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TITLE: **Blood Lead Survey of Children in Selected Areas in the Philippines (2021-2022): Updated Report**

IMPLEMENTING AGENCIES: Pure Earth-Philippines/Food & Nutrition Research Institute, Department of Science & Technology

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INTRODUCTION

Lead poisoning has been recognized as a global health burden. Children and pregnant women, especially those who live in areas of high exposure and have poor access to health services, are at greatest risk. Lead poisoning is a preventable disease. Thus blood lead level determination is essential for screening, surveillance and detection of exposure and poisoning.

In the Philippines, several studies have been conducted with regards to lead exposure of children and women of reproductive age group. Majority of these studies involving children were done in Luzon, and mostly in areas where lead was documented in environmental media and workplace samples (Regal, 2001; Maramba, et al., 2003; Suplido & Ong, 2003; Dioquino & Panganiban, 2010; Panganiban, 2017). Furthermore, there were studies that aimed to establish a baseline or background blood lead level among children (Fagela-Domingo, et al., 1984; Gole, et al., 1984; Suplido, et al., 2003; Riddell, et al., 2007). However, these studies were not nationwide in scope and covered different age groups (Table 1). Thus, to date, there is no true national survey that can provide data on the background lead levels among different pediatric age-groups in the country.

The Pure Earth-Philippines, in collaboration with the Philippine Food and Nutrition Research Institute (FNRI) of the Department of Science and Technology, embarked on a blood lead survey among vulnerable populations in the country, specifically children and pregnant women. The survey was part of the 2021 National Nutrition Survey (NNS). The NNS is the only survey being conducted in the country that collects blood samples from representative population to assess a wide range of nutrition parameters.

Table 1: Selected Studies on Blood Lead Levels Among Children in the Philippines

Title of Study/Authors	Year	Location	Number of Children	Age Group (months/years)	Mean Blood Lead Levels (BLL) (ug/dL)
Blood lead, free erythrocyte protoporphyrin and delta-aminolevulinic acid dehydratase levels (referenced from Suplido ML, David A, et al.)	1984	Metro Manila communities, Luzon Rural communities	570 801	4 months – 14 years	22.86 24.14

Gole Cruz RV, Fagela-Domingo C, et al.			Note: Only 554 with blood lead determination		
Health and environmental assessment among residents of a community near a battery recycling plant (Cortes-Maramba NP, Panganiban LR, et al.)	1999	Central Luzon Region	40	9.68±3.58 (7-12)	12.92±4.087 (range 7-25)
Lead Exposure Among Small-Scale Battery Recyclers, Automobile Radiator Mechanics, and Their Children in Manila, the Philippines (Suplido ML and Ong, CN)	1999	Manila, National Capital Region, Luzon	20	Battery recyclers: 6.37±3.99 Radiator mechanics: 6.28±3.96	49.88 11.84
Blood lead levels and cognitive function of child scavengers in Smokey Mountain (Regal MAS)	2001	Metro Manila, Luzon	149		20.37 ug/dL
Blood Lead Levels in Filipino Grade School Children in Three Selected Urban Areas: Olongapo City, Metro Cebu and Metro Davao (Suplido ML, David A, et al.)	2003	Olongapo City, Metro Manila, (Luzon) and Metro Davao (Mindanao)	1,756	6.7 (SD 0.9) and 12 (SD 1.1) School children	5.39 (SD 4.42) with 7.5% with BLL>10 ug/dL
Elevated blood-lead levels among children living in the rural Philippines (Riddell TJ, Solon O, et al.)	2003-2004	30 districts nationwide	2,861 (100 per district)	6 months to 5 years	6.9 ug/dL 21% with BLL > 10
Health effects of lead exposure among 6–7-year-old children in 3 barangays in Central Luzon near an abandoned used lead acid battery (ULAB) plant (Dioquino CPC, Panganiban LCR)	2010	Central Luzon Region	74	6-7	8.004 (SD 1.81) with 16.2% with BLL >10
Blood lead levels of children in four lakeshore villages in the Calabarzon Region, Philippines (Panganiban LR, Bermudez ANC, et al.)	2012-2013	Calabarzon Region, Luzon	100	7.72±0.79 (range 6-9)	4.56±3.01 (range 1.33-22.4) 22% with BLL >5 (mean of 8.46±4.36
Health status of children exposed to lead-contaminated soil near a lead smelting plant in Central Luzon, Philippines (Panganiban LCR)	2017	Central Luzon Region	15	10.07 range (2-16)	50.77 (20.3 - >65)

