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Prenatal exposures to mercury (Hg) and lead (Pb) have been extensively studied and found to have multiple adverse health effects on the developing fetus. While blood concentration levels of these two toxic metals have been documented in several major parts of the world, no such exposure evaluation has been done for the Caribbean region. This paper confirms that neonates in the Caribbean are being exposed to both Hg and Pb and highlights the need to implement surveillance programs that continuously monitor, intervene, and evaluate the levels of these toxic elements to ensure that they are reduced as far as possible.

Mercury and lead blood concentrations in pregnant women from 10 Caribbean countries

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Abstract

Maternal mercury (Hg) and lead (Pb) blood concentrations were measured in a total of 442 samples taken from pregnant and delivering women in 10 Caribbean countries. Hg was detected in all 10 countries with the geometric mean ranging from a low of 0.83 μg/L (Jamaica) to a high of 3.13 μg/L (Grenada). When compared to comparable U.S. and Canadian data, Hg concentrations in Caribbean women are on average more than 2 times higher. With the exception of St. Kitts & Nevis, Pb was detected in at least one of the samples taken from the other 9 countries with two countries—Grenada and St. Vincent – having Pb detected in ≥ 60% of those sampled. In these two countries, the Pb concentrations ranged from a low of 1.17 μg/dL (Grenada) to a high of 1.98 μg/dL (St. Vincent). Compared to comparable U.S. and Canadian data, Pb concentrations in Caribbean women are generally higher than that measured in North America. This study confirms that neonates in the Caribbean are being exposed to both Hg and Pb and highlights the need to implement surveillance programs that continuously monitor, intervene, and evaluate the levels of these toxic elements to ensure that they are reduced as far as possible.

Keywords: mercury; lead; heavy metals; prenatal exposure; Caribbean

1. Introduction

Concerns regarding the adverse health effects of prenatal exposures to heavy metals such as mercury (Hg) and lead (Pb) have been extensively examined and documented.[1-5] Both of these known toxic metals have been found widespread in the environment with resultant human exposure and uptake confirmed.[6] Maternal blood levels of Hg and Pb have been found to be highly correlated with levels measured in the umbilical cord.[7] It has been found that the developing fetus is especially susceptible to the uptake of Hg and Pb since these metals readily cross the placenta from mother to baby.[4, 5, 7-9]

The consumption of ocean fish, and in particular predator fish such as tuna, shark, swordfish, and marlin, can led to very high Hg concentrations in the form of methylmercury.[10, 11] The consumption of ocean fish forms a significant source of protein for many persons in the Caribbean.[12] Major historical sources of lead exposure in the Caribbean have been mainly limited to the use of leaded gasoline and lead-based paints, however, these have been phased out in most Caribbean countries. Although there are no major current sources of lead exposure that can be identified in the Caribbean, given that this heavy metal does not biodegrade, this implies the potential of long-lasting exposures, as has been shown elsewhere.[13] Hence, there is a need to evaluate if Pb exposures are still taking place and at what levels throughout the Caribbean.

Maternal blood Hg and Pb concentrations have not been extensively researched and documented in the Caribbean. As part of a Canadian Global Health Research Initiative's (GHRI) Teasdale-Corti grant programme funded research initiative, the Caribbean EcoHealth Programme[14] launched a study entitled "Prenatal exposures to Persistent Organic Pollutants (POPs), heavy metals and zoonoses" whose prime focus was to determine whether prenatal exposure to POPs, other commonly used classes of pesticides such as organophosphates, carbamates, phenoxy herbicides, and pyrethroids, and two heavy metals, Hg and Pb, was occurring in the Caribbean. The evaluation of pyrethroid exposures in the 10 Caribbean countries that participated in this study is reported elsewhere.[15] This paper reports on the findings of Hg and Pb concentrations in the 10 Caribbean countries where this study was successfully executed.

