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HUMAN EXPOSURE TO MERCURY IN FISH IN MINING AREAS IN THE PHILIPPINES

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Mercury pollution in most parts of the regions in the world are caused by the release into the environment of metallic mercury used in the recovery of gold by the crude method of amalgamation. Currently, countries such as in Brazil, Ghana, Tanzania, Philippines, Indonesia, China and Vietnam with roughly 10 million people are estimated to be involved in these activities. In China alone, 13 % of the total gold output is said to be produced from the amalgamation process which accounts for 20 tons of Hg released into the environment. China ranks fifth in the world gold production output with South Africa having the largest total gold production. Presently, in 55 countries engaged in small-scale mining activity it was estimated that 8.25-10.1 million people have been directly involved with an additional 80-100 million being dependent on this activity for their livelihood. For 10 Asia-Pacific countries, it was estimated that total employment from small-scale mining is from 6.0-6.6 million which would account for 73% of the global estimates.

In the Philippines, there are 2 main sources of Hg pollution, mined Hg deposits and use of mercury in gold extraction in at least 20 provinces in the country. Presently, there are significant small-scale gold mining operations in several artisanal gold mining activities using mercury has proliferated in various parts of the country since the early 1980’s. In Southern Philippines which is actively engaged in this activity , 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]. Mining and processing operations include crude methods in digging, tunneling, timbering as well as in the use of the toxic chemical mercury in the extraction of gold from the ore. Equally important are the serious environmental and health-related problems that arise from these activities.

Intensified small-scale gold mining activities and processing have concomitant health; social and environmental problems which include environmental sanitation, mercury intoxication and indiscriminate disposal of mercury along with conglomeration of people in the mining communities characterized the problems noted in these areas. Occupational inorganic mercury poisoning may be a possible source of mercury exposure especially during blowtorching operations. Aside from this, processing operations have also affected the health of the people in the lowlands.

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.

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). In the Amazons, it was noted that temperate conditions are important parameters in the production of methyl mercury in the aquatic environment. It is also important to determine the existing chemical speculation of mercury present in the environment as well as in man which will be the basis for the formulation of appropriate intervention and control measures as well as the management and treatment (3).

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.

Studies on the health and environmental impact of mercury as a result of natural and anthropogenic sources have been reported worldwide. Foremost of which during the post-war era is the outbreak of Minamata Disease in 1956 in certain villages around Minamata Bay in Kumamoto Prefecture, Japan. Clinical and epidemiological studies were undertaken among the Canadian-Indian population groups to assess their level of exposure to methylmercury through the consumption of fish. Signs and symptoms associated with methylmercury exposure have been reported (4).

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.

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.

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 at least four times greater sensitivity to methylmercury, the fetus absorbed the compound from the mother and thus protected her from poisoning. Levels in the mother's blood and urine increased immediately after delivery. Mercury could also be passed to the infants through their mother's milk. In previous studies undertaken, because the fetuses absorbed the mercury, some women have no symptoms other than elevated hair levels. Children with serious symptoms died within two months of birth. When the illness is prolonged, they were susceptible to other disease such as pneumonia which is the primary cause of death. Survivors were often retarded and epileptic. Swedish scientists have established that individuals who ate fish with elevated mercury levels had more of an uncharacteristic chromosome damage than a control group. Cells of the central nervous system that have been once damaged do not recover in this study, cord blood and umbilical cord will be collected from mother and child to determine levels of mercury body burden.

In Canada, it was reported that mercury discharged by a chlor-alkali plant, methylated in the aquatic ecosystems and bioaccumulated to significant levels (up to 24 ppm) in the fish eaten by the people. As a result many residents developed high mercury levels of 660 ppm. Health examinations showed that 11 out of 99 individuals had neurological findings possibly attributable to methylmercury, e.g. tremor or ataxia, however, neurologists were unable to make a definitive diagnosis when confounders (e.g. such as age and lifestyles) were taken into consideration (Wheatley, 1996). As part of the assessment of fetal exposure, 2,405 umbilical cord blood samples were taken. 523 cord blood samples (21.8%) were found to have levels greater than 20 ppb, i.e. above the “acceptable range”. Neurological examinations performed on the children showed no findings that could be attributed to methylmercury.(4)

