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Technical Note

Management of Mercury Waste in an Institution of São Paulo State Health Secretary, the Case of Butantan Institute

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Abstract: Metallic mercury is a species of interest for public health and the environment due to its high toxicity. The activities related to health assistance are among the important sources of anthropic emissions of mercury. There are alternatives to the use of mercury which are safe and economically viable for almost all its applications the health care. The São Paulo State Secretary of Health published Resolution SS-SP no. 239 on 12/07/2010, prohibiting the purchase, the use and the storage of mercury containing products in the institutions under its jurisdiction and determined that they should be disposed of following the accepted procedures. Instituto Butantan is a biomedical research center of the São Paulo State Secretary of Health and is responsible for the production of vaccines and serums for prophylactic and curative use. It also develops scientific research related to public health. In order to comply with the Resolution SS-SP no. 239, the Environment Management (EM) in collaboration with the Purchase Section and the Quality Assurance Department (QAD) replaced all mercury containing thermometers in the Institute. 183.0 kg of waste were sent to a company specialized in mercury phase-out process, through which the distilled mercury was extracted and the other materials were decontaminated.

Keywords: mercury waste; management of hazardous waste, health, environment, thermometers

1. INTRODUCTION

Mercury (Hg) is a silvery-white heavy metal with an atomic number of 80. Among its unique properties, it is the only metal, which is liquid under standard conditions for temperature and pressure, with a melting point of −38.83 °C and a boiling point of 356.73 °C [1]. This is also the narrowest liquid state temperature range among all metals. It is a poor heat conductor, but it conducts electricity fairly well [2].

Among its many applications, mercury is used in gold and silver mining, in mercury barometers, in some types of thermometers, in electrical and electronic applications, in fluorescent lamps and in dental amalgam fillings. Chemical compounds of mercury are used in batteries, in biocides in paper industry, in paints, and on seed grain, antiseptics in pharmaceutical products, reagents for laboratories, and as catalysts [3].

Half of the atmospheric mercury emissions originate from natural sources, such as volcanoes. The other half is human-generated and originates from such activities as stationary combustion, the production of gold, nonferrous metal, caustic soda, cement and mercury [4] and from the disposal (eg, land filling, incineration) of mercury containing products, such as batteries, medical equipment, fluorescent bulbs, thermometers and thermostats [3]. A large proportion of this is medical waste from health care facilities.

Mercury vapors may be fatal if inhaled and harmful if absorbed through the skin and the respiratory mucosa. Approximately 80% of the total inhaled mercury vapor is absorbed by the blood in the lungs. As it spreads through the organism, it may affect the nervous, digestive, respiratory, excretory and immune systems, causing tremors, impaired

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vision and hearing, paralysis, insomnia, emotional instability, fetal developmental deficits, attention deficit and developmental delays during childhood [3, 5].

The World Health Organization (WHO), the Occupational and Safety Health Administration (OSHA), and the National Institute Occupational Safety and Health (NIOSH) all treat mercury as an occupational hazard and have established specific occupational exposure limits [3]. Occupational exposure has resulted in broad-ranging functional disturbance, including erethism, irritability, excitability, excessive shyness, and insomnia. Upon continuing exposure, a fine tremor develops and may escalate to violent muscular spasms. Tremor initially involves hands and later spreads to the eyelids, lips, and tongue. Long-term, low-level exposure has been associated with more subtle symptoms of erethism, including fatigue, irritability, loss of memory, vivid dreams, and depression [6].

The World Health Organization (WHO) issued a policy paper in 2005 and the World Medical Association passed a resolution in 2008 calling for short, medium, and long-term measures to substitute mercury-based medical devices with safer alternatives [3].

In Brazil, São Paulo was the first state to establish a resolution against the use of mercury based medical devices. The São Paulo State Secretary of Health (SES-SP) published Resolution SS-SP no. 239 on 12/07/2010 [8], prohibiting the purchase, the use and the storage of mercury containing materials in the care facilities of SES-SP and established the procedures for its disposal in all units licensed for waste reception, treatment and disposal.

Instituto Butantan (IBu), a research institute of the São Paulo State Secretary of Health, started its activities at the beginning of the 20th Century, producing anti-plague and antivenom serums. Currently, IBu is recognized as one of the largest biomedical research centers in the world and one of the main producing centers of vaccines, antivenom and antitoxin serums for both prophylactic and curative purposes in Brazil. It is located in an area of 723,565 m^2 in the city of São Paulo, Brazil, and currently employs 2,000 professionals including researchers, support staff and students. It operates in three main areas: production of immunobiologicals, scientific research and cultural development. The Institute develops Biological and Biomedical research related directly and indirectly to public health, in over 30 laboratories and keeps a vivarium that produces, keeps and supplies laboratory animals within the required genetic and sanitary standards to be used in research and in immunobiological production testings. IBu has a park open to the public, three museums and a hospital specialized in the treatment of accidents caused by venomous and poisonous animals. The hospital works uninterruptedly and provides support for the whole country in its areas of expertise. It also offers postgraduate and extension courses.

