid yard or play areas, and house sides. Sample extraction was by trace metal grade nitric acid, and inorganic analysis was conducted with a Spectro Ciros® Inductively Coupled Plasma Emission Spectrometer (ICP-ES). Detailed methods about extraction and analysis are published [11]. The 2000 map is the basis for the pre-Katrina data used in this study. The biomonitoring data provided by LHHCLPP was stratified by census tracts and matched with soil lead data.

Post-Katrina, 10 years after the flood, the same research team was reestablished to survey and remap post-Katrina Orleans Parish. In addition to the same personnel, the same procedures and analytical instrumentation were used as for the 2000 survey of the city. The advantage of having the same personnel and laboratory instrumentation for the post-Katrina survey is that it increases confidence in the comparability of the results. As in the case with the pre-Katrina survey, children's biomonitoring data from LHHCLPP was stratified by census tracts and matched with soil lead data.

2.3 The pre-and post-Katrina data sets of New Orleans

The lead dust in soil data from the City of New Orleans's (plus a small number of St. Bernard and Jefferson Parish residential communities) (census tracts, n=172) and the blood lead biomonitoring responses of children living in the same communities before and after Hurricane Katrina were compiled [12]. Pre- and ten years post-Hurricane Katrina data is matched by census tracts (n=172). Total numbers of samples include: lead dust in soil (n=3238 and 3243, for pre- vs. post-Katrina, respectively), and children's blood lead (n=38,861 and 17,473, for pre- vs. post-Katrina, respectively). Table 1 is a compilation of soil lead and blood lead data results for both surveys.

PRE-KATRINA	N CTs	N Soil	SL CTs	N BL	BL CTs	%BL ≥ 5	POST-KATRINA	N CTs	N Soil	SL CTs	N BL	BL CTs	%BL ≥ 5
			Med ppm	(1000s)	Med	µg/dL				Med ppm	(1000s)	Med	µg/dL
All Census Tracts (CTs)	176	3314	280	39.6	5	49.2	All Census Tracts (CTs)	176	3320	132	17.7	1.8	10.9
Median Soil Pb < 280 mg/kg	88	1654	84	21.6	3.6	37	Median Soil Pb <132 mg/kg	88	1648	45	10.9	1.2	5.8
Median Soil Pb $\geq$ 280 mg/kg	88	1660	552	17.9	6.3	64	Median Soil Pb $\geq$132 mg/kg	88	1672	299	6.9	2.4	18.9
Pre-1940 Housing <30.98 %	88	1663	96	22.9	3.7	39	Pre-1940 Housing <46.97 %	88	1663	50	11.1	1.2	5.8
Pre-1940 Housing $\geq$30.98 %	88	1651	512	16.7	6	63.4	Pre-1940 Housing $\geq$46.97 %	88	1657	281	6.7	2.4	19.3
$\geq$ 4363 m from Post Office	88	1669	91	21.6	3.6	36.9	$\geq$ 4363 m from Post Office	88	1663	58	10.7	1.2	6.2
< 4363 m from Post Office	88	1645	531	18.0	6.3	64.1	< 4363 m from Post Office	88	1657	243	7.1	2.3	18

Table 1: Pre- and Post-Katrina data is stratified by census tracts (CTs) for each of the following categories: median soil Pb (SL), median percent of pre-1940 housing, and median distance from the Central Post Office. The corresponding blood Pb (BL) is then listed for each of the categories. Note the consistency of SL and BL results < median vs. $\geq$ median for each of the categories. Units are: SL=mg/kg or ppm and BL= µg/dL. Modified from Mielke et al. [12].

2.4 Statistical analysis

Statistical analysis is by non-parametric tests that treat the data in a distribution-independent manner, i.e., no assumptions about normality [13]. The statistical tests have evolved from the work of R.A. Fisher, the Father of Modern Statistics. The test analysis is referred to as Multi-Response Permutation Procedures (MRPP). The statistical model focuses on the actual data (no transformations or truncation) in ordinary Euclidian geometric space [13,14]. Data and findings from spatial and temporal comparisons is displayed and communicated using GIS technology in the same way as it reported for the 2000 database [11]. All comparisons yielded an extremely small P-value ($\ll$

0.0001).

