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Environmental and Human Exposure Assessment Monitoring of Communities near an Abandoned Mercury Mine in the Philippines: A Toxic Legacy

Presented By:

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Background of the Study

- **Research Grant by the International Atomic Energy Agency (IAEA)**
- **Institute where research was carried out :**
 - **Department of Health**
 - **National Poisons Management and Control Center, UP-Manila**
 - **National Institute for Minamata Disease**



Background Information



Study areas: three barangays namely, Santa Lourdes, Tagbueros and San Jose situated approximately 14 km north of Puerto Princesa, Palawan.

Control areas were Bgys. Bagong Silang, Pagkakaisa and Pag-asa

2 M tons of mine-waste calcines (retorted ore) were produced during mining (1955-1976)

Approximately 1 M tons of tailings from the PQMI roasting plant was discarded along the Honda Bay coastline during the 1960's

Ultimately used for the construction of a 400m long jetty, Sitio Honda Bay

Mine was closed in 1976

A substantial community (p >2000 inhabitants) settled in the nearby barangays, engaged in fishing





Review of existing studies

- Kapauan, et.al (1982)
- Benoit, et. al (1994)
- Environmental Management Bureau – DENR (1994)
- Department of Health (1995)
- British Geological Survey (1996)
- USGS and the University of Minnesota (2001)



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IAEA study of the DOH/UP-NPMCC.....



Methodology

- Study Population
 - § Pregnant women and infants (N=25,25)
 - § Mother and child (N=25,25)
 - § Control area
 - § Pregnant women and infants (n=10,10)
 - § Mother and child (N=10,10)
 - § Inclusion criteria
 - § Resident of the 3 barangays for at least 5 years
 - § Mothers aged 18-39 y.o with good nutritional status and relatively healthy
 - § Pregnant mother-infant
 - § Volunteers willing to be included in the study
 - § with informed consent



METHODOLOGY



Study Population

§ Exclusion criteria

- § Those with anatomic and physiologic deformities among children
- § Those with dental amalgam fillings (>2 teeth)
- § Those with clinical diseases such as CVD (moderate/severe), etc.
- § Intake of ACE inhibitors, anti-epileptic drugs and other pharmacologic drugs i.e. intake of antibiotics
- § history of seizures
- § Pregnancy in the 1st and 2nd trimester
- § Presence of pre-eclampsia and eclampsia



Methodology

- Study Population
 - § Exclusion criteria
 - § Persistent/current infection
 - § Hepatic amoebiasis
 - § Intake of recreational drugs of abuse, smoking, drinking of alcoholic beverages, etc.
 - § Pesticide exposure
 - § Nightly use of mosquito coil, > 2x /week spraying
 - § Regular cosmetics use for the last 5 years I.e hair dye for more than 5 years,

 - § those who refused to be included in the study
 - § those who do not meet the inclusion criteria



METHODOLOGY

- **Sample size**
 - 120 persons were included in the study
- **Component 1: Health assessment**
 - social preparation of the community
 - interview questionnaire (socio-demographic profile, age, sex, educational attainment, lifestyle, diet, drugs, medical history)
 - face to face interview with respondents



Selection Criteria

- **sampling based on inclusion/exclusion criteria**
- **a 10% drop-out rate was considered and selection of replacements were done at random**
- **confidentiality of health information was assured**
- **Consent form was administered**
- **appropriate management of health findings**



Component 1: Health assessment

- Health history: present illness/complaints, past history, family history, reproductive history/outcome; pediatric history
- Occupational exposure history (pesticide use, etc.)
- vital signs ; pulmonary function tests specifically PEFr
- comprehensive medical and neurological examination including a modified mental status examination
- biological monitoring



Component 1: Medical Examination

Mother at the time of examination

Hematology: hemoglobin, hematocrit, WBC, differential count, ESR, Reticulocyte count, platelet count, peripheral blood smear

Liver function tests: ALT/Ast; Prothrombin time

Kidney function tests: urinalysis, BUN, creatinine

Blood total mercury and methylmercury level

Hair total mercury and methylmercury level

Peak expiratory flow rate (PEFR)



Component 1: Medical Examination

Maternal Biomarkers will include maternal hair, cord whole blood and maternal cord

