What Is in the Caribbean Baby? Assessing Prenatal Exposures and Potential Health Outcomes to Environmental Contaminants in 10 Caribbean Countries

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ABSTRACT

Objectives: *To assess prenatal exposures and potential health outcomes to environmental toxicants such as persistent organic pollutants (POPs), commonly used pesticides, and two heavy metals – mercury (Hg) and lead (Pb) – in 10 Caribbean countries.*

Subjects and Methods: *For each participating Caribbean island, approximately 50 maternal blood and urine samples were collected and analysed for POPs such as polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs), other common classes of pesticides used in the Caribbean such as organophosphates (OP), carbamates, chlorophenols and pyrethroids, and for Hg and Pb. Data obtained from the participating countries were compared with those from the United States of America and Canada.*

Results: *A total of 438 samples were analysed from 10 Caribbean countries. Persistent organic pollutants were detected in almost all samples, however, these were generally low compared with comparable North American results. Evidence of exposure to PBDEs, OPs, carbamates and chlorophenols was also established. Caribbean pyrethroid concentrations were generally much higher than those recorded for North American women. Caribbean Pb maternal blood levels were generally lower than in North America, whereas Hg blood levels were two to three times higher. In almost all of the samples taken in this study, exposures to multiple chemicals were taking place at the same time.*

Conclusion: *This first Caribbean-wide exploratory biomonitoring study on the concentrations of several toxicants in maternal samples taken from 10 Caribbean countries clearly reinforces the need for Caribbean primary care physicians and other public health officials to encourage their patients, and in particular pregnant women, to reduce their exposures to these environmental contaminants as far as it is feasible to do so.*

Keywords: Environmental exposures, persistent organic pollutants, pesticides, pregnancy, prenatal exposure

¿Qué hay en los Bebés del Caribe? Evaluación de las Exposiciones Prenatales y los Resultados Potenciales para la Salud a Causa de Contaminantes Ambientales en 10 Países del Caribe

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RESUMEN

Objetivos: *Evaluar las exposiciones prenatales y los resultados potenciales para la salud a causa de sustancias tóxicas ambientales, tales como los contaminantes orgánicos persistentes (COP), los pesticidas comúnmente usados, y los dos metales pesados – mercurio (H_g) y plomo (Pb) – en 10 países del Caribe.*

Sujetos y métodos: *De los participantes de las islas del Caribe, se recogieron un total de aproximadamente 50 muestras de sangre y orina maternas. Las muestras fueron entonces analizadas para determinar la presencia de COPs, tales como los bifenilos policlorados (PCD) y los éteres difenílicos polibromados (PBDE), otras clases comunes de plaguicidas utilizados en el Caribe como organofosfatos (OF), clorofenoles, carbamatos y piretroides, así como los metales pesados Hg y Pb. Los datos obtenidos de los países participantes fueron comparados con los de los Estados Unidos de América y Canadá.*

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Resultados: *Se analizaron un total de 438 muestras de 10 países del Caribe. os contaminantes orgánicos persistentes se detectaron en casi todas las muestras, aunque generalmente a niveles bajos en comparación con los resultados similares de América del Norte. También se estableció la evidencia de la exposición a PBDE, OF, carbamatos y clorofenoles. Las concentraciones de piretroide en los casos del Caribe, eran generalmente mucho más altas que las registradas para las mujeres de América del Norte. Los niveles de Pb en la sangre materna en el Caribe, eran generalmente más bajos que en América del Norte, mientras que los niveles de Hg fueron de dos a tres veces mayores. En casi todas las muestras tomadas en este estudio, las exposiciones a múltiples sustancias químicas estaban teniendo lugar al mismo tiempo.*

Conclusión: *Este primer estudio exploratorio de biomonitoreo a nivel de todo el Caribe, enfocado en las concentraciones de varias sustancias tóxicas en muestras maternas de 10 países del Caribe, refuerza claramente la necesidad de que los médicos de atención primaria en el Caribe así como otros funcionarios de salud pública, estimulen a sus pacientes – en particular a las embarazadas – a que reduzcan su exposición a estos contaminantes ambientales, en la medida en que sea factible hacerlo.*

Palabras claves: Exposiciones ambientales, contaminantes orgánicos persistentes, plaguicidas, embarazo, exposición prenatal

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INTRODUCTION

Prenatal exposures to persistent organic pollutants (POPs) such as dichlorodiphenyltrichloroethane (DDT), polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs), other classes of pesticides like organophosphates (OPs), carbamates and pyrethroids, and the heavy metals mercury (Hg) and lead (Pb) have all been associated with multiple adverse health outcomes. This is especially the case for the developing fetus where these toxicants are known to interfere with hormonal and neurological development, the immune system, and other physiological functions (1–4).

