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HEALTH AND ENVIRONMENTAL IMPACT OF MERCURY IN THE PHILIPPINES USING NUCLEAR TECHNIQUES

[1]NELIA CORTES-MARAMBA, [1]J.P. REYES, [1]L.C.P. PANGANIBAN, [2]ANA TRINIDAD FRANCISCO-RIVERA, [3]M.L. SUPLIDO, [4]HIROKATSU AKAGI

[1]National Poisons Control and Information Service, Philippine General Hospital, UP Manila, Taft-Avenue, Manila, Philippines
Nuclear Research Institute, National Institute for Minamata Disease
[2]Occupational Health Division, Non-Communicable Disease Control Service, 2nd Floor, Bldg13, Department of Health, San Lazaro Compound, Rizal Avenue Sta. Cruz, Manila
[3]UP-Open University, Manila, Philippines
[4]National Institute for Minamata, Disease-Japan

Abstract

Mercury pollution in most parts of the regions in the world are caused by release into the environment of metallic mercury used in the recovery of gold by an amalgamation technique with subsequent mercury emission into the atmosphere by blowtorching operations. Significant small-scale gold mining operations in other countries such as Tanzania, Philippines, Indonesia, China and Vietnam have been reported with roughly 10 million people estimated to be involved in these activities
Artisanal gold mining activities using mercury has proliferated in various parts of the country since the early 1980's. In Southern Philippines, it is estimated that a small-scale gold processor utilizes one kilogram of mercury every week or an average of fifty-two kgs./yr. Production is estimated at 30 kilograms of gold per day. It has been estimated that 140 tons of mercury flux has been dumped directly into the river systems from small-scale gold mining operations in one of the gold rush areas in the country In the 1980's, gold rush activities intensified in Northeastern Mindanao providing livelihood opportunities to about 80,000-120,000 people at the height of mining activities in the area [1].

In gold mining areas it should be noted that transformation in the natural environment of inorganic mercury to methylmercury occurs which can easily bioaccumulate in fish and other organisms through the aquatic food chains. Therefore, there are two main exposure pathways of mercury contamination that can affect the human population in gold mining areas. First, gold miners and workers are exposed to inorganic mercury due to direct inhalation of mercury during gold recovery processes and second, people living along the river systems and depending on riverine products for food sources can be exposed to methylmercury mainly thru fish consumption.
Presently, environmental and health monitoring conducted by several government agencies in the recent past were limited to the determination of total mercury only. Previous studies undertaken focused mainly on the exposure of adults and workers to mercury during mining/processing operations.

Fifty-three (53) research subjects were selected by stratified random sampling in a mining community in Sibutad, Zamboanga del Norte, Philippines. There were 40 (75.47%) adults aged from 26 to 50 years and 13 children aged 6 months to 11 years.
Environmental monitoring results showed that ambient air monitoring of three sampling station exceeded the standards for mercury in ambient air. Water quality monitoring of a drinking water source showed a slightly higher level than that obtained from a nearby river. Mercury levels in marine/aquatic samples ranged from 4.03-62.97 ng/g for total mercury and 3.75-35.98 ng/g in 9 species. These levels were below the recommended USFDA standard of 500 ng/g. The proportion of methyl mercury ranged from 22.98%-89.78%.

Hair samples in 51 respondents showed total mercury and methylmercury levels which ranged from 0.95-68.68 ng/g and 0.73-5.81 ng/g. The proportion of methyl mercury in hair ranged from 2.66-99.98%. 10 had elevated total mercury levels and 23 with elevated methylmercury levels.

Blood samples from 50 respondents showed total mercury and methylmercury levels ranged from 2.74-29.47 ug/L and 1.63-23.11 ug/L. A total of 23 blood samples from the 50 tested showed total mercury values will be followed up for possible detoxification while 10 had elevated methylmercury levels.

1. INTRODUCTION

Crude methods employed also contributed to the landslides and accidents causing deaths and injuries to workers and the community alike. Forest trees were also cut-down and used in mining operations, thus contributing to the loss of the topsoil and decrease in agricultural productivity. Accordingly, mine waste tailings are dumped into small water tributaries in the area. These resulted in the heavy siltation of water systems affecting irrigation to the farmlands as well as fishing activities in these areas. Water systems and tributaries eventually drain into larger water bodies thereby posing health and environmental risk to a greater number of people.

Based on present studies on the biotransformation of mercury in the environment, methylation of inorganic mercury to produce methyl mercury is due to the action of microorganisms that ultimately bioconcentrate in significant levels in the food chain particularly in marine and aquatic products. Small-scale mining operations have affected tributaries and water systems in the country that also relies heavily on fishing as a source of livelihood as well as the daily food fare among the low income sectors in the area. Aside from this, cattle, livestock and agricultural production have also been affected by these mining activities because of contamination of irrigation and water systems. Farmers in the area reported a significant decrease in palay production in the area as well as deaths in farm animals attributed to the pollution. Fish kills were also reported in these areas.

