Assessment Of Lead Exposure To Children In A Historically Contaminated Area, Copsa Mica, Romania

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Assessment of lead exposure to children in a historically contaminated area, Copsa Mica, Romania

Xiangting Meng

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Department: School of Public Health
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Committee Member: Eugen Gurzau
Abstract

Copsa Mica is an industrial town with primary zinc and lead smelter operating from 1930s to 1990s in northwestern Romania. Even after the shutdown of the factory and a series remediation effort, lead is ubiquitous in its environment and remains as a big risk for local health. Previous study evaluating the blood lead level of children in this region revealed a range of mean from 20.51µg/dL to 53.04 µg/dL, which exceeded the recognized CDC guidelines. The paper aims at providing detailed information about spatial distribution of lead in soil and dust to better understand the lead exposure and choose the most appropriate intervention strategies to bring down the BLL in children to safe level. Soil and dust samples were collected in situ at Copsa Mica. Samples were sealed and transported to Environmental Health Center laboratory for lead analysis using X-Ray Fluorescence Spectrometry. Predicted Blood lead levels for children were calculated in IEUBK model using measured soil lead and dust lead as input data. Basic descriptive statistics were derived for both environmental lead exposure and predicted blood lead level. Correlation analysis was conducted between lead concentrations in different exposure media. GIS analysis was derived for soil lead concentration and predicted BLL. The study shows that there is a moderate association between lead in outdoor soil and outdoor dust. The lead in soil greatly exceeds the safe level and remains a major contributor to elevated BLL. The predicted BLL reveals an exposure level higher than 10 µg /dL. Several hotspots were identified through GIS analysis and site specific intervention method were given to bring the BLL down to the safe level.
Acknowledgement

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1. Introduction

1.1 Health Effects of Lead

Lead is a naturally occurring toxic metal found in the Earth’s crust. Its widespread use in painting, gasoline, battery, pipes as well as industrial processes has resulted in extensive environmental contamination, human exposure and public health threats in many parts of the world \[1\]. It is a highly poisonous metal that has adverse health effects on certain organ systems, such as the central nervous system, the cardiovascular system, kidneys, and the immune system \[2\]. Once entering the body, lead will either bind with sulfhydryl groups on enzymes or mimic other metals to interfere their proper functions \[3, 4\]. Long-term exposure to lead is found to result in decreased cognitive functions, kidney damages, anemia, impaired respiratory function and an increase in blood pressure \[5, 6\].

Children are more susceptible to lead exposure because they have greater absorption rate than adults and their developing physiological systems making them more vulnerable \[7, 16\]. The accidental ingestion of soil and dust during outdoor play also increases their chance of exposure compared to adults. Over-exposure of lead to children will result to central nervous system effects, reduced IQ, and impaired growth \[8-10\]. Blood Lead Level, which is an effective biomarker to reflect lead exposure, should be no more than 10 µg /dL according to Centers for Disease Control and Prevention’s (CDC) Advisory Committee on Lead Poisoning. In 2012, the CDC further lowered the blood lead level (BLL), at which public health intervention should from 10 µg /dL to 5 µg /dL \[18\], while they also stated that there is ultimately no safe level for lead exposure. However, the action level that currently adopted by Europe is still 10 µg /dL, so this article will still use 10 µg /dL as the safe level \[19\].

1.2 Lead exposure in Copsa Mica

As public-health concerns are expressed about lead exposure to vulnerable population, it is of great importance to use currently applicable methods to qualitatively and quantitatively assess environment lead exposure. Blood Lead Level, as a direct exposure assessment approach, is widely adopted to reflect the internal dose of lead. It integrates all exposure pathways and reveals an exact exposure level that results to toxic effects \[20\]. Therefore most of the standard use BLL as a reflection of lead exposure. However, environment monitoring of lead concentration in different exposure media is of equal importance, since it provides us with information about exposure sources and pathways. This will help to understand the severity of exposure and leads to the choice of different intervention
methods. Questionnaires and visual inspections should also be used to collect behavioral information. This article uses the combined method of environmental monitoring and predicted BLL to assess children’s exposure to lead in Copsa Mica, an industrial town with primary zinc and lead smelter operating from 1930s to 1990s in northwestern Romania.

