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ORIGINAL RESEARCH

The Global Burden of Lead Toxicity Attributable to Informal Used Lead-Acid Battery Sites

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Abstract

BACKGROUND Prior calculations of the burden of disease from environmental lead exposure in low- and middle-income countries (LMICs) have not included estimates of the burden from lead-contaminated sites because of a lack of exposure data, resulting in an underestimation of a serious public health problem.

OBJECTIVE We used publicly available statistics and detailed site assessment data to model the number of informal used lead-acid battery (ULAB) recyclers and the resulting exposures in 90 LMICs. We estimated blood lead levels (BLLs) using the US Environment Protection Agency's Integrated Exposure Uptake Biokinetic Model for Lead in Children and Adult Lead Model. Finally, we used data and algorithms generated by the World Health Organization to calculate the number of attributable disability adjusted life years (DALYs).

RESULTS We estimated that there are 10,599 to 29,241 informal ULAB processing sites where human health is at risk in the 90 countries we reviewed. We further estimated that 6 to 16.8 million people are exposed at these sites and calculate a geometric mean BLL for exposed children (0-4 years of age) of 31.15 μg/dL and a geometric mean BLL for adults of 21.2 μg/dL. We calculated that these exposures resulted in 127,248 to 1,612,476 DALYs in 2013.

CONCLUSIONS Informal ULAB processing is currently causing widespread lead poisoning in LMICs. There is an urgent need to identify and mitigate exposures at existing sites and to develop appropriate policy responses to minimize the creation of new sites.

KEY WORDS informal economy, lead poisoning, low- and middle-income countries, soil pollution, disability adjusted life years, recycling

INTRODUCTION

Contaminated soils at polluted "hot spots"—active and abandoned mines, smelters, industrial facilities, and chemical waste sites—threaten the environment and human health globally. In high-income countries (HICs), substantial progress has been made toward identifying and remediating hazardous waste sites and thus in reducing exposures and disease. In low- and medium-income countries (LMICs), by contrast, the extent and severity of soil contamination at these sites has not been adequately mapped or quantified.[1] Information on the burden of disease attributable to hazardous exposures at contaminated

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sites has not previously been available for inclusion in estimates of the global burden of disease by either the Institute for Health Metrics and Evaluation (IHME) or the World Health Organization (WHO).[2,3]

Toxic Sites Identification Program. To close the information gap regarding soil pollution at industrial hot spots in LMICs and its effects on human health, Pure Earth (PE; formerly Blacksmith Institute) launched the Toxic Sites Identification Program (TSIP) in 2008.[4]

The central element of TSIP is a protocol for rapid field-based identification and assessment of hazardous waste sites in LMICs. This protocol has been adapted from the standard source-pathway-receptor model for field assessment of toxic sites in use by the US Environmental Protection Agency (USEPA) and was specifically adjusted by PE to accommodate field application in LMICs by nonprofessional local investigators trained through the program.[5,6] At each site, environmental samples are collected, photographs are taken, and key characteristics are documented. Completed assessments are entered into an online database. To date 2591 sites in 49 countries have been assessed.

The basic approach is to identify a single key pollutant at each site. The key pollutant is the dominant contaminant at a site whose concentrations are most significantly elevated above relevant environmental standards. Lead, mercury, hexavalent chromium, and highly toxic environmentally persistent pesticides have been the key pollutants most commonly identified. Estimates of environmental contamination and disease burden are attributed solely to the key contaminant and not to any other hazardous materials that may be present at a site. This bias likely underestimates the true environmental burden of disease.

PE has collaborated with local partners and secured support from national and international funders to remediate some of the most hazardous sites identified through TSIP. In these remediation efforts, extensive site mapping is undertaken to characterize the spatial distribution of contaminants, consultations are held with local area residents to help design the most effective and appropriate interventions, and biological samples of residents are taken, as appropriate, before and after remediation.

From 2012 to 2014, PE and researchers from the Mount Sinai School of Medicine in New York City, used data collected as part of the TSIP to calculate the burden of disease resulting from exposures at contaminated sites. The effort focused on 3 countries in Southeast Asia: India, Indonesia, and the Philippines. Chatham-Stephens et al.[7] used sampling data from individual sites and existing demographic information to conduct an exposure assessment. Dose-response was calculated using USEPA reference doses and slope factors[8] for noncarcinogenic and carcinogenic chemicals, respectively. An estimated incidence of disease was thus determined for various age groups. Finally, deaths (years of life lost [YLL]) were determined, and appropriate WHO disability weights (DW), discounting, and age weights were applied to calculate resulting years lost due to disability (YLD). YLD and YLL were summed at all sites and presented in the aggregate. The authors found that 828,722 disability adjusted life years (DALYs) resulted from contaminated sites in those 3 countries alone. A second paper[9] applied this same method to 3 additional countries in Latin America.

Sites Captured by TSIP. The TSIP method is not designed to survey all contaminated sites in a country. Rather sites are prioritized based on their perceived effect on human health. Moreover, finite resources limit the number of site visits. Relevant government agencies, academics, and others are interviewed to assist investigators to identify sites, although a systematic identification process similar to the National Priorities List of USEPA[10] is not in place. Underestimation of the number of sites and the attributable burden of disease therefore results.

To obtain data on the number of sites captured by TSIP relative to the total number of contaminated sites in a country and thus to assess the degree of underestimation, PE conducted a systematic census of hazardous waste sites in Ghana in 2014-2015.[11] Ghana was selected for this analysis because it is an LMIC with a heterogeneous industrial base and a highly urban population (51%).[12] Assessors targeted a randomly selected number of geographic quadrats for comprehensive assessment. The investigators physically walked all accessible streets in each quadrat to visually identify sites. Visual identification was supplemented by field-based sampling with portable x-ray fluorescence instruments to test soils for metals (InnovX Delta Series, Olympus, Bridgeport, CT, USA). The investigators identified 72 sites in the sampled quadrats. They then extrapolated these data to the country as a whole using 1 of 2 methods. The first method (regional), which used cluster random