2. Materials and Methods

2.1. Ethics and Governmental Approvals

Ethics approval to conduct this study was first sought and obtained from the institutions where the principal investigators of this study were based (Laval University, Canada, and St. George's University, Grenada). Additionally, before this study was commenced in any island, ethics approvals were also sought from each Caribbean island's local ethics or institutional review board. If a Caribbean country lacked a local ethics or institutional review board, other mechanisms were put in place such as asking that the Ministry of Health put together a committee to review this study before any samples were taken. In addition to ethics approval, governmental approval, typically through the Ministry of Health within each country, was also sought and obtained before commencement of the study.

2.2. Study protocols

Once ethical and governmental approvals were secured, local nurses and laboratory technicians were identified in each country with the assistance of the local Ministry of Health and trained to collect samples in their respective country. Thus, in each of the 10 countries where this study was executed, locally trained nurses recruited the pregnant and delivering women to participate in this study, obtained their informed consent, and collected the samples.

Locally trained laboratory technicians processed all samples collected by the nurses according to a standardized protocol. Whole blood samples were initially stored in the main hospital in 3 ml plastic EDTA vacutainers at 4°C to avoid freezing and then 1.5 ml each transferred into two 2 ml plastic screw-cap vials and stored at -20°C prior to shipment to the laboratories. All the vials used in this study were transparent Sarstedt vials (www.sarstedt.com) and alcohol-based swab disinfectants were used. The collection and processing of all samples was done using established Laboratoire de Toxicologie of the Institut national de santé publique du Québec (INSPQ) laboratory protocols for Hg and Pb analyzes. Samples were then packed by International Air Transport Association (IATA) certified technicians and shipped in IATA certified boxes packed with dry ice to the Caribbean EcoHealth Programme's mobile Atlantis Mobile Laboratory (AML) facilities and the INSPQ laboratory located in Quebec City, Canada, for analysis. It is noted that the INSPQ laboratory is the reference laboratory for human toxicology in the Province of Quebec, Canada, and this laboratory participated in the Canadian quality assurance/quality control (QA/QC) program of the Canadian Northern Contaminants Program. Besides analyzing most of the samples collected in this study, the AML was used to train local technicians in advanced laboratory techniques. All training was done by INSPQ laboratory technicians and any aberrant sample findings were sent to the INSPQ to be rechecked. For the duration of this study, the AML was set up first in Grenada, then moved to Dominica, and then finally to Barbados. The lab was resident in each of these islands for approximately 10 months.

2.2. Study population and sampling

The recruitment and sampling procedure used in this study was based on the highly successful implementation of the Arctic Monitoring and Assessment Programme (AMAP, www.amap.no)[2]. Following this protocol, pregnant and delivering women ≥ 18 years coming to the main hospital or health clinics to receive prenatal care or deliver were invited to participate in this study by local nurses. Most samples were taken before delivery, however, in some cases these were taken after delivery. As in the AMAP protocol, the Caribbean prenatal exposures research protocol sets a goal of 50 mothers ≥ 18years for each country.

2.2. Laboratory analyzes

All Hg analyzes were done at the AML with the exception of Grenada and St. Vincent and all Pb analyzes were done at the AML with the exception of Grenada's Pb analyzes. To assess comparability between the two laboratories (AML and INSPQ) where Hg and Pb were re-analyzed, tests based on equality of means were conducted on sub-samples.

In the AML, blood total Hg concentrations were determined by cold-vapor atomic absorption spectrometry (Pharmacia Mercury monitor, model 100). Samples were first microwave-digested with nitric acid and then stannous chloride was added to reduce the Hg to its elemental state. Blood Pb concentrations were determined by graphite furnace atomic absorption spectrometry (Perkin Elmer, model ZL 4100). Samples were diluted with an acid solution containing Triton X-100 and ammonium phosphate and injected directly into the instrument. The limits of detections (LODs) for Hg and Pb were 0.2 µg/L (1 nmol/L) and 1 µg/dL (5 nmol/L), respectively.

At the INSPQ toxicology laboratory, determination of total Hg and Pb blood levels was performed by inductively coupled plasma mass spectrometry (ICP-MS). Blood samples were diluted in ammonium hydroxide and the metals brought to their elementary form by passing them through an argon plasma before being identified by mass spectrometry. All samples were analyzed on a Perkin Elmer Sciex, Elan 6000 ICP-MS (DRC II for mercury) instrument. The LODs for Hg and Pb were 0.1 µg/L (0.5 nmol/L) and 0.02 µg/dL (0.1 nmol/L) respectively, and each run of samples included a standard. The inter-assay variability for Hg and Pb measurements was 2.1% and 2.8% respectively.