3. Results and Discussion

The results summarized in Table 1 indicate remarkable changes in New Orleans 10 years after Hurricane Katrina. Overall, median soil lead underwent a reduction from 280 mg/kg pre-Katrina to 132 mg/kg post-Katrina. In each of the categories listed in Table 1 notable reductions in post- vs. pre-Katrina soil lead and blood lead results. For example, in the case of lead dust in soil (i.e., SL) equal or above the median the lead decreased from 552 mg/kg to 299 mg/kg. Similar results are shown for each of the categories.

The decreases of environmental quantities of lead in soil surfaces (i.e., ~2.5 cm depth) of New Orleans are shown in the map, Figure 2. The map visually displays the soil lead results shown in Table 1.
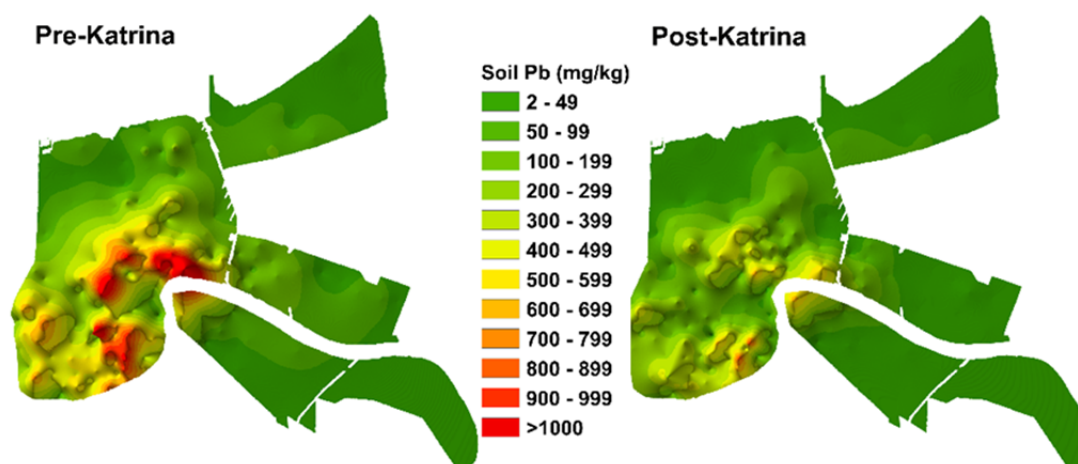
Figure 2: Maps of pre-Katrina and 10 years post-Katrina quantities of lead dust in the soils of New Orleans (including small areas of neighboring St. Bernard Parish. The reduction of soil lead in post-Katrina New Orleans occurred because of the combination of low lead sediments washing into the city, the direct influence of storm surge waters on diluting the surface lead dust, and construction activities that brought in large amounts of low lead soil. The overall result was a major reduction of lead dust in the soils of all communities of New Orleans.

