WORKSHOP "*MERCURY CONTAMINATION AND ITS IMPACT IN HUMAN HEALTH IN BRAZIL*"

2018 Global Health International Conference

"Building Alliances in Global Health"

Florida International University, Miami, Florida

May 22 – 25, 2018

WORKSHOP "*MERCURY CONTAMINATIN AND ITS IMPACT IN HUMAN HEALTH IN BRAZIL*"

MERCURY EXPOSURE EFFECTS ON BRAZILIAN CHILDREN'S HEALTH

Profa Carmen Fróes Asmus / Prof. Volney Camara
Medicine School - Federal University of Rio de Janeiro
carmenfroes@iesc.ufrj.br

MERCURY EXPOSURE EFFECTS ON BRAZILIAN CHILDREN'S HEALTH

FOCUS

- **WHY MERCURY?**
- **WHY CHILDREN?**
- **WHICH ARE THE MERCURY EXPOSURE EFFECTS ON BRAZILIAN CHILDREN'S HEALTH?**
- **HEALTH SURVEILLANCE OF MERCURY EXPOSED POPULATIONS IN BRAZIL**

EPIDEMIOLOGY: WHY MERCURY?

MERCURY EXPOSURE EFFECTS ON BRAZILIAN CHILDREN'S HEALTH

1) Metallic Mercury

is used to make an amalgam with gold (for each 1 kilo of gold we need, more than 1 kilo of mercury)

2) Methyl Mercury

is much more toxic than the Metallic Mercury

General population is contaminated by fish intake, especially riverine and Indians.

MERCURY EXPOSURE EFFECTS ON BRAZILIAN CHILDREN'S HEALTH

Mercury is very toxic! For the whole body but specially for the nervous system.

CHILDREN: MERCURY EXPOSURE

1) of the fetus via the placenta,
2) by breast milk intake in breast-feeding and then
3) fish intake

- **Change in performance on cognitive tests and changes in the neurological development.**
- **Prenatal exposures (high levels): cerebral palsy, microcephaly, hyperreflexia, poor motor skills, intelligence, vision and hearing.**
- **Prenatal exposures (relatively low levels) - sub-clinical effects: Delays / deterioration of neurobehavioral development - cognitive, language, motor, adaptive behavior, and socio-emotional domains.**

EPIDEMIOLOGY: WHY CHILDREN?

MERCURY EXPOSURE EFFECTS ON BRAZILIAN CHILDREN'S HEALTH

Exposure in children is higher compared to adults: Higher body surface area, the greater respiratory rate and increased intake of fluids and food in relation to body weight. Exposure via placenta

Methylmercury: Greater absorption during breastfeeding (decrease after the beginning of the intake of other foods)

It is also greater the possibility of an adverse health effect: Organ systems of children are still under development: blood-brain barrier, respiratory, kidney and immune systems, enzymatic capacity of detoxification of chemicals (ATSDR, 1999).
ETC, ETC. ETC…..

FOCUS

MERCURY EXPOSURE EFFECTS ON BRAZILIAN CHILDREN'S HEALTH

Froes Asmus CIR, Camara VM, Landrigan PJ, Claudio L, **A Systematic Review of Children's Environmental Health in Brazil**, *Annals of Global Health* (2016), doi: 10.1016/j.aogh.2016.02.007.

- ✓ **Eligibility criteria :** the study population was constituted of Brazilian children, from birth to 18 years old, and in the intrauterine period (studies including total population were added when they provided individualized age–specific data);
- ✓ **There was no limit to time of publication (years);**
- ✓ **The literature search** was conducted in the following key resources: PubMed (MEDLINE), Scopus and Web of Science with the MeSH Terms: Environmental exposure AND Brazil (filters: Human, Child (birth - 18 years) and Affiliation Author); Virtual Health Library (databases Scielo and Lilacs) with the DeCS Terms: Child OR adolescent AND Environmental exposure AND Brazil.

FOCUS

MERCURY EXPOSURE EFFECTS ON BRAZILIAN CHILDREN'S HEALTH

Systematic Review 1995 - 2015:

- ❑ 30 articles published about exposure of children to mercury
- ❑ 27 studies in Amazon Region (West and North) and 3 in Southeast region
- ❑ 16 studies: Effects on Children's health from Birth until 10 years old.
- ❑ 10 studies: Mother – infant pair
- ❑ Lactating women: 1 / Pregnant women: 1

AMAZON REGION:

- ✓ **A body of studies has been performed with riverine and urban children in the Amazon region;**

- ✓ **Objective: To investigate the nutritional status and the physical growth and neurodevelopment (social, emotional, language, and cognitive domains);**

Main Results

1. **The exposure to mercury has occurred mainly through fish eating and breastfeeding**
2. **Hair mercury concentration was employed as an exposure biomarker to methyl-Hg in almost all studies.**[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17]

AMAZON REGION:

3. **A significant correlation between maternal hair-Hg with respective children's hair-Hg was observed in all these studies.**