Metal smelters can be a source of lead emission. The major sources of lead pollution near smelter are: gases aerosols, dusts, and particulate deposition; wastes from the ore-flotation processes, including waste waters; wastes from the processing operations; metallurgical slag from both the new and old plants\(^{[12]}\). Some non-routine activities, such as structural dismantling of the smelter, smelter slag stored on site, are also considered as potential sources. Lead is then transported from emission sources to community through smelter stack emissions and fugitive emissions, which are caused by activities such as transporting, dumping, storing ore; slag dumping, leaks and other uncontrolled discharges\(^{[13]}\). The use of smelter slag as landfills is also another transport pathway since lead in slag is bio-accessible\(^{[14]}\).

Copsa Mica has ubiquitous lead in the environment and is representative of this problem. A previous study has shown that soil lead concentrations in this area ranges from \(\leq 50\) PPM to 60,000 PPM\(^{[11]}\), which greatly exceeds the EPA standard of 400 PPM in play areas and 1,200 PPM average for bare soil in the rest of the yard. A pilot study conducted from 2002-2009 to evaluate the BLL of children (n=86-34) in this region revealed a range of mean from 20.51\(\mu\)g/dL to 53.04 \(\mu\)g/dL, up to a magnitude higher than the CDC reference value. It is important to assess the lead environment exposure and identify the major exposure pathways for children, and provide targeted interventions strategies to remediate children’s BLL based on those information.

1.3 Objects

Both the exposure pattern and pilot study stand for the hypothesis that soil and dust contamination may be major exposure pathways in Copsa Mica. Although other exposure pathways through air, diet and water may also elevate BLL in children, they have much less contribution compared to soil and dust\(^{[17]}\). Therefore I will focus on the study of soil and dust lead concentration to understand the environment lead exposure in Copsa Mica.

The overall objective of this study is to provide the local residents and community with more detailed information about the spatial distribution of lead in soil and dust. We hypothesized that environmental lead exposure influence the health related outcomes. Lead remediation strategy should
be applied to places with high lead exposure. However, the differences in lead exposure, relief of the area, population construction will result to the choice of different strategies. Therefore, the study aims to build a high resolution map of soil and dust lead concentration in Copsa Mica, along with the spacious distribution of susceptible population to help us to choosing the most appropriate intervention strategies for each small unit and thus effectively bring down the BLL in children to safe level. The specific objectives of this study are (1) use a geographic information systems-based analysis for environmental exposure mapping to provide a high-resolution map of soil lead levels in Copsa Mica and (2) predict children’s Blood Lead Level for each small unit using IEUBK model, and (3) combine information on soil and dust lead concentration and predicted BLL to examine the contribution of each exposure pathway and guide the choice of intervention strategies.

2. Methods

Study Area: Copsa Mica is a town that located in the northwestern Romania. A primary zinc and lead smelter, SOMETRA, and carbon black plant, Carbosin, were built there and remained active since 1930s. The plants were shut down during late 1990s with the enactment of forest and environmental protection. The study area includes the smelter, the town Copsa Mica, and a village adjacent to it, Thalluimum. The reason we choose Thalluimum is that The Thalluimum is located within the 3 kilometer buffer from the smelter stack and a pilot study has shown great pollution in this area from smelter. Samples were taken from private locations in 2014 which were mainly local residence, and from public locations in 2018 including the kindergartens, schools and play yards where children have access to outdoor activities.

