

National Inventory of Mercury Release into Different Environmental Sectors Estimated by United Nations Environment Programme (UNEP) Toolkit in Costa Rica

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Abstract

This paper summarizes the national inventory of mercury released into all environmental sectors (air, water, land, impurity in products, general wastes and sector specific treatment/disposal) for the year 2008 in the country of Costa Rica, using the United Nations Environment Programme (UNEP) mercury toolkit. The data collection about the input and output of mercury for the year 2008, was carried out during the years 2014 and 2015. The data used for estimation are mainly obtained from the Costa Rican Government's official publications. The research was developed in order to create a national inventory of mercury releases into all environmental sectors in order to aid mercury management in Costa Rica. Total input and output of mercury, distribution into different environmental sectors, major contributions by mercury sources ("steps" "categories" and "subcategories") are discussed. The standard estimation of total mercury input is 7174.00 kg/year. The biggest mercury input are "waste treatment and recycling" (3086.00 kg Hg, 43.17%) and "general consumption of mercury in products, as metal mercury and as mercury containing substances" (3189.00 kg Hg, 44.62%). The total mercury released is 31,689.29 kg/year. The biggest emission of mercury corresponds to the source "waste treatment and recycling" (28,359.29 kg/year, 89.49%). The "air" is the main impacted environmental sector due the different mercury inputs. A total of 28,155.60 kg/year (88.55%) is released in this media. Only 1635.10 kg/year (5.16%) of the total mercury emissions is deposited in the environmental sector named "general waste". The rest of the environmental sectors evaluated are impacted with less of 3.00% of the total mercury released.

Keywords

Costa Rica, Mercury, Environmental Sectors, Air, Wastes, Input,

1. Introduction

Mercury can be released into the environment from both natural and anthropogenic sources [1]-[6]. Anthropogenic sources of mercury emissions have a significant impact on global pollution [7]. With the increasing use of mercury in industrial processes and products, mercury release into the environment from anthropogenic sources has been reported worldwide [8]-[16]. The recent estimates by United Nations Environment Programme (UNEP) show that the global anthropogenic emissions of mercury into the atmosphere in 2010 were 1960 tons [17]. The major source category identified were artisanal small scale gold mining (37%), coal combustion (all uses) (24%), primary production of nonferrous metals (Al, Cu, Pb, Zn) (10%), cement production (9%), large-scale gold production (5%), consumer product waste (4%) [16]. Mercury released into the atmosphere as a result of human activity becomes part of the natural pool of mercury in the environment, and, may then be continuously deposited and re-emitted, resulting in an ongoing legacy of mercury contamination [17] [18] [19]. Mercury is a well-known neurotoxin that damages the kidneys and many body systems including the nervous, cardiovascular, respiratory, gastrointestinal, hematologic, immune, and reproductive systems. It is especially toxic to humans and wildlife because it is readily absorbed by the body and can accumulate in places such as the brain [20].

In spite of the negative impacts of mercury to the environment and human health, the world's population is still being exposed to various forms of mercury through inhalation, consumption of contaminated food or water, and exposure to substances containing mercury [21]. In order to protect the environment and public health from the negative impacts of mercury, handling and disposing products containing mercury, throughout a sound environmental management is extremely important. It is important to identify mercury sources (develop mercury inventories) in order to be able to take effective action to prevent, minimize and manage mercury products. Inventories are important tools for identifying, quantifying and characterizing mercury sources. Mercury inventories may be used to establish a baseline for quantities of mercury-added products produced, circulated/traded or in use, and commodity mercury and wastes consisting of elemental mercury and wastes containing or contaminated with mercury. Besides, mercury inventories can be used to establish an information registry to assist with safety and regulatory inspections; obtain the accurate information needed to draw up plans for lifecycle management of mercury; and assist with the preparation of emergency response plans; and track progress towards reducing and phasing out mercury [22].

