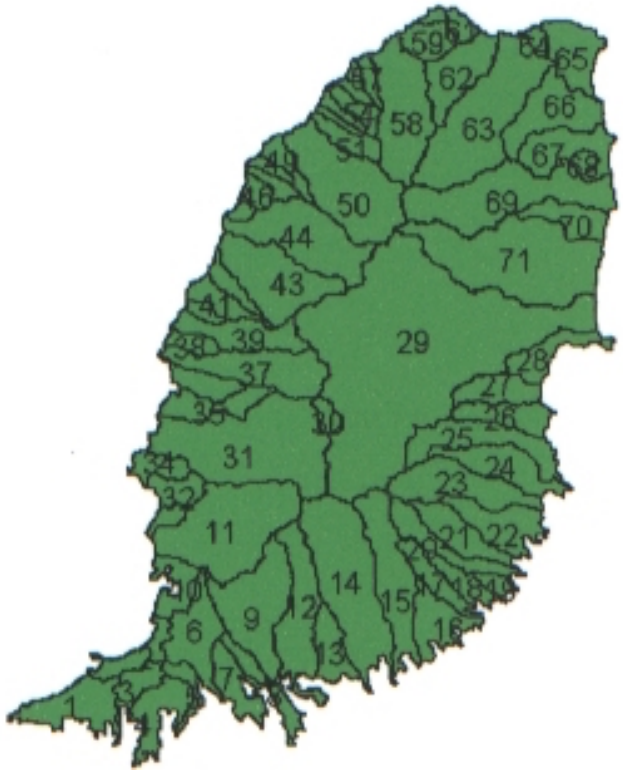
Impact of pesticide contamination on surface water sources in Grenada



St. George's University
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Grenada

CWWA
CARIBBEAN WATER AND WASTEWATER ASSOCIATION

Presented at
Caribbean Water & Wastewater Association's 25th Annual Conference and Exhibition
Port of Spain, Trinidad
October 24-28, 2016

Demographics

Key Demographics

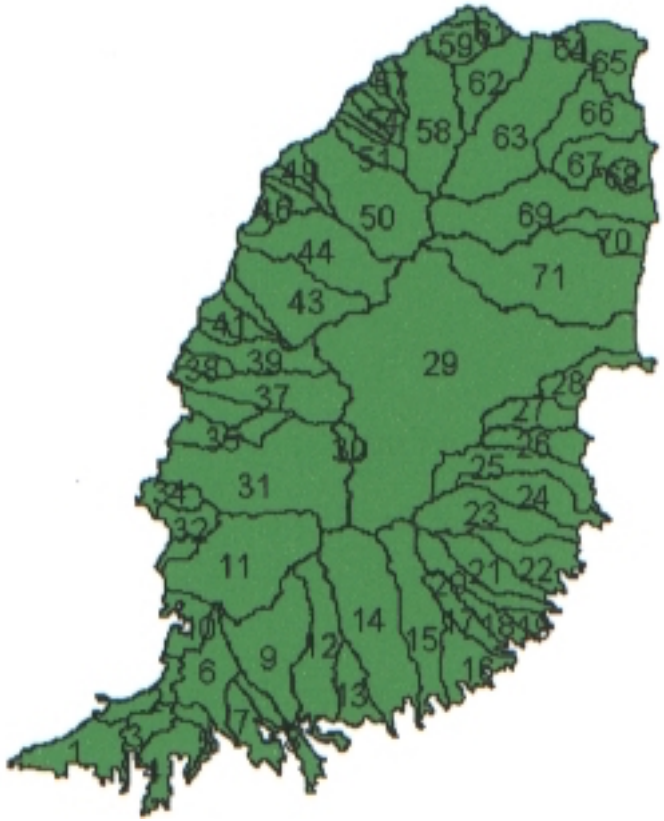
- Population: 110,000
- GDP (per capita): $11,800
- Labor force – by occupation
  - Agriculture: 11%
  - Industry: 20%
  - Service: 29%

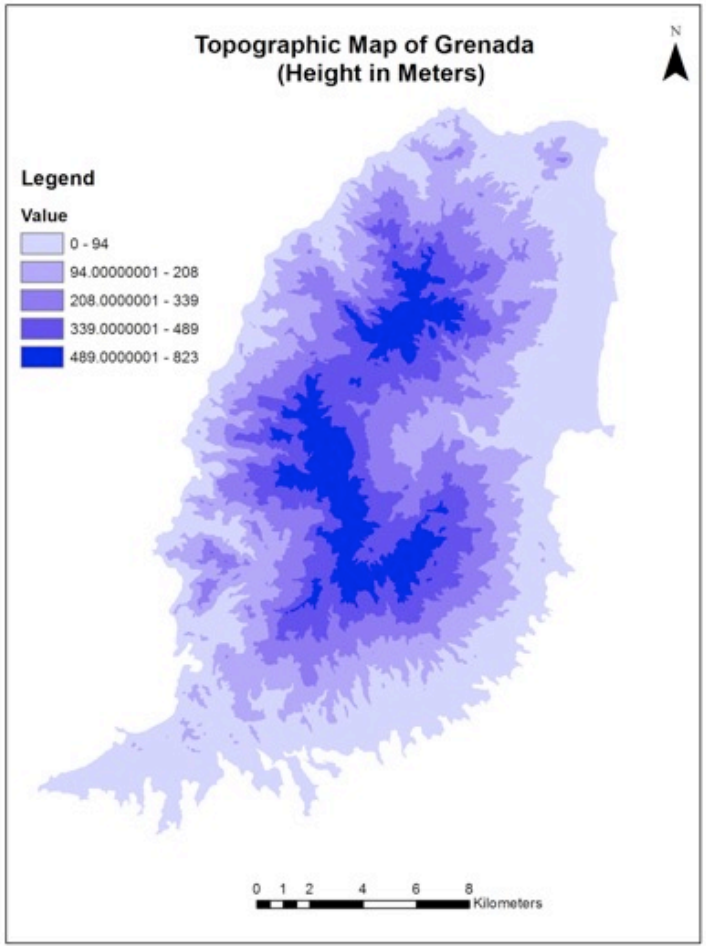
Grenada

Geomorphology and Topography of Grenada

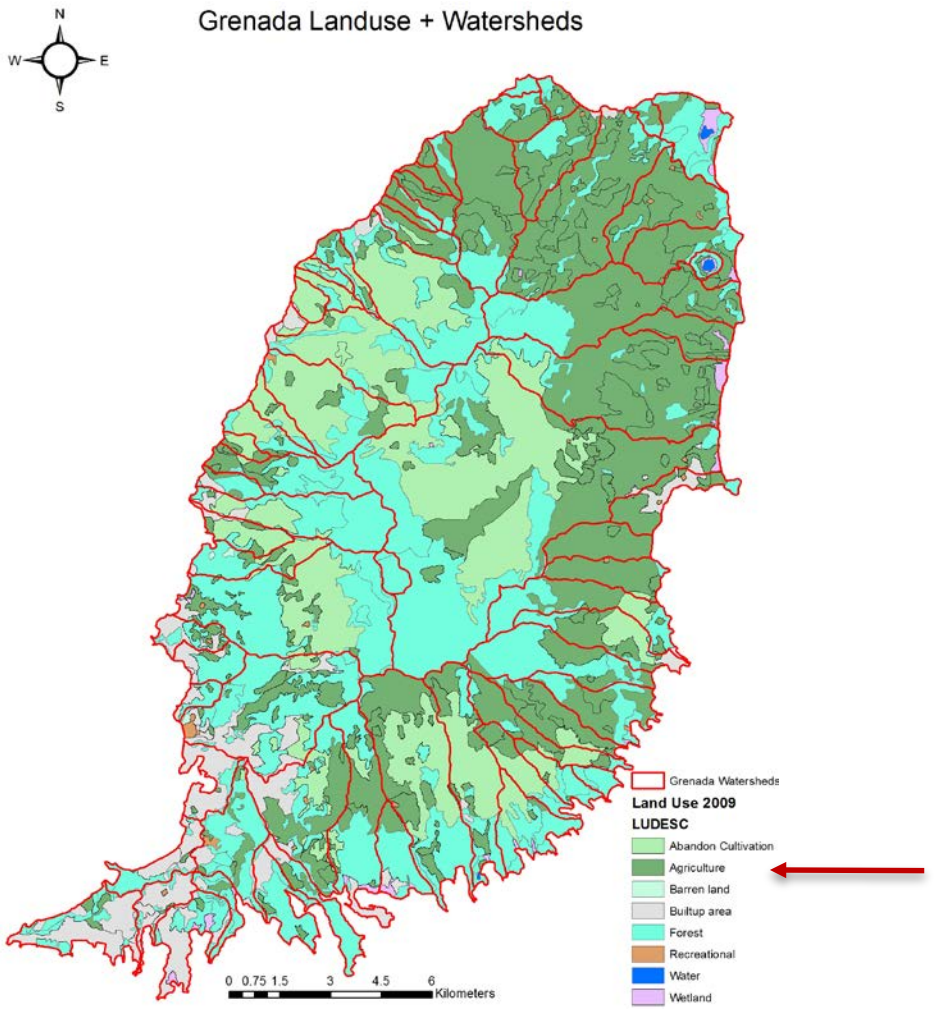
- Approximately 70% of the mountain slopes in Grenada have a gradient greater than 20˚ which predisposes terrestrial resources to rapid water runoff and land degradation.
- Land based sources of pollution ultimately affects the marine environment through leaching, washout and fallout.
- **Agricultural activities** in the form of chemicals used and waste generated are the main sources of non-point pollution of the upland watersheds.

