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Alternatives of management and disposal for mercury thermometers at the end of their life from Mexican health care institutions

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A B S T R A C T

Mercury releases from used thermometers at the end of their life in the Mexican health sector are estimated to be 2166 kg/year. Some actions are being implemented at the hospital level to eliminate the use of mercury thermometers in some cities. This study evaluated the impact of policy alternatives for the sound management of mercury released from used thermometers using a life cycle assessment with Umberto software and Ecoinvent databases. The results identified that the elimination of open dumping and increasing the recycling rate of mercury up to 60% will lead to the highest net benefits compared with the use of virgin materials in new products. This study showed different scenarios of recycling and end of life practices in the management of mercury waste from glass thermometers in Mexico to know the environmental burdens of each treatment strategy and identified recommendations for development of public policies for handling of this type of waste with focus in the decrease of associated risks. It was demonstrated that increase of recycling allows reducing the environmental impacts caused by the use of raw materials and that decrease of landfills for deposit of mercury waste, preventing uncontrolled emissions of mercury to the atmosphere.

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1. Introduction

Mercury, for its unique physical–chemical properties and its characteristics of toxicity, persistence and bioaccumulative potential (when present in its organic form), has been a cause of concern in most countries and several studies have been made to characterize these properties (Oliveros and Johnson, 2002; EPA, 2008).

Some of the main concerns lies in its potential to be transported in the atmosphere over long distances due to its volatility and long life time (six months to two years), its bioaccumulation in the aquatic food chain, and its ability to transform into more toxic compounds such as methylmercury (Gaona, 2004; UNEP, 2002).

Most air emissions take place in the form of elemental mercury (gaseous). The remaining emissions take place as particles in the form of inorganic mercury (such as mercuric chloride). These forms have a shorter life time in the atmosphere and can be deposited on land or water bodies at a distance between 100 and 1000 km from its original source (UNEP, 2002). In spite of the recent advances in establishing the mercury air cycle (air to land and oceans), the pattern of flows at the local, regional or global level is still unknown (UNEP, 2013).

Mercury exists in the environment in various chemical species: elemental mercury: Hg^0; monovalent mercury: mercurous ion or mercury (I), $(Hg–Hg)^{2+}$; divalent mercury: ion mercuric or mercury (II), Hg^2. It also exits in organic forms such as organometallic compounds in which the mercury is covalently bound to one or two carbon atoms to form: methylmercury (CH_3Hg_x), phenylmercury ($C_6H_5Hg_x$) Methoxyethyl ($CH_3OC_2H_4Hg_x$) and Dimethyl $(CH_3)2Hg$ (WHO, 2003).

Mercury and its compounds are highly toxic especially to the developing nervous system. Its toxicity depends on the reactivity of the chemical species, the quantity, the route of exposure and the vulnerability of the exposed organism. Methylmercury is one of the most hazardous and bioaccumulative of mercury compounds (Shao et al., 2012; Mergler et al., 2007). Humans can be exposed to mercury by many routes, including food consumption (mainly fish), occupational and household exposure, dental amalgams, etc. (ATSDR, 1999; Mergler et al., 2007).

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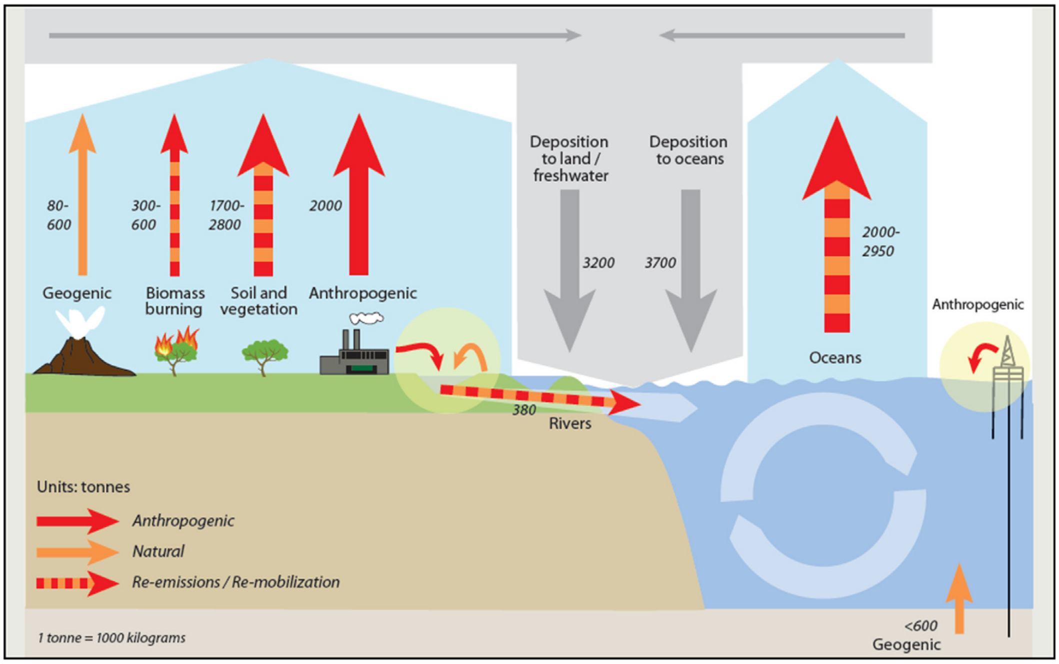