The United Nations Environment Programme (UNEP) is conducting studies with the goal of a worldwide reduction in mercury [7]. These programmes re-

quire estimates of the national emissions of mercury from major sources in each country [7]. One resource to estimate the mercury emissions is the Toolkit for Identification and quantification of Mercury Releases [23]. The toolkit helps countries to build their knowledge base by compiling a mercury inventory that identifies sources of mercury releases in their country and estimates or quantifies the releases. The Toolkit is a simple and standardized methodology for producing consistent national and regional mercury inventories [23]. The Toolkit has been applied in a number of countries [23]. In this paper the national inventory of mercury input and release into different phase media for the year 2008 using the UNEP mercury Toolkit is presented. The main objective of this paper was to create a national inventory of mercury releases into all media (air, water, land, impurity in products, general wastes and sector specific treatment/disposal) in order to aid mercury management in Costa Rica.

2. Methodology

The national mercury release inventory, with release from each sector and into all media for the year 2008 was carried out using the mercury Toolkit 2013. The Toolkit can be found on UN Environment Chemicals Branch's website: <http://www.unep.org/chemicalsandwaste/what-we-do/technology-and-metals/mercury/toolkit-identification-and-quantification-mercury-releases> [23]. The brief methodology is presented in the following paragraphs.

2.1. Mercury Identification and Quantification of Input and Release

“Toolkit for identification and quantification of mercury releases”, version 1.0, March 2010 with separate electronic Excel spreadsheets [23] were used for calculations. The Toolkit provides a methodology, associated input factors and output distribution factors for estimating mercury releases into all media (air, water, land, products and wastes).

2.2. Toolkit for Identification and Quantification of Mercury Releases

The “Toolkit for identification and quantification of mercury releases”, the “Toolkit”, is intended to assist countries to develop a national mercury releases inventory. It is an MS Excel program balance and provides a standardized methodology and accompanying database enabling the development of consistent national and regional mercury inventories. The “Toolkit” has been revised in 2015 based on experiences in using it and new data and exists in two versions: “Inventory Level 1” provides a simplified version of the Toolkit, as well as calculation spreadsheets and a reporting template, to make the development of an overview mercury inventory considerably easier, “Inventory Level 2” is the comprehensive version, including a detailed description of all mercury sources, useful for anyone wishing to learn more about a specific mercury release source, including environmental authorities and researchers.

Toolkit Electronic Inventory Level 1 Spreadsheet for Calculation of Estimates of Mercury Inputs and Releases

The Inventory Level 1 is aimed at assisting developing countries and countries with economies in transition so the default factors need to reflect the input and release scenarios predominant in these countries. In Inventory Level 1, the electronic spreadsheet uses medium input and release factors (called output distribution factors) for the calculation of the mercury inputs and releases, and presents the results as “standard estimates” with no uncertainty interval. These calculated “standard estimates” are simplified results of inputs and releases and may as such be above or below the actual inputs and releases in the country of study.

2.3. Data Sources

The data collection about the input and output of mercury in Costa Rica during 2008, was carried out during the years 2014 and 2015. The data used for estimation are mainly obtained from the Costa Rican Government’s official publications. Whenever published information were lacking, data was collected from other reports, publications, communication with experts in the field, facility operation data, industry inspections and personal communications and so on. When data were not available for the reference year, data from the adjacent years were used. The activity rate data (fuels, raw materials consumption, production of goods etc.) for the reference year were obtained mainly from official source coming from the Government, for example: data collection from official documents, Costa Rican Statistical Information Service (INEC), National Institute of Environmental Research (MINAET), Ministry of Public Health (MPH), Public Universities Information Centers, National Administration Center for Industries, National Customs Agency. The activity rates were collected and converted into appropriate units required for the Toolkit by screening and using the proper selection of input factors. In the case of that data about input factors and output distribution factors were not available during the data collection process, relevant data coming from the literature were included in the electronic spreadsheets.

3. Results and Discussion

3.1. Mercury Release Sources Identified in Costa Rica

Major source Categories and Subcategories of mercury release listed in the UNEP toolkit, which are found in Costa Rica during the period of the study are listed in **Table 1**.

The data included in the previous table shows only the mercury sources found in Costa Rica during the year of the study. The total input of each mercury sources (for each section of the UNEP toolkit “step”, “category” and “subcategories”) is shown in **Table 2**. However, for some mercury sources do not was enough information. Therefore, some inputs (kilograms) of mercury were not quantified. According with the data gathered, 20 categories and 30 subcategories

Table 1. Major source categories and subcategories of mercury release found in costar rica (listed in the UNEP toolkit).