The development of these activities results in the generation of a high volume and diversity of wastes, which includes common wastes, organic waste, recyclable waste, pruning, rubble, wood, infecting waste, carcass and wood shavings, chemical wastes and egg powder from specific process of vaccine production. Part of these wastes is characterized as Health Service Waste (HSW), which due to their physical, chemical or biological properties, may present risks to human health and environment. In Brazil, HSW is classified in five different groups according to RDC ANVISA 306 (2004) [9] being Group A: wastes with presence of biological agents, including animal carcass; Group B: wastes containing dangerous or not chemical substances; Group C: radioactive discards; Group D: organic wastes compared to household wastes, including recyclable wastes; and Group E: sharps. These wastes are commonly generated in productive processes in industrial plants, in research laboratories and visiting areas, and may be considered as dangerous wastes when presenting risks of flammability, corrosiveness, reactivity, toxicity and/or pathogenicity [10]. In addition to HSW, Butantan generates a huge volume of common solid wastes, that even without risk, need an environmentally correct destination, such as pruning, civil construction wastes (restoration and building), among others.

According to Brazilian legislation, the destination of wastes generated inside the institution should meet the federal, state and municipal laws. Among legal requirements, there is the need of implementing a Waste Management Program.

In these terms, the Board of Directors of IBu, committed with environmental issues and fulfillment of legislation, established on January 2012 the implementation of Waste Management Program of Instituto Butantan (PGRIB), whose purpose is properly managing the wastes resulting from diverse activities developed in IBu, from generation to final destination or disposal. The actions proposed in

PGRIB aim at reducing the generation of wastes, safety and awareness of all people involved, in order to reduce the negative effects on the environment and human health.

According to IBu's Waste Management Program [11], 58 areas, including laboratories working in different research lines, vaccine and serum production plants, quality control, stock, outpatient clinic and Hospital Vital Brasil, produce chemical waste. The high complexity and diversity of the substances and mixtures generated by these different activities makes chemical waste management at the institute a great challenge.

As part of this program and specifically to comply with Resolution SS-SP nº 239 [8], among other important actions, IBu replaced all mercury containing thermometers.

The objective of this paper is to present the Mercury Waste Management Process at Butantan Institute.

2. MATERIAL AND METHODS

The method employed in this work involved the following steps:

1. Bibliographical survey on hazardous waste and the current rules in the country, particularly regarding mercury waste management;
2. Diagnosis of the mercury waste generation in the different sections of IBu;
3. Description of the procedures for mercury waste management;
4. Data processing.

Our first step in this work was to perform a bibliographical survey of the regulatory framework regarding mercury waste management in the country, in all federal, state and municipal spheres as well as of IBu's own internal regulations. The pertinent documents found were: National Policy of Solid Waste (PNRS), Federal Law 12.305 of 2010 [12], which regulates on the instruments and guidelines relating to the management of solid waste; Resolution RDC 306/2004 [9] of National Health Surveillance Agency (ANVISA - Agência Nacional de Vigilância Sanitária), which establishes the technical regulation for the management of health care waste; State Policy of Solid Waste; State Law 12.300/2006 [13], which establishes the guidelines and instruments for the integrated and shared management of solid waste in São Paulo State; Municipal Law 13.478/2002 [14], which establishes the organization of the Urban Sanitation System of São Paulo City; and Resolution SS-SP no. 239/2010 of SES-SP [8], which prohibits the purchase, the use and the storage of mercury containing materials in their assistance facilities.

The qualitative and quantitative inventory of the existing mercury containing equipment at IBu was made by filling out a form distributed to all IBu's sections, including the following information: generating area, model, scale and condition of the equipment. Equipment in stock was also included in the inventory. Mercury containing equipment, both in good conditions and broken, as well as liquid mercury waste, were identified and quantified.

In this work, only the replacement and disposal of mercury containing thermometers were addressed. The intact thermometers were packed and stored in approved drums for inland transport of hazardous products, while the broken thermometers were stowed under water in order to avoid mercury evaporation [9, 15]. Liquid mercury was then packed hermetically like the intact thermometers.

The packages were properly identified, sealed, weighed and sent for mercury treatment and recovery in a specialized company, authorized by the Environmental Agency of São Paulo State (Companhia Ambiental do Estado de São Paulo – CETESB), as established in RDC - ANVISA no. 306/2004 [9]. The treatment of mercury waste involves heating at a temperature of 480 °C at low pressure in a process called demercuration. The distilled mercury is extracted with a purity of 99.9% while other materials are decontaminated in the process. Figure 1 shows all stages of the process in a flowchart.

