**Full Proposal: Reducing blood-lead levels by eliminating the informal used lead-acid battery (ULAB) recycling industry through ULAB buy-up. (Work in progress)**

## Literature Review

Lead has a long history of use by humankind, having been a key ingredient in cookware, bullets, plumbing, cosmetics, currency, construction, industry, paint, and gasoline. For the most part, however, humanity has come to realize that the damage caused by lead’s toxic effects outweigh its usefulness. There is one notable exception: car batteries. Today, about 85% of lead produced goes into lead-acid batteries.[[1]](#footnote-1) Lead-acid is used to power the overwhelming majority of such batteries: no cost-effective alternative exists.

Cars use batteries for ignition, and then, after the car has started for powering the electrical components within the car, such as the radio. At the end of a battery’s life (typically around 5 years of constant use for a car), the battery can be broken down into its individual components, the majority of which can be recycled, including lead. Ideally, this happens in a strictly-regulated recycling plant in order to entirely prevent the risk of lead exposure. This is what happens in the US, where formal recycling accounts for 100% of lead production.[[2]](#footnote-2)

However, in the developing world, a disturbing amount of lead for car batteries is sourced from informal recycling[[3]](#footnote-3), which consists of little more than breaking the battery into its components by smashing it with an axe, dumping the waste wherever is convenient, and smelting the lead into ingots in an open fire. Obviously, this results in catastrophic lead exposure for those doing the recycling, but also, because these informal operations often operate near residential areas, the externalities can be enormous.[[4]](#footnote-4) Waste from liquid components of the battery often contaminate community drinking water, while dust from the fires coat the surrounding area with lead-laced particulates.

The lead released into the environment by improper recycling practices workly works its way into the bodies of those in the community. Once consumed, lead is absorbed by the blood, where it cycles out of the body within about a month.[[5]](#footnote-5) However, due to its chemical similarity to calcium, lead within the bloodstream can get absorbed by the bones. Lead deposits in bones will remain for decades, only to be released back into the bloodstream periodically. More worrying is the lead that manages to breach the blood-brain barrier. Once in the brain, lead lingers for around two years, wreaking havoc on the central nervous system.

In addition to building our bones and teeth, calcium is an important neurotransmitter. Once lead is in the brain, it effectively jumps the calcium queue, preventing calcium uptake reducing signal strength between neurons. Lead also lingers in the synapse between neurons, occasionally triggering calcium-sensitive neurons to fire without having received the appropriate signal.[[6]](#footnote-6) Even at low blood-lead levels, lead has myriad additional direct neuropharmcologically toxic effects on the brain, such as neuronal apoptosis and necrosis (two different forms of neuron cell death), disrupted neuronal metabolism through damage to the mitochondria, reduced neuroplasticity through inhibited protein kinase C expression[[7]](#footnote-7), and suppressed dopamine-system activity.

Lead exposure is especially harmful to children. In addition to the neuropharmacological effects of lead in the brain, lead has considerable neurodevelopmental effects, to which children’s brains, which are still developing, are uniquely sensitive. Adults’ brains have significantly less neuroplasticity, and therefore are more resistant to permanent damage. The problem for children is compounded by two additional facts. The first is that children are more likely than adults to ingest lead — a result of their playing outside, crawling on the ground, putting their hands and other body parts and objects in their mouths, and consuming more food and drinks per body weight than adults[[8]](#footnote-8). The second is that a higher proportion of lead ingested by children gets absorbed into the bloodstream than lead ingested by adults[[9]](#footnote-9) — a result of their less developed blood-brain barriers.[[10]](#footnote-10) Children in developing countries are even further at risk due to poor nutrition (specifically, diets low in calcium, iron, or vitamin C), which increases lead absorption at a given level of exposure.[[11]](#footnote-11)

The effects of neurodevelopmental damage from lead exposure in children ranges from insidiously inconspicuous to catastrophic. Lead inhibits neurite growth in the hippocampus[[12]](#footnote-12), inhibits synaptic pruning[[13]](#footnote-13), inhibits glial growth and maturation in the cerebellum,[[14]](#footnote-14) and disrupts thyroid hormone transport into the brain[[15]](#footnote-15), all of which significantly alter brain architecture. In addition, childhood lead exposure permanently stunts typical dopamine and glutamine system development. And unlike the neuropharmacological effects of lead, the neurodevelopmental effects cannot be reversed. Once the damage to the brain architecture is done, it’s done. The brain of somebody that who has had prolonged exposure to elevated lead levels will be smaller, specifically in the prefrontal cortex[[16]](#footnote-16), and less nimble for the rest of their life.