ID	Categories and sub-categories of mercury release sources	ID	Categories and sub-categories of mercury release sources
2	Step 2: Energy consumption and fuel production	5.2.5	Open fire waste burning (on landfills and informally)
2.1	Category: Fuel consumption	5.3.1	Waste deposition/landfilling
2.1.2	Other coal uses (sum for all other uses)	5.3.2	Informal dumping of general waste
2.1.3	Combustion/use of petroleum coke and heavy oil	6	Step 6: General consumption of mercury in products, as metal mercury and as mercury containing substances
2.1.4	Combustion/use of diesel, gas oil, petroleum,	6.3	Category: Electrical switches and relays with mercury
2.1.6	Biomass fired power and heat production	6.4	Category: Light sources with mercury
2.1.7	Charcoal combustion	6.4.1	Fluorescent tubes (double end)
2.2	Category: Fuel production	6.4.2	Compact fluorescent lamp
2.2.2	Oil refining	6.4.3	Other Hg containing light sources
	Step 3: Domestic production of metals and raw materials	6.5	Category: Batteries with mercury
3.2	Category: Gold mining with mercury amalgamation	6.5.1	Mercury oxide (button cells and other sizes); also called mercury-zinc cells
3.2.2	Gold extraction with mercury amalgamation-with use of retorts	6.5.2	Other button cells (zinc-air, alkaline button cells, silver-oxide)
3.3	Other high volume materials production with mercury releases	6.5.3	Other batteries with mercury (plain cylindrical alkaline, permanganate, etc.)
3.3.1	Cement production	6.6	Category: Polyurethane (PU, PUR) produced with mercury catalyst
3.3.2	Pulp and paper production	6.9	Category: Medical blood pressure gauges
4	Step 4: Domestic production and processing with intentional mercury use	6.10	Category: Other manometers and gauges with mercury
4.1	Production of chemicals and polymers	6.11	Category: Laboratory chemicals
4.2.8	Paints with mercury	6.12	Category: Other laboratory and medical equipment with mercury
4.2.9	Skin lightening creams and soaps with mercury chemicals	6.7	Step 7: Crematoria and cemeteries
5	Step 5: Waste treatment and recycling	7.1	Category: Crematoria
5.2	Category: Waste incineration	6.2	Category: Cemeteries

Table 2. Input of mercury (kg Hg/year), for each section of the UNEP toolkit (“step”, “category” and “subcategories”). Costa Rica, 2008.

Step	Kg Hg/year	Category	Kg Hg/year	Sub-Category
Step 2: Energy consumption and fuel production	306.00	Fuel consumption	98.00	Other coal uses (sum for all other uses)
				Combustion/use of petroleum coke and heavy oil
				Combustion/use of diesel, gasoil, petroleum, kerosene
				Biomass fired power and heat production (wood, etc.)
Step 3: Domestic production of metals and raw materials	432.00	Fuel production	208.00	Charcoal combustion
				Oil refining
		Gold mining with mercury amalgamation	1.00	Gold extraction with mercury amalgamation-with use of retorts
		Other high volume materials production with mercury releases	431.00	Cement production
Step 4: Domestic production and processing with intentional mercury use	88.00	Production of products with mercury content	88.00	Pulp and paper production
				Paints with mercury
Step 5: Waste treatment and recycling	3086.00	Waste incineration	2750.00	Open fire waste burning (on landfills and informally)
		Waste deposition/landfilling	336.00	Waste deposition/landfilling
				Waste water treatment
		Use and disposal of products with mercury content	678.00	Dental amalgam fillings (“silver” fillings)
		Thermometers	468.00	Medical Hg thermometers
		Electrical switches and relays with mercury	633.00	Electrical switches and relays with mercury
				Fluorescent tubes (double end)
		Light sources with mercury	78.00	Compact fluorescent lamp (CFL single end)
Step 6: General consumption of mercury in products, as metal mercury and as mercury containing substances	3189.00	Batteries with mercury	63.00	Other Hg containing light sources
				Mercury oxide (button cells and other sizes); also called mercury-zinc cells
				Other button cells (zinc-air, alkaline button cells, silver-oxide)
				Other batteries with mercury (plain cylindrical alkaline, permanganate, etc.)
		Polyurethane (PU, PUR) produced with mercury catalyst	136.00	Polyurethane (PU, PUR) produced with mercury catalyst
		Medical blood pressure gauges (mercury sphygmomanometers)	884.00	Medical blood pressure gauges (mercury sphygmomanometers)
		Other manometers and gauges with mercury	23.00	Other manometers and gauges with mercury
		Laboratory chemicals	45.00	Laboratory chemicals
		Other laboratory and medical equipment with mercury (porosimetry, pycnometry, hanging drop electrodes = polarimetry, etc.)	181.00	Other laboratory and medical equipment with mercury (porosimetry, pycnometry, hanging drop electrodes = polarimetry, etc.)
		Step 7: Crematoria and cemeteries	46.10	Crematoria
		Cemeteries	1.00	Cemeteries
TOTAL	7147.00		7147.00	