The purchase of new thermometers suitable for each case was performed by the Purchase Section of IBu and then sent to Quality Assurance Department (QAD) for calibration. The replacement of mercury containing thermometers with new calibrated instruments was performed under the coordination of Environment Management (EM).

3. RESULTS AND DISCUSSION

Our diagnosis showed that, of all mercury containing equipment to be collected and replaced to comply with Resolution SS-SP no. 239, 2050 were mercury thermometers. 487 of these were in 26 research laboratories, 332 were in production areas and 1231 were in quality control sections, stock, museums, outpatient clinic and Hospital Vital Brasil. Figure 2 shows the distribution in percentage of these thermometers.

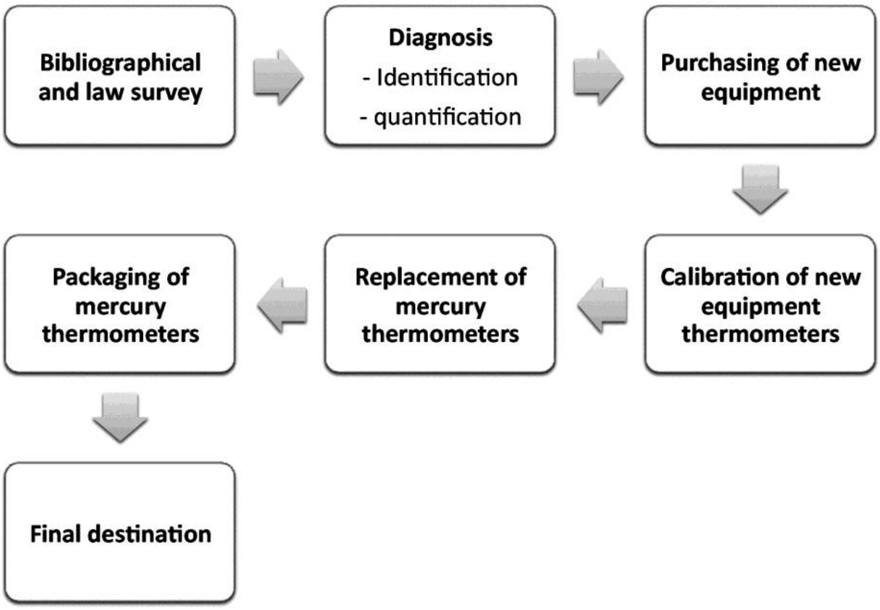

Figure 1. Stages of the mercury thermometers replacement for alternative thermometer.

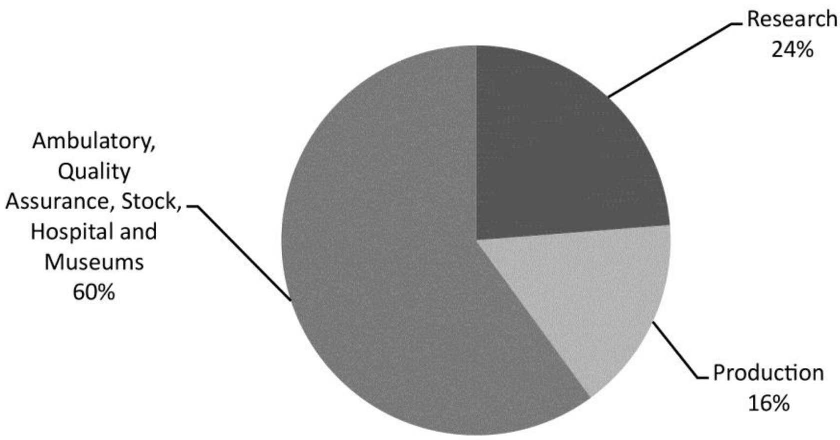

Figure 2. Areas of Instituto Butantan where thermometers containing mercury were found.

Thermometers are pieces of equipment that measure the temperature variation, using different principles. There are several types which differ from each other by the thermometric unit; in the liquid thermometers, the unit is the volume of liquid that, when oscillating, changes the height of liquid column. In the gas thermometers, the unit is the gas volume (if the pressure remains constant) or the gas pressure (when the volume is constant) and in the platinum resistance thermometer, the unit is the electrical resistance of a wire of such metal [16]. The bulb that contains the liquid is adapted to a small (capillary) diameter which aims to highlight the dilation or contraction of the substance, increasing the reading accuracy [17, 18].

Several types of thermometers exist, differering from each other by the thermometric unit and principle. In liquid thermometers, the height of the liquid column changes as it expands or contracts in response to temperature changes [16]. In these thermometers, the bulb that contains the liquid is connected to a small diameter tube (capillary) in order to highlight the dilation or contraction of the substance, increasing the reading accuracy [17, 18].