OBJECTIVES

The main objectives of the survey were (1) to establish the background blood lead levels among children, and pregnant women from different regions in the country; and (2) to identify potential sources of lead exposure and the health risks they pose to these populations.

METHODOLOGY

The target population for the survey was 3,200 children. Determination of lead among different age groups was the original plan. However, this was not feasible because of logistical constraints. Thus, the study team agreed on the 6-9-year age group for this initial survey because blood sample collection from this age group would be less difficult.

The participants were randomly selected among the participants of the NNS. The list of the NNS participants was taken from the Philippine Statistics Authority. An informed consent was secured. Data collection involved demographic profile, environmental history and information on the potential sources of lead exposure. Blood samples were collected and sent to the National Reference Laboratory, East Avenue Medical Center for blood lead determination, using Atomic Absorption Spectroscopy. The hemoglobin determination was done at the FNRI laboratory.

The survey was conducted in November 2021-June 2022. Analysis of data for descriptive statistics, one-way Analysis of Variance (ANOVA) and bivariate correlation were performed using Statistical Package for the Social Sciences (SPSS) Version 29.

RESULTS & ANALYSIS

Two thousand nine hundred thirty-two children were examined with a response rate of 91.62%. It was noted that not all regions were covered and there were fewer children from the Visayas. The survey population included 13 regions covering 20 provinces/districts/cities. (Table 2).

Table 2: Frequency distribution of children by geographic location (island/region/province/district/city), November 2021-June 2022 (N=2932)

Island/Region/Province/City	Number	Percent
Luzon	1247	42.53%
Region 1 (Ilocos Sur, Pangasinan)	266	
Region 3 (Bataan)	99	
Region 4A (Lucena City, Quezon;)	56	
Region 4B (Marinduque, Palawan, Romblon)	459	
Cordillera Autonomous Region (CAR) (Benguet)	134	
National Capital Region (NCR) 2nd District (Cities of Marikina, Pasig) 3rd District (Cities of Navotas, Valenzuela)	233	

4th District (Cities of Muntinlupa, Pasay, Paranaque)		
Visayas	389	13.27%
Region 7 (Cebu)	333	
Region 8 (Leyte)	56	
Mindanao	1296	44.2%
Region 9 (Zamboanga del Sur, Zamboanga Sibugay)	424	
Region 10 (Lanao del Norte)	324	
Region 12 (Sarangani)	141	
Caraga Region (Surigao del Norte)	98	
Autonomous Region in Muslim Mindanao (ARMM) (Lanao del Sur)	309	
TOTAL	2932	

Fifty three percent of the children in this survey were males and 47% were females. Their mean age was 8.15 ± 1.15 years old (range: 5.99-9.99). The mean ages of children across the 3 geographic areas were not statistically different (*p*= .418) (Table 3). The children from Mindanao were younger compared to those from Luzon and Visayas.

Table 3: Frequency distribution of children according to age and sex from selected provinces/cities in Luzon, Visayas & Mindanao, November 2021-June 2022 (N=2932)

Demographic Profile	Islands (Number)			TOTAL No. (%)
	Luzon	Visayas	Mindanao	
Sex				
Male	673	215	675	1563 (53.31)
Female	574	174	621	1369 (46.69)
Age				
P= .418[1]	8.17±1.14 (6-9.99)	8.19± 1.15 (6-9.98)	7.79 ± 1.26 (5.99-9.98)	8.12 ± 1.16 (5.99-9.99)

[1] One-way Analysis of Variance (SPSS, Ver 29)

Nutritional Status

Majority (87.10%) of the children in this survey had normal nutritional status using the WHO BMI by age classification (2007). It was observed that there were more children from the Visayas (10.54%) who were malnourished as compared with those from Mindanao (6.87%) and Luzon (8.98%) (Table 4).