were determined as mercury inputs during 2008. **Table 2** indicates, “step 5-waste treatment and recycling” as the biggest mercury source. In other hand “step 4-domestic production and processing with intentional mercury use” is the smallest mercury source. Related with the categories quantified, the biggest mercury source corresponds to “waste incineration”.

Contrary, the categories named “cemeteries” and “gold mining with mercury amalgamation” are the two sources with minor kg of mercury produced during the year of study. The highest quantity of mercury coming from the subcategories evaluated comes from the subcategory named “open fire waste burning (on landfills and informally)”.

3.2. Mercury General Input (Steps)

The total input of mercury estimated was 7174.00 kg (year 2008). The share of the “steps” quantified is shown in **Figure 1** and **Table 3**, the total kilograms of mercury input coming from each step are the following: 3189.00 kg (44.62%) for “general consumption of mercury in products, as metal mercury and as mercury containing substances”, 3086.00 kg (43.17%) for “waste treatment and recycling”, 432.00 kg (6.05%) kg in the case of “domestic production of metals and raw materials”, 306.00 kg (4.28%) for “energy consumption and fuel production”, a total of 88.00 kg (1.23%) for “domestic production and processing with intentional mercury use” and 46.10 kg (0.65%) for “crematoria and cemeteries”. Step 5 (“Waste treatment and recycling”) and step 6 (“General consumption of mercury in products, as metal mercury and as mercury containing substances”) are the two main sources of mercury inputs, representing 44.62% and 43.17% of the total mercury, respectively. The rest of the sources (steps) accounts for less than 15.00% of the total mercury input during year 2008.

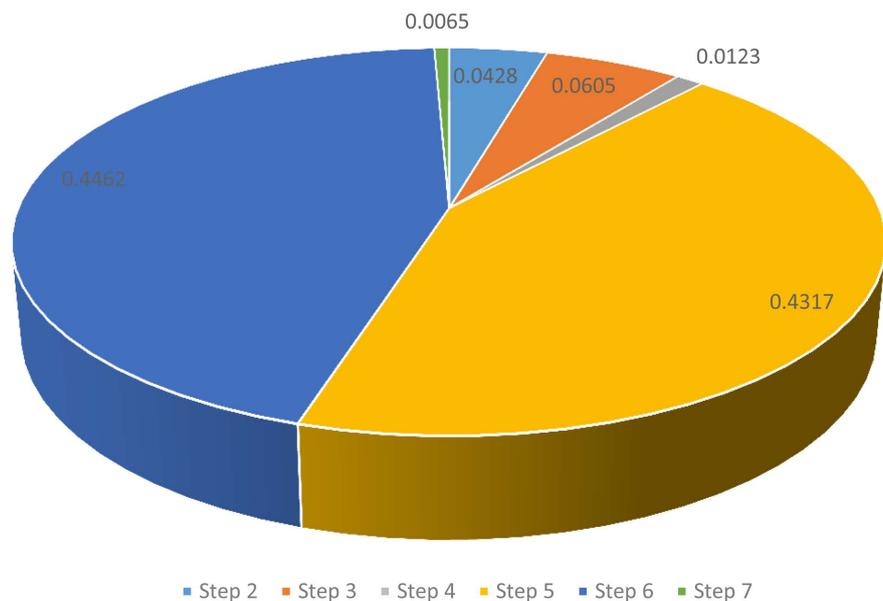


Figure 1. Percentage distribution of mercury input from “steps” (total input = 7147.00 kg/year).