Environmental Sample Collection: 27 sample sites from public locations, including schools, kindergartens, playgrounds, football fields, are chosen in 2018. Each site was sampled for outdoor soil and outdoor dust. In 2014, 20 samples sites in households were chosen. The outdoor soil samples were taken from gardens within each households. The dust samples collected in 2014 including dust from children’s right hand, yard, kitchen and bedroom. The average lead concentration of kitchen dust and bedroom dust is taken as the indoor dust exposure. The lead concentration of yard dust is taken as the outdoor dust exposure.
For soil sampling, at each site, research members prepared a 1 square foot area of undisturbed soil and collected 2cm of top soil from the 5 points in the chosen square as a non-composite, representative sample of the location. Samples were labeled and sealed in uncontaminated plastic bags and transferred to the Environmental Health Center laboratory. The geographic data was recorded with a portable GPS unit at the center of each sample area. A checklist including the location, sampling data, sampling type, surrounding information was recorded for each site. Each site is classified as proximity to one of the five areas: roads, hazardous waste site, industrial site, farms and residential area. The vicinity of any garden, lives tocks and grown vegetables were also recorded.

Outdoor dust were sampled using the wipe sampling technique. Research members prepared a 2 square foot area, collected all the dust within and sealed in plastic bags. A similar checklist was also recorded for dust at each site. The outdoor soil and dust samples were dried, grinded and filtered in Environmental Health Center laboratory. I used x-ray fluorescence spectrometry under standard soil lead analysis methods\textsuperscript{[15]} to analyze for lead and other mineral analytes.

A Previous study conducted in 2014 has chosen 20 local residence as indoor soil and dust sample locations. At each locations, garden soil, street soil and yard soil samples were collected. For indoor dust, dust samples in indoor yard, bedroom, kitchen and on right hand were collected separately. The sample were analyzed using x-ray fluorescence spectrometry in Environmental Health Center as well.

\textbf{Children Blood Lead Level Prediction}: The predicted Blood Lead Level was calculated using IEUBK Model (Integrated Exposure Uptake Biokinetic Model for Lead in Children, IEUBK\textsuperscript{win} version 1.1). The aim of this model is to predict BLL in young children exposed to lead from several sources including soil, dust, air, water and diet. The model is a four-step process (exposure, uptake, biokinetic, and probability distribution) that mathematically and statistically links environmental lead exposure to BLL for a population of children aging from 0 to 7 years old. In my study, the uptake and exposure parameters from air, water and diet remain in default, while soil and dust lead concentration for each site were put in to calculate the predicted BLL for children in age group 1-2. For 2018 data, the predicted BLL for combined soil and dust exposure, only soil exposure and only dust exposure was calculated to see the contribution of soil and dust to total BLL. However, since the dust samples
collected in 2014 has different units from the model and it is hard to conduct transformation, the predicted BLL was calculated with only soil exposure.

**Geostatistical Analysis:** Geographic Information System (GIS) is an effective tool for exposure assessment. In that it provides an integrated platform for analyzing spatial patterns and individual level factors. The geographic data were collected using the iPhone (version 6s) GPS app. Transformation from DMS(Degrees, Minutes, Seconds) to decimal degrees were conducted based on the formula:

\[
\text{Decimal Degrees} = \text{Degrees} + \frac{\text{Minutes}}{60} + \frac{\text{Seconds}}{3600}
\]

The outdoor soil, predicted BLL and intervention method for each sample sites were be mapped in ArcMap (version 10.3). Interpolation using the IDW (Inverse Distance Weighted) method were applied to represent the spatial distribution of lead in soil, predicted BLL and intervention method. The three interpolation maps together identified hotspots of elevated BLL in Copsa Mica and point out site specific intervention strategies.