Table 4: Frequency distribution of nutritional status of children from selected provinces/cities in Luzon, Visayas & Mindanao, November 2021-June 2022 (N=2931)

WHO Classification of Nutritional Status According to BMI by Age	Island (Number)			Total No. (%)
	Luzon	Visayas	Mindanao	
Severe Thinness	22	11	11	44
Thinness	90	30	78	198
Normal	1044	329	1180	2553 (87.10 %)
Overweight	64	10	17	91
Obesity	27	9	9	45
Total	1247	389	1295	2931

Laboratory Examinations

The average blood lead level of all children from the 3 islands was 1.96 ± 1.26 ug/dL (range of 1.42-38.35). The non-detectable levels were assigned the value of 1.42 ug/dL using the formula Limit of Detection(LOD)/√2 where LOD was 2 ug/dL.

The mean blood lead level of Visayas were higher than those from Luzon and Visayas. However, one-way ANOVA using Welch Test showed no significant statistical difference in mean blood lead levels across the 3 islands (p=.182) (Table 5).

The average hemoglobin level for all children was 13.05 ± 1.0 g/dL (range of 7.3-22). The mean hemoglobin level of Luzon children was lower than those of the other 2 islands. One-way ANOVA showed a significant difference in the mean hemoglobin levels of children from the 3 islands [F (2,2929) = 21.60, p= <.001). A post-hoc multiple comparisons using Games-Howell Test showed that the mean hemoglobin level of children from Luzon was significantly different from the mean hemoglobin levels of children from Mindanao and Visayas. (p= <.001) (Table 11).

Table 5: Mean blood lead and hemoglobin levels of children from selected provinces/cities in Luzon, Visayas, Mindanao, November 2021-June 2022 (N=2932)

Laboratory parameter	Island			p value[1]
	Luzon (n=1247)	Visayas (n=389)	Mindanao (n=1296)	
Blood lead level (ug/dL)	1.92 ± 1.10 (1.42-11.16)	2.06 ± 1.22 (1.42-12.06)	1.96 ± 1.41 (1.42-38.35)	.182
Hemoglobin (g/dL)	12.91± 1.03 (7.3-17.8)	13.20± 1.06 (10.6-22)	13.14 ± 0.94 (8.6-16.5)	< .001

[1] One-way Analysis of Variance (SPSS Ver 29)

Using the U.S. Centers for Disease Control & Prevention (US-CDC) public health action level for lead, 257 or 8.76% of all children in this study had BLLs ≥ 3.5 ug/dL (Table 6). This is 9 in 100