Sources of Water in Grenada





Land Use and Watersheds



Use of Pesticides in Grenada

- Use of pesticides unregulated and unmonitored
- Most farmers rely almost entirely on chemical control
- Most farmers lack the necessary knowledge and guidance concerning pesticide usage

Grenadian Farmer Demographics

Descriptor	
Number of Farmers	9,345
Gender Male	71%
Median Age (Males)	51 yr
Median Age (Females)	53 yr
Number of farms < 1 Acre	52%
Number of farms < 2 Acres	71%

Source: FAO Agriculture Census 2012

Grenadian Farmers' Pesticide Use

Pesticide Type	N = 9,345	%
Fungicides	432	5%
Herbicides	637	7%
Insecticides	716	8%
Other pesticides	383	4%

Source: FAO Agriculture Census 2012

Threats to Freshwater Ecosystems

- Pollution from agricultural chemicals and waste
- Agricultural practices in watershed areas introduce chemical residues into these ecosystems
- Heavy sediment load of streams as a result of erosion cause by the removal of vegetation
- Farming too close to the banks or farming on slopes that are too steep
- Washing of gears and equipment laden with agricultural chemicals in streams

Farming practices in Grenada

- Most vegetable crops are affected by a number of pests and diseases
- Farmers rely almost entirely on chemical control
- Most farmers lack the necessary knowledge and guidance concerning pesticide usage
- Pesticides often prove ineffective because of inappropriate usage
- Several pests have apparently developed some degree of resistance towards certain pesticides

Tropical Fruits and Vegetables

Sample of Approved Insecticides for Grenada

Insecticides (active ingredients)		
Temephos	Clomazone	Chlorfenapyr
Thiamethoxam	Fipronil	Profenofos
Pirimiphos methyl	Deltamethrin	Imidacloprid
Nylar and Linalool	Cypermethrin	Dimethoate
Pyriproxyfen	Dimethyltoluamide	Carbaryl
Permethrin	Diazinon	Spinosad
Propoxur	Trichlorfon	Cyromazine
Flumethrin	Pyrethrins	Oxamyl
Resmethrin	Malathion	Methoprene
Chlorpyrifos	Hydramethylnon	Indoxacarb
Tetramethrin	Azadirachtin	Diafenthiuron
d-allethrin	Abamectin	Cypermethrin

Sample of Approved Herbicides for Grenada

Herbicide (active ingredient)	
Bentazon	Pendimethalin
Bromoxynil	MSMA
Metribuzin	Sethoxydim
Fluazifop butyl	Diquat
Paraquat dichloride (gramoxone)	Glyphosate
Diuron	2,4-D

The Big Question:

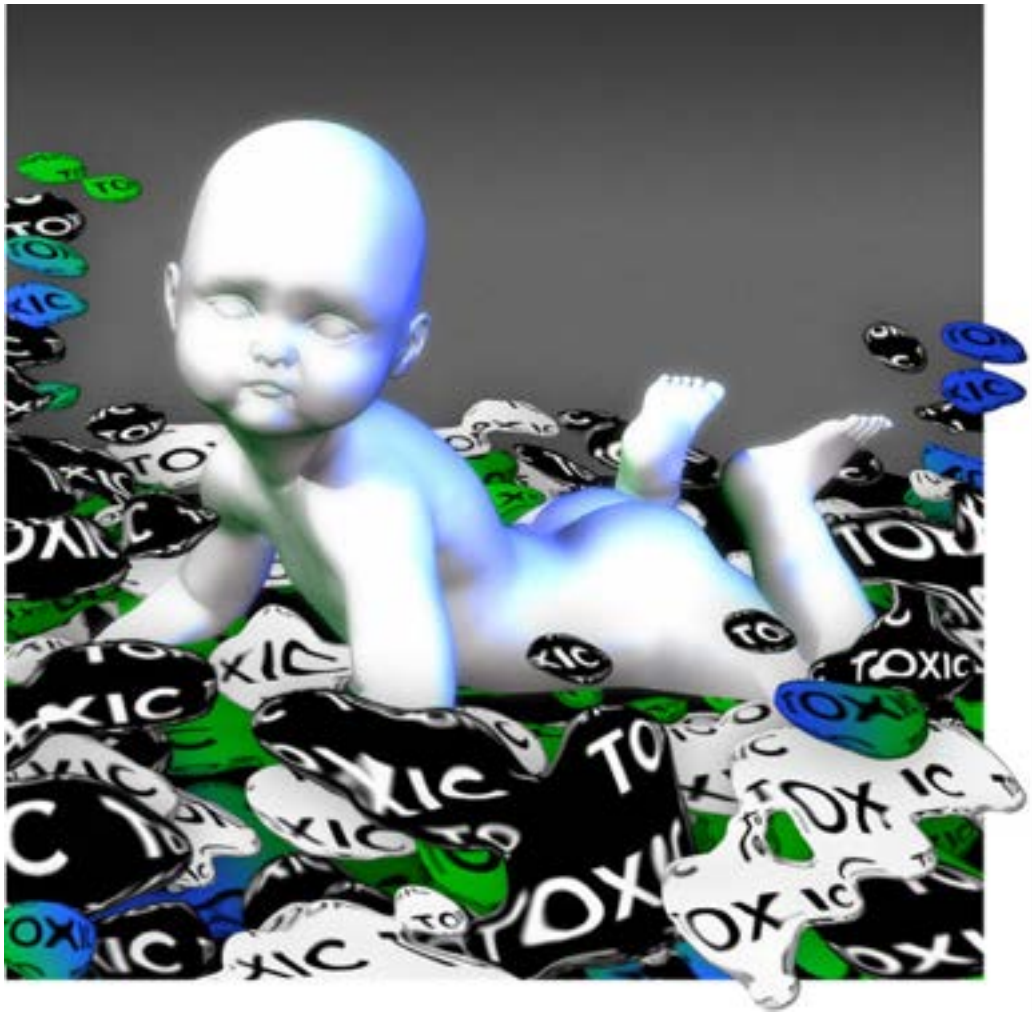
- Are Grenada's water sources being contaminated by pesticides?