**Statistical Analysis:** Environmental exposure data was analyzed using R (R studio, version 9.4). Basic descriptive statistics were derived for of soil samples, dust samples and predicted BLL. T-test were derived for outdoor soil vs. outdoor dust, outdoor dust vs. indoor dust to see whether the lead in different exposure media has same exposure level or not. Correlation analysis were conducted for outdoor soil vs. outdoor dust, outdoor dust vs. indoor dust and outdoor soil vs. indoor dust to examine for potential association. There are sites with extreme high lead concentration, which may be due to unusual behaviors such as burying lead contained products around households. Those sites, taken as outliers, may have large influence on the overall association and should be examined individually. Therefore both the analysis with original dataset and with the removal of outliers were performed. Outliers are identified as those observations that lie outside 1.5 * IQR (Inter Quartile Range), where IQR is the difference between 75th and 25th quartiles.

### 3. Results

3.1 Descriptive Data of environmental lead exposure

Table 1 and Figure 1 show the descriptive data about the soil lead concentrations and dust lead
concentrations.

For 27 soil samples collected in 2018, the geometric mean of lead concentration is 1028.44ppm, the mean is 2870.3ppm. The minimum concentration is 35.7ppm and the maximum concentration is 18198.7ppm. For 27 dust samples collected in 2018, the geometric mean of lead concentration is 522.5ppm, the mean is 699.7 ppm. The minimum value is 103.3ppm and the maximum value 4491.5ppm.

For 20 soil samples collected in 2014, the geometric mean of lead concentration is 1146.7ppm, the mean is 1465.8ppm. The minimum value is 215.0ppm and the maximum value is 4496.6ppm. For 20 outdoor dust samples collected in 2014, the geometric mean of lead concentration is 39.8 μg/cm$^2$, the mean is 53.2 μg/cm$^2$. The minimum value is 11.6μg/cm$^2$ and the maximum value is 142.1μg/cm$^2$.

Although there is much higher variance within outdoor samples, on average, lead concentrations in households’ soil and dust samples are lower than that in outdoor. What’s more, the lead concentration of outdoor dust in public areas is greater than outdoor dust in private territory.

### Table 1 Descriptive Data for soil and dust samples.

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>1st Qu</th>
<th>Median</th>
<th>3rd Qu</th>
<th>Max</th>
<th>Mean</th>
<th>GeometricMean</th>
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<td>1041.6</td>
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<td>18198.7</td>
<td>2870.3</td>
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<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>2018outdoorDust(ppm)</td>
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<td>379.7</td>
<td>572.8</td>
<td>701.6</td>
<td>4491.5</td>
<td>699.7</td>
<td>522.5</td>
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<td>(n=27)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>2014Soil(ppm)</td>
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<td>939.2</td>
<td>1084.9</td>
<td>1771.2</td>
<td>4496.6</td>
<td>1465.8</td>
<td>1146.7</td>
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<td>(n=20)</td>
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<td></td>
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<tr>
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<td>19.0</td>
<td>37.3</td>
<td>77.3</td>
<td>142.1</td>
<td>53.2</td>
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<td>11.9</td>
<td>56.31</td>
<td>8.1</td>
<td>-</td>
</tr>
<tr>
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</table>

3.2 Correlation Between outdoor soil and outdoor dust samples

T-test and correlation analysis were then conducted to examine the associations between lead concentrations in different exposure media. If any association exists between the soil lead concentration and dust lead concentration, the actual effect of intervention will be greater than the
expected since we can reduce the lead concentration in soil and dust simultaneously.

As shown in Figure 1, the correlation for soil and dust samples collected in 2018 is -0.015, the lead concentration in soil and dust is negatively correlated. There is basic no association between outdoor soil and dust. Site 3, 12, 13, 20, 21 and 25 are identified as outliers. The soil and dust lead concentration for these six sites are: (17991, 352), (6813, 572), (5661, 550), (1774, 4491), (5690, 1401) and (18198, 590). Site 20 and 21, located close to smelter stake, are very close to each other and have extreme high dust lead concentration. Site 3, 12, 13, 21 and 25 have high soil lead concentration. After deleting these three sites and re-conduct the correlation analysis, the correlation coefficient between soil and dust increases to 0.338. They are positively moderately correlated.