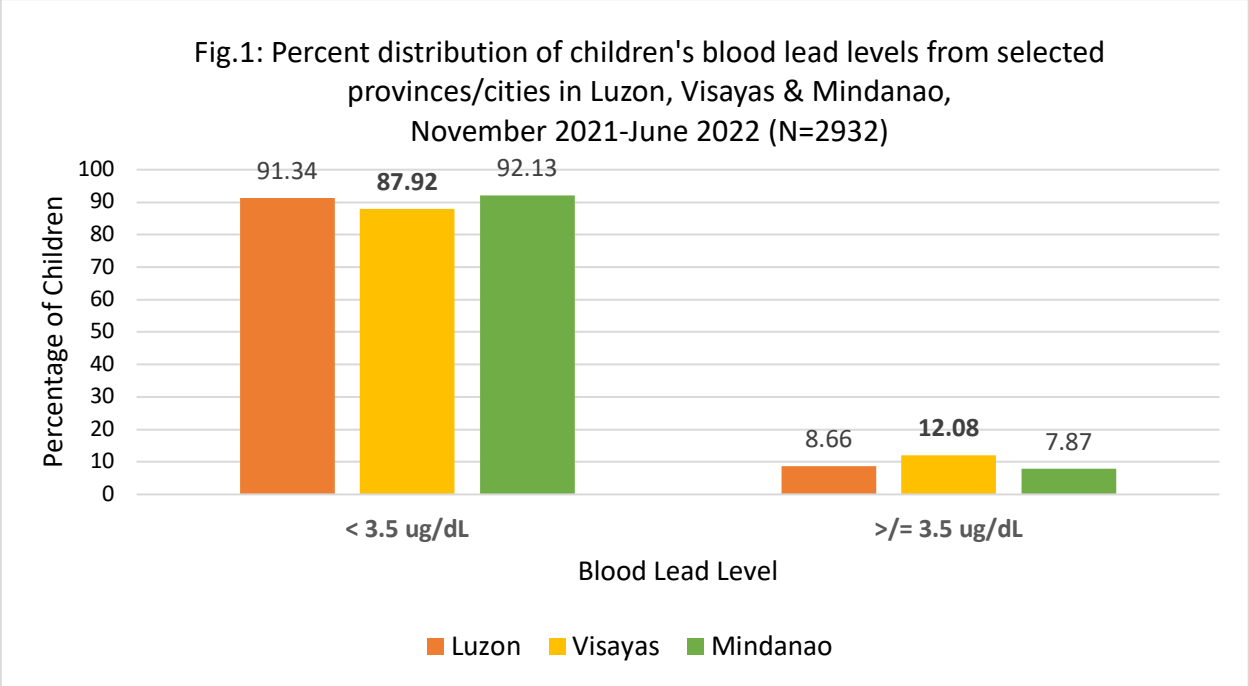
children or a prevalence of 9,000 in 100,000 population. Using this value, the estimated number of children with BLLs ≥ 3.5 ug/dL for a population of 11.95 children of ages 5-9 years old (Philippine Statistics Office, 2020), is 1.05 million.

Furthermore, it was observed that majority of children from the Visayas (12.08%) had BLLs above or equal to the action level (Fig. 1). A Pearson chi-square test was performed to assess the relationship between the geographical locations and the blood lead levels. A significant relationship was obtained for these two variables at X^2 (2,2932) = 6.67, *p*=.036. This would mean that the blood lead level is related to the geographical location.

Table 6: Frequency distribution of children with BLLs below and above the US-CDC action level from selected provinces/cities in Luzon, Visayas, Mindanao, November 2021-June 2022 (N=2932)

Island	Number of Children (%)[1]		TOTAL
	< 3 .5 ug/dL	≥ 3.5 ug/dL	
Luzon	1139 (91.34)	108 (8.66)	1247
Visayas	342 (87.92)	47 (12.08)	389
Mindanao	1194 (92.13)	102 (7.87)	1296
Total	2675	257	2932

[1]*p*=.036, Pearson chi-square, SPSS version 29



Three hundred sixty-nine or 12.58% of all children had anemia with hemoglobin < 12 g/dL as defined by Goyena, et al. (2020) (Table 7, Fig. 2). There were more children from Luzon who had hemoglobin of < 12 g/dL. A Pearson chi-square test showed significant relationship between geographic location and hemoglobin level at X^2 (2,2932) = 27.08, *p*= < .001.

Table 7: Frequency distribution of children with normal and low hemoglobin levels in selected provinces/cities in Luzon, Visayas, Mindanao, November 2021-June 2022 (N=2932)

Island	Number of children (%)[1]		Total Number
	< 12 g/dL	≥ 12 g/dL	
Luzon	203 (16.28)	1044 (83.72)	1247
Visayas	36 (9.25)	353 (90.75)	389
Mindanao	130 (10.03)	1166 (89.97)	1296
Total	369	2563	2932

[1]*p*= < .001 Pearson chi-square, SPSS Version 29

Fig. 2:Percent distribution of children with normal and abnormal hemoglobin levels from selected provinces/cities in Luzon, Visayas & Mindanao, November 2021-June 2022 (N=2932)