Jessamine Eden, Grenada

Picture: David Roberts

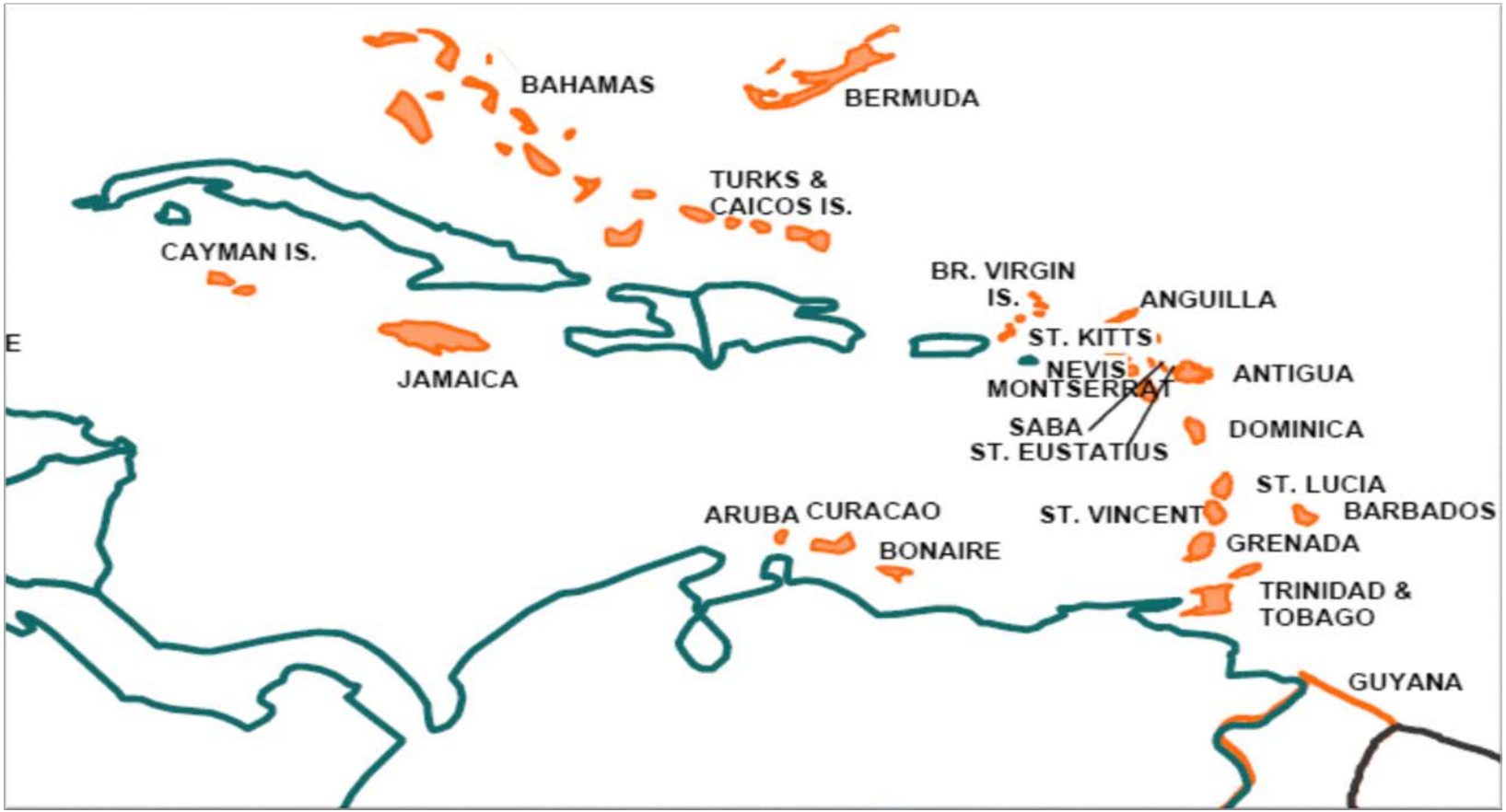
- Most likely Yes
- Unknowns
  - What types?
  - How much?
- Look at surrogate measure: Human Exposure

Human Indicators of Pesticide Contamination of Surface Water Sources



Assessing prenatal exposures to pesticides in 10 Caribbean countries

Data taken from **Human Monitoring of Exposure to Persistent Organic Pollutants (POPs), Pesticides, Metals and Zoonosis** Study



Methodology

The Atlantis Mobile Laboratory:
An Environmental and Public Health Tool

Funded by the Canadian Foundation for Innovation, Canadian Government, Laval University, and the XL Foundation

- ***Self sufficient*** mobile laboratory
- Provides ***accessibility*** of fully functional lab to remote areas
- Facilitates ***training*** and ***knowledge/skills transfer*** where it is most needed

The Atlantis Mobile Laboratory:
Analytical Toxicological Lab Module

Methodology: **Sampling & Analysis Strategy**

- **Sampling strategy**
  - Take 50 maternal blood samples
  - Take 50 maternal urine samples
- **Sampling Analyzes**
  - POPS in blood serum
  - Pesticides in Urine
    - Pyrethroids
    - Organophosphates
    - Carbamates

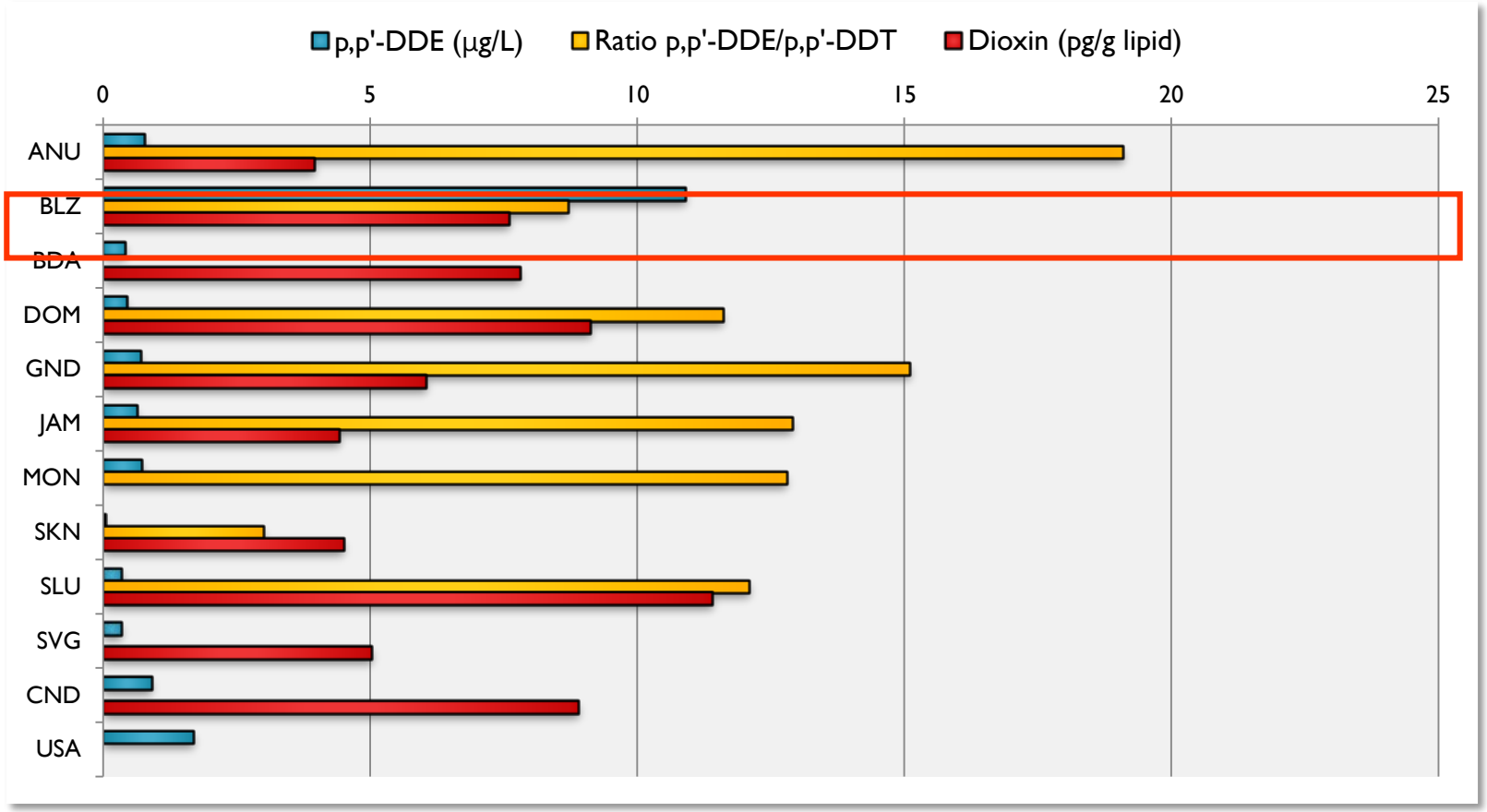
RESULTS

What is in the Caribbean Baby?