2.2. Statistical analyzes

An analysis of variance (ANOVA) test was conducted to determine whether Hg and Pb geometric means were different among the 10 Caribbean countries. Multiple comparison tests and contrasts were used in order to identify which of the 10 Caribbean countries have means significantly higher than their counterparts. Hg and Pb data from each island, as well the overall Caribbean Islands data were compared with those recorded from the U.S. and Canada based on non-overlapping confidence intervals. The U.S. Hg and Pb data were extracted from the Centers for Disease Control and Prevention's *Fourth National Report on Human Exposure to Environmental Chemicals, Updated Tables, March 2013* which is based on the U.S. National Health and Nutrition Examination (NHANES) survey.[16] Specifically, the NHANES 2009-2010 sample of 65 pregnant women (based on pregnancy status at the time of health examination) aged 20-42 years was used. For the Canadian data, geometric mean Hg and Pb concentrations were obtained from the Canadian Health Measure Survey (CHMS) sample of 651 women aged

20-39 conducted from 2007-2009.[17] It is noted that the CHMS samples were also analyzed at the INSPQ laboratory, the same laboratory used to conduct the Hg and Pb analyzes for this study.

Given that the distributions of contaminants in human fluids are typically right skewed, and to ensure that assumptions of normality and variance stabilization were met, log-transformations were applied to all measured concentrations and geometric means calculated. The 50th percentile (median) and the 95th percentile was also calculated and presented for comparison purposes. Because of small *n* in the Caribbean countries, distribution-free confidence intervals for percentiles were calculated.

In order to enhance comparability of these results taken from the Caribbean pregnant women with their U.S. and Canadian counterparts, only the results from the countries where these heavy metals were detected in more than 60% (threshold used in the CHMS protocol) of the cases were reported. For samples with non-detected concentrations of Hg and Pb, these were assigned a value equivalent to one half of the level of detection (LOD) limit, 0.20 µg/L and 0.52 µg/dL respectively

All analyzes were carried out using the GLM procedure in the statistical software program of SAS, version 9.3 (SAS Institute, Cary, NC).

3. Results

Between August 2008 to April 2011, out of 442 blood samples taken from pregnant or delivering women from 10 Caribbean countries, 436 Hg and 441 Pb analyzes were successfully performed (**Table 1**). The target of 50 samples in each island was not obtained for each island due to logistical constraints as well as some of the samples on delivery to the lab not having sufficient material in order to carry out the analyzes. For Montserrat, given this island's very small population size, the decision was taken to keep the number of samples taken in this island to 15.

Tests conducted in order to assess comparability between the two laboratories (AML and INSPQ) found no significant differences detected between the two labs results.

Table 1 Sample and population characteristics for the 10 Caribbean countries where the CEHP POPs study was executed

Country (Country Code)	Total Population[1]	Total No. of Samples Collected	No. of Hg Analyzes	No. of Pb Analyzes	Previous Delivery (%)	Avg Age (yrs)	Age range (yrs)
Antigua & Barbuda (**ANU**)	89,018	40	39	39	N/A[2]	N/A[2]	N/A[2]
Belize (**BLZ**)	327,719	50	50	50	73.9	24.4	18 to 36
Bermuda (**BDA**)	69,080	50	50	50	46.0	24.9	18 to 38
Dominica (**DOM**)	73,126	48	48	48	61.7	28.8	19 to 44
Grenada (**GND**)	109,011	52	52	52	65.4	26.5	18 to 44
Jamaica (**JAM**)	2,889,187	47	47	47	63.8	26.1	18 to 42
Montserrat (**MON**)	5,164	15	15	15	62.5	28.8	19 to 31
St. Kitts & Nevis (**SKN**)	50,726	44	44	44	N/A[2]	N/A[2]	N/A[2]
St. Lucia (**SLU**)	162,178	46	46	46	67.5	29.4	19 to 38
St. Vincent & the Grenadines (**SVG**)	103,573	50	45	50	70.0	26.7	18 to 42
Total/Average		**442**	**436**	**441**		**27**	

[1] Source: Central Intelligence Agency (https://www.cia.gov/library/publications/the-world-factbook/index.html)
[2] Age of participants was not reported by this country's data collection team.