The cognitive consequences of the hindered brain developing in childhood inhibits learning,[[17]](#footnote-17) attention span,[[18]](#footnote-18) perseveration avoidance,[[19]](#footnote-19) fine-motor functioning[[20]](#footnote-20), reaction time, cognitive flexibility, abstract reasoning,[[21]](#footnote-21) and verbal fluency[[22]](#footnote-22) through adulthood. Many, but not all, of these symptoms of long-term lead damage would be captured by an IQ test, making it a helpful means of quantifying the damage: a blood-lead level of a measly 5 µg/dL — a level exceeded by approximately one third of the children alive today[[23]](#footnote-23) — is estimated to cause a 3–5 point drop in IQ[[24]](#footnote-24). This is astounding. An extremely conservative estimate, using expected lifetime earnings losses as a result of the lower bound of estimated reduction in IQ attributable to lead[[25]](#footnote-25), calculated a global cost of over $1 trillion, or 1.2% of worldwide GDP.[[26]](#footnote-26)

This does not take into account the behavioral effects of long-term lead exposure which are border and more amorphous, but perhaps even more pronounced than the cognitive damage described above. The strongest evidence of behavioral effects are the correlations between elevated blood-lead levels and violent crime[[27]](#footnote-27), but similar effects can be seen in teenage pregnancies[[28]](#footnote-28), attention deficit hyperactivity disorder (ADHD)[[29]](#footnote-29), juvenile delinquency[[30]](#footnote-30), risky behavior[[31]](#footnote-31), grade repetition[[32]](#footnote-32), and school suspensions[[33]](#footnote-33). Although most such studies are from the US due to data availability, the evidence that does exist from other countries is just as compelling.[[34]](#footnote-34)

These behavioral effects are no surprise given the role of the prefrontal cortex — the area of the brain that is most obviously damaged by lead exposure — in drawing the connection between future consequences and current actions.[[35]](#footnote-35)Put simply, the more lead in your brain, the more trouble you have accessing what Kahnamen and Tversky have called “System 2” processes (impulse control, decision-making, logic, reasoning)[[36]](#footnote-36), which explains both the reduced IQ and increased crime.

The body of evidence presents a complete and compelling story. Even small amounts of lead in the environment works its way into the central nervous system of children, triggering a cascade of cognitive deficiencies and behavioral problems that set them on a troubled path towards an even more troubled adulthood. Innocent-seeming behavioral challenges in childhood, such as ADHD or trouble at school, progress to larger and larger behavioral challenges, such as juvenile delinquency, teenage pregnancies, and violent crime, as short-term neuropharmacalogical effects turn into long-term neurodevelopmental deficits.

It is hard to imagine that there is a single more consequential issue in development economics. The tentacles of the lead kraken are wrapped around every development subfield. Reducing lead exposure has been shown to significantly improve health outcomes[[37]](#footnote-37), income[[38]](#footnote-38), homicide rate[[39]](#footnote-39), and academic achievement[[40]](#footnote-40). Given the current understanding of the effects of lead on IQ and self-control it is not a stretch to hypothesize that reducing lead exposure will also improve risk assessment, malnutrition, substance abuse and addiction, behavioral biases (such as hyperbolic future discounting), clientalism and ethinc voting, labor supply and productivity, or any issue you can think of that currently plagues developing countries. If there is a poverty trap, lead is surely the leading suspect.