Results:
Samples collected

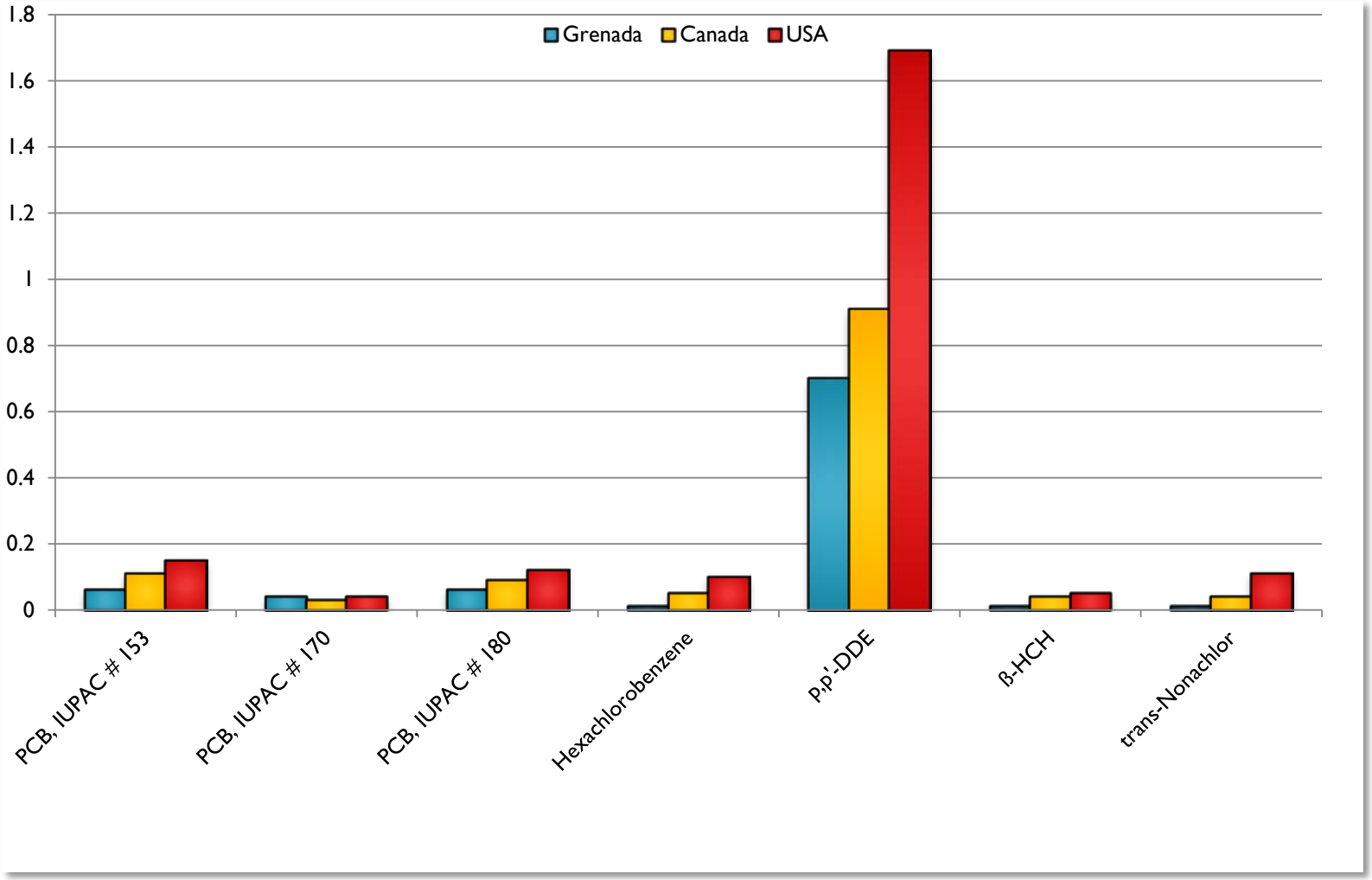
COUNTRY	Number of participants
Grenada	51
St-Lucia	47
St-Vincent/Grenadines	50
Dominica	48
Jamaica	47
Montserrat	15
St. Kitts / St. Nevis	44
Antigua / Barbuda	40
Belize	50
Bermuda	50