The United Nations Environment Programme (UNEP) and the World Health Organization has identified the adverse effects of mercury pollution as a serious global problem for human health and the environment (UNEP, 2002; UNEP, 2013). Global assessments show that the contribution of anthropogenic processes can be considerable since emissions for 2005 were estimated between 1926 and 2320 ton/year (Pacyna et al., 2010; Pirrone et al., 2010). The annual average global mercury emissions related to contaminated sites can account for 137–260 ton/year from which 70–95 ton/year correspond to air emissions and from these, 67–65 Mg/yr can be transported by hydrological processes (Kocman et al., 2013).

On the other hand, the health sector is one of the most important sources of mercury emission and one of the most demanding worldwide because of the uses in medical equipment, including thermometers, among others. Mercury emissions to the environment occur when one of these devices is spilled or broken (WHO-HCWH, 2010; Kuepouo, 2013).

In Mexico, data on thermometers used in the health sector were reported in 1999 in the Preliminary Inventory of Mercury Releases elaborated by Acosta and Asociados (2001). This estimation was based in the consumption of thermometers per number of hospital beds in Mexico, in which the estimation considered 1 broken thermometer per week for every 4 hospital beds. On the other hand, few studies have been performed in Mexico on mercury emissions. De la Rosa et al. (2006) reported that in landfills gaseous mercury emission ranges between 12.5 and 52.4 ng m^{-3}.

Considering that mercury in thermometers can vary from 0.6 to 1 g (UNEP, 2005; Díaz, 2011; Kuepouo, 2013) and according to official statistics in Mexico, there are 160,017 beds in the different public and private hospitals (Acosta and Asociados, 2001). It is also deemed that there is a thermometer for each bed and 1 out of 4 break per week, this represents a release of mercury from 2166 kg/year according to the last official estimation (INE, 2008).

In Mexico, the health sector started a program to replace mercury thermometers for safer alternatives that minimize impacts to health and the environment, addressing the problem of releases from mercury thermometers.

With respect to the estimated national inventory releases, it is important to apply the methodology of life cycle assessment for thermometers at the end of their life in Mexico through modeling the flow of materials and energy to determine the environmental impacts of the disposal of mercury thermometers.

The life cycle assessment (LCA) is defined as the evaluation of flows of materials and energy as well as the potential environmental impacts throughout the life cycle of a product or in the stages where a product is analyzed. The life cycle of a product includes several stages from the extraction of raw materials to product manufacturing and fabrication of materials and auxiliary equipment, production and product use, transport and equipment, managing of wastes, including disposal and recycling. The term product includes goods and services (Finnveden et al., 2009). The LCA is increasingly used in the development, implementation and monitoring of environmental policies, and in the private sector for continuous improvement of the environment. LCA helps in solving an environmental problem while avoiding the creation of others by deleting transfers from one part of the life cycle to another and by calculating the impacts on the environment and human health (ECJRC, 2010). This concept is an approach from “cradle to grave” in all stages of life of a product from extraction of materials, transportation, waste disposal, etc. (EPA, 2003; UNEP, 2004; EPA, 2006).

The aim of this study is to develop the life cycle assessment for different scenarios for the management of mercury thermometers at the end of their life in Mexico through modeling of impacts of the different alternatives to provide elements to authorities to issue environmental policies for its sound management.

2. Materials and methods

The method used was a life cycle assessment (LCA) based in the standard ISO 14,040–14,048 (Roy et al., 2009; Bouvart et al., 2013; Soares et al., 2013) and its corresponding standards in Mexico (IMNC, 2007; IMNC, 2008). This approach considers the end of life management of mercury thermometers in Mexico (Dandres et al., 2011). LCA approach allows the characterization of the potential

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