3.1 Consequences of lead exposure on morbidity

Figure 1 in the introduction describes life expectancy within New Orleans communities. Life expectancy is related to lifelong morbidity, chronic diseases, and community wellness. There are numerous conditions that influence life expectancy including stress, learning ability, behavioral disorders, violence, family conditions, socio-economic situation, etc [15]. In New Orleans, as illustrated by the data in Table 1, the quantity of lead in communities is strongly associated with the blood lead of children living in the same communities. Figure 3 combines blood lead (BL) and soil lead (SL) in New Orleans to illustrate further the associations for each census tract. Figure 3 also depicts the reductions that have occurred in BL and SL in post-Katrina compared with pre-Katrina. Note however, that despite the soil dust lead and blood lead reductions, the exposure disparity continues after Katrina. In both pre- and post-Katrina data, the highest soil lead and blood lead census tracts characterize the inner-city communities and the lowest soil lead and blood lead census tracts represent the outer-city communities.
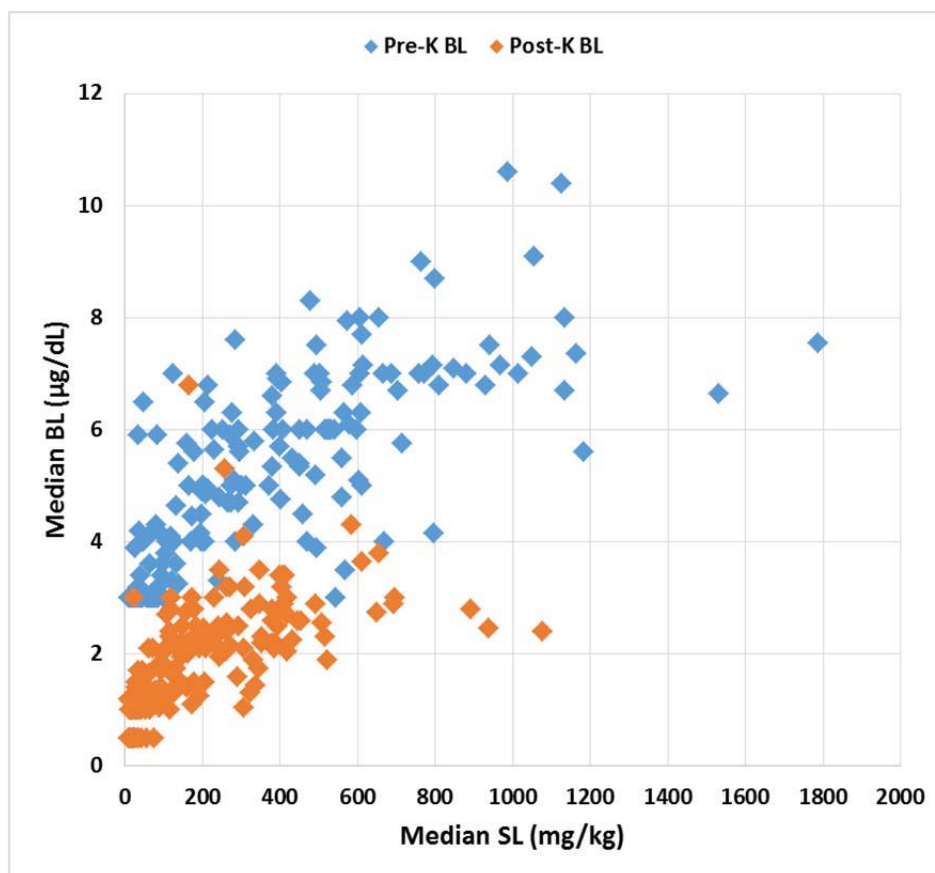
Figure 3: Pre-and post-Katrina soil lead and blood lead in New Orleans. The New Orleans pre- vs. post Katrina combination of soil lead (SL) medians by census tracts and blood lead (BL) medians by census tracts. Note the reduction of post-Katrina SL compared with pre-Katrina SL. Even more extraordinary is the decrease in post-Katrina BL compared with pre-Katrina BL. The environmental signaling differences of before and after Hurricane

Katrina strongly suggests the possibility that an effective intervention of children's lead exposure could be attained by actions centered around reducing the amount of lead dust in the surface soils of lead contaminated communities of New Orleans.

Multiple studies have demonstrated the lifelong consequences of childhood lead exposure [16,17]. The consequences are borne on morbidity, wellness, and life expectancy. Early childhood lead exposure translates into a long list of clinical outcomes, including learning deficits [18], aggravated assault [19], risk of Alzheimer's disease [20], motor neuron disease [21], and eclampsia [22]. Long-term studies conducted in Dunedin, New Zealand and Rhode Island are among the latest studies on the societal effects of lead. The research from New Zealand's University of Otago Dunedin Study shows that among more than 500 children who grew up in the era of leaded petrol had reduced IQ and social standing by the age of 38 compared with children who were spared high lead exposure during the era of leaded gasoline [23]. Rhode Island has a robust lead screening program whereby three-quarters of the children are screened at least once by the time they reach 18 months, far above the national average. The hypothesis that reductions in blood lead levels have been responsible for a significant part of the observed decreases in antisocial behavior among youths and young adults in recent decades is supported by a collaborative Princeton and Brown University study [24].