One of the most commonly used substances is alcohol. Ethanol is used for low temperatures measurements, where mercury freezes (-38.9 °C) and, because it is colorless, dyes are generally added in order to facilitate reading [18, 19]. But, although it boils at 79 °C, from 60 °C on there is formation of large amounts of steam that can damage the glass tube, making the temperature measuring range of an ethanol thermometer much more restrictive as compared to mercury.

Mercury, on the other hand, is an excellent thermometric substance when used in temperature range of -30 °C to +320 °C. It does not stick to the glass and its metallic appearance facilitates reading. Generally speaking, substances that present uniform volumetric expansion can be used as thermometric materials, as long as the fusion and boiling temperature limits of the substance are respected [20, 21].

Table 1 shows an overview of the main substances used in liquid thermometers together with their operating limits and their most common abbreviations.

Electronic thermometers function based on electric sensors, such as thermocouples, resistance thermometers and thermistors (resistors that show large resistance variation due to temperature variation [22]), in addition to the infrared radiation sensors, which do not require physical contact between the thermometer and the object whose temperature we want to measure. Electronic thermometers can operate from -273 °C to +1200 °C, but they are expensive and are not suitable for kinds of experiments.

Mercury thermometers used to be given preference because of their precision over a wider temperature range, in addition to their low cost. Our survey showed that the temperature measurement needs at IBu are between -50 °C and +300 °C, but other liquid thermometers have much more restrictive temperature ranges. However, a set of thermometers containing ethanol, pentane and toluene, in addition to digital thermometers provide a wide measurement range (-200 to +1200 °C), therefore, meeting the demands at IBu.

Table 1. Main filling liquids for thermometers and their operating limits.

Filling liquid	Abbreviation	Lower limit (°C)	Upper limit (°C)
Mercury	Hg	-38.5	+357
Pentane	C_5H_{12}	-200	Approx. +35
Ethanol	C_2H_6O	-110	Approx. +100
Toluene	C_7H_8	-90	Approx. +100

So, once the survey data were analyzed, the purchase section started the procedures for the purchase of new thermometers according to the needs of each section at IBu, both in number and temperature range. 233 ethanol thermometers, 40 toluene thermometers, 7 pentane thermometers and 343 digital thermometers, with a total temperature measuring range between -100 °C and +300 °C, have already been ordered. The new thermometers were calibrated by the Quality Assurance Department (QAD) before delivery. In a joint effort between Environment Management (EM) and the QAD, for each mercury thermometer collected a new, calibrated one was delivered.

Studies show that a single broken thermometer, if not properly cleaned, can increase the internal levels of mercury in the air above the EPA reference values of the Agency for Toxic Substances and Disease Registry (ATSD) causing adverse health effects [23]. Although the lethal mercury level is unknown, exposure to elemental mercury vapor above $1x10^{-6}$ – $2x10^{-6}$ mg/m^3 for a few hours causes acute chemical bronchitis and pneumonia. Two hours after exposure, it damage to the lungs is observed through the formation of a membrane called hyaline and, finally, the occurrence of pulmonary fibrosis [23].

90% of the collected mercury containing thermometers were in good conditions, while only 10% were damaged. Thus, the 1845 residual intact thermometers were packed in order to avoid breaking with subsequent contamination and stored in plastic drums approved for the conveyance of hazardous products to the final destination. The 205 broken thermometers were submerged in water to decrease mercury evaporation, since mercury is extremely volatile at room temperature. The liquid mercury waste, weighing around 0.15 kg in total, was hermetically sealed, packed and stowed in approved plastic drums for conveyance of hazardous products.

The intact thermometers generated 78.9 kg of mercury waste. The broken ones, plus water, generated 104 kg of material to be disposed 0.15 kg of liquid mercury waste were also generated, totalizing 183.0 kg of mercury waste. The disposal of mercury containing products is a global concern and it has also been widely discussed in Brazil. Different forms of treatment have been proposed [4, 24].

Given the current Resolution SS-SP no. 239, of 12/07/2010 [7], which determines that mercury waste shall be disposed in facilities approved for its receipt, treatment and disposition, all the mercury waste was sent to a specialized company.

With the approval from the Waste Commission and Environment Management, the procedures for the disposal of mercury waste were added to the Waste Disposal Practical Guide of Instituto Butantan [25].

4. CONCLUSION

The replacement of mercury containing thermometers with others, causing less impact to the environment and to health, followed a series of integrated stages between the Quality Assurance and Purchase Sections of IBu under the coordination of Environment Management. The use of equipment containing alternative liquids such as ethanol, toluene and pentane, and even electronic equipment, contributes to the safer performance of the activities in the different sectors minimizing the operating and environmental risks

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