Despite the overwhelming evidence, reducing lead exposure has not been a top priority within the development community. In fact, across all papers that have been published over the course of the 45 year history of the Journal Of Development Economics, a whopping one paper has even mentioned lead poisoning[[41]](#footnote-41). However, the recent report by UNICEF and Pure Earth entitled *The Toxic Truth: Children’s Exposure to Lead Pollution Undermines a Generation of Future Potential* aims to change that. It identifies lead exposure as perhaps the single biggest threat to the future wellbeing of children in the developing world, and car batteries as the biggest source of that exposure.

This problem is only growing. For example, the number of cars in low- and middle-income has more than tripled since 2000.[[42]](#footnote-42) As a result, it is estimated that there is currently over 800,000 tons of lead stored in lead-acid batteries in Africa alone.[[43]](#footnote-43) It is paramount that as little of this lead slips through the cracks of the formal recycling industry and into the environment. Because once it’s there, it is extremely difficult and expensive to remove — remediation of lead-contaminated sites is extremely difficult and expensive. Such efforts are worthwhile because it virtually eliminates the chance of another child being affected by simply being around these sites. But for the children who were already exposed to them, it may be too late: chelation therapy can mediate some of the long term effects, but few families in the developing world can afford such expensive treatment. Instead, those children will never reach their potential.

The primary goal of this intervention is to prevent the creation of more contaminated sites by eliminating unsafe lead recycling practices through increasing the economic viability of formal recycling facilities.

## Details of Proposal

The goal of the project is simple: replace unsafe lead-acid battery recycling processes with safe ones. There are three distinct steps to achieving this goal.

### Phase I: Locate communities plagued by unsafe lead-acid battery recycling.

Much of the work of Phase I has already been done. It can be safely assumed that countries that have children with the highest average blood-lead levels are the ones that are most likely to be affected by unsafe battery recycling practices: these countries are overwhelmingly low- and middle-income, and can generally be found in South Asia and Sub-Saharan Africa.[[44]](#footnote-44) Country-level average blood-lead levels from the IMHE shows a few exceptions to that generalization, among which Guatemala, Honduras, Haiti, Peru, Bolivia, Egypt, Yemen, Iran, Afghanistan, Tajikistan, Cambodia, Philippines, and North Korea were the most notable.

In order to narrow down the country selection perhaps even determine specific areas to target, I can consult the [Toxic Sites Identification Program](https://www.contaminatedsites.org) (TSIP), which is a list maintained by Pure Earth that documents locations that have suffered pollution levels high enough to cause acute health issues. Backyard battery recycling easily qualifies, and such activities are the cause of a significant fraction of the TSIP.

### Phase II: Identify the safest alternative for those communities.

The gold standard for safe lead-acid battery recycling was set forth by the United Nations Environment Program (UNEP) at the Basel Convention in 2004 with the “Technical Guidelines for the Environmentally Sound Management of Waste Lead-acid Batteries”.[[45]](#footnote-45) The report details procedures for collecting, transporting, storing, and recycling used lead-acid batteries that minimize risk of exposure to lead by workers and, even more importantly, risk of lead contamination to the surrounding environment. In order to prevent lead emissions, any recycling center would have to abide by those guidelines at minimum. A select few safety features include the use of Hammer Mill breakers (instead of machetes and axes), smokestack emission scrubbers, [[46]](#footnote-46)

Auditing and regular monitoring is required to ensure that any recycling center is doing so, even those that have proper government approval. Therefore, due diligence should be performed in order to verify that the safety procedures are being abided by, and that those procedures have been effective in keeping lead exposure to a minimum. Test soil, water, blood lead levels, blah blah blah.