Results:
Persistent Organic Pollutants **(POPs)**

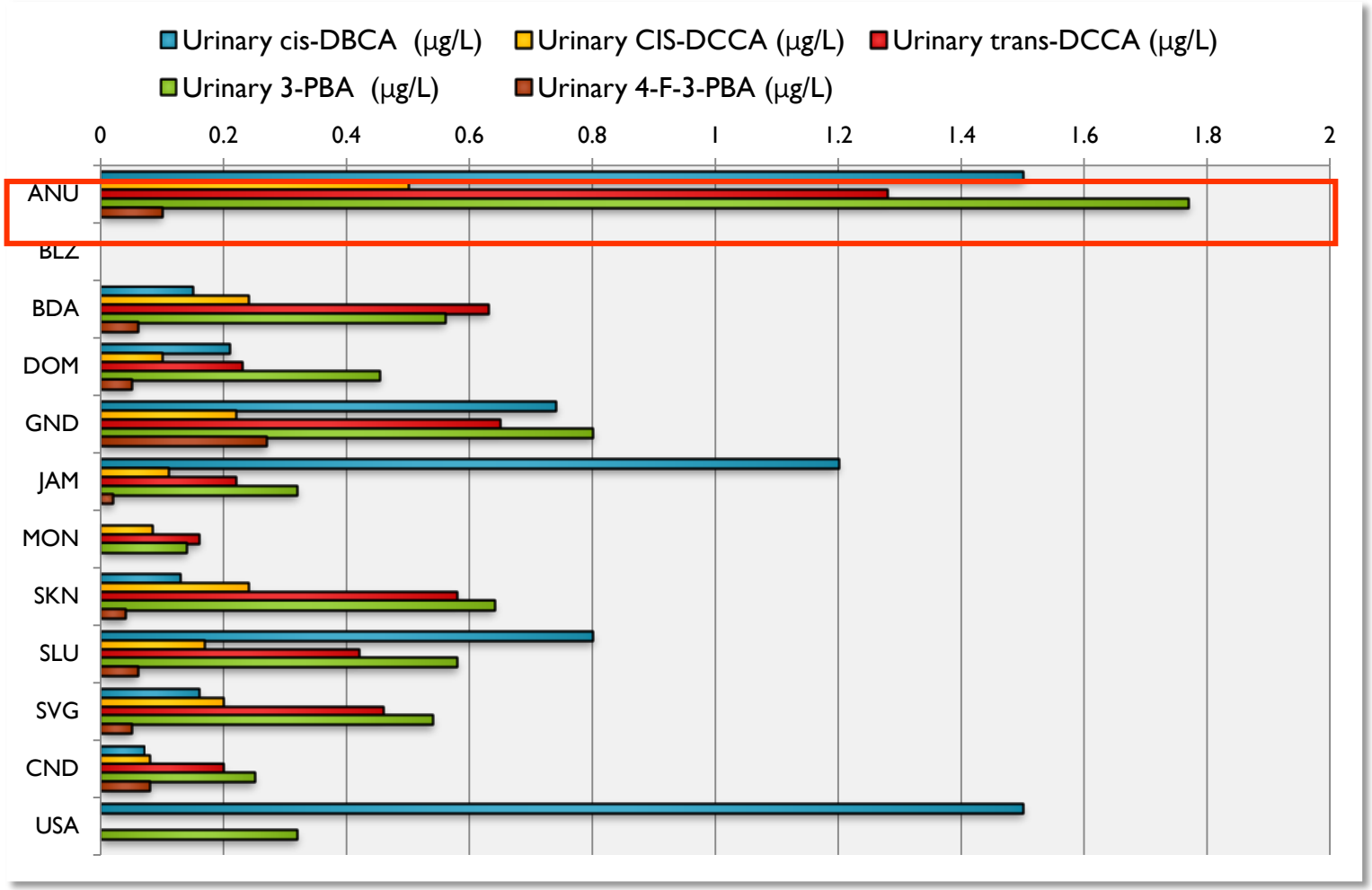


Results

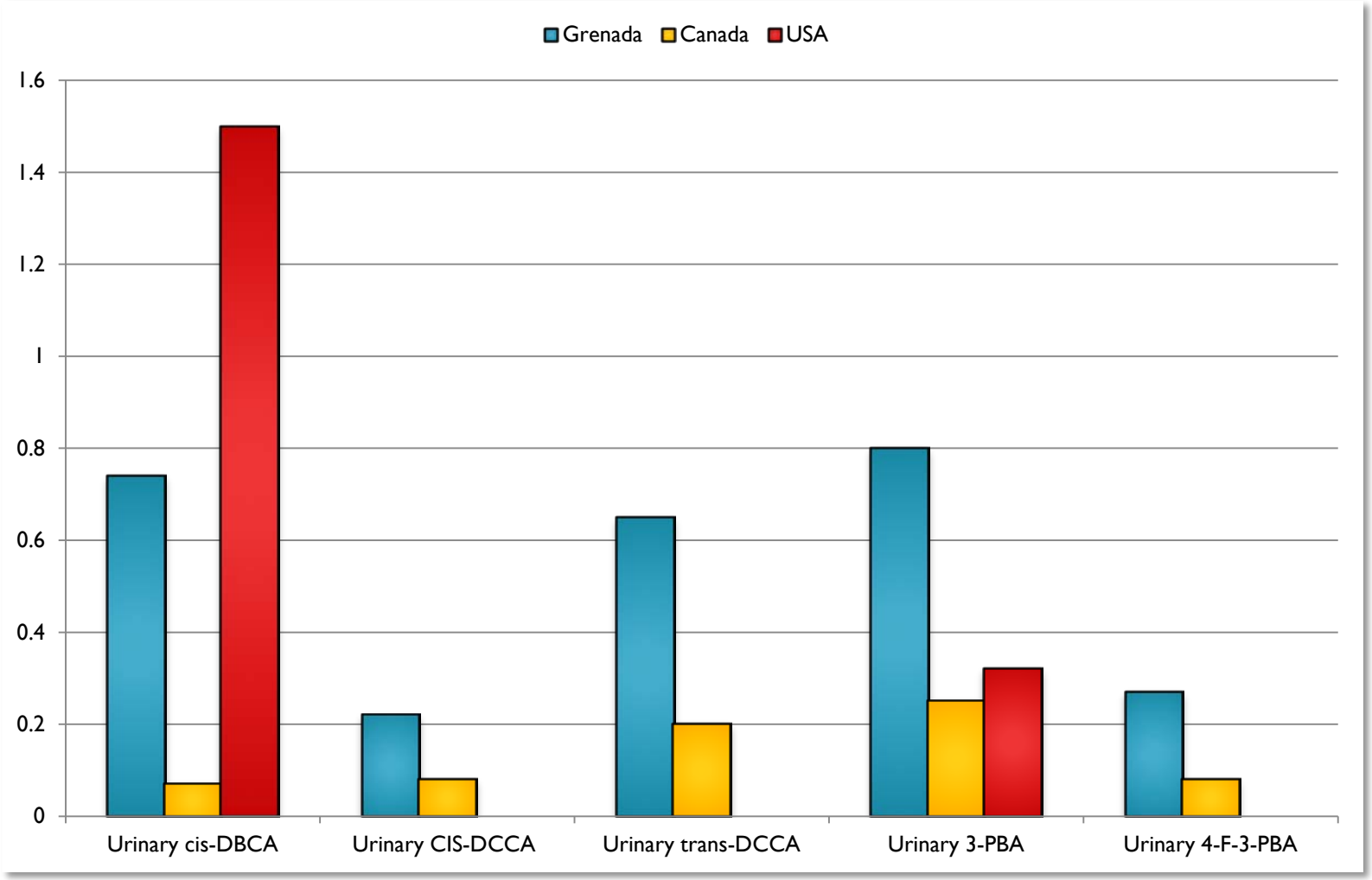
POPs: Grenada vs. U.S./Canada (µg/L)