Table 4 shows the input of mercury (kg Hg/year) for each categories and subcategories for the “Step 5-waste treatment and recycling”. A total of 89.11% of 3086.00 kg of the mercury input correspond to “waste incineration”, the rest 10.88% obeys to the category “waste deposition/landfilling”. **Table 4**, also point out the percentage distribution for each subcategory into the corresponding category and step. Related with the category “waste incineration”, the only subcategory of mercury input is “open fire waste burning”, this subcategory represents 89.00% of the total mercury input for step 5 (“Waste treatment and recycling”). In the case of the category “waste deposition/landfilling”, a total of 123.00 kg of mercury correspond to the subcategory “waste deposition/landfilling” and a total of 213.00 kg of mercury belongs to the subcategory “wastewater treatment”.

Table 5 shows the input of mercury (kg Hg/year) for each categories and subcategories for the “Step 6-general consumption of mercury in products, as metal mercury and as mercury containing substances”. The category named

Table 3. Distribution of mercury input from “steps” (total input = 7147.00 kg/year).

Step	Name	Input	
		%	Kg Hg/year
Step 2	Energy consumption and fuel production	4.28	306.00
Step 3	Domestic production of metals and raw materials	6.05	432.00
Step 4	Domestic production and processing with intentional mercury use	1.23	88.00
Step 5	Waste treatment and recycling	43.17	3086.00
Step 6	General consumption of mercury in products	44.62	3189.00
Step 7	Crematoria and cemeteries	0.65	46.10
Total		100.00	7147.00

Table 4. Input of mercury (kg Hg/year) for each categories and subcategories for the “Step 5: Waste treatment and recycling”.

Step		Category			Sub-Category			
Name	kg Hg/year	Name	kg Hg/year	% of the corresponding step	Name	kg Hg/year	% of the corresponding category	% of the corresponding Step
Step 5: Waste treatment and recycling	3086.00	Category: Waste incineration	2750.00	89.11	Open fire waste burning (on landfills and informally)	2750.00	100.00	89.00
		Category: Waste deposition/landfilling	336.00	10.88	Waste deposition/landfilling	123.00	36.60	4.00
					Waste deposition/landfilling	213.00	63.40	7.00
Total		N/A	3086.00	100.00	N/A	3086.00	N/A	100.00

Table 5. Input of mercury (kg Hg/year) for each categories and subcategories for the “Step 6: General consumption of mercury in products, as metal mercury and as mercury containing substances”.

Step		Category			Sub-Category			
Name	kg Hg/year	Name	kg Hg/year	% of the corresponding step	Name	kg Hg/year	% of the corresponding category	% of the corresponding Step
Step 6: General consumption of mercury in products, as metal mercury and as mercury containing substances	3189.00	Use and disposal of products with mercury content	678.00	21.26	Dental amalgam fillings (“silver” fillings)	678.00	100.00	21.26
		Thermometers	468.00	14.67	Medical Hg thermometers	468.00	100.00	14.67
		Electrical switches and relays with mercury	633.00	19.85	Electrical switches and relays with mercury	633.00	100.00	19.85
		Light sources with mercury	78.00	2.45	Fluorescent tubes (double end)	40.00	51.28	1.25
					Compact fluorescent lamp (CFL single end)	8.00	10.25	0.25
					Other Hg containing light sources	30.00	34.46	0.94
		Batteries with mercury	63.00	1.97	Mercury oxide (button cells and other sizes); also called mercury-zinc cells	36.00	57.14	1.13
					Other button cells (zinc-air, alkaline button cells, silver-oxide)	7.00	11.11	0.22
					Other batteries with mercury (plain cylindrical alkaline, permanganate, etc.)	20.00	31.74	0.94
		Polyurethane	136.00	4.26	Polyurethane	136.00	100.00	4.26
		Medical blood pressure gauges	884.00	27.72	Medical blood pressure gauges	884.00	100.00	27.72
		Other manometers and gauges with mercury	23.00	0.72	Other manometers and gauges with mercury	23.00	100.00	0.72
		Laboratory chemicals	45.00	1.41	Laboratory chemicals	45.00	100.00	1.41
		Other laboratory and medical equipment with mercury	181.00	5.67	Other laboratory and medical equipment with mercury	181.0	100.00	5.67
Total	N/A	3189.00	100.00	N/A	3189.00	N/A	100.00	