At present, small-scale gold mining activities utilizing mercury is being actively undertaken in at least ten provinces namely: Benguet, Camarines Norte, Negros Occidental, Zamboanga del Norte, Zamboanga del Sur, Bukidnon, Agusan del Norte, Agusan del Sur, Surigao del Norte and Davao del Norte (2). Mercury was also mined and produced in the country in the early 50's specifically in Palawan where quality assurance and environment control technology had neither been implemented nor required. Aside from the occupational exposure to inorganic mercury, another area of concern is the direct discharge of mercury into the environment. It is estimated that an average of 20 tons of mercury had been released annually into the river bodies of Mindanao Island alone (2).

Worldwide, reported cases of mercury poisoning have been attributed to occupational exposures commonly associated with mercury vapor. Illicit gold extraction using mercury had also resulted in mercury poisoning not only in adults but also in children. Toxicity and deaths have likewise occurred from the medicinal use of inorganic mercury compounds. Scientific reviews and literature on dental amalgams and vaccinal Hg etiology (thimerosal) its subsequent risk to human health have also been reported

Mercury and its compounds are highly toxic. Acute health effects reported include kidney failure following exposure to high concentrations of inorganic mercury. Allergic skin reactions were also reported following contact with mercury. Mercury vapor causes erosive bronchitis and bronchiolitis with interstitial pneumonitis. These symptoms may be combined with signs caused by effects on the CNS, such as tremor or increased excitability. Workers acutely exposed to mercury exhibited chest pain, dyspnea, cough, haemoptysis and evidence of interstitial pneumonitis.

Clinical manifestations of methyl mercury intoxication differ from inorganic mercury. Methyl mercury has been noted to be one of the most potent neurotoxic compounds known to man and known to cross blood-brain barriers in pregnant women, which result in conditions similar to those associated with infantile cerebral palsy. Cases of fetal type Minamata Disease which were caused when the mothers had been exposed to methylmercury during pregnancy, were also reported. Minamata disease was also fatal in some cases. Clinically, diverse symptoms are manifested which include sensory disorders in the distal portion of the extremities, cerebellar ataxia, concentric constriction of the visual field, central disorder of ocular movement, central hearing impairments and central disequilibrium (5,14).

With chronic exposure to inorganic mercury, one of the critical organ will be the kidneys. The central nervous system is also affected characterized by weakness, fatigue, forgetfulness, anorexia, loss of weight and disturbance of the gastrointestinal tract function. At higher exposure levels, the characteristic mercurial tremor appears as a fine trembling of the muscles, interrupted by coarse shaking movements. This begins peripherally in the fingers, eyelids and lips and has the characteristic of intentional tremor. In progressive cases, it may develop into generalized tremor involving the entire body, with intermittent violent chronic spasms of the extremities. This is often accompanied by changes in personality and behavior, with loss of memory, increased excitability, severe depression and even delirium and hallucination. Another characteristic feature of mercury vapor intoxication is severe salivation and gingivitis. Instances of proteinuria and even nephrotic syndrome have also been reported.

A number of health studies already undertaken in the past were mainly focused on the occupational exposure of small-scale gold miners utilizing mercury in the gold processing/refining process. Environmental and exposure assessment is limited to total mercury determination. It should be borne in mind though that methylation of mercury can possibly occur and ultimately bioaccumulate to a significant level in the aquatic flora and fauna. Thus, most of the communities in the mining areas and possibly the general population would be at risk of exposure to toxic levels of mercury especially those whose diet includes consumption of marine/aquatic products. Although it is difficult to specifically identify the risk probability that the population have been exposed to, this study will investigate the extent of mercury pollution and its impact on the health and the environment.

In the Philippines, workplace monitoring for ambient air and workplace monitoring showed levels ranging from 0.168-0.388 and 3.535-6.458 mg Hg/m^3 respectively in gold processing areas which exceeded the recommended permissible levels for mercury concentration (DENR, 1987). Fish and shellfish monitoring results also showed levels above the recommended level of 0.5 ppm (Range 0.679-1.071 ppm). Mercury levels from tailing ponds, canals and river systems were found to be 450 ppb, 120 ppb and 0.02 ppb respectively. Coastal waters likewise contain mercury from 0.36 ppb to 0.55 ppb. The allowable levels are set at 2 ppb.

In 1988, a study entitled an Integrated Surveillance of the Health and Environmental Impacts of Mercury Exposure in Gold Processing was undertaken in Davao del Norte (Maramba, N., Torres, E., et.al) to determine the extent of health impairment from mercury exposure. Results of the study revealed that 60% (139/230) of the mineworkers resided within 500 m from their workplace. Most of the subjects were either smokers (63%) or drink alcoholic beverages (73%). 26% (60/230) of the workers used some form of protective devices such as facial cover or masks, boots and gloves, alone or in combination. Pertinent findings on physical examination showed gray or focal deposits in the gingiva among 106 (47%) of the workers. Thyroid enlargement was seen in 24 (11%) while decreased breath sounds were noted in 36 (16%) of those examined. The study also showed statistically significant association of blood mercury levels with the duration of work, eosinophil count and serum glutamic amino transferase (9).