Persistent organic pollutants are organic chemical substances that resist environmental degradation and hence persist in the environment. Over time, they bio-accumulate in animal and human tissue and as a result have the potential to cause significant adverse impacts on human health (5, 6). Their toxic effects can be elicited *via* multiple mechanisms such as disruption of the endocrine system, oxidation stress and epigenetic changes (7). In the Caribbean, POPs have been extensively used for different purposes including agriculture and vector control (8). While most countries have formally banned the use of the so-called legacy POPs, several Caribbean countries have acknowledged past use of several of these compounds – in particular dieldrin, DDT, toxaphene and aldrin. Given that POPs can persist in the environment, biota and humans for periods of time measured in decades, their concentrations will decrease only slowly in populations that have been previously exposed. Further, given that significant concentrations of POPs may persist in the environment for many years, this may cause local foods to be contaminated for a long period of time even if the use of these chemicals has been stopped.

Due to the known environmental hazards of using POPs and the global push to eliminate their use, several Caribbean countries have switched over to using other classes of pesticides such as organophosphates (OPs), carbamates and pyrethroids. While these classes of pesticide may not be as persistent and hence potentially damaging to human health as POPs, evidence of their effects on perinatal life is only now being extensively studied. There is thus a need to assess exposure of Caribbean populations to these chemicals in areas where they are used. For example, OPs, while less persistent in the environment, exhibit much higher acute toxicities (9). Prenatal exposure to propoxur (Baygon), a common carbamate pesticide used in the Caribbean, was found in a Philippines study to have a significant negative relationship with motor development of children at two years of age, after controlling for confounders (10). Pyrethroids, another very common class of pesticides used in the Caribbean to control for household insects, are known neurotoxicants (11). Heavy metals such as Hg and Pb are known to interfere with the normal development of the nervous system of the fetus (12, 13).

As part of a Canadian Global Health Research Initiative's (GHRI) Teasdale-Corti grant programme funded research initiative, this study was conducted with the aim to determine whether prenatal exposure to multiple environmental contaminants was occurring in the Caribbean.

SUBJECTS AND METHODS

All 15 Caribbean member states of the Caribbean Community (CARICOM) were approached to participate in this study. Within the allowed timeframe to conduct this study, ethics and governmental approvals were successfully obtained from 10 CARICOM member states. Once ethical and governmental approvals were secured, with the assistance of the local Ministry of Health, nurses and laboratory technicians were identified in each country and trained to collect samples. Thus, in the 10 countries where this study was executed, locally trained nurses recruited the pregnant or delivering women to participate in this study, obtained their informed consent, and collected the samples.

The recruitment and sampling protocol (including determination of sample size) used in this study was adapted from those used in a similar exposure assessment programme carried out in circumpolar countries (5). Based on logistical and statistical considerations, a goal of recruiting 50 pregnant women within a narrow age range in each country was set. Further details on the study design and sampling protocols used in this study are provided elsewhere (14).

From August 2008 to April 2011, a total of 438 samples were successfully analysed from pregnant or delivering women from the 10 participating Caribbean countries. Maternal blood and urine samples were collected and analysed for POPs, other commonly used classes of pesticides in the Caribbean, and two heavy metals – mercury and lead. All samples were collected from pregnant or delivering women who were recruited in healthcare settings, typically the sole main hospital or major polyclinic health centres located in each country.

Laboratory analyses

All samples were initially processed in the main hospital located in each country and stored at -20 °C prior to shipment to the laboratories used in this study. For shipment, samples were packed by International Air Transport Association (IATA) certified technicians and then shipped in IATA certified boxes packed with dry ice initially to a mobile laboratory facility used in this research study called the Atlantis Mobile Laboratory (AML) and then to the Laboratoire de Toxicologie of the Institut National de Santé Publique du Québec (INSPQ) located in Quebec City, Canada, for analysis. In addition to analysing most of the samples collected in this study, the AML was used to train local technicians in advanced laboratory techniques. Institut National de Santé Publique du Québec laboratory technicians did all the training 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 laboratory was resident in each of these countries for approximately 10 months.