B1. Conduct neuro-behavioral performance tests on children and analyze association between the test results and the mercury exposure during pregnancy taking various potential confounding factors

Infants would be evaluated by a neurologist between the age of 0, 3, 6, 12, 18 and 24 months

a. the primary neurological optimal score which reflects infants functional abilities, reflexes, responsiveness and stability of state at 2 weeks of age

b. overall neurological examination, increased muscle tone and deep tendon reflexes



Component 1: Medical Examination

B1. Children evaluated 1 to 2 years

a. motor development milestones: sits without support, creeps and gets up into standing position with support, finger tapping, motor function, attention, visual-spatial function, short-term memory or whatever test deemed applicable



Description of the Denver Developmental Screening Test (DDST II)

- This tool is designed for apparently well children between birth and six years of age administered by assessing a child's performance on various age-appropriate tasks to detect potential developmental problems.
- The child's performance is compared with that of other children of the same age based on a variety of tasks which covers the personal-social, fine-motor-adaptive, language and gross motor functions



Component 2:

Environmental Assessment

§ establish sampling stations based on the selection of study site and assess the following:

§ drinking water supply

§ river quality assessment

§ sediment/soil contamination

§ air quality (ambient)

§ marine life



Analytical Procedures

- Samples were analyzed at the National Institute for Minamata Disease-Japan
- All samples were analyzed for total and methylmercury content using atomic absorption spectrophotometry (AAS) and gas chromatography-electron capture detector methods
- Routine laboratory examination were done at the Palawan Provincial/Bethany Hospitals.



Ethical considerations:

- **The volunteer/guardians signed a letter of informed consent prior to inclusion in the study. Confidentiality of information and freedom to withdraw from the study anytime was stipulated. Those found to have health findings will be provided with the appropriate management, as necessary.**



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Environmental Monitoring Results



Table 1: Air Sampling

Mercury Level (ng/m³)

Area	May, 2003	August, 2003	November, 2003
Tagbueros	64.87	0.88	2.09
Pagkakaisa	5.84	2.18	
Bagong Silang	3.8	2.27	1.58
Sta. Lourdes		0.61	3.08
San Jose		1.67	1.75

US-EPA: 0.4 ug/m³



Table 2: Rice samples

Rice samples	T-Hg conc. (ng/g)
R1 (XQ)	3.08
R2 (Regular)	3.61



Table 3: Total Mercury Concentration in Drinking Water Samples, Palawan, 2002



Sampling Site	Mean+/-SD (ng/ml)	Range	Number
Sta. Lourdes			
Local water district	0.001165+/-0.00023	0.001-0.0013	2
Deep well	0.0237+/-0.0208	0.0018-0.057	5
Tagbueros			
Deep well	0.123+/-0.14	0.0024-0.305	4
San Jose			
Deep well	0.0192+/-0.0164	0.0058-0.042	4
Bagong Silang			
Water district	0.004+/-0.0036	0.0002-0.0085	5
Pagkakaisa			
Water district	0.0188+/-0.0191	0.0007-0.0456	4



Table 4: Total Mercury Concentration of Surface Water, Palawan, 2002

Sampling Site	PQMI jetty	Puerto Princesa Bay	Honda Bay
Mean +/-SD	0.1773 +/-0	0.002+/-0.00195	0.12+/-0.055
Range	0.1773	0.001-0.0053	0.0811-0.1589
Number	1	4	2

RP-DENR Standards: 2 ng/L~0.002 ng/ml

September 23 -30, 2006

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Table 5: Total mercury concentration of Soil Samples, Palawan, 2002



Sampling Sites	Sta. Lourdes	Tagbueros	San Jose	Pagkakaisa	Bagong Silang	Mine tailings near Honda Bay
Mean+/- SD	1.07+/-1.3	71.24+/-84.65	2.75+/-5.38	0.485+/-0.44	0.06+/-0.02	261.13+/-294.05
Range	0.012-2.79	0.045- 168.72	0.04-10.82	0.09-1.09	0.04-0.08	3.68- 566.81
No of samples	5	4	4	4	4	4

US EPA Primary Remediation Goal (PRG) for Hg = 23 mg/kg

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Table 6: Total and Methylmercury Levels in Fresh Fish