In a similar study undertaken in Bicol (Maramba N., Robles, E., de Vera, G. et.al), 7 out of 99 miners were found to have elevated mercury blood levels with 4 miners undergoing detoxification management.

Recently, the Department in collaboration with the UP-National Poisons Control and Information Service conducted a study was undertaken on the Health Assessment for Mercury Exposure Among Schoolchildren in Apokon, Tagum, Davao del Norte showed that environmental quality monitoring for total mercury sediment levels ranged from 0.55 ug/g dry weight while water samples from river systems exhibited mercury levels from 0.0728–0.0784 ppb. Fish samples collected showed levels ranging from 1.07-438.8 ppb for total mercury and 0.71-377.18 ppb for methyl mercury. Methyl mercury content in fish ranged from 56-99% (10).

Laboratory results showed that total mercury hair samples in schoolchildren ranged from 0.278 –20.393 ppm while methyl mercury levels were from 0.191-18.469 ppm. Methyl mercury represented 45.96%-99.81% of the total mercury levels in hair. Total blood mercury levels ranged from 0.757-56.88 ppb while methyl mercury blood levels ranged from 1.36-46.73 ppb. Summary of physical examination results showed that predominant findings include underheight, gingival discoloration, adenopathy, underweight and dermatologic abnormalities among children. Significant neurological findings include 17.07% with cranial nerve abnormalities characterized with 23 (6.9%) had deficits in the VIII, 10 (3%) II and 8(2.4%) I. 17 (5%) of the schoolchildren had sensory deficits while the same percentage showed reflex abnormalities. 13 (3.9%) had cerebellar deficits while 5 (1.5%) had motor nerve abnormalities.

To properly understand the actual extent of mercury contamination affecting human populations and the ecosystems, it is imperative to evaluate not only total mercury levels in human hair and other samples, but also the levels of methylmercury in the samples. In practice, it is often difficult to analyze minute quantities of methylmercury contained in the samples. Therefore, highly sensitive and precise analytical techniques are much desired for total mercury as well as methylmercury the detection capability of which surpasses conventional standards (8).

New sensitive and reliable methods for the determinations of both total and methylmercury content in environmental and biological samples have been developed by the National Institute for Minamata Disease-Japan (Akagi and Nishimura, 1991). The precision and accuracy of these methods have been repeatedly verified by inter-laboratory calibration exercises including the analysis of standard reference materials such as IAEA 085, 086 and 142 (Horvat, et. al, 1997).

Radiotracer techniques are potentially powerful for investigating the transformation and pathways of chemical pollutants in the aquatic environments, however, only few studies have used such techniques to survey the environmental behavior of mercury. Early studies include that of Beckert, et al (1974) who utilized 203 Hg tracer to study the formation of organomercury compounds in soils contaminated with inorganic mercury (11,12). In this study, laboratory analysis will include conventional (i.e. atomic absorption spectrophotometer) and application of nuclear techniques. A comprehensive and scientific assessment of the health and environmental impact of mercury will be undertaken to determine the health and environmental impact of mercury within the small-scale gold mining community. Results of the study will ensure that vital, scientific and evidence-based inputs will be provided to the government's policy direction and standard setting.

1.1. Detailed Research Objectives

General Objective:

- To determine the health and environmental impact of mercury compounds

Specific Objectives:

- To determine the health and environmental profile/status of the mining community.
- To describe the socio-demographic characteristics of the groups included in the study
- To determine the presence and severity of adverse health effects of exposure to mercury compounds
- To determine possible risk factors associated with adverse health effects.
- To determine the levels/speciate mercury concentration in biological and environmental samples to be collected from members of the study population and compare results of various analytical methods
- To establish inter-laboratory comparative techniques in collaboration with international institutes
- To determine possible correlation between environment and health status.
- To undertake needed medical management of disease conditions including detoxification, if necessary.

1.2. Methodology

Social preparation of the communities have been undertaken in coordination with the local government units. Arrangements were made through trained personnel from the Centers for Health Development. An interview tool was prepared and pre-tested and translated into the local dialect and re-translated into its original form. Medical history were likewise obtained through an interview questionnaire. Field interviewers had an orientation seminar to ensure conformity of data to be generated. Prior informed consent for the medical examination and blood extraction among children were signed by the subject's parents or guardians. Randomized selection of subjects were undertaken. Subjects were selected based on a preliminary survey of the community relative to the Knowledge, Attitudes and Practices study undertaken in 1999 (Sunio).