RESULTS OF FISH MONITORING STUDIES:

During the gold rush period in the early 1980’s, fish and shellfish monitoring results 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 were set at 2 ppb. A more comprehensive study was undertaken in 1988 (Torres) where mercury in fish samples ranged from 0.047-2.059 ug/g. two fish samples showed high level of mercury content, five times higher than the set standard of 0.5 ug/g. No methyl mercury analysis was undertaken at this time. The author concluded that although the fish samples were still below the tolerable limit set by WHO, the increasing levels of mercury in the rivers draining to the gulf and in the Gulf itself.

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 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). Total mercury in fish were still below the recommended levels by the US FDA.. The fishes were reportedly coming from the nearby town of Pantukan which is also actively engaged in small-scale gold mining. Fish samples collected showed a higher percentage of methyl mercury content except for one sample. Seaweed collected had a level of 6.39 mg/kg for total mercury while methyl mercury levels were non-detectable. All fish samples were within the recommended US FDA standards of 0.5 ug/g for mercury content (6).

However, if we are to compare the results with the WHO environmental criteria for mercury concentrations in fresh water fish from non-polluted areas of 100-200 ng/g (0.1-0.2 ug/g), 3 fish species exceeded the recommended limits.(7,8)

Results of mercury levels in fish samples as compared with the WHO criteria showed that mean levels in grunt, gopher and tuna (bariles) were elevated, with the tuna recording the highest level of 438.8 ng/g for total mercury and 377.18 ng/g for methyl mercury. The mean proportion of Me-Hg to T-Hg in all fish samples were in the range of 56.16-99.38% indicating that most of the mercury in the fish sampled were in the form of methylmercury. The gopher had registered the highest percentage of methyl mercury content.

Table 3. Marine samples analyzed for Total and Me-Hg

FISH SAMPLE	Mean THg (ng/g)	Mean Me-Hg (ng/g)	Mean % Me-Hg
Bariles (tuna)	438.8	377.18	85.96
Bugaong (grunt)	107.85	103.09	97.86
Lapu-Lapu (gopher)	102.37	101.69	99.38
Tuna	84.8	83.84	98.87
Banak (mullet)	29.38	27.97	95.20
Tamban (indian sardines)	26.44	24.25	91.72
Maya-Maya A (napper)	18.31	17.24	93.32
Bangus (milkfish)	12.92	10.36	80.19
(i) Tilapia	10.33	9.895	95.40
Seaweed *	6.39	nd	nd
Peret (small tuna)	5.74	5.485	95.95
Samaral A	1.34	0.725	56.16

USFDA standards = 0.5 ug/g or 500 ng/g

WHO(for non-polluted water bodies) = 100-200 ng/g

n.d = non-detectable

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.

The dietary intake of the people examined, fish being one of their staple diets have a significant contribution to their overall mercury intake. This could be attributed to the fact that the fish habitat significantly showed elevated levels of total mercury specifically in water and sediment samples collected. Anthropogenic sources of mercury pollution in the environment in the area could be attributed to the mining processes which discharges mercury into the river systems and the ambient air This significantly contributes to the mercury intake of the children. Thus, the schoolchildren are exposed to at least two forms of mercury - inorganic and methyl mercury simultaneously.

In a former mercury mines in Palawan, several studies of the environmental impact were undertaken prior to 1990, Kapuan, et.al., (1982) undertook a preliminary assessment of Hg concentrations in sediments of Honda Bay which is a reclaimed area from cinnabar ore in Puerto Princesa, reported concentrations of 2.433 mg/kg for jetty wastes and up to 0.190 mg/kg for nearshore interfacial sediment. In 1994, however, a more comprehensive study of the geochemistry of sediments of close proximity to Sitio Honda Bay (Benoit, et.al) provided evidence that the Hg concentration of the jetty substrate may be higher that previously envisaged (up to 560 mg/kg). The British Geological Survey study in Palawan showed that the Sitio Honda Bay jetty exerts a marked localised influence on sediment quality. The average interfacial Hg concentration in Honda Bay sediments (c. 40 ug/kg) lies within the global background range. (Williams, et.al, 1996). Mercury concentrations in six species of fish from Honda Bay were found to fall within the ranges typically encountered for analogous species worldwide. Median Hg values for all analyzed species was within the USFDA threshold of 0.5 ppm. Human Hg body burdens among 130 subjects indicate that all Palawan residents in the study are subjected to high Hg exposure as compared with a control population. Estimated mean blood Hg values ranged from 8.8-17.6 ng/ml for the five sub-groups, with a maximum individual value of 74.1 ng/ml. Such values are typical of populations consuming fish at a daily frequency.