3.1. Hg (μg/L) concentration results

Hg was detected in all 10 Caribbean country samples with the geometric mean ranging from a low of 0.83 μg/L (Jamaica) to a high of 3.13 μg/L (Grenada) (**Table 2**). The Caribbean women's Hg concentrations were found on average to be more than 2 times higher than those found in U.S (0.75 μg/L) and Canada (0.70 μg/L) with the exception of Jamaica and Bermuda where measured mercury concentrations were likely comparable to those found in North America (**Table 2**). In multiple comparison tests among the Caribbean countries, Grenada with the highest geometric mean Hg concentration was significantly different than the other nine countries ($p < 0.0001$), while Bermuda and Jamaica who both had the lowest geometric means were also significantly different than other eight countries ($p < 0.0001$).

Table 2 Geometric mean and selected percentiles of blood Hg (µg/L) and Pb (µg/dL) concentrations for 10 Caribbean countries along with comparable U.S. and Canadian (CND) results

Mercury (µg/L)	N	Detected in % of N	% of N > 5.8 µg/L	GM 95%CI	Median 95%CI	95th 95%CI	Maximum
ANU	39	97	5	1.86 (1.46-2.37)	1.95 (1.58-2.35) ^	6.59 (4.14-9.87)	9.87
BZE	50	92	18	2.16 (1.59-2.92)	2.34 (1.84-2.76)	13.35 (5.81-21.78)	21.78
BDA	50	71	0	0.84**L (0.62-1.13)	1.03 (0.72-1.56)	3.10 (2.89-4.87)	4.87
DOM	48	92	0	2.21 (1.66-2.94)	2.94 (1.94-3.56)	6.95 (6.14-8.52)	8.52
GND	52	100	21	3.13**H (2.57-3.81)	3.01 (2.61-3.81)	9.63 (6.62-20.06)	20.06
JAM	47	66	6	0.83**L (0.58-1.17)	0.97 (0.52-1.51)	6.40 (3.70-7.75)	7.75
MON	15	93	0	2.05 (1.26-3.33)	2.22 (1.43-3.76)	5.61 (4.68-5.61)	5.61
SKN	44	93	8	1.85 (1.41-2.41)	2.00 (1.69-2.62)	6.06 (4.92-8.12)	8.12
SLU	46	98	2	2.18 (1.82-2.61)	2.19 (1.84-2.91)	4.79 (4.32-8.28)	8.28
SVG	45	100	22	2.64 (1.92-3.63)	2.81 (1.36-3.81)	11.63 (9.03-48.14)	48.14
Caribbean Is.	436	90	9	1.82 (1.65-2.00)	2.09 (1.91-2.36)	7.22 (6.22-9.23)	48.14
CND	651	-	-	0.70 (0.52-0.92)	0.80 (0.59-1.02)	4.77 (2.07-7.46)	-
U.S	65	82	-	0.75 (0.58-0.92)	0.72 (0.53-1.11)	2.81 (1.54-3.32)	3.96

Lead (µg/dL)	N	Detected in % of N	n > 5 µg/dL	GM 95%CI	Median 95%CI	95th 95%CI	Maximum
ANU	40	5	1				
BZE	50	8	0				
BDA	50	8	0				
DOM	48	42	1				
GND	52	100	0	1.17 (1.03-1.33)	1.09 (0.99-1.26)	2.48 (2.07-4.14)	4.14
JAM	47	4	0				
MON	15	7	0				
SKN	44	0	0				
SLU	46	7	0				
SVG	50	98	1	1.98**H (1.75-2.24)	2.07 (1.86-2.28)	3.52 (2.90-7.87)	7.87
Caribbean Is.[d]	102	99	2	1.52 (1.37-1.68)	1.46 (1.24-1.74)	3.11 (2.69-7.87)	7.87
CND	651			0.89 (0.81-0.98)	0.86 (0.77-0.96)	2.05 (1.78-2.32)	-
U.S	65	97		0.64 (0.57-0.71)	0.64 (0.53-0.83)	1.25 (1.03-1.52)	2.02