A complete physical, mental status and neurobehavioral examination of the subjects were undertaken. Behavioral evaluation have been evaluated by a group of examiners who were blinded to the subject's mercury exposure status until all data had been encoded and entered into a computer database. Blood and urine specimen for each subject for laboratory testing included the following:

- Mercury: total and methyl compounds
- CBC with platelet and reticulocyte count
- Peripheral blood smear
- FBS, BUN, Creatinine and electrolytes
- ALT/AST, alkaline phosphatase
- Protime
- Urinalysis
- Fecalysis with occult blood
- CXR for subjects 18 y.o and above, as needed

- ECG for subjects 50 y.o. and above, as needed
- EMG-NCV testing for those with blood lead levels above permissible levels and/or history of seizures, as needed
- Vital signs including Blood Pressure readings
- Pulmonary function tests specifically PEFR

Biological and environmental samples were collected for mercury determination. All samples were analyzed for total and methylmercury content thru atomic absorption spectrophotometric (AAS) method at the UP-Manila laboratory using the modified method developed by NIMD-Japan (Akagi, 1998). As to the application of nuclear techniques, there had been several delays in the analysis due to the inability of the nuclear institute to analyze the sample. The research staff will consider other nuclear techniques that might be available in the country. Routine laboratory tests have been undertaken at a reference laboratory of a government hospital.

A team from UP-National Poisons Control and Information Service complemented by local health workers conducted the health examination. The team comprised of specialists in toxicology, neurology and occupational medicine. The Occupational Health staff in collaboration with the local health personnel conducted the environmental monitoring.

1.3. Study Design

Cross-sectional study.

1.4. Variables

1. Socio-demographic data: Age, Sex, Marital status, Occupation
2. Life style (e.g. alcohol consumption, smoking, diet, source of drinking water etc. and other possible risk factors)
3. Distance of house from mine tailings/Duration of residence
4. Anthropometrics
5. Vital signs (respiratory rate, heart rate, blood pressure readings)
6. Pulmonary function (PEFR)
7. Frequency of signs and symptoms
8. Medical/Occupational History
9. Exposure to pesticides, heavy metals, etc.
10. Health status in the past year prior to examination
11. Current and past medications
12. Developmental/pediatric history
13. Laboratory parameters
14. Neurobehavioral parameters

1.5. Description of research setting and population

1.5.1. Study Area

The study site selected was the small-scale gold mining community in Sibutad, which is located in the northern part of Zamboanga del Norte. Selection of the study site depended on the accessibility, peace and order condition and cooperation of the stakeholders. Sibutad is classified as a 5th class municipality with a land area of 13,372 has and a population of 19,571. Major agricultural products include corn, coconut and rice production. Other sources of livelihood are marine/aquatic resources and gold extraction.

Gold mines were located in the sitio of Libay, 5.0 km from the poblacion with the mining sites located very near the Murcielagos Bay where the tailing ponds were directly discharging into the water bodies. It was estimated that 200-300 people were engaged in gold processing activities. In a pre-survey of the mining community done in 1999, 51% of population were females and 49% were males. 42% of the people belong to the 15-44 age group.

Leading causes of morbidity in the community were mainly upper respiratory tract infection, skin problems, wounds, hyperacidity and nutritional deficiency. Meanwhile leading causes of mortality include pneumonia, disease of the circulatory system, bleeding peptic ulcer, cancer and liver diseases.

In 1997, the Department of Agriculture reported mercury contamination of fish and shellfish in Murcielagos Bay exceeding the permissible limit of 0.5 ppm.

1.5.2. Study Population

Inclusion criteria

- Household within a mining community (at least 3 members/household)
- Engaged in mining activity for at least 5 years
- Willing to be included in the study
- With informed consent

Exclusion criteria

- Migrated from other mining areas
- Those previously included in preliminary studies
- Those who refuse to be included in the study
- Those who fail to meet the inclusion criteria

Selection was undertaken using a table of random numbers where each household was assigned a specific number. A map of the households will be prepared in coordination with the local government units. A 10% drop-out rate will be considered and selection of replacements will also be done at random.

1.5.3. Sampling selection

- random selection

1.5.4. Sample Size

- Workers directly exposed to mercury (blowtorching/amalgam squeezing)

No. of years	Number
1-4 years	10
5-9 years	10
>10 years	10

- Community members (mother and child)

		Number
- Newborn, neonate and infants – 0-36 mos.		5
- Toddlers – 37 mos. to 83 mos.		5
- Children – 7-12 years		5
- @60 persons will be included in the health assessment study		

1.6. Research Instruments and Tools

Component 1: Health Assessment

- social preparation of the community
- interview questionnaire (socio-demographic profile, lifestyle, diet, medical history)/face to face interview with respondents
- vital signs
- pulmonary function tests specifically PEFR
- comprehensive medical and neurological examination including a modified mental status examination
- biological monitoring

Biological samples to be collected:

- hair *blood *urine

Component 2: Environmental Assessment

- establish sampling stations based on the selection of study site and assess the following:
- drinking water * river quality
- effluent discharge *sediment/soil contamination
- air quality (ambient/personal/workplace) *marine life

Environmental samples to be collected:

- fish/shellfish *water:river quality, drinking water, effluent
- sediment/soil *air

1.7. Ethical considerations

Confidentiality of health information has been assured by the study proponents. It was stipulated in the consent form that respondents are free to withdraw from the study anytime. In the course of the health examination, those found with health findings were appropriately provided with medications/treatment or referral, as the case may be.