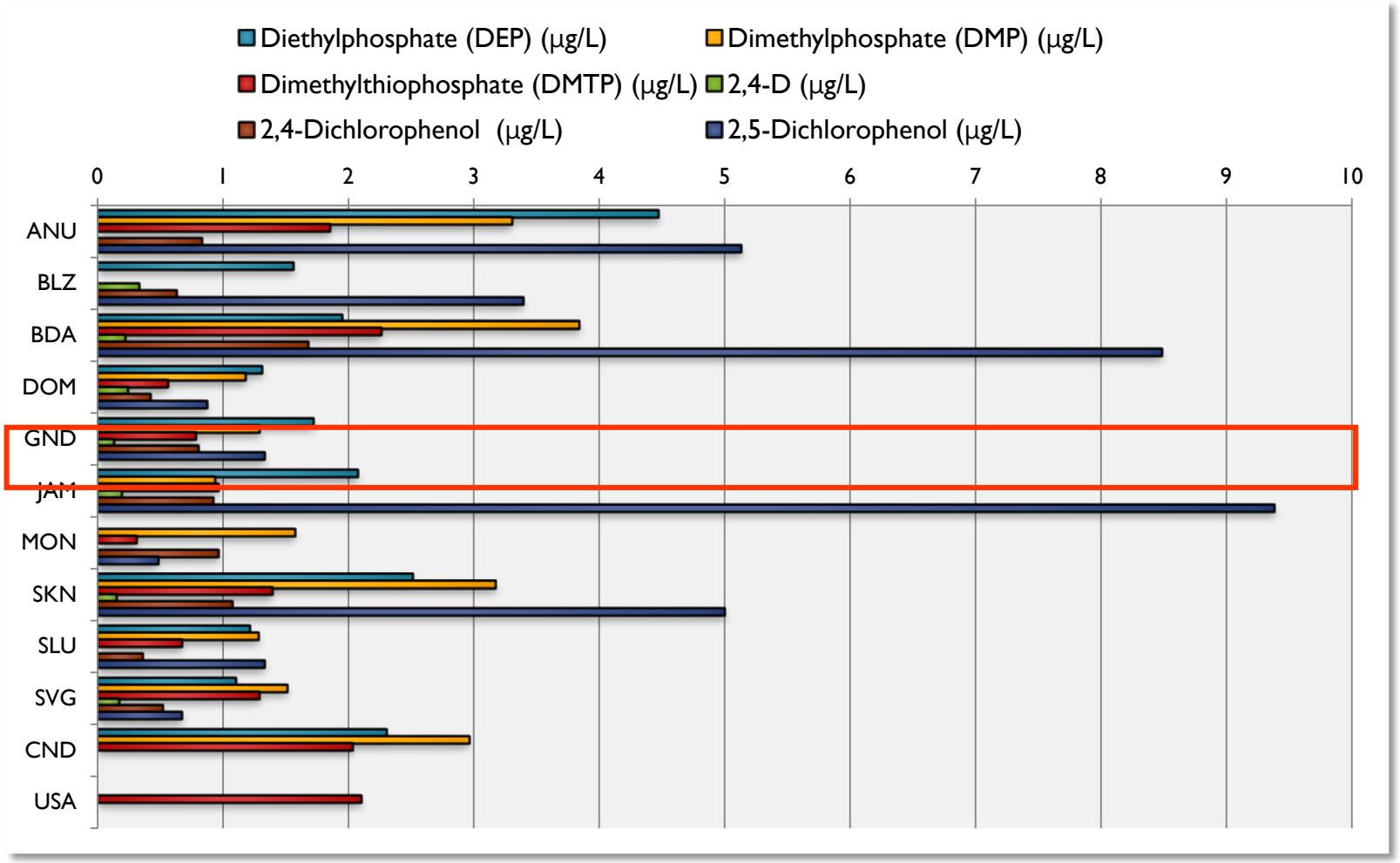
Results:
Pyrethroid Pesticides



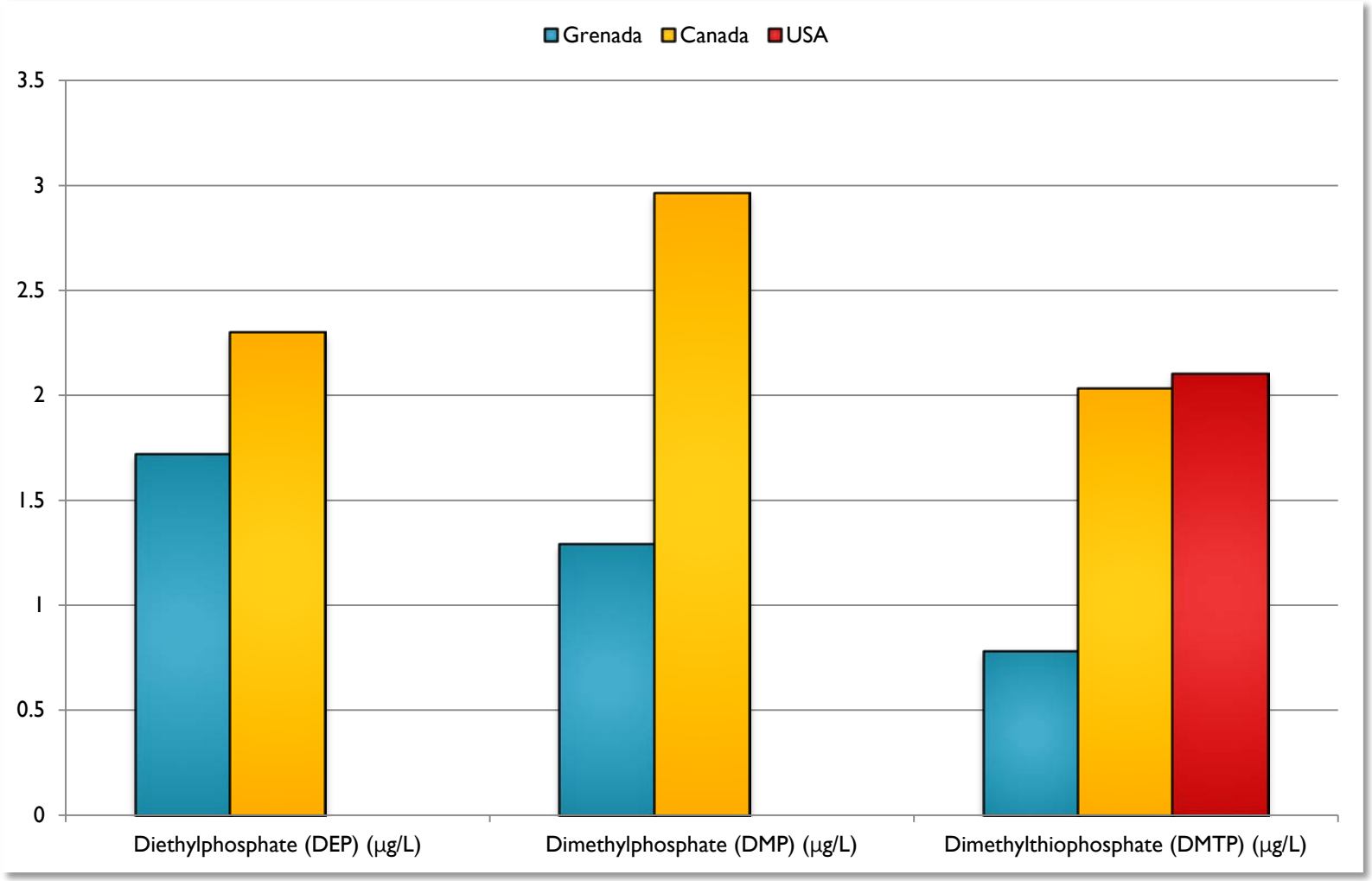
Results:
Pyrethroid Pesticides:
Grenada compared to Canada and U.S. (µg/L)



Results:
Organophosphate Pesticides



Results:
Organophosphate Pesticides:
Grenada compared to Canada and U.S. (µg/L)



Summary of All Country Results: **Hg, Pb, Pyrethroids, POPs, OPs**

Indicator	*ANU (N=40)*	BLZ *(N=50)*	BDA *(N=50)*	DOM *(N=48)*	GND *(N=51)*	JAM *(N=47)*	MON *(N=15)*	SKN *(N=44)*	SLU *(N=47)*	SVG *(N=50)*	CND	USA
Heavy Metals	**ANU** *(N=40)*	**BLZ** *(N=50)*	**BDA** *(N=50)*	**DOM** *(N=48)*	**GND** *(N=52)*	**JAM** *(N=47)*	**MON** *(N=15)*	**SKN** *(N=44)*	**SLU** *(N=46)*	**SVG** *(N=52)*	**CND**	**USA**
Mercury (µg/L)	1.86	2.16	0.84	2.21	3.14	0.83	2.06	1.85	2.19	2.64	0.69	0.86
Mercury (% detected)	97	92	71	92	100	66	93	93	98	100		
Lead detected n out of N (%)	2(5%)	4(8%)	4(8%)	100%	100%	2(4%)	1(7%)	0	3(7%)	100%		
Lead (µg/dl) in n detected	0.59	0.56	0.56	3.67	1.17	0.54	N/A	0	0.54	1.99	1.34	1.29
Pyrethroids	**ANU** *(N=22)*	**BLZ** *(N=15)*	**BDA** *(N=15)*	**DOM** *(N=48)*	**GND** *(N=50)*	**JAM** *(N=45)*	**MON** *(N=7)*	**SKN** *(N=15)*	**SLU** *(N=20)*	**SVG** *(N=10)*	**CND**	**USA**
Urinary cis-DBCA* (µg/L)	1.50	0.85	0.15	0.21	0.74	1.20	N/A	0.13	0.80	0.16	0.07	1.5
Urinary CIS-DCCA (µg/L)	0.50	0.07	0.24	0.10	0.22	0.11	0.08	0.24	0.17	0.20	0.08	N/A
Urinary trans-DCCA (µg/L)	1.28	0.14	0.63	0.23	0.65	0.22	0.16	0.58	0.42	0.46	0.2	N/A
Urinary 3-PBA (µg/L)	1.77	0.21	0.56	0.45	0.80	0.32	0.14	0.64	0.58	0.54	0.25	0.32
Urinary 4-F-3-PBA* (µg/L)	0.10	0.05	0.06	0.05	0.27	0.02	N/A	0.04	0.06	0.05	0.08	N/A
POPs	**ANU** *(N=39)*	**BLZ** *(N=50)*	**BDA** *(N=50)*	**DOM** *(N=47)*	**GND** *(N=50)*	**JAM** *(N=47)*	**MON** *(N=15)*	**SKN** *(N=44)*	**SLU** *(N=46)*	**SVG** *(N=50)*	**CND**	**USA**
PCB, IUPAC # 118 (µg/L)	0.01	N/A	0.01	0.02	0.01	0.04	0.02	0.02	0.01	0.02	N/A	N/A
PCB, IUPAC # 138 (µg/L)	0.04	0.01	0.02	0.03	0.04	0.05	0.04	0.03	0.03	0.07	N/A	N/A
PCB, IUPAC # 153 (µg/L)	0.07	0.01	0.03	0.06	0.06	0.07	0.07	0.07	0.07	0.12	0.11	0.15
PCB, IUPAC # 156 (µg/L)	0.01	N/A	N/A	0.01	0.01	0.01	0.01	N/A	0.01	0.01	N/A	N/A
PCB, IUPAC # 170 (µg/L)	0.02	N/A	N/A	0.01	0.04	0.02	0.01	0.02	0.02	0.03	0.03	0.04
PCB, IUPAC # 180 (µg/L)	0.04	0.01	0.13	0.04	0.06	0.04	0.04	0.04	0.05	0.08	0.09	0.12
Hexachlorobenzene (µg/L)	0.03	0.02	0.02	0.05	0.01	0.02	0.06	0.05	0.03	N/A	0.05	0.1
p,p'-DDE (µg/L)	0.78	10.9	0.41	0.44	0.70	0.63	0.72	0.04	0.34	0.34	0.91	1.69
p,p'-DDT (µg/L)	0.03	1.18	N/A	0.04	N/A	0.02	0.03	0.01	0.02	N/A	N/A	N/A
Ratio p,p'-DDE/p,p'-DDT	19.1	8.7	N/A	11.6	15.1	12.9	12.8	3.0	12.1	N/A	N/A	N/A
ß-HCH (µg/L)	0.01	N/A	N/A	0.01	0.01	N/A	0.01	N/A	0.01	0.01	0.04	0.05
trans-Nonachlor (µg/L)	0.01	N/A	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.04	0.11
Dioxin (pg/g lipid)	3.96	7.60	7.8	9.12	6.05	4.42	N/A	4.50	11.4	5.03	8.9	N/A
Organophosphates	**ANU** *(N=15)*	**BLZ** *(N=15)*	**BDA** *(N=15)*	**DOM** *(N=15)*	**GND** *(N=15)*	**JAM** *(N=15)*	**MON** *(N=15)*	**SKN** *(N=15)*	**SLU** *(N=15)*	**SVG** *(N=15)*	**CND**	**USA**
Diethylphosphate (DEP) (µg/L)	4.47	1.56	1.95	1.31	1.72	2.07	N/A	2.51	1.21	1.10	2.3	N/A
Dimethylphosphate (DMP) (µg/L)	3.30	N/A	3.84	1.18	1.29	0.93	1.57	3.17	1.28	1.51	2.96	N/A
Dimethylthiophosphate (DMTP) (µg/L)	1.85	N/A	2.26	0.56	0.78	0.96	0.31	1.39	0.67	1.29	2.03	2.1
2,4-D (µg/L)	N/A	0.33	0.22	0.24	0.13	0.19	N/A	0.15	N/A	0.17	N/A	N/A
2,4-Dichlorophenol (µg/L)	0.83	0.63	1.68	0.42	0.80	0.92	0.96	1.07	0.36	0.52	N/A	N/A
2,5-Dichlorophenol (µg/L)	5.13	3.39	8.48	0.87	1.33	9.38	0.48	5	1.33	0.67	N/A	N/A