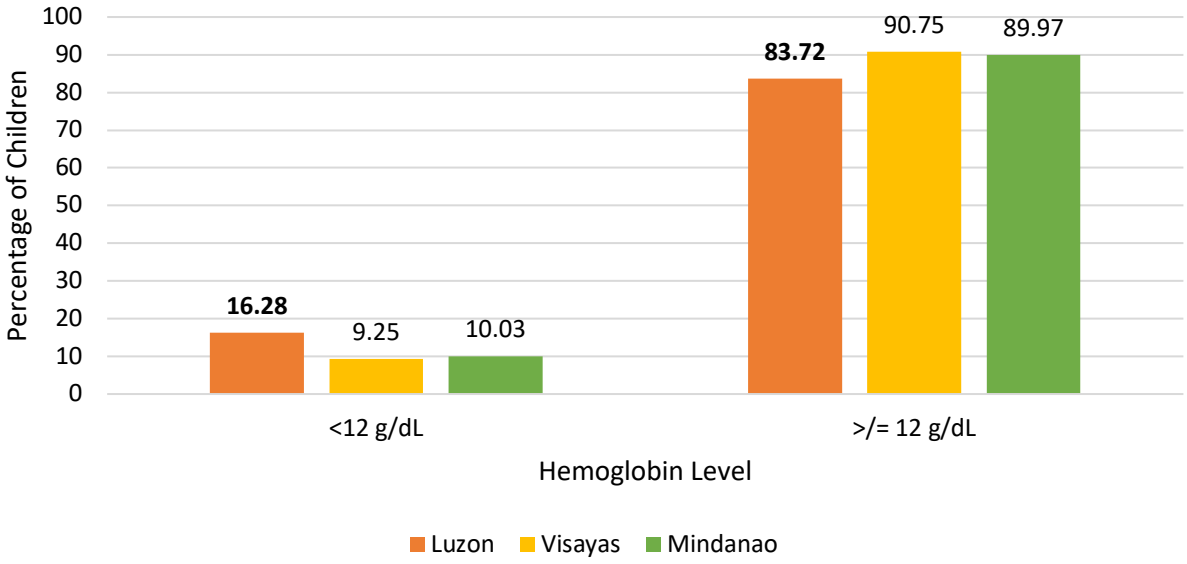


Table 8 shows the comparison between hemoglobin and blood lead levels of children in this survey. It was noted that 39 (1.54%) of children had low hemoglobin levels and BLLS ≥ 3.5 ug/dL. Using Pearson chi-square test, no significant relationship was found between hemoglobin and blood lead levels at X^2 (1,2932) = 1.717, *p*=.190. However, evaluation of the

data per island showed that there was a significant association between blood lead levels and hemoglobin among children from the Visayas (Table 9).

Table 8: Comparison between hemoglobin and blood lead levels among children from selected provinces/cities in Luzon, Visayas & Mindanao, November 2021-June 2022 (N=2932)

Parameters		Hemoglobin Level (g/dL)		Total Number
		< 12	≥ 12	
Blood Lead Level (ug/dL)	< 3	330	2345	2675
	≥ 3.5	39	218	257
Total		369	2563	2932

Table 9: Comparison between children's hemoglobin and blood lead levels by island, November 2021-June 2022 (N=2932)

Island	No. (%) of Children with BLL ≥ 3.5 ug/dL and Hb < 12 g/L	*p*-value[1]
Luzon	21 (1.68)	.351
Visayas	28 (2.06)	.05
Mindanao	10 (0.77)	.937

