REVIEW ON THE ENVIRONMENTAL MERCURIAL EXPOSURE AND ITS MECHANISM IN CAUSING NEUROLOGIC CONDITIONS

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Abstract: The sources of mercury (Hg) are both natural and man-made, the latter was considered as the major contributor of environmental mercury. The study aims to elucidate factors affecting the human health and pathophysiology of neurologic conditions from mercury exposure. Preferred Reporting Items for Systematic review and Meta-Analysis protocol guideline was used in reviewing the published journals from year 2000- 2020. The effects of mercury on human health depend on concentration, length of exposure and rate of elimination from the body. With prolonged exposure and high level of mercury concentration that bio-accumulated in the brain, deleterious and irreversible neurologic damage were observed. The provinces with mining activities in the Philippines recorded a very high level of mercury vapor concentration that necessitates immediate evacuation of residents in the area. Mercury triggers brain inflammation and brain cell damage that may affect its normal function. Neurologic conditions that may develop after an exposure to mercury are Autistic spectrum disorder and Alzheimer's disease.

Key words: environmental mercury; neurologic conditions; hazardous wastes

1.INTRODUCTION

Mercury (Hg) is a naturally occurring chemical element found in the earth's crust. It is a shiny white metal that is liquid at room temperature but when exposed, can evaporate to become invisible, odorless toxic gas. Inhalation of toxic gas, exposure to contaminated soil and water, or accidental ingestion of elemental mercury and methylmercury can cause many deleterious effects on humans. The effects may vary depending on the concentration of exposure (Genchi et al. 2016). Volcanic eruption, earthquake, mining and burning fossil fuels are the usual sources of mercury (Azevedo et al. 2012).

Studies on mercury contamination in the Philippines are few. The study aims to elucidate factors affecting the human health and neurologic conditions from mercury exposure. It also provides information on environmental contamination of mercury in the Philippines, its sources, use and routes of exposure to mercury.

2. METHODOLOGY

This review paper is a systematic and comprehensive review of reports from journals and related articles that were published from 2000-2020. Preferred reporting items for systematic review and meta-analysis protocol guideline was followed in the preparation of this paper. Quantitative

studies about mercury in soil, report about local areas with mercury contamination and journals that discussed the mechanism or pathophysiology of neurologic conditions from mercurial exposure were included. However, journals about mercury contamination in both soil and water, other heavy metals and also articles that did not discuss the effects of mercury contamination were excluded.

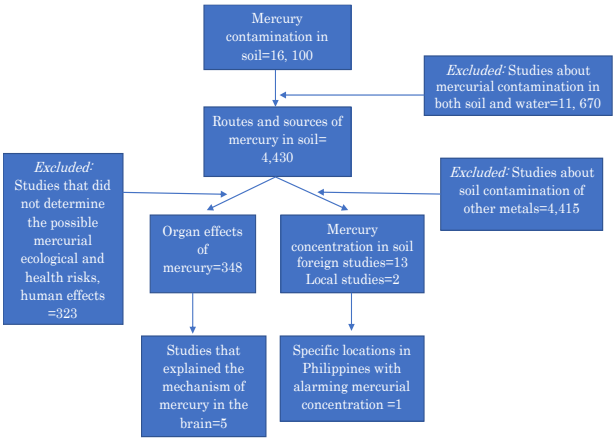

Fig.1. Review process of related journals

3. RESULTS AND DISCUSSION

3.1. Sources and Uses of Mercury

Mercury is a heavy metal that can be present indoor and outdoor coming from several sources, either natural or man-made. Its natural sources are volcanic eruption, weathering of rocks, forest fires and earthquakes while the broken medical and energy equipment are some man-made sources. Mercury is also an important material to address human energy needs such as batteries, electrical switches and fluorescent lamps, in protecting agriculture crops such as fungicides and other pesticides-containing mercury, and in medical equipment such as thermometers, incubators, aneroid manometer, amalgam dental fillings (WHO 2000, Azevedo et al. 2012 and Sun et al. 2020). In the Philippines, it was estimated that about 5,387 kg mercury per year were released to the environment particularly from power generation (Peralta and Pausing 2008).

3.2. Routes of exposure

The routes of exposure to mercury are through ingestion, inhalation and through contact with the skin. However, the different forms of mercury vary in terms of entry and absorption into the human body. Once absorbed, it may spread to different organs hematogenously (ATSDR 2015).

3.2.1. *Ingestion of mercury*

Methylmercury, the organic form, is mainly absorbed within the gastrointestinal tract. Individuals may ingest foods (plants and animals) and drink water that are contaminated with mercury (Azevedo et al. 2012; Cryderman et al. 2016). Ingested inorganic mercury can be absorbed by the intestines but at approximately less than 10% of the mercury in the body. Once absorbed in the intestine, the circulatory system will spread methylmercury to different vital organs including the brain and kidneys (ATSDR 1999 and Genchi et al. 2016).