* 95% CI – 95% confidence interval. ^ Distribution-free confidence limits for percentiles for Caribbean data.
[a] Canadian Hg and Pb results based on the CHMS Cycle 1, 2007-2009 females ages 20-39.
[b] U.S. Hg and Pb results based on the NHANES 2009-2010 pregnant women ages 20-42 years results.
[c] Percent detected above LOD values. Geometric mean and percentiles results are calculated only for those countries where at least 60% of samples were above the LOD. The LOD was replaced by LOD/2 in the means calculation.
[d] Only results for (DOM and SVG) with 60% above LOD were added.
**H Significantly higher than the other countries. **L Significantly lower than the other countries.

In seven of the Caribbean countries sampled, 32 (7%) of the 436 samples in which Hg was detected in this study had Hg concentrations above the US guideline of 5.8 µg/L with seven (2%) of these samples being above the WHO and Canada guideline of 12 µg/L which is based on provisional tolerable weekly intake (PTWI) of 1.6µg/kg bodyweight (Table 2). These 7 samples came from Belize (13.4 µg/L, 21.8 µg/L, 21.1 µg/L), two from Grenada (20.1 µg/L, 12.0 µg/L), and two from St. Vincent (42.1 µg/L, 48.1 µg/L).

3.2. Pb (µg/dL) concentration results

In 7 of the 10 Caribbean countries that participated in this study Pb was found in less than 10% of those sampled (Table 2). When found, however, Pb concentrations were generally higher than those measured in North America. Pb was found in ≥ 60% of the samples in 2 of the 10 Caribbean countries—Grenada (100%) and St. Vincent (98%). Overall, Pb concentrations in these two Caribbean islands (1.52 µg/dL) were higher than those measured in North America with St. Vincent having concentrations approximately 2-3 times higher (1.98 µg/dL) as those measured in Canada (0.89 µg/dL) and U.S. (0.64 µg/dL)(**Table 2**). Comparison tests between these two Caribbean countries where Pb was found in ≥ 60% of the samples revealed that Pb concentrations were statistically higher in St. Vincent ($p < 0.0001$).

Overall, Pb was detected in 137 (31%) of the 441 samples analyzed. Of these positive samples, three – one in Antigua (31.1 µg/dL), one in Dominica (12.4 µg/dL), and one in St. Vincent (7.9 µg/dL) – were found to be over the current Center for Disease Control and Prevention's (CDC) 5µg/dL reference value which is based on the calculated 97.5th percentile of the NHANES-generated blood Pb level distribution in children 1-5 years old.[18]

4. Discussion

4.1. Caribbean women Hg concentration findings

The Hg concentrations in pregnant and delivering Caribbean women are on average more than 2 times higher when compared to comparable U.S. and Canadian data. These results clearly indicate that high Hg exposures are an important public health issue that needs to be addressed by the region's governments and policy makers.

The biological Hg concentration level currently considered 'safe' varies from 5.8 µg/L in the U.S. to 12 µg/L as recommended by the World Health Organization (WHO) and Canada. Based on these thresholds, 32 (7%) samples out of the 436 blood samples in which Hg was detected in this study had Hg concentrations above the US guideline of 5.8 µg/L with seven (2%) of these samples being above the WHO and Canada guideline of 12 µg/L. These above-guideline high exposure cases indicate the need to continuously monitor and educate the population at large, and pregnant women in particular, of the need to ascertain and minimize their exposures to Hg.