***Marques et al, 2013**: 647 mother-infant pair: high fish-eating communities (urban, n = 232; rural, n = 35; and Riverine, n = 262) and low fish-eating tin-miner settlers (n = 120).*

- *The correlation coefficients between maternal and newborn hair were high and statistically significant for mothers living in **urban (r = 0.66, p < 0.001), rural (r = 0.89, p < 0.001**), and **Riverine (r = 0.89, p < 0.001)** communities not for tin miner settlers (r = 0.07, p = 0.427).*
- *After 6 months: in the mother-infant par with **exclusive breastfeeding,** the **high correlation coefficients and statistical significance kept on for all groups,** except for Tin miners.*

4. **The publications assessed maternal exposure to methylmercury and birth weight[18] and trans-generational fish-methylmercury transfer [19, 20, 21, 22, 23, 24, 25, 26, 27, 28.]**

Marques et al, 2013: *1,433 mother-infant pair: traditional riverines (n = 396), riverines who had moved to urban (n = 676) and rural (n = 67) settings, and tin miner settlers (n = 294).*

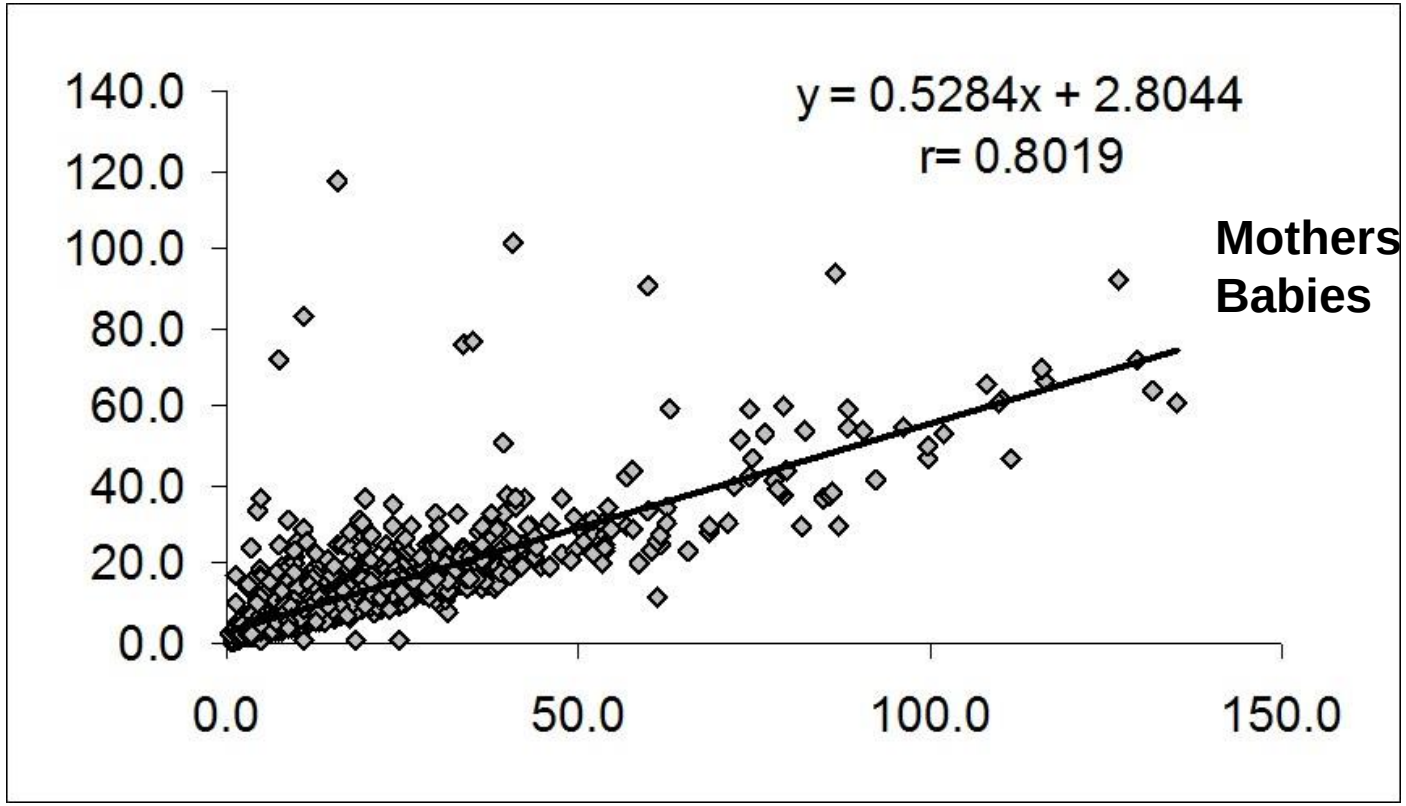
- *Birth weight was significantly different among groups but did not show a pattern consistent with that of fish consumption (and HHg).*
- *A multiple regression analysis showed that only family income and gestational age had a significant impact on birth weight.*