It may be necessary to bring in foreign expertise to bring the local recycling centers up to code. An example to be followed was set in Senegal by a collaboration between the International Lead Management Center (ILMC), Pure Earth (then known as the Blacksmith Institute), the University of Dakar, and the Senegalese government in 2013, resulting in the construction and operation of a Basel-compliant recycling center outside of Dakar and the shutdown of most informal recycling operations.[[47]](#footnote-47)

However, our research might indicate that there is no recycling facility within the country that can feasibly be made to operate safely and without causing any pollution. In that case, the safest recycling option for the selected country would be abroad, perhaps in Europe. The Öto-Institut has conducted an intervention that may serve as a model in this scenario, where used batteries were shipped completely intact and unaltered directly from Ghana to Germany: beyond merely collecting and shipping the batteries, not a single step of the recycling process happened in Ghana.[[48]](#footnote-48)

### Phase III: Facilitate the implementation of that alternative.

Depending on the exact details of the supply chain of the selected country, this step could require multiple approaches. Interviews conducted with Gordon Binkhorst of Pure Earth (2021) reveal that the typical lifecycle of a lead-acid battery in Africa looks something like this:

1. A new battery is imported from abroad.
2. Battery is used, either in a car or as an uninterruptible power supply, until depleted.
3. Battery is disposed of.
4. Battery is acquired by a scrap collector.
5. Battery is sold to an informal recycler.
6. Battery is broken down into its raw components.
7. The used lead is smelted into ingots.
8. Lead ingots are exported for sale to a lead purification facility.
9. Purified lead is sold to a battery manufacturer.

The key step of this chain that must be broken is step 7: the vast majority of the pollution that comes from informal recycling is a result of the open fires used to smelt the lead into ingots. In order to prevent this open-air smelting, the intervention must make it more profitable for people to sell the battery as a whole (i.e., before it’s been recycled) than its components. Therefore, my proposal is for the implementing partner to offer to buy batteries directly from scrap collectors, in order to intercept them before they are lost to the informal recycling industry.

In fact, the goal should be to acquire what is known as “wet” batteries: batteries where the sulfuric acid solution has yet to be drained out of the battery casing. Because this liquid acid is unable to be recycled therefore worthless to the recyclers, scrap collectors or metal dealers will often drain the batteries by dumping the acid onto the ground. This reduces the weight of the battery, improving transportation efficiency, but the improper disposal of the acid solution causes serious lead contamination of the soil and can contribute significantly to the lead exposure levels of the local community. Worse still is when the lead slabs are removed from the battery and transported in the open air.[[49]](#footnote-49) It is best that step 6 be prevented as well.

Once collected, the used batteries will be transported and sold to the approved safe recycling center identified in Phase II. The difference between the price at which the used batteries were purchased by the implementing partner and the price at which they were sold to the safe recycling center will probably constitute a significant loss; otherwise, this would be happening already. Therefore, the intervention effectively subsidizes the increased cost of opting for safe lead recycling.

### Buy-in Considerations

Ideally, the intervention will not eliminate the livelihoods of very many people, if at all. Scrap collectors and others participating in the informal recycling industry could be employed by the implementing partner directly as used battery collectors. In addition, the increased volume of batteries processed by the formal recycling center should provide an employment opportunity for those who were participating in the informal sector might be especially qualified.

In fact, over time, one could imagine this program leading to the development of an entire formal battery recycling industry. Hopefully, with appropriate oversight, the growth of the formal industry will eventually price out backyard recyclers through economies of scale. That is the ultimate goal: to make the safest option truly be the cheapest option.

## Data Collection and Analysis

The data collected will be used to answer a simple question: how much did the intervention reduce total lead exposure? The nature of the intervention necessitates a differences-in-differences design will be used to compare two pre-selected groups: children who live near informal lead recycling operations, and children who don’t. Blood-lead levels will be the primary indicator, but other proxies of lead exposure, such as lead content in the soil, water, in the home, etc., may be as useful if not more so because of the short half-life of lead within the bloodstream.

Serious effort must be put into drawing the boundary between treatment and control groups to strike the proper balance between avoiding spillovers (where some control subjects are inadvertently treated) and avoiding noncompliance (where some treatment subjects are inadvertently untreated), both of which would dilute the effect size and, likely, the significance. How exactly this is done will depend on the country selected for the intervention, and what the used battery supply chain looks like within that country. For example, if the intervention results in the elimination of a cluster of large, industrialized informal recyclers in one small sector of the major city, as might be the case in Ghana or Kenya, then the boundary between treatment and control will be defined as the line where the pollution from that sector would reasonably stop. On the other hand, if the intervention results in the snuffing out of a great number of backyard smelters throughout the country, as might be the case in Cameroon or Ethiopia, then it might be impossible to draw a within-country boundary.