Figure 1. Correlation between soil and outdoor dust samples in 2018

The mean lead concentration in soil is 2870.28 ppm while the mean lead concentration in dust is 699.72 ppm. The t-test of the 2018 soil and dust samples has p-value of 0.02657, which is less than 0.05, therefore we reject the null hypothesis that the true difference is same and admit that that the lead concentration in outdoor soil and dust samples are different.

Figure 2 shows the correlation between lead concentrations in 2014 soil samples and outdoor dust samples. The correlation coefficient is 0.497, the lead concentration is positively correlated between soil and outdoor dust. The correlation is comparatively strong.

The mean lead concentration in outdoor dust is 53.165 μg/cm² while the mean lead concentration in soil is 1465.785 ppm. The t-test of the 2014 soil and outdoor dust samples has p-value of 2.623e-05, which is less than 0.05, therefore we reject the null hypothesis that the true difference is same and admit that that the lead concentration in outdoor dust and soil are different in 2014 samples.
3.3 Correlation Between indoor dust and outdoor dust samples, indoor dust and outdoor soil samples

The correlation analysis is also conducted between indoor dust and outdoor dust, indoor dust and soil.

The correlation coefficient for indoor and outdoor dust is -0.131, they are negatively correlated. There is outlier where we detected highest indoor dust lead concentration (in bedroom). After deleting it, we observe that the correlation changes to 0.156. Even though they are positively correlated, the association is still not significant.

Figure 3. Correlation between indoor dust and outdoor dust samples in 2014

The correlation for soil and indoor dust is -0.229, the correlation is quite weak between soil lead concentration and indoor dust lead concentration. The outliers are identified as Site 12 (with highest indoor dust concentration) as well as Site 7 and 19 (with highest soil concentration). After deleting this two points the correlation changes to -0.023. They are still negatively correlated and the association is too weak to exist.
In summary, after excluding the effect of extreme points, the outdoor dust lead concentration is positively associated with soil lead concentration in samples collected both in 2014 and 2018. The lead concentration in indoor dust has no association with lead either in outdoor dust and outdoor soil. The lead in outdoor can be a good approximate of lead exposure in environment, and removing the lead in soil can also reduce the lead exist in outdoor dust.

3.4 Predicted Blood Lead Levels

The predicted BLL for children aged in 1-2 years old are shown in Figure 5. Given the situation that the unit of dust samples collected in 2014 is in mg/cm², which is inconsistent with the input unit in IEUBK model, and the transformation is hard to conduct, the predicted BLL for samples in 2014 is calculated only based on soil lead concentration. 6 out of 20 sites have predicted BLL higher than 10 µg/dL. For samples in 2018, both outdoor soil and dust are considered as exposure media. Among the 27 sites we sampled, 16 sites exceed the standard.
If we remove all the soil from sites and leaving only dust there as exposure source, 20 of those 22 sites will have predicted BLL lower than 10 µg /dL. Site SB20 and SB21 will still have predicted BLL of 23.4µg /dL and 10.6µg /dL separately. The soil and dust lead concentration is (1774.84, 4491.50) ppm for site SB20. And (5690.54, 1401.27) ppm for site SB21. The extreme high lead concentration in dust is the primary reason leading to the failure of removing soil only. If we remove all the dust from the sites sampled in 2018 and leaving only soil as exposure source, 5 sites will have predicted BLL lower than 10 µg /dL, they are sites SB7, SB8, SB9, SB11 and SB18. The remaining 11 sites still have predicted BLL exceeding 10 µg /dL.

From the results we can recommend that removing dust for sites SB7, SB8, SB9, SB11 and SB18 will take the BLL below the standard 10 µg /dL. All the rest need control for soil lead exposure. However, for sites SB20 and SB21, we need to remove both dust and soil to reach the standard level. One noticeable thing is that for all sites sampled in 2014, soil lead exposure is the main exposure.