Statistical methods

Data obtained from the 10 participating Caribbean countries were compared with those from the United States of America (USA) and Canada. The USA data were extracted from the National Health and Nutrition Examination Survey (NHANES) 2003–2004 survey for POPs, organophosphate and carbamates metabolites. In the NHANES study, analyses were conducted at the United States Centers for Disease Control and Prevention (US CDC) and included approximately 3000 participants. The Canadian data were obtained from the Canadian Health Measure Survey (CHMS) which was conducted from 2007–2009.

Given that measured human contaminant concentrations are typically right skewed, geometric means instead of arithmetic means were calculated since these provide a better measure of central tendency. To enhance comparability of these results taken from the Caribbean women with their USA and Canadian counterparts, results are presented for the environmental contaminants which were above the limit of detection (LOD) in more than 60% (threshold used in the CHMS protocol) of the samples. For samples with non-detected concentrations, these were assigned a value equivalent to one half of the LOD limit. All analyses were carried out using the GLM procedure in the statistical software programme of SAS, version 9.3 (SAS Institute, Cary, NC).

RESULTS

From August 2008 to April 2011, a total of 438 participant blood and urine samples were collected and analysed from 10 Caribbean countries (Table).

Dichlorodiphenyltrichloroethane, a pesticide which was once commonly used worldwide but now is either banned or used in very controlled settings for vector control purposes,

Table: Sample and population characteristics for the 10 Caribbean countries that participated in the study

Country (country code)	Total population[1]	Total no. of samples collected	Mean age (years)	Age range (years)
Antigua and Barbuda (ANU)	89 018	39	N/A[2]	N/A[2]
Belize (BLZ)	327 719	50	24.4	18 to 36
Bermuda (BDA)	69 080	50	24.9	18 to 38
Dominica (DOM)	73 126	47	28.8	19 to 44
Grenada (GND)	109 011	50	26.5	18 to 44
Jamaica (JAM)	2 889 187	47	26.1	18 to 42
Montserrat (MON)	5164	15	28.8	19 to 31
St Kitts and Nevis (SKN)	50 726	44	N/A[2]	N/A[2]
St Lucia (SLU)	162 178	46	29.4	19 to 38
St Vincent and Grenadines (SVG)	103 573	50	26.7	18 to 42
Total/Average		**438**	**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

was found in 60% of the samples taken in Antigua and Barbuda, Belize and Montserrat. The highest geometric mean recorded came from Belize (1.18 μg/L). DDE (1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene), a major metabolite of DDT, was measured in at least 60% of the samples taken in Antigua and Barbuda, Belize, Bermuda, Dominica, Grenada, Montserrat, St Lucia and St Vincent and the Grenadines, with Belize again having the highest geometric mean (10.9 μg/L). Three congeners of PCB (138, 153 and 180) were present in almost all of the Caribbean women sampled in this study.

Levels of organophosphate metabolites were similar to those found in Canada and the USA. The carbamate pesticide metabolite 2-isopropoxyphenol was not detected in Jamaica or Belize, however, in other countries, this metabolite was detected in about 20% of the samples. There was also evidence of exposure to chlorophenols and PBDEs.

Pyrethroid metabolite concentrations in Caribbean pregnant women were generally higher in the 10 Caribbean countries than levels reported for North American women. The geometric mean concentration of cis-2,2 dibromovinyl–1,2-dimethylcylopropane-1-carboxylic acid (cis-DBCA), a key pyrethroid metabolite, was significantly higher in Jamaica (0.07 μg/L) and Antigua and Barbuda (0.11 μg/L) than in the other eight Caribbean countries together ($p < 0.0001$ and < 0.0012, respectively). Further details and results of the evaluation of pyrethroid exposures in the 10 Caribbean countries that participated in this study are reported elsewhere (15).

Mercury was detected in all Caribbean country samples with the geometric mean ranging from a low of 0.83 μg/L to a high of 3.13 μg/L. When compared to relevant USA and Canadian data, Hg levels in Caribbean women were on average more than two times higher. With the exception of St Kitts and Nevis, Pb was detected in at least one of the samples taken from the other nine 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 to a high of 1.98 μg/dL. Compared to comparable USA and Canadian data, Pb concentrations in Caribbean women are generally higher than that measured in North America.