5. **The mercury transfer during pregnancy was examined in 3 studies[15, 16, 17]. The methyl mercury concentrations were assessed in umbilical cord blood (newborn) and venous blood (mother) in 2 studies [15, 16] .**

Dutra et al, 2012: *At birth, a significant correlation was observed (Spearman correlation coefficient = 0.315; p = 0.002) between cord blood and maternal venous blood levels.*

Cord Blood Hg: Median: 10 µg/L; Mean: 14 µg/L

2000 - Correlation between mercury levels in blood of mothers (1,510) and cord blood of newborns (1,510) from Tapajós Basin, Itaituba, Pará Brazil, 2000/2001



Mothers 11,52µg/L
Babies 16,68µg/L

Santos E.O.; De Jesus I.M; Câmara V.M.; Brabo E.D.S.; de Jesus M.I.; Fayal K.F.; Asmus Froes C.I.R. Cad Saude Publica, 2007, 23 (suppl 4), S622-S629.

They also searched on neurodevelopment related with exposure to mercury [23, 24, 25, 26, 27, 28, 29].

•HHg: Hair mercury concentrations;

•Methyl mercury (MHg) and Ethyl-mercury (EthylHg) from TCV: Thimerosal vaccine, combined with adjuvant-Al (Tetanus toxoid, Hepatitis B and DTP vaccines).

•Riverine children and TOKS (tin-ore kilns and smelters): The TOKS are children of families living in the vicinity of tin-ore processing facilities. Exposure to lead .

•GDS: Gesell development scores. The scores of results from Gesell neurodevelopment tests applied for the assessed domains (motor skills, language development, adaptive behavior, and personal social behaviors).

•Lefèvre Evolutional Neurological Test (*): motor and sensory neurological development tests

RB	Context	Main Results
[23]	Assessment of methylHg (from breastfeeding and fish eating) and ethylHg from TCV in three groups: urban, fisherman and cassiterite miners.	**Inverse significant correlation (r = -0.2300; P = 0.0376) between HHg and GDS for urban infants**, but not for the "miners" infants (r = 0.1336; P = 0.0862) and "fisherman" infants (r = 0.1666; P = 0.5182)
[24]	Neurodevelopment (GDS): riverine children < 5 years.	Mean (SD) of HHg ($\mu g \cdot g^{-1}$): Infants: 4.33 (1.7). **Most of the children (76%) showed adequate GDS. Methylmercury exposure had not impact on GDS.**
[25]	Exposure to mercury. Neurodevelopment (GDS): at 6, 36, and 60 months.	Length of lactation was positive and significantly correlated with GDS at 60 months; **HHg was inverse and significantly correlated with GDS at 6 months (r = _0.333; P=0.002) and 60 months (r= _0.803; P=0.010).**
[26]	Neurodevelopment (GDS): at birth and at 6 months in exclusively breastfed infants.	Median [range] of HHg ($\mu g \cdot g^{-1}$): Fetal: 1.59 [0.05 - 19.65]; 6 months:1.81 [0.02 - 32.95]. **Most of the infants (74%) had normal GDS. Mothers of infants with multiple delays also showed the lowest range of income and level of education.**
[27]	Neurodevelopment (GDS): children under 5 years of age living in a transitioning (tin-mining) area of the western Amazon	Mean (SD) of HHg ($\mu g \cdot g^{-1}$): Children: 2.56 (1.67); Infants: 2.28 (1.15). **The multivariate model showed that breastfeeding, a fish consumption biomarker (HHg), maternal education, and child's age were statistically significant associated with specific domains (language and personal-social) of the Gesell scale.**
[28]	Neurodevelopment: GDS and milestones related to walking and talking - exposure to EtHg and MeHg. Two groups of study: fishing community and TOKS.	Median (range) of Mercury Hair concentration ($\mu g \cdot g^{-1}$): "fisherman":3.5 [1.0, 8.7]; "TOKS":2.2 [0.5, 8.6]; $p<0.05$. **There was NO distinctive pattern of neurodevelopment associated with either HHg or EtHg exposure. Nutritional status was significantly associated with GDS.**
[29]	Neurological development Tests (*) in 2 groups of riverine children: Higher (exposed) and lower (control) fish eating to mercury.	Mean (SD) of HHg ($\mu g \cdot g^{-1}$): Exposed: 5.37 (± 3.35µg.g-1); Control: 2.08 (± 1.37µg.g-1). **High performance rates considered "non-normal" and "refusals" in both the study group and control group in all tests applied.**

Main Results- continuation

6. The results met in these studies have suggested an association between high exposure to mercury from different sources (methylmercury assessed from hair and ethylmercury assessed from vaccination cards) and poor neurobehavioral outcomes.[22, 23]

7. Nevertheless, the researchers considered that the living conditions, the cultural patterns[29] the nutritional status[28] and the maternal education[26, 27] could have been interfering with the results observed and must be considered in the evaluation of the effects of this metal on the cognitive ability of the studied population.