If the groups are well-defined and the boundaries are properly drawn, then the effect sizes should be large. In that case, it will be tempting to measure outcomes downstream of lead exposure, such as crime or IQ. However, these will be flawed measures for two reasons. The first flaw is that these behavioral and cognitive outcomes are a result of altered brain structure and chemistry, which would not manifest itself until many years later, once the children’s brains have fully developed — or, in the case of those with significant lead exposure, failed to fully develop properly. This would necessitate long-term subject tracking that is beyond the scope of this project. The second flaw is that the parallel trends assumption may not hold: there are obviously many significant pre-intervention differences between the treatment group (those who are close enough to informal lead recycling to be subject to its pollution) and the control group (those who are not), and those differences may cause in divergences or convergences in outcomes that we can’t predict without observing the counterfactual.

Instead, the downstream outcomes can be estimated by projecting results from the existing literature on lead-driven effects onto our estimate of lead reduction. For example, a 2009 paper by Gould attempted to place a conservative cost to overall GDP as a function of average blood-lead levels.[[50]](#footnote-50) This will build on the methodology used by that and a 2018 paper by Ericson.[[51]](#footnote-51) The cost effectiveness can be calculated by comparing the GDP gains as a result of these downstream benefits to the costs of the intervention.

If it is foreseen that this project will persist for more than a few years, a long-term study can be conducted to directly measure the behavioral outcomes.

## Conclusion

A ULAB recycling facility that successfully prevents lead emissions faces myriad costs, both fixed and marginal: high-tech equipment, highly skilled labor to operate that equipment, and diligent monitoring of processes and maintenance of equipment to verify that the labor and the equipment are working as expected. On the other hand, a facility that does not concern itself with lead emissions faces no such costs: it does not take any special equipment or training to smash open the plastic casing and toss the lead slabs into an open fire. The inefficiencies of preventing pollution push the market towards to the inexpensive, unsafe ULAB recyclers.

This is a textbook scenario requiring government intervention: the costs of unsafe ULAB recycling are transferred to society via externalities in the form of pollution. It has been shown that the costs of this pollution are tremendous, and, by all accounts, dwarf the costs of preventing that pollution. Ideally, the governments of Africa would be able to correct this externality, as have governments in the developed world. However, this is easier said than done. Banning informal recycling accomplishes little because the operations are extremely small and mobile: if a government shuts down an informal operation in one part of town, at least one more new one will quickly pop up elsewhere, creating an infinite game of Whack-A-Mole: Pollution Edition.

Instead, governments will have find more creative methods. My proposal is one such example. Another would be to follow the lead taken by Brazil, which implement what they call *Logística Reversa* (“Reverse Logistics”) to curtail their informal ULAB recycling industry.

Lead has plausibly attributed as the cause of a huge range of social phenomena, from “White Flight”[[52]](#footnote-52), to the demise of the Roman Empire[[53]](#footnote-53), the mysterious rise (and subsequent fall) of crime in the US in the 1990s[[54]](#footnote-54), to the difference in IQ across races found in Charles Murray’s *The Bell Curve*[[55]](#footnote-55). Let’s make sure the list ends there.

Buybacks/deposit systems? Get the government involved? Social education campaigns don’t work, neither do regulations. Brazil success story.