Summary of All Country Results: **Polybrominated flame retardants (PBDEs)**

Polybrominated flame retardants (PBDEs)	ANU *(N=10)*	BLZ *(N=10)*	BDA *(N=10)*	DOM	GND	JAM *(N=10)*	MON *(N=10)*	SKN *(N=10)*	SLU *(N=10)*	SVG *(N=10)*	CND	USA
PBB_IUPAC153 (µg/kg lipid)	0.001	0.001	0.0014	N/A	N/A	0.0012	0.0014	0.0013	0.0012	0.0013	N/A	2.72
PBDE_IUPAC100 (µg/kg lipid)	0.002	0.002	0.0018	N/A	N/A	0.0012	0.0014	0.0027	0.0014	0.0013	N/A	3.77
PBDE_IUPAC153 (µg/kg lipid)	0.001	0.002	0.0027	N/A	N/A	0.0021	0.0020	0.0026	0.0015	0.0013	N/A	N/A
PBDE_IUPAC17 (µg/kg lipid)	0.002	0.002	0.0020	N/A	N/A	0.0018	0.0019	0.0020	0.0019	0.0019	N/A	N/A
PBDE_IUPAC47 (µg/kg lipid)	0.004	0.009	0.0115	N/A	N/A	0.0034	0.0042	0.0083	0.0060	0.0026	N/A	N/A
PBDE_IUPAC99 (µg/kg lipid)	0.002	0.004	0.0034	N/A	N/A	0.0013	0.0015	0.0027	0.0019	0.0013	N/A	N/A

Summary of **Pesticide** Results

- POPs (Organochlorines) and Dioxins
  - Generally very low
- Organophosphates
  - OP metabolites were consistently detected in ≥ 60% of the samples from Antigua & Barbuda, Bermuda, Jamaica
  - Generally levels same as those seen in U.S./Canada
- Carbamates
  - 2-isopropoxyphenol (2-IPP) detected in seven of the 10 Caribbean countries with a detection frequency around 30%

Summary of Results *(cont'd)*

- Phenoxy acid
  - 2,4-dichlorophenoxyacetic acid (2,4-D) ranged from 20% in Grenada to a maximum of 67% in Belize
- Chlorophenols
  - 2,4-dichlorophenol (DCP) geometric means ranged from 0.52 µg/L in St Lucia to a maximum of 1.68 µg/L in Bermuda. Several extreme concentrations of 2,5-DCP were detected in four Caribbean countries—Belize (1100 µg/L), Bermuda (870 µg/L), Jamaica (1300 µg/L), and St Kitts and Nevis (1400 µg/L)
  - 2,4,5-TCP, 2,4,6-TCP, and pentachlorophenol were rarely detected
- Pyrethroid
  - Generally higher than U.S./Canada levels

POP results

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journal homepage: www.elsevier.com/locate/envres

Prenatal exposure to persistent organic pollutants and polybrominated diphenyl ethers in 10 Caribbean countries

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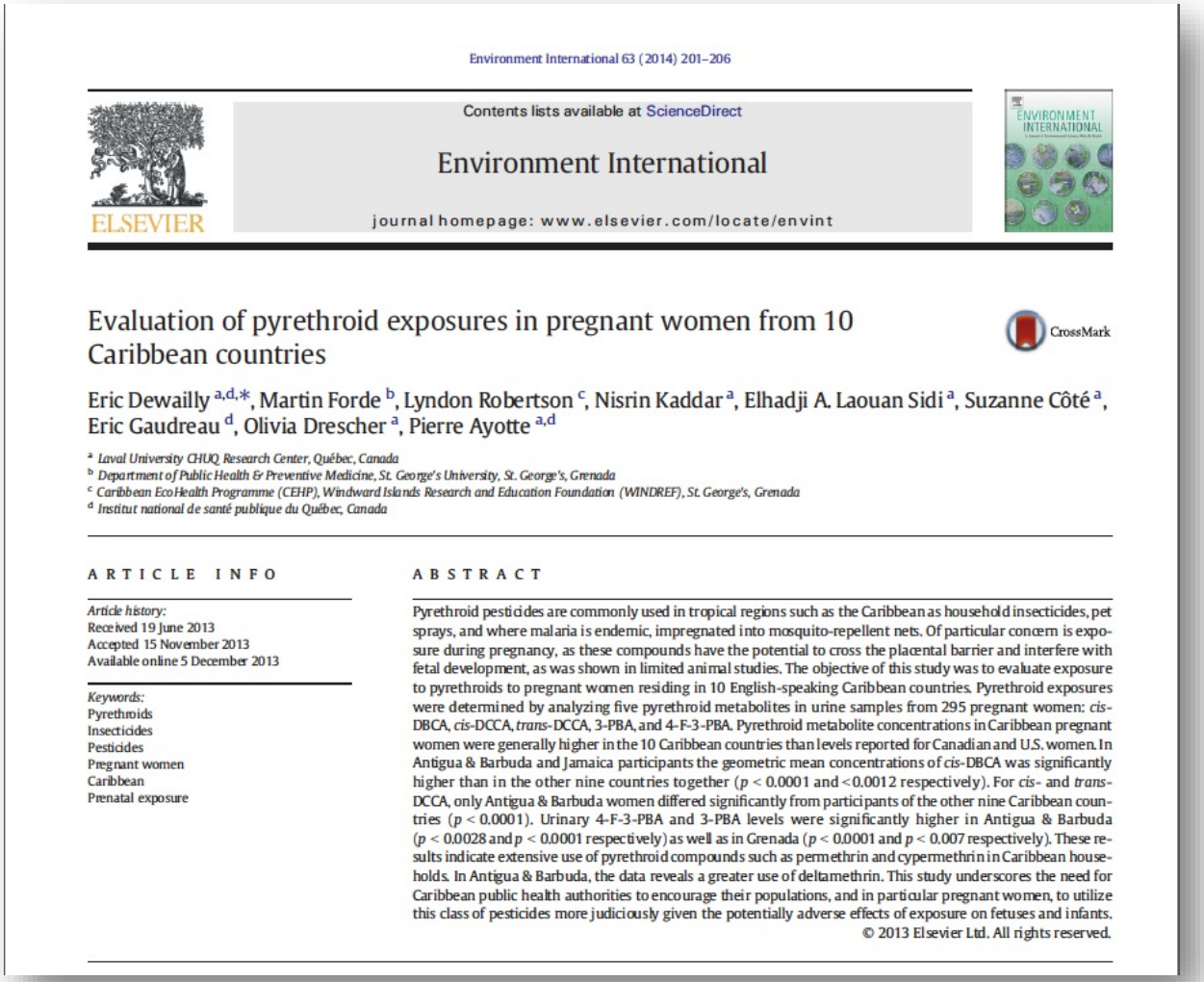
Prenatal exposure