SOUTHEAST REGION: Determination of Mercury Biologic Concentrations in children

Farias et al, 2008: *Total hair mercury (mg.kg^{-1}) in children from a coastal population in Cananéia, São Paulo State, Brazil:*

Reference	AREA	Total HHg (mg.kg-1) Mean (DP)	IC
Barbosa et al, 2001	North Amazon	18,52 (10,04)	0,51 – 45,89
Santos et al, 2000	North Amazon	5,84 (4,91)	1,09 – 20,46
Marques et al, 2013	West Amazon	5,37 (3,35)	0,58 – 17,14
Marques et al, 2007	North Amazon	21,06 (14,38)	0,10 – 94,50
Farias et al, 2008	Southeast Region	0,48 (0,35)	<0,01 – 3,33

WHO: 2.0 mg.kg-1 (for an adult population unexposed to Hg).

Contribuição para o estabelecimento de níveis de referência para a concentração de mercúrio no sangue de crianças na cidade do Rio de Janeiro

A Contribution for the establishment of reference values for total mercury levels in blood of children from Rio de Janeiro

Olga Leticia Penido Xavier[1], Carmen Ildes R. Fróes Asmus[2], Anamaria Testa Tambellini[3], Armando Meyer[4], Volney de Magalhães Câmara[5]

Reference Values -WHO

Limites Biológicos		
Sangue	5 – 10 µg/L (mercúrio total)	WHO, 2008 [1]
Urina	50 µg/g creatinina (mercúrio total)	WHO, 2008 [1]
Cabelo	7 µg/g**	WHO, 2008 [1]

Tabela 4. Média geométrica e intervalo de confiança da concentração de mercúrio total (µg/L) nos escolares participantes do estudo e outros estudos internacionais selecionados

Estudo, Ano, País	Média de mercúrio total (µg/L)	IC95%	Referências
Presente estudo, 2009, Brasil	0,51	–	–
Czech Republic, 2001–2003	0,43	1,19–2,02	Batáriová et al.[18]
GerES, 2003–2006, Alemanha	1,0	0,6–1,0	Wilhelm, Schulz e Schwenk[16]
NHANES, 2003–2006, Estados Unidos	0,44	0,36–0,48	Caldwell et al.[15]
CHMS, 2007–2008, Canadá	0,31	0,23–0,43	Wong e Lye[17]

Rio Birth Cohort Study of Environmental Exposure and Childhood Development

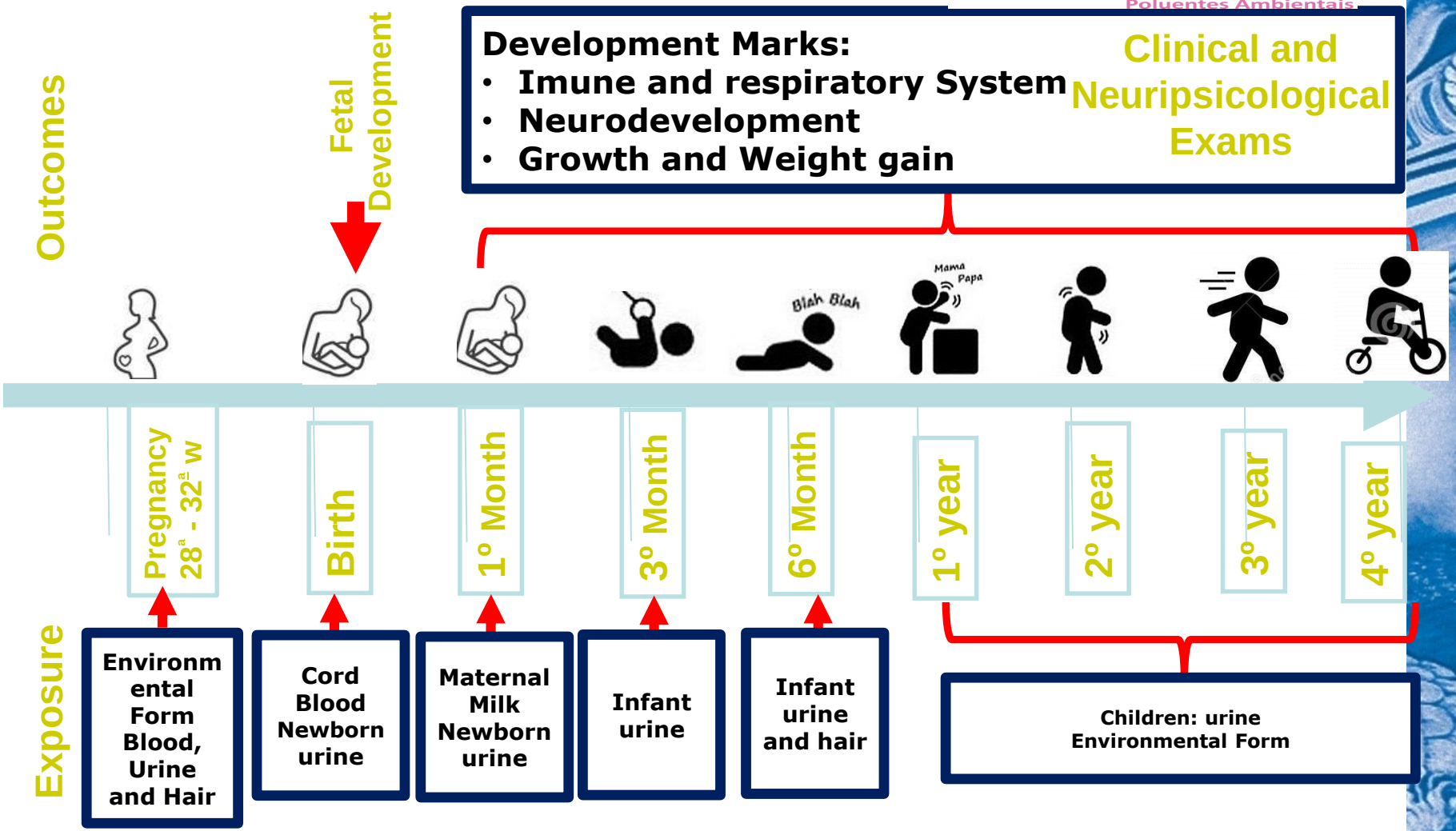
- To investigate alterations in childhood development associated with exposure to environmental pollutants, from pregnancy until the age of 4.
- The study population will be all children born at the Maternity School of Federal University of Rio de Janeiro, Rio de Janeiro/Brazil, from July 1st, 2019 to June 30th, 2020.
- The study will collect social, demographic and health information, in addition to biological samples from parents and newborns.