1. "Generation of used lead-acid batteries in Africa - The Lead ...." 11 Apr. 2016, <https://www.econet.international/fileadmin/user_upload/ULAB_Generation_African_Countries_final_20160411.pdf>. Accessed 13 Jan. 2021. [↑](#footnote-ref-1)
2. "The toxic truth | UNICEF." 30 Jul. 2020, <https://www.unicef.org/reports/toxic-truth-childrens-exposure-to-lead-pollution-2020>. Accessed 9 Jan. 2021. [↑](#footnote-ref-2)
3. "tery Recyclers in Addis Ababa, Ethiopia - The Lead Recycling ...." <https://www.econet.international/fileadmin/user_upload/PAN__Ethiopia_Lead_Recycling_Africa_Project_Report_1_2016.pdf>. Accessed 14 Jan. 2021. [↑](#footnote-ref-3)
4. "Review: Lead exposure in battery manufacturing ... - PubMed." <https://pubmed.ncbi.nlm.nih.gov/21793732/>. Accessed 9 Jan. 2021. [↑](#footnote-ref-4)
5. "Lead neurotoxicity in children: basic mechanisms and clinical ...." <https://academic.oup.com/brain/article/126/1/5/299373>. Accessed 13 Jan. 2021. [↑](#footnote-ref-5)
6. "Lead neurotoxicity in children: basic mechanisms and clinical ...." <https://academic.oup.com/brain/article/126/1/5/299373>. Accessed 8 Jan. 2021. [↑](#footnote-ref-6)
7. "Inhibition of brain protein kinase C subtypes by lead - PubMed." <https://pubmed.ncbi.nlm.nih.gov/8437124/>. Accessed 14 Jan. 2021. [↑](#footnote-ref-7)
8. "Principles of Pediatric Environmental Health - Cover ... - ATSDR." 17 Jan. 2013, <https://www.atsdr.cdc.gov/csem/csem.asp?csem=27&po=0>. Accessed 13 Jan. 2021. [↑](#footnote-ref-8)
9. "Childhood Lead Poisoning - World Health Organization." <https://www.who.int/ceh/publications/leadguidance.pdf>. Accessed 13 Jan. 2021. [↑](#footnote-ref-9)
10. "An age-specific kinetic model of lead metabolism in humans.." <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1519877/>. Accessed 13 Jan. 2021. [↑](#footnote-ref-10)
11. "Lead toxicity, a review of the literature. Part 1 ... - PubMed." <https://pubmed.ncbi.nlm.nih.gov/16597190/>. Accessed 13 Jan. 2021. [↑](#footnote-ref-11)
12. "Inorganic lead may inhibit neurite development in cultured rat ...." <https://pubmed.ncbi.nlm.nih.gov/7676445/>. Accessed 13 Jan. 2021. [↑](#footnote-ref-12)
13. "Dendritic alterations of cerebellar Purkinje neurons ... - PubMed." <https://pubmed.ncbi.nlm.nih.gov/10965154/>. Accessed 13 Jan. 2021. [↑](#footnote-ref-13)
14. "Developmental exposure to lead interferes with glial and ...." <https://pubmed.ncbi.nlm.nih.gov/8658511/>. Accessed 13 Jan. 2021. [↑](#footnote-ref-14)
15. "Transthyretin, thyroxine, and retinol-binding protein in human ...." <https://pubmed.ncbi.nlm.nih.gov/11294981/>. Accessed 13 Jan. 2021. [↑](#footnote-ref-15)
16. "Decreased Brain Volume in Adults with Childhood Lead ...." 27 May. 2008, <https://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.0050112>. Accessed 13 Jan. 2021. [↑](#footnote-ref-16)
17. "Deficits in psychologic and classroom performance ... - PubMed." <https://pubmed.ncbi.nlm.nih.gov/763299/>. Accessed 13 Jan. 2021. [↑](#footnote-ref-17)
18. "Cognitive and sensorimotor functions in 6-year-old children in ...." <http://europepmc.org/abstract/med/9761589>. Accessed 13 Jan. 2021. [↑](#footnote-ref-18)
19. "Neuropsychological correlates of low-level lead exposure in ...." <https://pubmed.ncbi.nlm.nih.gov/8459785/>. Accessed 13 Jan. 2021. [↑](#footnote-ref-19)