Health assessment of community members within 10 km of the Hg mines showed that majority of old people who were residents in the area and former miners had elevated blood mercury levels requiring detoxification. 10 children with elevated blood mercury levels with positive PE findings were also detoxified. However, correlation studies comparing a similar area with naturally occurring undeveloped Hg rich resource showed negligible levels of Hg in health and environmental media.

In the thirty-third report of the Joint FAO/WHO Expert Committee on Food Additives (JECFA), it was recommended that the permissible tolerable weekly intake (PTWI) for methylmercury in adults be maintained at 200 ug (3.3 ug/kg body weight) (WHO, 1978, WHO 1989b). However, the committee noted that pregnant women and nursing mothers are likely to be at greater risk.(8)

Studies have shown that a daily methylmercury intake of 0.48 ug/kg b.w. will not result in any detectable adverse effects. However, a daily intake of 3-7 ug/kg bw would cause adverse effects on the nervous system, manifested as an approximately 5% increase in the incidence of paraesthesia. It has been estimated that humans have a daily intake of about 2.4 ug methylmercury from all sources, and a daily uptake of approximately 2.3 ug..

The level of mercury in fish, even for humans consuming only small amounts (10-20 g of fish/day) can markedly affect the intake of methylmercury. Daily mercury intake, elimination, retention and excretion will depend on a number of factors. Research studies should also include special populations at risk including children, pregnant and nursing women and the elderly. Calculations indicate that an intake of 50 ug/day in an adult would involve a risk of about 0.3% of the symptoms of paraesthesia, whereas an intake of 200 ug/day would involve a risk of about 8% (8).

Reports so far prepared by research groups of various countries on mercury content in human hair have confirmed a correlation between mercury levels and the amount of fish consumed (Lodenius, 1992). Mercury levels found in human hair (as total mercury) in the Amazons ranged from 0.2 to 240 ppm. These data indicate that pollution originating from metallic mercury from gold mining affects people in the areas neighboring gold fields and even people living in far from such areas. The increase of mercury fluxes into the environment from gold mining activities in developing countries is likely to amplify Hg pollution problems and its concomitant health effects. It is necessary to understand the dynamics of Hg methylation and distribution in the environment in order to properly evaluate the availability of mercury for bioaccumulation in fish and other organisms, and the long term impact of mercury pollution.

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. So 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).

CONCLUSIONS

The current situation of mercury pollution have contributed to the mercury burden of people living in these contaminated sites. The metallic mercury used extensively and directly discharged into the environment is responsible for the formation of methyl mercury in the natural environment, which eventually leads to the bioaccumulation in the human body via the food chain. Thus, there is a need to conduct long term monitoring to gain a more comprehensive understanding of the sources, kinetics, environmental behavior and toxicity of Hg including its impact into the community especially the high risk groups i.e pregnant women and children.

RECOMMENDATIONS

1. There is a need to establish a laboratory to undertake a comprehensive inorganic and methyl mercury determination in these areas to provide the necessary guidelines to the community especially to high risk groups such as pregnant women and children.
2. Education of high risk groups e.g. pregnant women/children
3. For the local government units to conduct the following
   - 3.1 Continue health and environmental monitoring activities in the affected areas
   - 3.2 Require establishments to install anti-pollution devices for air pollution and waste treatment recovery/treatment facilities.
   - 3.3 Relocation of ballmilling/refining process into an industrial zone
   - 3.4 Remediation/mitigation measures in the environment should be undertaken to ensure that exposure limits to mercury will be kept at a minimum or within permissible limits.
   - 3.5 Conduct monitoring of fish especially those with high levels.

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