Pipa UFRJ

Projeto sobre a Infância e Poluentes Ambientais

Rio Birth Cohort Study of Environmental Exposure and Childhood Development

Pipa UFRJ
Projeto sobre a Infância e Poluentes Ambientais



Rio Birth Cohort Study of Environmental Exposure and Childhood Development

Pipa UFRJ

Projeto sobre a Infância e Poluentes Ambientais

PILOT STUDY: September, 2017 – July, 2018

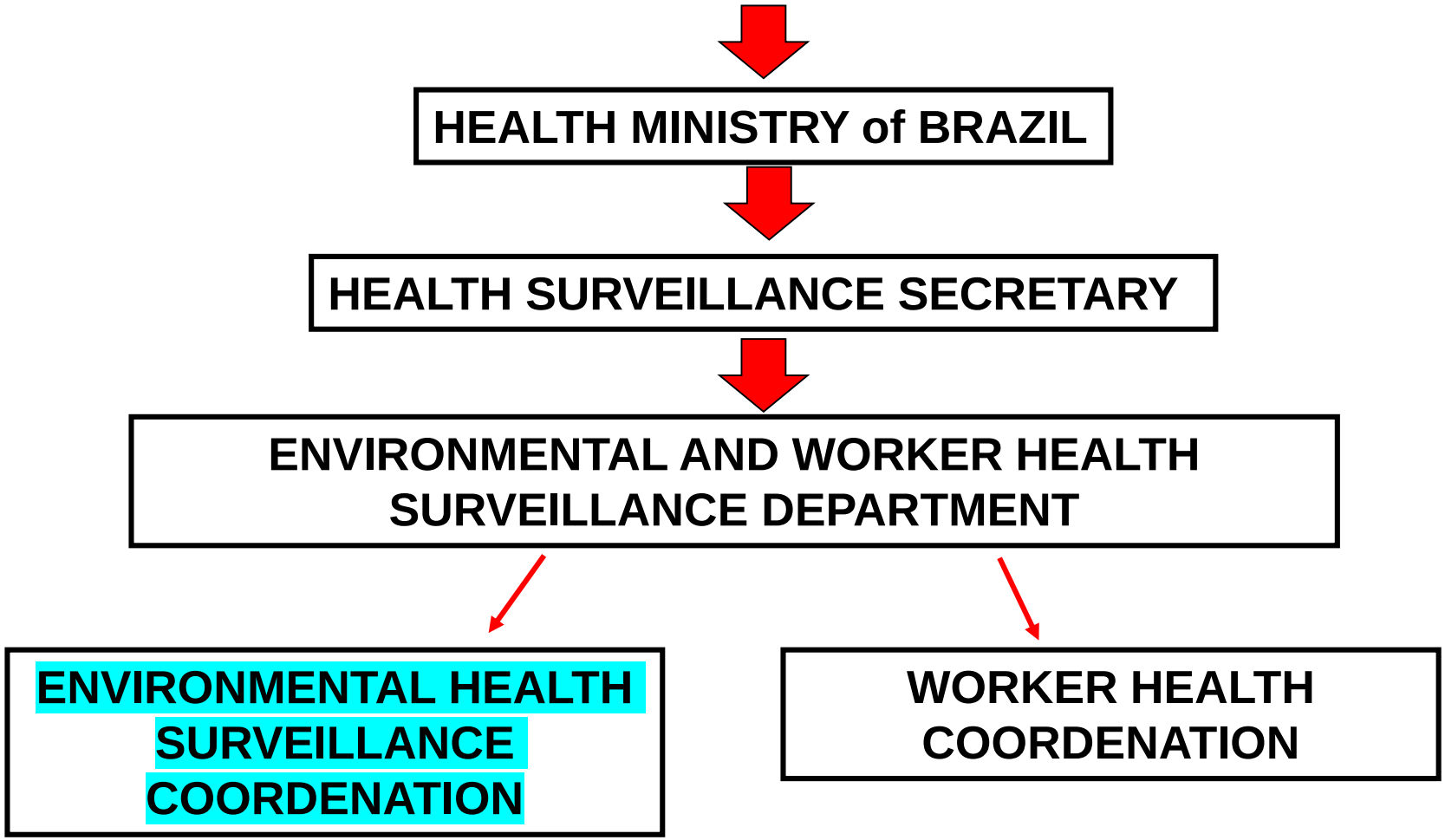
147 children – mother pair

Preliminary results: 20 mother- newborn pair

Mercury µg/L	Median	Geometric Mean	P95
Cord Blood	3,85	3,80	6,78
Maternal Blood	3,1	3,48	8,21

MERCURY EXPOSURE EFFECTS ON BRAZILIAN CHILDREN'S HEALTH

HEALTH SURVEILLANCE OF MERCURY EXPOSED POPULATIONS IN BRAZIL



MERCURY EXPOSURE EFFECTS ON BRAZILIAN CHILDREN'S HEALTH

ENVIRONMENTAL HEALTH SURVEILLANCE COORDENATION