2. METHODS

2.1. Environmental Sampling

Field sampling for the Analysis of Metals compiled by Dybern (15) and NIOSH Method 6009 for the determination of mercury in air samples were implemented. EPA methods for the collection of environmental samples were followed. Sampling stations were designated within the mining community.

2.2. Biological Samples

Samples were collected and transported in accordance with CDC and WHO procedures.

2.3. Analytical Procedures

Laboratory methods developed by the National Institute for Minamata Disease-Japan were applied in this research study (3). Sample preparation for total mercury analyses for blood, urine, hair and fish tissues included pre-treatment and digestion of the samples through the addition of nitric-perchloric and sulfuric acid solution. The digested sample was then heated at the prescribed range of 230-250°C for 20 minutes and then cooled before filling up with water up to the 50 ml for analysis. Detection limit is 0.5 ng of Hg. Sample was then analyzed by cold vapor atomic absorption spectrophotometry/mercury analyzer and X-ray fluorescence method. For methylmercury analysis, samples were analyzed using gas-chromatography-electron capture detector. Combined techniques of dithizone extraction, back extraction into alkaline Na_2S, re-extraction with dithizone have been applied. Detection limit is 5 ng of Me Hg/g. For the analysis of methylmercury in hair, an acid leaching process has been used utilizing aqueous HCl solution at high temperatures, together with the use of an organic solvent for extraction. Analysis was done through Gas Chromatographic methods. Personnel trained at the NIMD-Japan under the direct supervision of Dr. Akagi performed the laboratory analysis. Biological and environmental wastes have been disposed of in accordance with set procedures and standards of the laboratory institutions.

Inter-laboratory comparison of four laboratories will be undertaken which will include the UP-Manila and the National Institute for Minamata Disease-Japan. Outline for the method is shown in Figs. 1 and 2 follows:

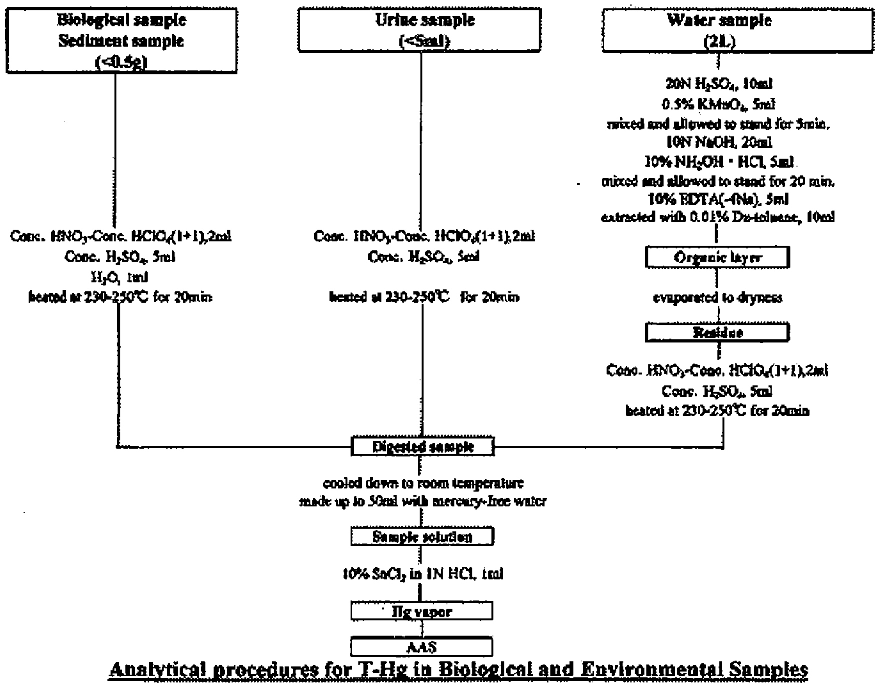

FIG 1: Analytical procedures for T-Hg in biological and environmental samples

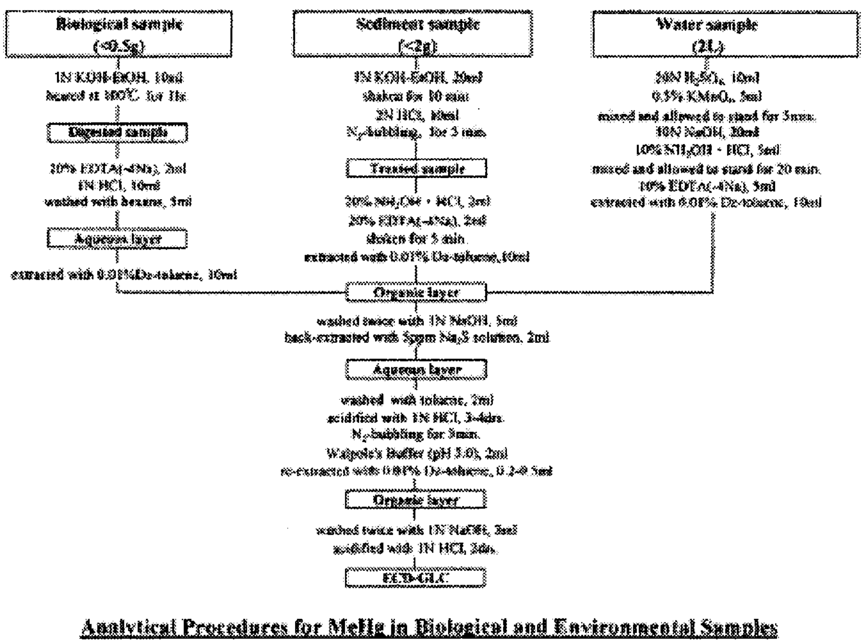

FIG 2: Analytical procedures for MeHg in biological and environmental samples

2.4. Analysis and Data Evaluation

Data were encoded using SPSS ver.8. A descriptive analysis of the basic demographic profile and physical findings has been undertaken. Socio-demographic profiles, physical examination findings and laboratory results have been compared using applicable parametric and non-parametric tests to determine statistically significant differences (p values ≤ 0.05). Regression analysis to determine statistical correlation had been undertaken. Both bivariate analysis and multiple regression analysis were done. Odds ratios and 95% confidence intervals have been computed for abnormal health findings.

2.5. Description of research carried out

Health assessment was done using face to face interviews supplemented with a standard questionnaire. The subjects underwent a comprehensive medical and neurological examination, the latter including a modified mental status test. Monitoring of vital signs and peak expiratory flow rate were conducted. Biomarkers using hair, blood and urine samples were analyzed for levels of total and methyl mercury.

Water, air and sediment/soil samples were collected for environmental monitoring for total and methylmercury. Samples of marine life were also analyzed.

Analysis have been done by comparing the results of cold vapor atomic absorption spectrometry and x-ray fluorescence technique. Methyl mercury levels were analyzed using gas chromatography with electron capture detector (ECD). In this report results of biomarkers were obtained using the atomic absorption and gas chromatography methods. The results using x-ray fluorescence technique will follow.

3. RESULTS OBTAINED

3.1. Socio-Demographic Profile

Fifty-three (53) research subjects were selected by stratified random sampling from a list of workers and community members directly and indirectly exposed to mercury from Sibutad, Zamboanga del Norte.

There were 40 adults (75.47%) aged from 26 to 50 years, of which 25 were male and 15 female, based on the inclusion/exclusion criteria of the study. Thirteen (24.53%) children aged 6 months to 11 years, with 5 (38.46%) male and 8 (61.54%) female, were also evaluated. (Table 1) Most of the workers resided in the community at an average of 14.36 years. On the average there were 5.325+/-2.39 family members in a household.

TABLE I: DISTRIBUTION OF RESPONDENTS BY AGE AND SEX, SIBUTAD, ZAMBOANGA DEL NORTE, PHILIPPINES, 2000

Parameter	Number	Mean +/- S.D. (yrs)
All Ages	53	29.13+/- 14.518
Children (0-11 yrs)	13 (24.53%)	6.49+/-3.65
Adults (18-50 yrs)	40 (75.47%)	36.57+/-6.72
Sex		
All Ages	53	
Males	30 (56.60%)	
Females	23 (43.40%)	
Children	13	
Males	5 (38.46%)	
Females	8 (61.54%)	
Adults	40	
Males	25 (62.5%)	
Females	15 (37.5%)	

Most of the adults or 28/39 (71.8%) were smokers with more than one half or 20/39 (51.3%) smoke during work periods. Consumption ranged from 3-20 sticks of cigarettes per day. Most of the smokers were males which accounted for 22/28 (78.57%) of the adults while the rest were females 6/28 (21.42%). Majority or 33/39 (84.62%) of the adults drink alcoholic beverages.

Seven households confirmed that they store mercury at their homes. Relative to their source of drinking water, majority or 37/53 (69.81%) have indicated natural spring as their primary source, the water district for 8/53 (15.09%) and deep well for 4/53 (7.55%) of the respondents. Only 5/53 (9.43%) bathed in the river. More than one fifth of the respondents or 12/53 (22.64%) use pesticides in their homes.