Figure 6. Changes in BLL after applying interventions
3.5 Spatial Distribution of Soil Lead and Predicted BLL

Figure 7 provides the spatial information of lead exposure in soil. The upper map shows the soil lead concentration collected at sample sites. Most of the samples sites, except for some located at the margin of the town, has soil lead concentration greater than 400 ppm, exceeding the EPA’s standard for lead in bare soil in play areas. The interpolation map using IDW method points out two hot spots in the town with highest soil lead concentration. Those two areas are located at the east of the stake smelter.

Figure 7. Spatial Distribution of Soil Lead Concentration

Figure 8 provides the spatial information of predicted BLL. As we can see from the upper map,
there is a trend that the predicted BLL is inversely proportional to the distance from smelter stake. The predicted BLL is smaller as the distance from the smelter is further. Samples sites at the margin of the town tend to have predicted BLL within the standard of 10 µg/dL, while samples sites at the central of the town have extreme high predicted BLL. The interpolation indicates that majority area in the town would have predicted BLL higher than standard. It also points out three hotspots with predicted BLL even higher than 20 µg/dL. Two of them are located close to the smelter and one is in Thalluimum, a very somevillage adjacent to Copsa Mica. The intervention should be applied to whole town with special focus on the pointed hotspots and places where vulnerable population resides.

Figure 8. Spatial Distribution of Predicted Blood Lead Levels

The Figure 7 and Figure 8 shows a certain degree of conformity. There are two hotspots overlap with each other. The extreme high soil lead concentration results to two hotspots of predicted BLL. However, there are some difference between two maps. The hotspot of predicted BLL, located to the southeast of the smelter stake, doesn’t correspond to extreme high lead concentration in the soil lead map. Since the blood lead level is estimated based on lead concentration of both soil and outdoor dust, we infer that the high outdoor dust concentration is also a contributor to this hotspot. The intervention map in Figure 9 and outdoor dust map in Figure 10 also prove the point that interventions on both
soil& dust should be applied to this area. The two hotspots in Figure 7 are identified in Figure 9 as area need intervention on soil. Moreover, Figure 9 also points that intervention on soil are needed in the area that is northwest to the smelter. However, this area is not identified in previous map and no sample sites are located in this area. More investigations are needed to figure the reason why this area is circled out.

Figure 9. Interpolation map of intervention method

Figure 10. Spatial Distribution of Outdoor Dust Lead Concentration (ppm)

4. Discussion

The study collected 47 outdoor soil, 47 outdoor dust and 20 indoor dust samples in total. The mean soil lead concentration in public area is 2870.3ppm (n =27, collected in 2018) and mean soil lead concentration in residential area is 1465.8ppm (n =20, collected in 2014). Given the EPA’s standard for lead in bare soil in play areas is 400 ppm and 1200 ppm for non-play area (ASTDR), the soil lead
in Copsa Mica greatly exceeds the safe level and its high level remains a big concern for elevated BLL in local children.

A correlation analysis showed a positive association between lead concentration in outdoor soil and outdoor dust, which implies that lead contained in outdoor dust may come from contaminated soil. The association between lead in outdoor soil and outdoor dust suggests that removal of lead in soil may lead to the reduction of lead concentration in outdoor dust. Therefore the intervention applied on a single exposure media may have greater impact than expected. We didn’t find any association between lead in indoor dust and outdoor dust, and the lead in indoor dust and outdoor soil. This may suggest that there are other sources for indoor lead exposure and the indoor lead is irrelevant from lead in outdoor environment. However, we need to further investigate on that point given we only have 20 samples for indoor dust.