ENVIRONMENTAL HEALTH SURVEILLANCE BRAZILIAN SYSTEM

HEALTH SURVEILLANCE OF CHEMICAL POLLUTANTS EXPOSED POPULATIONS

- **Health Surveillance of Populations living in contaminated areas**
- **Drinking Water Quality Surveillance Brazilian Program**

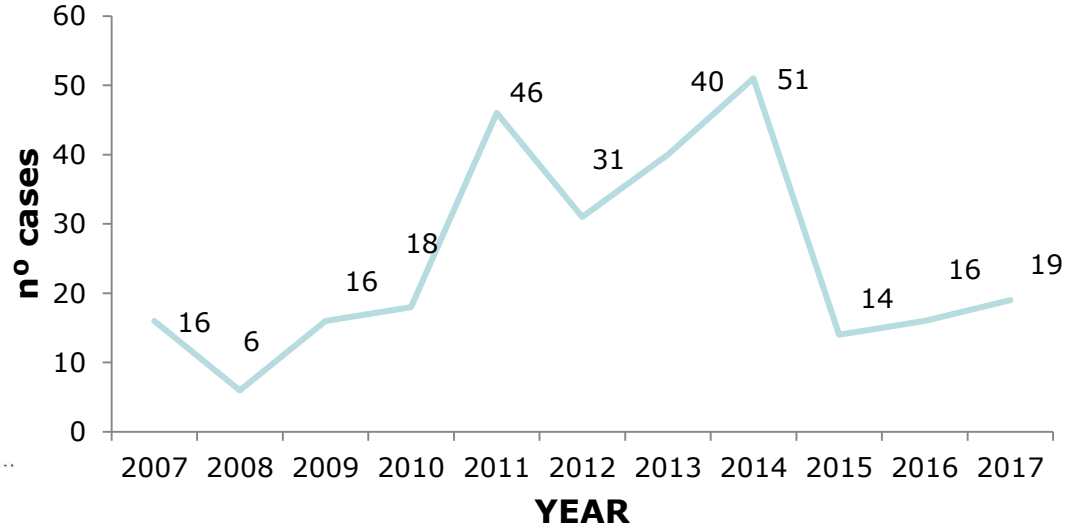
Develop integrated health actions aimed at the adoption of measures to prevent risk factors, promote and surveillance the health of populations exposed to chemical pollutants.

MERCURY EXPOSURE EFFECTS ON BRAZILIAN CHILDREN'S HEALTH

HEALTH SURVEILLANCE OF MERCURY EXPOSED POPULATIONS IN BRAZIL

Spatial distribution of Mercury intoxication cases, 2007 to 2017, Brazil (places in which there was the register of one case, at least).

Number of Mercury intoxication cases, domestic and occupational acidentes, 2007 to 2017, Brasil.