[1] Pearson chi-square, SPSS Version 29

Potential Sources of Exposure

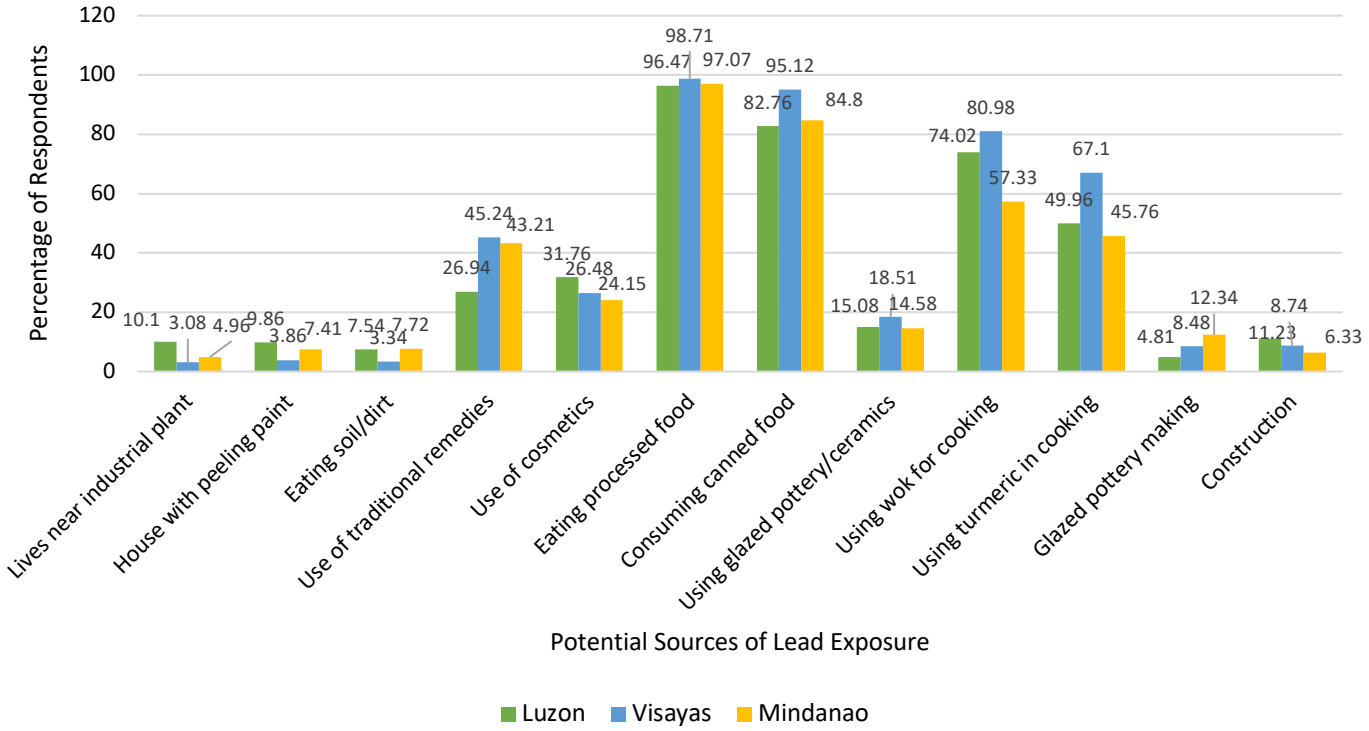
Table 10 and Fig. 3 show the activities with potential sources of lead as reported by participating households in this survey. The top 5 reported sources in general and the specific islands were eating of processed food (97.03%), consuming canned food (85.30%), using wok for cooking (67.56%), using turmeric in cooking (50.38%) and use of traditional remedies (35.56). These are home-based activities.

Table 10: Frequency distribution of activities with potential environmental sources of lead exposure of children from selected provinces/cities in Luzon, Visayas, & Mindanao, November 2021-June 2022 (N=2932)

Potential sources of exposure	Island (Number)[a]			Total No. (%)
	Luzon	Visayas	Mindanao	
Lives next or located within 1 km of industrial plant	126	12	63	201 (6.86)
House with peeling or chipping paint	123	15	96	234 (7.98)
Eating soil or dirt	94	13	100	207 (7.06)
Use of traditional remedies	336	176	560	1072 (35.56)