3.2.2. *Inhalation of mercury*

Metallic mercury is released and suspended into the air, then transported to other places for at least one (1) week until one (1) year before it is deposited into the ground (Begani et al. 2013) that may be ingested from contaminated soil and water. Regardless of amount of inhaled or ingested mercury, it will be transported

to different organs. Metallic mercury is converted into inorganic mercury in the brain, embeds in it, and destroys the neurons and other brains cells. Immediate evacuation are advised in areas with > 10,000 ng (10 ug) per cubic meter of mercury in the air based on ATSDR (ATSDR 1999, Broussard et al. 2002, NHDES 2019, and Wang et al. 2020). Based on the findings of Ban Toxics (2011), the affected provinces are those with several industries and mine sites. Table 1 shows the summary of mercury vapor concentration in selected provinces in the Philippines as reported in Ban Toxics (2011).

Table 1. Summary of mercury vapor concentration in the mining provinces of the Philippines (Ban Toxics, 2011)

SPECIFIC LOCATION	MERCURY VAPOR CONCENTRATION (nanogram Hg per cubic meter)
BENGUET	
Miners Barracks	30,000.0
CAMARINES NORTE	
Gold processing area	30,000.0
Actual Amalgamation	30,000.0
Brgy. Malaguit residential	5,516.2
ROMBLON	
Brgy. Tagkayo-Open pit miners barracks	>30,000.0
Brgy Tagkayo-Planning area	19,010.7
Brgy Ipil Creek (Actual mercury and gold recovery)	5, 474.1
PALAWAN	
Sitio Pulang Lupa-Mercury mine site	1,488.8
Honda Bay-Mercury stockpile	1,093.8

3.2.3 Cutaneous entry

It is rarely observed in acquiring methylmercury but when it occurs, the organic form may also spread to the brain through the bloodstream. However, its neurologic involvement is less severe than inhalation. (ATSDR 1999, WHO 2000 and Gao et al. 2018). In Palawan, Philippines, the rice farmers are susceptible to mercury through dermal absorption from a paddy soil aside from ingestion of rice crops (Appleton et al. 2006).

3.3. Factors affecting the health risks

The increasing concentration of mercury in the body is affected by the length of exposure, concentration, and rate of elimination from the body. It takes time for the mercury to be excreted in the urine and feces, 26 days and 5 days, respectively (WHO 2003). The continuous exposure to the source contributes to mercury accumulation in the body, with deleterious effects in vital organ like the brain. Other factors that contribute in bio-accumulation include exposure to contaminated air with high mercury concentration, greater than 4ug /day or 0.2 ug /cubic meter, poses a health risk. Regular exposure such as 40-hours work exposure per week and/or 7-day exposure is considered continuous Hg exposure. If there is continuous exposure to mercury despite its elimination from the body, the recovery of the affected organs including the brain will be impossible (Broussard et al. 2002, WHO 2003).

3.4. Mercury-associated neurologic conditions and related mechanisms

Increased blood mercury concentration affects several organs but significant changes in an individual were observed once mercury has reached the brain. The common neurologic effects of mercury are motor

and sensory disturbances, personality changes and learning disabilities (Broussard et al. 2002, WHO 2003 and NHDES 2019). Neurologic conditions from mercury exposure are autism spectrum disease, Alzheimer's disease and alteration in brain function as shown in Table 2.

Autism spectrum disease is due to dysregulation in the genes and environmental factors. During pregnancy, it may affect the fetal brain development. Mercury promotes the release of reactive oxygen and reactive nitrogen species and hydrogen peroxide that prevent astrocytes in guarding the neurons against brain damage. Moreover, mercury also alters the normal mitochondrial functions that result in brain cell destruction (Ip et al. 2003, Karagas et al. 2012 and Morris et al. 2017). Meanwhile, mercury may reach the brain and may affect the vision and cognitive function particularly the attention and thinking skills. Moreover, mercury contributes in excessive production of tau protein that result in the formation of neurofibrillary tangles. These neurofibrillary tangles are observed in Alzheimer's disease (Rafiee et al. 2020). Moreover, exposure to mercury triggers brain inflammation from the release of tumor necrosis factor, interleukin-1 and cytokine. It causes the slow firing of neuronal signals that explains the altered cognitive function (Siblerud et al. 2019).

Table 2. Neurologic effects of mercurial exposure

NEUROLOGIC CONDITIONS	REFERENCES
Autistic Spectrum Disorder	Morris G, Puri B, Frye R, Maes M (2018)
Alzheimer's disease	Siblerud R, Mutter J, Moore E, Naumann J and Walach H (2019)
Effects on attention and executive function	Rafiee A, Delgado-Saborit J, Sly P, Quemerals B, Hashemi F, Akbari S, Hoseini M (2020)

4. CONCLUSIONS

Mercury triggers abnormal functioning of the brain and may cause irreversible neurologic effects presented in Autistic spectrum disorder and Alzheimer's disease. The factors that contribute to ill health effects of mercury depend on concentration, length of exposure and rate of elimination from the body.

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