DISCUSSION

The findings of this study clearly indicate that Caribbean fetuses are exposed to multiple chemical toxicants.

For most of the POPs in general, relatively low concentration levels were found in pregnant Caribbean mothers. However, DDE, the major metabolite of DDT, was found in all the samples taken in this study. This is indicative that past exposure to DDT did take place. In the case of Belize, DDT was detected in the majority of Belizean women at relatively high concentration levels. The high exposure levels to DDT in Belizean women were not surprising since the Ministry of Health in Belize has allowed the importation of DDT into this country for the specific use in mosquito control as part of their malaria control programme. These high levels of human exposure to DDT in Belize should lend support to efforts to look for less toxic chemical alternatives, especially since evidence is mounting that the mosquito malaria vector is increasingly becoming resistant to the toxic action of DDT (16). Also, only in Belize was exposure to the insecticide Mirex detected in 68% of the samples, pointing to past widespread use of this chemical in that country and this chemical's robustness to persist in the environment for very long periods of time.

For organophosphates and carbamates where acute toxicity is the primary concern, little is currently known of the long-term chronic effects of low dose during pregnancy. In this study, OP metabolite concentrations were in the low range. Chlorophenols, because of their broad-spectrum antimicrobial properties, are used as preservative agents and disinfectants and also as herbicides, fungicides and insecticides. In general, low levels of the metabolites of chlorophenols were found with the exception of 2,5-dichlorophenol which was high in the following Caribbean islands: Antigua and Barbuda (5.14 μg/dL), Bermuda (8.48 μg/dL), Jamaica (9.38 μg/dL) and St Kitts and Nevis (5.01 μg/dL). This could be explained by the frequent use of toilet deodorants and mothballs which contain para-dichlorobenzene.

For the 10 Caribbean countries that participated in this study, exposures to pyrethroids were found at levels typically seen in tropical environments. This is because pyrethroids, especially deltamethrin, have many uses ranging from agricultural use to home pest control. For example, pyrethroids are one of the primary ingredients in ant chalk. For Antigua and Barbuda, St Lucia and Jamaica, it is clear that deltamethrin is the most widely used pyrethroid. These results highlight the need to educate Caribbean persons, and in particular pregnant women, on the need to use this class of pesticides more judiciously given that the evidence in now mounting that pyrethroids can and do pose adverse health consequences to the developing fetus.

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 to the NHANES and CHMS population-based findings. There is no evidence to suggest, however, that pregnant women presenting themselves for delivery in each of the 10 Caribbean countries' main health care institutions during the sampling 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 of most 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.

There are also potentially some limitations placed on the interpretation of these results due to the limited sample size. However, the sampling protocol used in this study was based on the highly successful implementation of the Arctic Monitoring and Assessment Programme [AMAP] (5). Whereas in

the AMAP protocol, a sample size target of 30 was set, this was increased to 50 for this study given that no prior systemic biomonitoring study on environmental contaminant exposure in the Caribbean had previously been done, and a larger sample size would be able to better cater for 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.

Based on the findings that prenatal exposure to many environmental contaminants is taking place in the Caribbean, future studies will now be required to explore and elucidate what are the sources and/or potential causes of these exposures. The call for a comprehensive, longitudinal Caribbean-based population survey similar to the ones in the USA (NHANES) and Canada (CHMS) is warranted since such a cohort survey will help yield information on not only the distribution and shape of the exposure profiles being experienced by persons living in the Caribbean, but will also help illuminate the risk factors that are associated with such exposures. Further, such a Caribbean population survey will, over time, provide regional governments and other non-governmental agencies working in the area of health promotion and protection the data necessary to verify whether any implemented intervention or policy is making any impact.

CONCLUSIONS

This study's findings clearly reveal that prenatal exposure to many highly neurotoxic and developmental toxicants is taking place throughout the Caribbean region. Future studies are now needed to elucidate what are the sources of these exposures so that appropriate preventative measures can be taken to avoid further exposures. These results also reinforce the need for Caribbean primary care physicians and other public health officials to encourage their patients, and in particular pregnant women, to reduce their exposures to these environmental contaminants as far as it is feasible to do so. Further, these findings point to the need for the region's policy-makers and governments to implement policies that will help further reduce, and eventually eliminate, the presence of these toxicants from the Caribbean region.

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