Area	Case Area	Control Area	p value*
THg (mg/kg _{fw})			0.0028
Mean	0.158+/-0.218	0.070+/-0.072	
Range	0.002-1.152	0.001-0.258	
Number	64	25	
MethylMercury			0.003
(mg/kg _{fw})			
Mean	0.132.1+/-0.171	63.06+/-63.77	
Range	0.0013-0.9316	0.0113-0.2089	
Number	64	25	
% Methyl Mercury			
Mean	88.13+/-18.15	90.07+/-10.44	
Range	6.26-100	68.60-100	
Number	64	25	

US-FDA:RPDA (T-Hg): 500 ng/g; Japan standards: T-Hg (400 ng/g); Me-Hg (300 ng/g)



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Health Findings



Results

- Socio-demographic characteristics of exposed and unexposed communities were comparable except for source of drinking water
- Medical complaints were comparable
- Physical Examination:
 - Mothers: comparable
 - Children: greater wasting/malnutrition and pallor in the exposed population



Biomarkers

- Blood Total Mercury
 - Mothers: 2.58 – 35.37 ng/mL
 - Children: 1.20 – 52.27 ng/mL
- Blood Methyl Mercury
 - Mothers: 2.27 – 28.47 ng/mL
 - Children: 1.18 – 52.27 ng/mL
- Hair Total Mercury
 - Mothers: 0.53 – 10.56 ng/mg
 - Children: 0.18 – 13.29 ng/mg
- Hair Methyl Mercury
 - Mothers: 0.53 – 7.06 ng/mg
 - Children: 0.16 – 8.01 ng/mg



Blood Hg Levels



Population	BLOOD TOTAL MERCURY Mean +/-SD (ng/ml)
Mothers	
Exposed	14.7 +/- 2.03
Unexposed	8.9 +/- 1.66
Children	
Exposed	14.6 +/- 3.12
Unexposed	5.48 +/- 0.62
Pregnant Mothers (1 year after delivery)	
Exposed	9.9 +/- 4.14
Unexposed	8.08 +/- 2.92
Babies at 1 year	
Exposed	6.6 +/- 4.8
Unexposed	3.06 +/- 1.03



METHYLMERCURY LEVELS IN BLOOD

Population	BLOOD METHYLMERCURY Mean +/-SD (ng/ml)
Mothers	
Exposed	12.06 +/-1.81
Unexposed	7.43 +/- 1.54
Children	
Exposed	13.24+/- 3.4
Unexposed	4.9 +/- 0.57
Pregnant Mothers (1 year after delivery)	
Exposed	8.56 +/- 3.66
Unexposed	7.09 +/- 2.10
Babies at 1 year	
Exposed	5.2 +/- 4.4
Unexposed	2.6 +/- 0.84



HAIR THg LEVELS

Population	HAIR TOTAL MERCURY Mean +/-SD (ng/ml)
Mothers	
Exposed	3.43 +/- 0.55
Unexposed	1.98 +/- 0.23
Children	
Exposed	2.74 +/- 0.50
Unexposed	1.54 +/- 0.21
Pregnant Mothers (1 year after delivery)	
Exposed	2.51 +/- 1.11
Unexposed	2.09 +/- 0.49
Babies at 1 year	
Exposed	0.98 +/- 0.58
Unexposed	0.77 +/- 0.71



METHYLMERCURY HAIR LEVELS

Population	HAIR METHYLMERCURY Mean +/-SD (ng/ml)
Mothers	
Exposed	2.8 +/- 0.38
Unexposed	1.68 +/- 0.20
Children	
Exposed	2.27 +/- 0.41
Unexposed	1.33 +/- 0.21
Pregnant Mothers (1 year after delivery)	
Exposed	2.11 +/- 1.06
Unexposed	1.89 +/- 0.46
Babies at 1 year	
Exposed	0.82 +/- 0.41
Unexposed	0.59 +/- 0.21



Neurodevelopment Scores

- Significant correlation between elevated hair mercury and abnormal fine motor SBI (screening for behavioral inventory) parameters; fine motor, language, SBI and personal/social at 1 month.
- Significant correlation between elevated total and methyl hair mercury and abnormal fine motor SBI at 6 months
- Significant correlation between elevated blood total mercury and abnormal overall Denver Screening Test II (DDST II)
- Significant correlation between elevated hair total mercury and abnormal personal/social scores of DDS.