Use of cosmetics, including talc powder	396	103	313	812 (27.69)
Eating processed food	1203	384	1258	2845(97.03)
Consuming canned food	1032	370	1099	2501 (85.30)
Using glazed pottery/ceramics	188	72	189	449 (15.31)
Using wok for cooking	923	315	743	1981 (67.56)
Household using turmeric in cooking	623	261	593	1477 (50.38)
Glazed pottery making	60	33	160	253 (8.63)
Construction	140	34	82	256 (8.73)

Fig. 4: Percent distribution of potential sources of lead exposure by respondents from selected provinces/cities in Luzon, Visayas & Mindanao, November 2021-June 2022 (N=2932)



DISCUSSION

This survey was able to cover 25 sites from the 3 big geographic islands of Luzon, Visayas and Mindanao and more regions (13 of 16) which were not covered by earlier studies. The conduct of the lead survey as part of the extended national nutrition survey and in partnership with FNRI

was the first collaborative effort in establishing the background blood lead levels in children in the country.

However, the sample population and the age group, limited to only the older children (6-9 years old), would not be enough to establish the background level of lead in the general pediatric population. Likewise, the laboratory method for lead determination had a limit of detection of 2 ug/dL. If the laboratory method had a lower limit of detection, better mean blood lead levels would have been established across the 3 islands.

Comparison of Blood Lead Levels in Children

The blood lead levels in previous Philippine studies (Table 1) showed elevated values, way above the action level of 5 ug/dL as stated in the WHO guideline for the clinical management of exposure to lead (WHO, 2021) and the US-CDC of 3.5 ug/dL (CDC, 2022). In this survey, the average blood lead levels of children from the selected cities and provinces in Luzon, Visayas and Mindanao were lower than the levels reported in previous studies. The values maybe reflective of the background levels of lead among Filipino children who do not have significant exposure to lead, or at the least, to a minimum level. Again, because of the small sample size, the available data cannot generalize as to the over-all background level of Filipino children in the country.

Nevertheless, the study was able to identify the relationship of geographic location and blood lead level with note of the Visayas island to have a higher mean blood lead level from those in Luzon and Mindanao. The study by Riddell, et al. (2007) on blood lead levels among children in the Visayas showed a mean BLL to be 6.9 ug/dL with 21% of the 2,861 children having BLLs > 10 ug/dL. However, the ages of the children were younger compared with this present survey. And although the population size in this current survey is far lower than the 2007 study, it is worth pursuing and prioritizing lead monitoring initiatives in the Visayas.

Comparing this survey's BLLs with the lead biomonitoring data in the United States (US EPA, 2022), the BLLs were higher than the U.S. data. In 2017-2018, the U.S. lead monitoring showed that the median blood lead of children for ages 6 to 10 years was 0.5 ug/dL. The 95% percentile blood lead level for this age group was 1.2 ug/dL. Furthermore, Egan et al. (2020) described BLL distribution among U.S. children ages 1-11 years from 1976-2016. The authors stated that the geometric mean BLL of children ages 6-11 years declined from 12.7 ug/dL in 1976-1980 to 0.60 ug/dL in 2011- 2016. This would indicate that Filipino children are still at greater risk to lead exposure and its adverse health effects compared with U.S. children.

Furthermore, when compared with background blood lead levels in 44 low-income and middle-income countries (Ericson et al., 2021), the mean blood lead values among children in the survey were lower than those from a number of Asian countries, such as China (4.17 ug/dL), Indonesia (5.2 ug/dL), Mongolia (3.82 ug/dL) and Thailand (5.12 ug/dL). The level is however higher than the Ethiopian level (1.66 ug/dL).

Correlation of Blood Lead and Hemoglobin Levels

In the Philippines, anemia is often due to iron-deficiency. It has been found that iron deficiency increases the risk to lead toxicity by increasing absorption of lead. On the other hand, lead impairs heme synthesis through enzyme inhibition, thereby affecting hemoglobin production. Studies have shown more and/or strong evidence that links the value of iron, together with calcium, Vitamin C and Vitamin D, in addressing lead toxicity (Ahamed, et al., 2007; Kordas K, 2017, WHO, 2021). It would have been valuable information if serum iron, calcium, Vitamin C and Vitamin D were determined in this survey.