It is possible that the Caribbean women who were sampled in this study were most likely exposed to Hg due to regular consumption of large predatory fish that have high methylmercury (MeHg) concentrations. Due to the continuing decrease in the abundance, and hence availability, of reef fish caught and consumed in the Caribbean, it is quite likely that Caribbean women are consuming more of the larger pelagic fish for which catch quantities are increasing in the region.[19] Further, in the Caribbean, the estimated per capita fish consumption rate is significantly greater than the world average of 18 kg/year.[19] Using the FAO's estimate of the total supply available for human consumption divided by the population total, this number can be used as a proxy of the per capita fish consumption rate. For Grenada, St. Vincent, and Dominica, the per capita food supplies were 44kg, 17kg, and 30kg respectively, suggesting high availability and fish consumption rates. Additionally, several studies looking at Hg levels in fishes caught in Caribbean marine waters have found that larger pelagic fish species such swordfish, marlin, and shark, have very high levels of MeHg.[20, 21]

There are also other potential sources for Hg exposure for Caribbean women. In a study of 46 Barbadian women fish folks[21], four women with exceptionally high hair mercury levels—361, 1404, 4012, and 5616 µg/g—were discovered. Follow-up investigations of these four women led to the identification of mercury-containing skin-lightening creams as the source of their high mercury readings with one of the creams being found to have 20,000 ppm of inorganic mercury.[22] This study thus highlights the need for vigilance in looking at alternative, non-traditional ways for Hg exposure within the Caribbean region.

While the majority of the blood samples taken in this study (91%) were below internationally set Hg concentration levels deemed 'safe,' evidence continues to mount that even at these levels of exposure, subtle adverse health effects can occur.[23] Further, one research study has shown that Hg levels in cord blood were almost double those of the mother which suggests that the fetus' Hg exposure levels may be much higher than that of the mother.[7] Thus, an overall goal of any policy program to reduce Hg exposures should be to drive these levels to the lowest level that is possible.

4.2. Caribbean women Pb concentration findings

While Pb concentrations in Caribbean women are generally low and when found lower than those measured in North America, there are exceptions such at St. Vincent which had a geometric mean concentrations more than 2 times higher (1.98 µg/dL) as those recorded in North

American women. Further, while Pb was detected in less than 60% of the samples taken from eight Caribbean countries, individual cases of high Pb exposures were found in several of these countries. Continued surveillance and further research are thus warranted to elucidate the sources and factors that contribute to pregnant women being exposed to this potent fetal neurotoxin.

The, in general, low prevalence of Pb concentrations found in this study's sample population might be in part attributed to the virtual elimination of the use of leaded gasoline in the Caribbean since 2000. It is harder, however, to determine what potential Pb exposures may be due to leaded paints since there are no laws specifically banning the import and use of leaded paints into the Caribbean. However, given that most of the region imports its paint products from the U.S. or Europe, and that whatever paints that are manufactured within the Caribbean lead in not used as an additive, it appears that this known possible source of exposure to Pb is also diminishing.

Notwithstanding the evidence that exogenous sources of Pb exposure appear to be limited and decreasing within the Caribbean region, this study found three women who had Pb concentrations above the CDC's reference value of 5µg/dL which is used to identify children with elevated blood lead levels. This implies that these women's unborn children have a greater exposure to lead than their peers. Further, several studies have shown that endogenous sources of Pb, such as Pb stored in bones, can be a significant source of fetal toxicity when released by the mother during pregnancy.[24-26] This finding lends further support for pro-actively monitoring blood Pb levels before pregnancy since there are no interventions that have been shown to reverse mobilization of Pb in pregnant women from past maternal Pb exposures and given that mobilized Pb stores can represents about 20% of blood Pb measured during pregnancy.[27]

4.3. Study limitations

Since a non-randomized population based sampling strategy was used in this study, there are some limitations placed on the comparability of these study results when comparing them to the NHANES and CHMS population-based sample results. Pregnant women presenting themselves for delivery at the country's main health care institution were targeted during the period this study was conducted in that country. There is no evidence to suggest, however, that those who were sampled during the sample collection period differed in any material way from those who were not sampled. Given that the majority of births in most of the Caribbean countries included in this study takes place in one or two healthcare facilities–typically the sole main hospital located on the island–and given that the populations on these islands are relatively small (<100,000) and homogenous, it is very likely that the samples which were taken in this study are representative of the population from which they were drawn. Further, while participants selected for this study were sampled over a relatively short one to two month period, there is very little seasonal variation in Caribbean lifestyle that we can infer and so the women included in this study are very likely similar to those who delivered at times outside this study's sampling window.