Neurodevelopment Scores

At age 1, there were significantly more children in exposed areas than the expected scores in the gross motor aspect of DDS with a likelihood ratio of 8.54 compared with children in unexposed areas

At age 2, there were more children in the exposed than unexpected group with lower than expected scores in language aspects of SBI (likelihood ratio of 5.9) and DDS (likelihood ratio of 4.75)



Conclusions

- Children in the exposed areas are disadvantaged healthwise in comparison with unexposed based on the following;
 - Greater malnutrition, wasting and pallor (proven by lower levels of hemoglobin)
 - Significantly higher blood total mercury levels of babies at 1 year of age acquired from the mother
 - Children at 2-3 years have significantly higher blood total and methylmercury levels and hair total and methylmercury values due to maternal and environmental exposures and intake of mercury/methylmercury contaminated fish.



Conclusions

- Children and babies in the exposed areas demonstrate low scores in several DDS and SBI parameters as early as 6 months of age, particularly in fine motor, gross motor, personal-social and language that have significant correlation with their Hg levels.



Conclusions

- Among mothers, those in the exposed areas have significantly higher hair total and MeHg levels compared with the unexposed area.
- In the exposed areas, the levels of total mercury in air, water and soil were significantly higher compared with the control values



Conclusions

- The levels of THg and MeHg in fishes from the exposed areas were significantly higher than those from the unexposed areas.
- The soil levels were highest in Honda Bay (566.81 mg/kg) which is 25 times the level requiring remediation (23 mg/kg)



Correlation

- Evaluation of the correlation between environmental mercury and biologic levels of mercury showed that there is a fair-good correlation between both maternal total and methylmercury levels (blood/hair) and fish methylmercury levels and water total mercury.
- The levels of blood and hair mercury in children are influenced by maternal mercury levels, eating of fish and seafood.



Recommendations

- Continuing health monitoring among children with markedly elevated levels of blood total and methyl mercury
- Continuing monitoring of fish mercury levels and issuance of fish advisories
- Provision of safe, potable drinking water in Tagburos, Sta. Lourdes and San Jose.
- Reactivation of a multi-sectoral Task Force Asoge to integrate and coordinate policies and activities including recommendations



Recommendations

- Remediation of Honda Bay and minimization of exposure to mine wastes
- Review of the sanitary landfill operations
- The Honda Bay area was not recommended to be a residential area
- Micronutrient supplementation



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Mercury Use in Schools



Total Student
Population = 2364

- High School = 1100
- Elementary = 1050
- Pre-school = 214

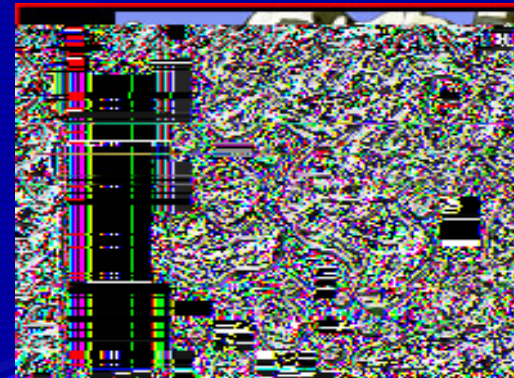
Total Staff = 140

- 69 Teachers
- 71 Support



Clinical History & Course

- Exposure: February 16, 2006 morning , 80 students, Gr 7, ages 13-14 years old and the Science teacher from St. Ambrose and St. Francis de Sales sections exposed to elemental mercury (approximately 150, 100 gms?)



- Mode of Exposure: Dermal and inhalational
- Onset of symptoms: Late afternoon-early evening
- Symptoms:

Headache	57.0%	Fever	26.0%
Pruritus	41.9%	Cough/colds	23.6%
Dyspnea	36.6%	Chest pain	20.4%
Weakness	35.5%	Muscle pain	17.2%
Dizziness	34.4%	Nausea	16.1%
Numbness	8.5%		
Redness/swelling of upper extremities	4.3%		

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Report

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