Most or 50/53 (94.33%) of the subjects were fish eaters which was the common food eaten in the community with 33/50 (66%) eat fish 3 times a day; 7/50 (14%), twice daily and 5/50 (10%) once daily.

3.2. Mercury Determination

There were 51 hair samples evaluated for total mercury levels and methyl mercury which ranged from 0.95-68.68 ng/g and 0.73-5.81 ng/g, respectively. The proportion of methyl mercury in hair ranged from 2.66-99.98%. 10 had elevated total mercury levels and 23 with elevated methylmercury levels.

Fifty (50) blood samples were analyzed for total mercury and methyl mercury determination which showed levels ranging from 2.74-29.47 ug/L and 1.63-23.11 ug/L, respectively. The proportion of methyl mercury in blood ranged from 29.38-97.30%. A total of 23 blood samples of the 50 tested showed elevated total mercury values and 10 had elevated methylmercury levels. (Table 2)

Hair samples from the 38 adult subjects showed 10 had elevated total mercury levels ($\geq$ 4 ppm) and 20 with elevated methylmercury levels ($\geq$2 ppm). Total blood mercury levels were elevated ($\geq$10 ppb) in 20 adults and 9 who had elevated methylmercury levels (>10 ppb). (Table 1)

Among the 9 children who were more than 3 years of age (range: 5-11 years), none had elevated total mercury levels (≥ 4 ppm) but 2 had elevated methylmercury levels (≥ 2 ppm) in the hair. Blood levels showed elevated total mercury levels (≥ 7.5 ppb) in two of the children and one child showed elevated methylmercury levels (≥ 10 ppb). (Table 2A).

Among the 5 children less than 3 years of age (range: 6 mos - 3 years), none had elevated total mercury levels (≥ 4 ppm) but one had elevated methylmercury levels (≥ 2 ppm) in the hair. Blood analysis showed one child with elevated total mercury levels (≥ 7.5 ppb) while all showed methylmercury levels within acceptable limits (≥ 10 ppb). (Table 2B).

TABLE II: MERCURY DETERMINATION IN HAIR AND BLOOD LEVELS, ZAMBOANGA DEL NORTE, PHILIPPINES, 2000

Parameter	Number	Range	Mean +/-S.D.
Blood (T-Hg Level)		ug/L	ug/L
All Age Group	50	2.74-29.47	10.71+/-6.00
Children	12	2.74-14.20	7.34+/-3.72
Adults	38	3.38-29.48	11.58+/-6.18
Blood (Me-Hg Level)		ug/L	ug/L
All Age Group	50	1.63-23.1066	7.51+/-4.66
Children	12	2.67-11.48	5.52+/-2.80
Adults	38	1.63-23.11	8.13+/-4.97
Blood (%Me-Hg Level)		(%)	(%)
All Age Group	50	29.38-97.30	69.70+/-15.37
Children	12	60.9-97.3	76.1+/-9.63
Adults	38	29.38-90.23	67.67+/-16.37
Hair T-Hg Level		(ng/g)	(ng/g)
All Age Group	51	0.95-68.676	4.41+/-9.55
Children	12	0.95-5.11	2.11+/-1.06
Adults	39	1.045-68.68	5.11+/-10.84
Hair (Me-Hg) Level		(ng/g)	(ng/g)
All Age Group	51	0.73-5.81	2.07+/-0.97
Children	12	0.73-3.21	1.68+/-0.68
Adults		0.86-5.81	2.197+/-1.02
Hair (%Me-Hg) Level		(%)	(%)
All Age Group	51	2.66-99.98	74.34+/-21.35
Children	12	53.69-99.98	81.21+/-12.5
Adults	39	2.66-99.6	72.2+/-23.13

3.3. Environmental Monitoring

Analysis of 9 marine sample showed a range of 4.03-62.97 ng/g (ppb) for total mercury and 3.75–35.98 ng/g for methyl mercury which were within the allowable limits set by the Bureau of Fisheries and Aquatic Resources (BFAR) in the Philippines (<500 ng/g). The proportion of methyl mercury ranged from 22.99-89.78%. (Table 3)

TABLE III: TOTAL AND METHYL MERCURY ANALYSIS OF FISH SAMPLES, SIBUTAD, ZAMBOANGA DEL NORTE, PHILIPPINES, 2000

Fish Samples

Sample	*No. of samples*	*Total Hg (ng/g) Range*	*Total Hg (ng/g) Mean+/-SD*
Samulo	2	18.98-22.80	20.89+/-2.7
Danggit (Siganid)	2	4.03-5.67	4.85+/-1.16
Talad	2	33.42-59	46.23+/-18.11
Mulmol	2	7.2-7.38	7.30-0+/.13
Clam	2	25.71-38.06	31.89+/-8.74
Blue crab	3	38.63-62.97	49.1+/-12.53
Solid	1	23.57	
Scallop	1	33.55	
Bugaong (Convex Lined Grunt)	1	32.58	