1. Underreporting of mercury intoxication cases
2. Reporting of acute cases: domestic and occupational accidents
3. Almost NONE register from Amazon region

MERCURY EXPOSURE EFFECTS ON BRAZILIAN CHILDREN'S HEALTH

CONCLUSIONS

1. This chronic exposure is demonstrated through the mercury concentrations in biological samples – blood (umbilical cord and maternal), urine, hair and maternal milk of population living in Amazon region.
2. This chronic mercury exposure can be determining the occurrence of **"underlying or subclinical" effects on children's health**, which do not have specific symptoms, therefore difficulting the establishment of a cause-effect relationship.
3. The current Brazilian Surveillance Systems are not prepared, and they are unable, to detect and to register this situation

Systematic Review Studies – Bibliography References

1. Santos E.C.; Câmara V.M.; Brabo E.S.; Loureiro E.C.; de Jesus I.M.; Fayal K.; Sagica F. Mercury exposure evaluation among Pakaanóva Indians, Amazon Region, Brazil. Cad de saude publica, 2003, 19, 1, 199-206.

2. Santos E.C.; de Jesus M.I.; Camara V.M.; Brabo E.; Brito L.E.C.; Mascarenhas A.; Weirich J.; Ragio L.R.; Cleary D. Mercury exposure in Munduruku Indians from the community of Sai Cinza, State of Pará, Brazil. Environm. Res, 2002, 90,2, 98-103.

3. Pinheiro M.C.; Crespo-López M.E.; Vieira J.L.; Oikawa T.; Guimarães G.A.; Araújo C.C.; Amoras W.W.; Ribeiro D.R.; Herculano A.M.; do Nascimento J.L.; Silveira L.C. Mercury pollution and childhood in Amazon riverside villages. Environ Int. 2007, Jan 33, 1, 56-61.

4. Marques R.C.; Dórea J.G.; Bastos W.R.; Malm O. Changes in children hair-Hg concentrations during the first 5 years: Maternal, environmental and iatrogenic modifying factors. Regulatory Toxicology and Pharmacology, 2007, 49, 1, 17-24.

5.Hacon 1 S.S.; Dórea 2 J.G.; Fonseca 3 M.F. Oliveira 4 B.A.; Mourão 5 D.S.; Ruiz 6 C.M.V.; Gonçalves 7 R.A.; Mariani 8 C.F.; Bastos 9 W.R. The influence of changes in lifestyle and mercury exposure in riverine populations of the Madeira river (Amazon basin) near a hydroelectric project. Int J of Env Res Pub Health, 2014, 11, 2437-2455.

6.Malm O.; Dórea J.G.; Barbosa A.C.; Pinto F.N.; Weihe P. Sequential hair mercury in mothers and children from a traditional riverine population of the Rio Tapajós, Amazonia: Seasonal changes. Environm. Res. 2010, 110, 7, 705-709.

7.Barbosa A.C.; Jardim W.; Dórea J.G.; Fosberg B.; Souza J. Hair mercury speciation as a function of gender, age, and body mass index in inhabitants of the negro river basin, amazon, Brazil. Archives of Environm. Contamination and Toxicol., 2001, 40, 3, 439-444.

8. Santos E.C.; De Jesus I.M.; Da Silva B.E.; BritoL.E.C.; Da Silva M.A.F.; Weirich J.; Câmara V.M.; Cleary, D. Mercury exposures in riverside amazon communities in Para, Brazil. Environm. Res. 2000, 84, 2, 100-107.

9.Vieira Rocha A.; Cardoso B.R.; Cominetti C.; Bueno R.B.; de Bortoli M.C.; Farias L.A.; Favaro D.I.; Camargo L.M.; Cozzolino S.M. Selenium status and hair mercury levels in riverine children from Rondônia, Amazonia. Nutrition. 2014, Nov-Dec 30, 11-12, 1318-23.

10.Marques R.C.; Bernardi J.V.; Dórea J.G.; Leão R.S.; Malm O. Mercury transfer during pregnancy and breastfeeding: hair mercury concentrations as biomarker Biol Trace Elem Res. 2013, Sep 154, 3, 326-32.

Systematic Review Studies – Bibliography References

11.Oliveira R.C.; Dórea J..G.; Bernardi J.V.; Bastos W.R; Almeida R. Fish consumption by traditional subsistence villagers of the Rio Madeira (Amazon): impact on hair mercury. Ann Hum Biol. 2010 Sep-Oct 37, 5,629-42.

12.Marques R.C.; Dórea J.G.; Fonseca M.F.; Bastos W.R.; Malm O. Hair mercury in breast-fed infants exposed to thimerosal-preserved vaccines. Eur J Pediatr. 2007 Sep 166, 9, 935-41.

13.Farias L.A.; Santos N.R.; Favaro D.I.; Braga E.S. Total hair mercury in children from a coastal population in Cananéia, São Paulo State, Brazil. Cad Saude Publica. 2008 Oct 24, 10, 2249-56.

14.Hacon S.; Yokoo E.; Valente J.; Campos R.C.; da Silva V.A.; de Menezes A.C.; de Moraes L.P.; Ignotti E. Exposure to mercury in pregnant women from Alta Floresta-Amazon basin, Brazil. Environ Res. 2000, Nov 84, 3, 204-10.

15.Santos E.O.; De Jesus I.M; Câmara V.M.; Brabo E.D.S.; de Jesus M.I.; Fayal K.F.; Asmus Froes C.I.R. Correlation between blood mercury levels in mothers and newborns in Itaituba, Pará State, Brazil. Cad Saude Publica, 2007, 23 (suppl 4), S622-S629.