While this study is the first to provide initial measures of the concentrations of Hg and Pb in maternal samples taken from 10 Caribbean countries, the variability of Hg and Pb concentrations measured from among these islands indicate that each island most likely has its own unique exposure profile. Further, the countries included in this study did not include any of the non-English speaking Caribbean countries. Thus generalizing these results to the whole

Caribbean region should not be done in lieu of determining exposure profiles for each individual Caribbean country.

Further, there are also some limitations placed on the interpretation of these results due to the limited sample size. As mentioned earlier, the sampling protocol used in this study was based on the highly successful implementation of the Artic Monitoring and Assessment Programme.[2] A notable departure from the AMAP protocol was the sample size of 50 given that no prior systematic biomonitoring study on heavy metals exposure in the Caribbean had previously been done, and a larger sample size would better be able to represent possible variability of exposure levels among different mothers within each country and between countries. Further, samples of size $n > 30$ are usually considered sufficient for most parametric tests that rely on the assumption of normality for the distribution of the outcome variable.

For the larger islands such as Jamaica and Belize, however, it is possible that even the samples of $n = 50$ were not large enough and that some selection bias may have occurred in the recruitment of pregnant mothers. In the case of Jamaica, its population is much higher (2.7 million inhabitants) compared to the other Caribbean countries that participated in this study. Belize's population is very heterogeneous characterized by multiple different subgroups differentiated by culture, language, and ethnicity for which a sample size of 50 pregnant women might not have provided a representative snapshot of the entire population.

The validity of comparing the findings from these 10 Caribbean countries with each other and with Canadian and U.S. results is hampered somewhat by the fact that different analytical laboratory techniques with differing LODs were used. In the AML, cold-vapor atomic absorption spectrometry with LODs of 0.2 µg/L and 1 µg/dL for Hg and Pb respectively was used to analyze the samples. At the INSPQ laboratory, Hg and Pb blood levels were determined by using ICP-MS which provided for LODs of 0.1 μg/L and 0.02 μg/dL respectively and which represents a 2 and 50 fold increase in sensitivity for samples analyzed at this laboratory compared to those analyzed at the AML. Fontaine et al.[28] compared ICP-MS and atomic absorption methods for blood Pb and Hg measurements at the INSPQ laboratory and obtained very strong correlations and low biases. We can therefore assume that both methods yield comparable results, however, the ICP-MS method is far more sensitive and hence more likely to pick up very low Pb concentration levels. Given that only the Grenada (both Hg and Pb) and St. Vincent (only Hg) heavy metal analyzes were done at the INSPQ laboratory and that these two countries had detected Pb in almost 100% of the samples taken, this gives support to the assumption that higher percentages of detected Pb might have been seen if ICP-MS was used to analyze all the samples collected in this study.

5. Conclusion

This first Caribbean exploratory biomonitoring study on the concentrations of Hg and Pb in maternal blood samples taken from 10 Caribbean countries clearly reveals that Caribbean fetuses are experiencing prenatal exposures to these potent neurological and developmental toxicants. The significance of such exposures during fetal development is further compounded by the fetus' physiological immaturity and longer lifetime over which any disease or disorder initiated by exposure to these two toxicants can develop. In this study, Hg and Pb were found in 93% and 31% respectively of the 442 samples tested. Given the much higher Hg levels seen in Caribbean women, systematic, continuous biomonitoring of Hg blood concentrations should be instituted, especially for pregnant women or those who plan to become pregnant and other high risk groups such as fisher folks and their families. While Pb concentration were generally very low, many individual high readings were found which indicates a need for future studies to try and elucidate what other risk factors, other than island of residence, might be causing these high Pb exposures and whether there is a potential for high risk in certain sub-populations living in the Caribbean. The results of this study therefore reinforce the need for Caribbean governments and public health officials to have programs in place that continuously monitor, intervene, and evaluate the levels of Hg and Pb found in persons who live in this region of the world to ensure that they are reduced as far as possible.

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