20. "Lead exposure and the motor developmental status ... - PubMed." <https://pubmed.ncbi.nlm.nih.gov/7678702/>. Accessed 13 Jan. 2021. [↑](#footnote-ref-20)
21. "Neurotoxicity in young adults 20 years after childhood ...." <https://pubmed.ncbi.nlm.nih.gov/9849536/>. Accessed 13 Jan. 2021. [↑](#footnote-ref-21)
22. "Residual cognitive deficits 50 years after lead ... - NCBI - NIH." <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1035497/>. Accessed 13 Jan. 2021. [↑](#footnote-ref-22)
23. "The toxic truth | UNICEF." 30 Jul. 2020, <https://www.unicef.org/reports/toxic-truth-childrens-exposure-to-lead-pollution-2020>. Accessed 9 Jan. 2021. [↑](#footnote-ref-23)
24. "Low-Level Environmental Lead Exposure and Children's ...." <https://ehp.niehs.nih.gov/doi/10.1289/ehp.7688>. Accessed 13 Jan. 2021. [↑](#footnote-ref-24)
25. "Cognitive deficits associated with blood lead concentrations." <https://pubmed.ncbi.nlm.nih.gov/11354334/>. Accessed 14 Jan. 2021. [↑](#footnote-ref-25)
26. "Economic costs of childhood lead exposure in low ... - PubMed." <https://pubmed.ncbi.nlm.nih.gov/23797342/>. Accessed 14 Jan. 2021. [↑](#footnote-ref-26)
27. "Regular Article How Lead Exposure Relates to Temporal ...." <https://www.sciencedirect.com/science/article/pii/S0013935199940458>. Accessed 13 Jan. 2021. [↑](#footnote-ref-27)
28. "Toxic Truth: Lead and Fertility | NBER." 18 May. 2018, <https://www.nber.org/papers/w24607>. Accessed 14 Jan. 2021. [↑](#footnote-ref-28)
29. "The Role of Lead Exposure on Attention-Deficit/Hyperactivity ...." <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4888135/>. Accessed 14 Jan. 2021. [↑](#footnote-ref-29)
30. "Lead and Juvenile Delinquency: New Evidence from Linked ...." 4 May. 2017, <https://www.nber.org/papers/w23392>. Accessed 13 Jan. 2021. [↑](#footnote-ref-30)
31. "LEAD EXPOSURE AND BEHAVIOR: EFFECTS ON ...." <https://onlinelibrary.wiley.com/doi/abs/10.1111/ecin.12202>. Accessed 14 Jan. 2021. [↑](#footnote-ref-31)
32. "Life after Lead: Effects of Early Interventions for Children ...." <https://www.aeaweb.org/articles?id=10.1257/app.20160056>. Accessed 14 Jan. 2021. [↑](#footnote-ref-32)
33. "Lead and Juvenile Delinquency: New Evidence from Linked ...." 30 Sep. 2019, <https://www.mitpressjournals.org/doi/abs/10.1162/rest_a_00814?mobileUi=0>. Accessed 14 Jan. 2021. [↑](#footnote-ref-33)
34. "Understanding international crime trends: The legacy of ...." <https://www.sciencedirect.com/science/article/pii/S0013935107000503>. Accessed 13 Jan. 2021. [↑](#footnote-ref-34)
35. "What Neuroscience Has to Say about Decision-Making | The ...." 13 Jan. 2017, <https://theeconreview.com/2017/01/13/what-neuroscience-has-to-say-about-decision-making/>. Accessed 14 Jan. 2021. [↑](#footnote-ref-35)
36. "Thinking, fast and slow. - APA PsycNET." <https://psycnet.apa.org/record/2011-26535-000>. Accessed 14 Jan. 2021. [↑](#footnote-ref-36)
37. "SocArXiv Papers | The effect of leaded gasoline on elderly ...." 22 Sep. 2019, <https://osf.io/preprints/socarxiv/rdy6g/>. Accessed 14 Jan. 2021. [↑](#footnote-ref-37)
38. "Monetary benefits of preventing childhood lead ... - PubMed." <https://pubmed.ncbi.nlm.nih.gov/17961540/>. Accessed 14 Jan. 2021. [↑](#footnote-ref-38)