Blood Lead and Health Effects

Studies have shown that even at very low levels, lead exposure is linked with various end-organ effects. For children, literature has demonstrated that the neurobehavioral effects of lead have been observed at levels as low as 2.4 ug/dL such that at present, no blood lead threshold has been established in children (Bellinger & Needleman, 2003; Canfied et al., 2003; Lanphear et al., 2000, 2005; Rossi 2008). Published estimates would suggest that the theoretical minimum risk of health effects of lead may occur at concentrations as low as 0-1 ug/dL (Pruss-Ustun et al., 2004). Studies among Filipino children (Dioquino, et al., 2010; Panganiban, et al., 2013) have shown that children with BLLs > 5 ug/dL had lower median IQ scores for the 3 domains of perceptual reasoning index, working memory index and processing speed index. The reverse relationship was observed more for perceptual reasoning index. The study of Solon , et al. (2008) demonstrated that a 1 ug/dL increase in BLL was associated with a 3.32 point decrease in cognitive functioning of children aged 6 months to 3 years and a 2.47 point decrease among children belonging to the 3-5 years age group.

Although the WHO guideline (2021) has recommended some interventions at blood lead levels of $\geq$ 5 ug/dL, it would still be prudent that the Philippine government takes the appropriate action even for BLLs that are below 5 ug/dL. This is because of the non-threshold nature of lead's effect on human health. The current lead levels of children from the survey sites pose some public health concerns because levels below the action or reference level can still cause neurodevelopmental deficits. The government should adapt strategies to identify potential exposures and implement appropriate plan to reduce and prevent these exposures.

The action level continues to be reviewed by regulatory agencies and scientific experts. Thus, in October 2021, the United States-Centers for Disease Control (US-CDC) has lowered the reference level to 3.5 ug/dL (CDC, 2022). The value was derived from the NHANES data from 2015-2016 and 2017-2018. This updated reference value would all the more persuade the government and other stakeholders to address current lead exposures.

Potential Sources

The survey showed home-based activities that maybe potential sources of lead among children and pregnant women. Thus, it would be interesting to find out if lead is present in these household materials. A home-based assessment is needed to provide evidence for direct exposure.

In contrast, responses regarding potential lead exposures from industrial plants were 6.86 % (Table 9). This observation differed from the identified sources of lead exposure in the studies of Suplido, et al (2003) and Gole Cruz, et al (1984) which were environmental in nature, such as the household's proximity to lead-emitting industries. Furthermore, the heavy traffic density was considered a significant exposure in the 1984 study. To note, the Clean Air Act was only enacted in 1999. Thus, gasoline was still a major source of lead exposure in 1984. Still, it is important to also investigate the other possible sources of lead in the survey areas such exposure to peeling/chipping paints, the use of traditional remedies, cosmetics and talc powder.

It is also worth exploring further the potential sources of lead exposure in the Visayas, considering the higher BLLs of children from the provinces in this area as compared with the other sites.

CONCLUSION & RECOMMENDATIONS

The initial findings showed that the mean BLL of all children from the 3 geographic islands was 1.96 $\pm$ 1.26 ug/dL (range of 1.42-38.35). It is below the WHO reference level of 5 ug/dL (2021) and the action level of 3.5 ug/dL as set by the US-CDC (2022). The values in children were higher than the background levels established in the United States, but lower than levels in Asian countries. The children from the Visayas have higher blood lead levels compared with children from Luzon and Mindanao. The potential sources of lead exposure were mostly home-based activities.

Since, there is no threshold level for lead exposure, it is important that the country adapts strategies that will guide health care professionals, especially public health experts, to implement actions to reduce and if possible, eliminate lead. One strategic action is the establishment of a lead monitoring and surveillance system. Activities include (1) the regular blood lead monitoring to better establish the background levels among Filipino children and pregnant women; (2) a home-based assessment for potential sources of lead exposure; and (3) development of diagnostic tools for early detection of lead exposure and the timely initiation of appropriate interventions to prevent onset or progression of disease.

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