16.Dutra M.D.; Jesus I.M.; Santos E.C.; Lima M.O.; Medeiros R.L.; Cavadas M.; Luiz R.R.; Câmara V.M. Longitudinal assessment of mercury exposure in schoolchildren in an urban area of the Brazilian Amazon. Cad Saude Publica. 2012 Aug 28, 8, 1539-45.

17.Barbosa A.C.; Silva S.R.L.; Dórea J.G. Concentration of mercury in hair of indigenous mothers and infants from the Amazon basin. Arch Environm Contamination and Toxicol, 34, 1, 100-105.

18. Marques R.C.; Bernardi J.V.; Dórea J.G.; Brandão K.G.; Bueno L.; Leão R.S.; Malm O. Fish consumption during pregnancy, mercury transfer, and birth weight along the Madeira River Basin in Amazonia. Int J Environ Res Public Health. 2013 May 28, 10, 6, 2150-63.

19. Marques R.C.; Bernardi J.V.; Dórea J.G.; Leão R.S.; Malm O. Mercury transfer during pregnancy and breastfeeding: hair mercury concentrations as biomarker. Biol Trace Elem Res. 2013, Sep 154, 3, 326-32.

20. Vieira S.M.; de Almeida R.; Holanda I.B.; Mussy M.H.; Galvão R.C.; Crispim P.T.; Dórea J.G.; Bastos W.R.Total and methyl-mercury in hair and milk of mothers living in the city of Porto Velho and in villages along the Rio Madeira, Amazon, Brazil. Int J Hyg Environ Health. 2013 Nov 216, 6, 682-9.

21. Oliveira R.C.; Dórea J.G.; Bernardi J.V.; Bastos W.R.; Almeida R.; Manzatto A.G. Fish consumption by traditional subsistence villagers of the Rio Madeira (Amazon): impact on hair mercury. Ann Hum Biol. 2010 Sep-Oct 37, 5, 629-42.

Systematic Review Studies – Bibliography References

22. Marques R.C.; Bernardi J.V.; Dórea J.G.; de Fatima R.; Moreira M.; Malm O. Perinatal multiple exposure to neurotoxic (lead, methylmercury, ethylmercury, and aluminum) substances and neurodevelopment at six and 24 months of age. Environ Pollut. 2014, Apr 187,130-5.

23. Dórea J.G.; Marques R.C.; Isejima C. Neurodevelopment of Amazonian infants: antenatal and postnatal exposure to methyl- and ethylmercury. J Biomed Biotechnol. 2012, 132876.

24. Marques R.C.; Dórea J.G.; McManus C.; Leão R.S.; Brandão K.G.; Marques R.C.; Vieira I.H.; Guimarães J.R.; Malm O. Hydroelectric reservoir inundation (Rio Madeira Basin, Amazon) and changes in traditional lifestyle: impact on growth and neurodevelopment of pre-school children Public Health Nutr. 2011 Apr 14, 4, 661-9.

25. Marques R.C.; Dorea J.C.; Bernardi J.V.E.; Bastos W.R.; Malm O. Prenatal and postnatal mercury exposure, breastfeeding and neurodevelopment during the first 5 years Cog Behav Neurol 2009, 22, 134–141.

26. Marques R.C.; Garrofe D.J.; Rodrigues B.W.; de Freitas R.M.; de Freitas F.M.; Malm O. Maternal mercury exposure and neuro-motor development in breastfed infants from Porto Velho (Amazon), Brazil. . Int J Hyg Environ Health. 2007 Jan 210, 1, 51-60.

27. Marques R.C.; Dórea J.G.; Leão R.S.; Dos Santos V.G.; Bueno L.; Marques R.C.; Brandão K.G.; Palermo E.F.; Guimarães J.R. Role of methylmercury exposure (from fish consumption) on growth and neurodevelopment of children under 5 years of age living in a transitioning (tin-mining) area of the western Amazon, Brazil. Arch Environ Contam Toxicol. 2012 Feb 62, 2, 341-50.

28. Dórea J.G.; Marques R.C.; Abreu L. Milestone achievement and neurodevelopment of rural Amazonian toddlers (12 to 24 months) with different methylmercury and ethylmercury exposure. J Toxicol Environ Health A 2014, 77, 13, 113.

29. Tavares L.M.; Câmara V.M.; Malm O.; Santos E.C. Performance on neurological development tests by riverine children with moderate mercury exposure in Amazon, Br Cad Saude Publica. 2005 Jul-Aug 21, 4, 1160-7.

30. Chevrier C.; Sullivan K.; White R.F.; Comtois C.; Cordier S.; Grandjean P. Qualitative assessment of visuospatial errors in mercury-exposed Amazonian children. Neurotoxicology. 2009 Jan 30,1, 37-46.

Gracias! **Obrigado!** **Thanks!**