Fish Samples

Sample	*No. of samples*	*Me-Hg (ng/g) Range*	*Mean+/-SD (ng/g)*	*% MeHg Range*	*Mean+/-SD*
Samulo	2	14.73-20.47	17.6+/-4.05	77.61-89.78	83.71+/-8.59
Danggit	2	4.14-7.89	3.95+/-0.28	72.89-93	82.99+/-14.15
Talad	2	23.84-35.98	29.91+/-8.59	60.96-71.33	66.14+/-7.33
Mulmol	2	4.37-4.38	4.37+/-0.01	59.13-60.76	59.95+/-1.15
Clam	2	5.91-9.7	7.81+/-2.68	22.99-25.48	24.24+/-1.75
Blue crab	3	28.55-34.03	31.28+/-3.87	73.90-74.53	74.21+/-0.44
Solid	1	20.42		86.64	
Scallop	1	23.24		69.27	
Bugaong	1	29.21		89.66	

US FDA = 500 ppb

Water quality monitoring of a drinking water source showed a slightly higher level of mercury as compared to the sample obtained from a creek (Table 4). Levels for receiving water bodies were elevated as compared with the national standard.

TABLE IV: WATER QUALITY MONITORING ANALYSIS FOR MERCURY

Water Samples

Sample	*Total Hg (ng/L)*
Drinking Water	9.39
Libay Creek	9.73

Drinking water quality = 1 ug/L
Receiving water bodies = 2 ng/L

Ambient air quality monitoring showed that mercury levels in three sampling stations exceeded the permissible limits (Table 5).

TABLE V: AMBIENT AIR QUALITY MONITORING FOR MERCURY

Air Samples

Sampling Station No.	***Total Hg (mg/m3)***
Lalab, Sibutad	13.44
Libay Elementary School	4.74
Libay Barangay Office	9.67

National Standard for Ambient Air = 0.015 mg/m3

Mercury levels in the sediment showed values within the standards set by the Netherlands.

TABLE VI: SEDIMENT ANALYSIS FOR MERCURY LEVEL

Sediment No.	***Total Hg (ng/g)***
Libay Creek (wet weight)	49.63
(dry weight)	35.28

Netherlands Standard = 0.3 ug/g

4. CONCLUSIONS DRAWN

- A significant number of biomarkers from adults showed elevated total and methyl mercury levels in both blood and hair.
- There were 23 subjects with elevated total blood mercury levels who could be candidates for possible chelation if other criteria are fulfilled.
- All marine samples analyzed showed values of total and methyl mercury within acceptable limits.
- Environmental monitoring results showed ambient air monitoring for mercury levels in three sampling stations exceeding permissible levels. Likewise mercury levels in the receiving water body and in the sediment exceeded the recommended standards.

REFERENCES

[1] Miranda, C., et.al., Evaluation of Mercury Toxicity Hazards Associated With Artisanal Gold Mining in Monkayo, Davao, Philippines, 1997

[2] Francisco, A.T.T., Focus on Small-Scale Gold Mining: Philippine Setting, Proceedings of the International Workshop on the Fate of Mercury in Gold Mining and Measures to Control Environmental Pollution in Various Countries, NIMD/Indonesia, 1996

[3] Akagi, H., Analytical Methods for Evaluating Human Exposure to Mercury Due to Gold Mining, Proceedings of the International Workshop on the Fate of Mercury in Gold Mining and Measures to Control Environmental Pollution in Various Countries, NIMD/Indonmesia, 1996

[4] Wheatley, B. and Paradis, S., Exposure of Canadian Aboriginal Peoples to Methylmercury, 1995

[5] Akagi, Hirokatsu, Studies on Mercury Pollution in the Amazon, Brazil, Global Environmental Research, Vol.2, No.2. 193-202, 1998

[6] Our intensive efforts to Overcome the Tragic History of Minamata Disease, Environment Agency of Japan, 1997

[7] Akagi, H., Improved Techniques in the Analysis of Total and Methylmercury in Biological and Environmental Samples, 1997

[8] Maramba, N., et.al., Integrated Surveillance of the Health and Environmental Impacts of Mercury Exposure, 1988

[9] Maramba, et.al., Health Assessment for Mercury Exposure Among Children Residing Near a Gold Processing and Refining Plant, 1999

[10] Guimaraes, J., Mercury Methylation in Tropical River and Lake Sediments: Important Sites and Influencing Factors Investigated Through Radiochemical Techniques, 1996

[11] Ueno, T., Vertical Distribution of Radionuclides and Mercury in Lake Sediments, 1996

[12] Environmental Health Criteria on Mercury: International Programme on Chemical Safety, WHO, Vols.1, 86, 101, 118

[13] Mercury, US-Center for Disease Control

[14] Dybern, B.I., Field Sampling and Preparation of Subsamples of Aquatic Organisms for Analysis of Metals and Organochlorines, FAO, UN, 1979