39. "Lead exposure and violent crime in the early twentieth century ...." <https://www.sciencedirect.com/science/article/pii/S0014498316300109>. Accessed 14 Jan. 2021. [↑](#footnote-ref-39)
40. "Early childhood lead exposure and academic achievement ...." <https://pubmed.ncbi.nlm.nih.gov/23327265/>. Accessed 14 Jan. 2021. [↑](#footnote-ref-40)
41. "Mines: The local wealth and health effects of mineral mining in ...." <https://www.sciencedirect.com/science/article/pii/S0304387818304875>. Accessed 14 Jan. 2021. [↑](#footnote-ref-41)
42. "Bret ERICSON | PhD | Doctor of Philosophy | Macquarie ...." <https://www.researchgate.net/profile/Bret_Ericson>. Accessed 14 Jan. 2021. [↑](#footnote-ref-42)
43. "Generation of used lead-acid batteries in Africa - The Lead ...." 11 Apr. 2016, <https://www.econet.international/fileadmin/user_upload/ULAB_Generation_African_Countries_final_20160411.pdf>. Accessed 13 Jan. 2021. [↑](#footnote-ref-43)
44. "The toxic truth | UNICEF." 30 Jul. 2020, <https://www.unicef.org/reports/toxic-truth-childrens-exposure-to-lead-pollution-2020>. Accessed 14 Jan. 2021. [↑](#footnote-ref-44)
45. "BASEL CONVENTION TRAINING MANUAL." <http://archive.basel.int/meetings/sbc/workdoc/tm-ulab/tm_ulab.pdf>. Accessed 15 Jan. 2021. [↑](#footnote-ref-45)
46. "Consequences of a Mobile Future: Creating an ...." 16 Dec. 2020, <https://www.weforum.org/whitepapers/consequences-of-a-mobile-future-creating-an-environmentally-conscious-life-cycle-for-lead-acid-batteries>. Accessed 14 Jan. 2021. [↑](#footnote-ref-46)
47. "Developing an environmentally sound lead-acid battery ...." <http://members.ila-lead.org/UserFiles/File/casestudies/ILA9644%20CS_Senegal_V03.pdf>. Accessed 15 Jan. 2021. [↑](#footnote-ref-47)
48. "Lead-acid batteries from Ghana successfully recycled." 11 Mar. 2014, <https://www.johnsoncontrols.com/media-center/news/press-releases/2014/03/11/leadacid-batteries-from-ghana-successfully-recycled>. Accessed 15 Jan. 2021. [↑](#footnote-ref-48)
49. "An investigation on used lead-acid battery (ULAB) recycling in ...." <http://www.econet.international/fileadmin/user_upload/CJGEA_ULAB_REPORT_KENYA.pdf>. Accessed 22 Jan. 2021. [↑](#footnote-ref-49)
50. "Economic costs of childhood lead exposure in low ... - PubMed." <https://pubmed.ncbi.nlm.nih.gov/23797342/>. Accessed 16 Jan. 2021. [↑](#footnote-ref-50)
51. "Cost Effectiveness of Environmental Lead Risk Mitigation in Low." 8 Feb. 2018, <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017GH000109>. Accessed 16 Jan. 2021. [↑](#footnote-ref-51)
52. "Flight From Urban Blight: Lead Poisoning, Crime and ...." 24 Sep. 2018, <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3245090>. Accessed 14 Jan. 2021. [↑](#footnote-ref-52)
53. "ScienceShot: Did Lead Poisoning Bring Down Ancient Rome ...." 21 Apr. 2014, <https://www.sciencemag.org/news/2014/04/scienceshot-did-lead-poisoning-bring-down-ancient-rome>. Accessed 14 Jan. 2021. [↑](#footnote-ref-53)
54. "Environmental Policy as Social Policy? The ... - De Gruyter." <https://www.degruyter.com/view/journals/bejeap/7/1/article-bejeap.2007.7.1.1796.xml.xml?language=en>. Accessed 14 Jan. 2021. [↑](#footnote-ref-54)
55. "Lucifer Curves: The Legacy of Lead Poisoning 1, Nevin, Rick ...." <https://www.amazon.com/Lucifer-Curves-Legacy-Lead-Poisoning-ebook/dp/B01I3LTR4W>. Accessed 14 Jan. 2021. [↑](#footnote-ref-55)