The mean predicted BLL based purely on soil lead and dust lead is 12.5 μg/dL. It exceeds the CDC’s threshold of 5μg/dL and WHO’s standard of 10 μg/dL, even though there is no safe level for BLL. The lead exposure from 22 out of 47 sampled sites leads to an estimated BLL in children higher than 10 μg/dL. The removal of lead in dust will lower the predicted BLL to less than 10 μg/dL for 5 over-exposed sites. And the removal of soil lead will make 20 out of 22 sites have estimated BLL within the WHO standard. There are two sites with extreme high soil lead and dust lead concentration need the intervention to be applied both on soil and dust. In general, soil lead had a larger impact than outdoor dust lead, while we couldn’t exclude the impact of dust.

GIS analysis points out two hotspots for soil lead concentration and three hotspots for predicted Blood Lead Levels. From the map we can see that the soil lead concentration in central town is greater than the standard 400 ppm and the majority of town would have predicted BLL higher than 10 μg/dL. The intervention map provides important information about which exposure media should be focused for intervention strategies.

The study aims at providing detailed information on environmental exposure of lead in Copsa Mica. It uses GIS to show spatial distribution of lead in soil and dust and identifies areas with high risk of lead exposure within the town. The study also combines the information of predicted blood lead levels to identify the major contributor of elevated BLL. Combining all information above, it provides guidance for the choice of lead remediation strategy that should be applied in the future.

There are several limitations in our study. First, the estimated effect of intervention is based on the
assumption that there is no association between each exposure media. The intervention applied on soil or dust wouldn’t affect the lead concentration in the other media. However, from the correlation analysis we see a moderate correlation between lead in outdoor soil and outdoor dust. A reduction of lead in soil may also leads to the decrease of lead concentration in dust. The overall intervention effect is an interaction of both soil and dust and may be greater than we estimated in this article. Further study regarding the relationship of lead in soil and dust may be greater than we estimated in this article. Further study regarding the relationship of lead in soil and dust and may be greater than we estimated in this article. Second, children can be exposed to lead through multiple sources such as water, diet and air. Since EU has abandoned the use of decorative lead paint over 40 years, the lead painted wall is not a major issue in this study[17]. This study only consider lead exposure from soil and dust. Even though soil and dust are the two biggest exposure pathway in Copsa Mica and they represent a large part of overall exposure, other exposure information should be collected and put into the IEUBK model to better predict children’s BLL. Thirdly, children’s behavior, such as time spent playing outside, personal hygiene, frequency and temporal sequence of hand wash, all contributes to the variation in actual blood lead levels. Questionnaires should be distributed to children to gather such information and modifications for personal behavior should be included in the future analysis. The last limitation exists in the measurement of blood lead level. Due to the challenge of gathering enough blood samples, this study uses predicted blood lead levels as a reflection of children’s lead exposure. Future research should focus on collecting blood samples from children in area identified as high risk in this study. Blood lead level reveals the internal dose of absorbed lead and is directly related with toxic effects of lead. It is not only a direct measure of lead exposure, but also a powerful supplement for the indirect approach of environmental monitoring of soil lead and dust lead concentration. By obtaining the information about BLL, we can integrate more exposure sources and analyze the contribution of each one, therefore give out more effective intervention strategies.

5. Conclusions

Copsa Mica is burdened with dangerous lead soil and dust concentrations adjacent to residences, playgrounds, primary schools, the soccer fields, and other similar sites. Children in this area are constantly overexposed to lead through outdoor activities and direct contact with contaminated soil. Our study shows that despite the shutdown of smelter decades ago, lead is still ubiquitous in Copsa Mica. Both soil lead and dust lead concentration greatly exceeds the EPA standard and leads to a
dangerous level of children’s blood lead level. Through spatial analysis, the study points out the hotspots and the site specific remediation strategy. Among all the sources, lead in outdoor soil has the biggest contribution to the elevated BLL and soil abatement is an absolutely necessary intervention for this region. Future research should also focus on blood lead screening to better understand and monitor the lead exposure in children.

References
[13]. Sullivan, M., Reducing lead in air and preventing childhood exposure near lead smelters: learning from the U.S.