ABSTRACT

Prenatal exposures to legacy persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs) and dioxin-like compounds (DLC), as well as polybrominated diphenyl ethers (PBDE), were analyzed in pregnant women from 10 Caribbean countries. A total of 438 samples were collected and descriptive statistics calculated and compared to comparable Canadian Health Measure Survey (CHMS) and U.S. National Health and Nutritional Examination Survey (NHANES) datasets. Maternal POPs blood concentrations were found to be generally relatively low in the Caribbean samples compared with the U.S. and Canada datasets. Evidence of exposure to DLC and PBDE was established. DLC levels ranged from a geometric mean low of 3.96 pg/g lipids in Antigua and Barbuda to a high of 11.4 pg/g lipids in St. Lucia. Several of the PBDEs (15, 17, 25, 28, 33, 100) were detected in less than 60% of the country's samples. For PBDE-47, significantly higher levels were found in Bermuda, while Jamaica recorded a significantly low level. The overall calculated concentration of PBDE-47 for the Caribbean (5.33 μg/kg lipids) was significantly lower than the concentrations measured for the U.S. (10.83 μg/kg lipids) and Canada (23.90 μg/kg lipids). This study confirms that prenatal expose to multiple environmental chemicals is taking place in the Caribbean and highlights the need to implement surveillance programs that continuously monitor, intervene, and evaluate the levels of these toxic environmental contaminants to ensure that they are reduced as much as possible and that the health risk to humans, in particular the unborn child, are minimized.

Pyrethroid results



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Evaluation of pyrethroid exposures in pregnant women from 10 Caribbean countries

Eric Dewailly [a,d,*], Martin Forde [b], Lyndon Robertson [c], Nisrin Kaddar [a], Elhadji A. Laouan Sidi [a], Suzanne Côté [a], Eric Gaudreau [d], Olivia Drescher [a], Pierre Ayotte [a,d]

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ABSTRACT

Pyrethroid pesticides are commonly used in tropical regions such as the Caribbean as household insecticides, pet sprays, and where malaria is endemic, impregnated into mosquito-repellent nets. Of particular concern is exposure during pregnancy, as these compounds have the potential to cross the placental barrier and interfere with fetal development, as was shown in limited animal studies. The objective of this study was to evaluate exposure to pyrethroids to pregnant women residing in 10 English-speaking Caribbean countries. Pyrethroid exposures were determined by analyzing five pyrethroid metabolites in urine samples from 295 pregnant women: *cis*-DBCA, *cis*-DCCA, *trans*-DCCA, 3-PBA, and 4-F-3-PBA. Pyrethroid metabolite concentrations in Caribbean pregnant women were generally higher in the 10 Caribbean countries than levels reported for Canadian and U.S. women. In Antigua & Barbuda and Jamaica participants the geometric mean concentrations of *cis*-DBCA was significantly higher than in the other nine countries together ($p < 0.0001$ and < 0.0012 respectively). For *cis*- and *trans*-DCCA, only Antigua & Barbuda women differed significantly from participants of the other nine Caribbean countries ($p < 0.0001$). Urinary 4-F-3-PBA and 3-PBA levels were significantly higher in Antigua & Barbuda ($p < 0.0028$ and $p < 0.0001$ respectively) as well as in Grenada ($p < 0.0001$ and $p < 0.007$ respectively). These results indicate extensive use of pyrethroid compounds such as permethrin and cypermethrin in Caribbean households. In Antigua & Barbuda, the data reveals a greater use of deltamethrin. This study underscores the need for Caribbean public health authorities to encourage their populations, and in particular pregnant women, to utilize this class of pesticides more judiciously given the potentially adverse effects of exposure on fetuses and infants.

Pesticides results

Environmental Science
Processes & Impacts

PAPER

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Evaluation of exposure to organophosphate, carbamate, phenoxy acid, and chlorophenol pesticides in pregnant women from 10 Caribbean countries

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Pesticides are commonly used in tropical regions such as the Caribbean for both household and agricultural purposes. Of particular concern is exposure during pregnancy, as these compounds can cross the placental barrier and interfere with fetal development. The objective of this study was to evaluate exposure of pregnant women residing in 10 Caribbean countries to the following commonly used classes of pesticides in the Caribbean: organophosphates (OPs), carbamates, phenoxy acids, and chlorophenols. Out of 438 urine samples collected, 15 samples were randomly selected from each Caribbean country giving a total of 150 samples. Samples were analyzed for the following metabolites: six OP dialkylphosphate metabolites [dimethylphosphate (DMP), dimethylthiophosphate (DMTP), dimethyldithiophosphate (DMDTP), diethylphosphate (DEP), diethylthiophosphate (DETP) and diethyldithiophosphate (DEDTP)]; two carbamate metabolites [2-isopropoxyphenol (2-IPP) and carbofuranphenol]; one phenoxy acid 2,4-dichlorophenoxyacetic acid (2,4-D); and five chlorophenols [2,4-dichlorophenol (DCP), 2,5-dichlorophenol (2,5-DCP), 2,4,5-trichlorophenol (TCP), 2,4,6-trichlorophenol (2,4,6-TCP), and pentachlorophenol (PCP)]. OP metabolites were consistently detected in ≥60% of the samples from Antigua and Barbuda, Bermuda, and Jamaica. Of the carbamate metabolites, 2-IPP was detected in seven of the 10 Caribbean countries with a detection frequency around 30%, whereas carbofuranphenol was detected in only one sample. The detection frequency for the phenoxy acid 2,4-D ranged from 20% in Grenada to a maximum of 67% in Belize. Evidence of exposure to chlorophenol pesticides was also established with 2,4-DCP by geometric means ranging from 0.52 μg L^{-1} in St Lucia to a maximum of 1.68 μg L^{-1} in Bermuda. Several extreme concentrations of 2,5-DCP were detected in four Caribbean countries—Belize (1100 μg L^{-1}), Bermuda (870 μg L^{-1}), Jamaica (1300 μg L^{-1}), and St Kitts and Nevis (1400 μg L^{-1}). 2,4,5-TCP, 2,4,6-TCP, and pentachlorophenol were rarely detected. This biomonitoring study underscores the need for Caribbean public health authorities to encourage their populations, and in particular pregnant women, to become more aware of the potential routes of exposure to pesticides and to utilize these chemicals more cautiously given the possible adverse effects such exposures can have on their unborn children and infants.

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Discussion and Conclusions

Are Grenadian surface waters being contaminated by pesticides?

Picture: David Roberts

What's happening in other Caribbean countries?

- There is a paucity of published data on the quantum and type of pesticides currently being used in most English speaking Caribbean islands
- In one recent review of pesticide use in Jamaica, it was found that while 87% of the annually imported pesticides into Jamaica are applied within agricultural or household settings, the fate of these locally applied pesticides is presently unknown.
- In another study that examined usage patterns of OP pesticides on vegetables in Trinidad found that 10% of examined vegetable produce exceeded internationally acceptable maximum residue limits (MRLs) for OPs. Furthermore, this study found that local farming practices related to the application of pesticides and subsequent harvest of treated crops raised concerns over the possibility of excessive residues on crops sold in local markets

Conclusions

- Grenadian as well as other Caribbean surface water sources likely being contaminated by pesticides
- Clear need for Caribbean governments and public health officials to have programs in place that continuously monitor, intervene, and evaluate all water sources in Caribbean so as to ensure that the threat of pesticide contamination is reduced as far as possible

Moral and Ethical Imperative

Shouldn't this be the safest place on earth?

Thank You!

- Questions?
- Concerns?
- Comments?

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