3.2 Natural vs. lead contaminated soil of New Orleans

The natural soils of New Orleans are derived from Mississippi River sediments. The sediments contain remarkably small amounts of lead, i.e. median of 5 (range 1-20) mg/kg [25]. The residential soils of New Orleans have become contaminated with lead dust sources from industrial emissions and consumer products. Few studies have scrutinized lead dust accumulated in urban soil and its influence on health, sustainability, and wellness at the scale of urban communities. The research conducted before and after Hurricane Katrina in New Orleans assists with filling the research gap by examining the association between lead dust in soil and children's blood lead responses [12,14,26]. The Mississippi River sediments are a massive resource of naturally low lead containing alluvial soil for landscape remediation of contaminated soil in New Orleans [27].

3.3 Reactive vs. proactive lead exposure intervention

The medical community faces a quandary. Pediatricians are required to test children's blood lead, although this requirement is inconsistent between states [28]. If blood lead levels are above CDC's reference value (currently 5 μg/dL and expected to decrease to 3.5 μg/dL soon) then the prescription involves educating the parents about sources of lead exposure and an inspection that focuses on lead-based paint and household dust cleaning. The dilemma for the medical community concerns reports that the prescribed lead intervention is in ineffective. For example, when states with well-established household lead cleanup program are compared with states without a household cleanup program no difference is observed in the children's exposure outcomes [29].

The critical gap involves the reactive handling of children's elevated lead exposure and the subsequent intervention methods used to treat elevated exposure. Cochrane Collaboration is a world-renowned, expert authority for

evaluating the effectiveness of medical interventions. The past two evaluations by Cochrane Collaboration concluded that the prescribed lead intervention is ineffective at reducing the blood lead of exposed children [9,10]. If an intervention is not effective then the healthcare community must do the research needed to modify the intervention [30]. Cochrane Collaboration noted a key research and knowledge gap regarding the role that lead dust in soil plays on children's lead exposure.

The combination of soil lead and blood lead in post- vs. pre-Katrina New Orleans (Figure 3) illustrates environmental signaling differences before and after Hurricane Katrina. The results provide evidence that an effective intervention of children's lead exposure would be attained by actions centered around robust lead dust reduction, such as by extensive landscaping in lead contaminated communities with clean soil. Despite the post-Katrina reductions of both soil lead and blood lead, the exposure disparity between the highest soil lead and blood lead and lowest soil and blood lead communities continues in New Orleans. A massive reservoir of low lead alluvial soils nearby New Orleans that render community landscaping activities achievable. According to these findings, reducing environmental lead would further reduce children's lead exposure and curtail lead exposure disparities between communities of New Orleans.

4. Conclusions

Pharmacology studies the chemistry of life and researches ways to support wellness. In New Orleans life expectancy is observed to be higher (77-80 years) in other communities and lowest (55-58 years) in inner-city communities. Environmental signaling researches the associations between chemicals in the exterior milieu and their influence on wellness. At the scale of New Orleans's communities, a strong association is evident between lead in the exterior environment and children's biomarkers of lead. Lead exposure during early childhood is recognized clinically as having lifelong and multiple negative health influences on morbidity and wellness. Hurricane Katrina flooded 80% of New Orleans, and 10 years after the event both soil lead and blood lead underwent a notable decrease. The massive nearby reservoir of low lead alluvial soil presents the feasibility to reduce lead exposure in New Orleans through a community-scale landscaping.

5. Acknowledgements

6. Conflicts of Interest Statement

The authors declare that they have no conflicts of interest concerning this manuscript.

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