“medical blood pressure gauges” provides 27.72% of the total mercury input for this step. Other two main contributions of mercury come from the categories

“use and disposal of products with mercury content” (21.26%) and “electrical switches and relays with mercury” (19.85%). The main mercury inputs (subcategories) are also shown in **Table 5**. The subcategories are the following: “medical blood pressure gauges (27.72%), “dental amalgam fillings” (21.26%), electrical switches and relays with mercury” (19.85%) and “medical Hg thermometers” (14.67%).

Figure 2 and **Table 6** show the percentage distribution for the total input of mercury for each category. Only 7 of the 19 categories studied have an individual percentage over 5.00% of the total mercury input. The most important category of mercury input is “waste incineration” (2750.00 kg Hg/year, 38.48%), especially because of the incineration of waste through “open fire” and due the deposition of waste on informal landfills. Other two important categories of mercury input are “medical blood pressure gauge” (884.00 kg Hg/year, 12.32%) and the “use and disposal of mercury of products with mercury contents” (678.00 kg Hg/year, 9.49%), principally because of the use of mercury sphygmomanometers and dental amalgam fillings, respectively.

3.3. Mercury Released into Different Environmental Sectors

Table 7 shows the mercury released into different environmental sectors. The total mercury released is 31,689.29 kg, from which 89.49% (28,359.29 kg) come from the “step 5” (waste treatment and recycling). The second most important “step” contributing to the environmental sectors is “general consumption of mercury in products, as metal mercury and as mercury containing substances” (step 6), however, the contribution only represents 8.37% of the total mercury release. The rest of the “steps” accounts for less than 2.00%. **Table 7** also indicates, that the most impacted environmental sector is “air”. A total of 28,155.60 kg (88.85%) of mercury is released in the air, especially because of the activity of

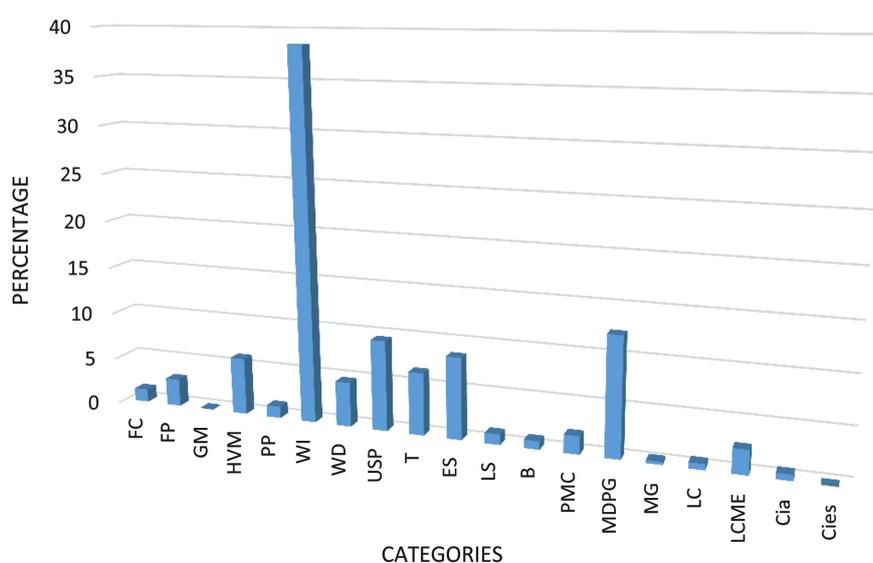


Figure 2. Percentage distribution of mercury input from “categories” (total input = 7147.00 kg/year).

Table 6. Percentage and kilograms distribution of mercury input from “categories” (total input = 7147.00 kg/year).

Category		Input	
ID	Name	Percentage	kg Hg/year
FC	Fuel consumption	1.37	98.00
FP	Fuel production	2.91	208.00
GM	Gold mining with mercury amalgamation	0.01	1.00
HVM	Other high volume materials production with mercury content	6.03	431.00
PP	Production of products with mercury content	1.23	88.00
WI	Waste incineration	38.48	2750.00
WD	Waste deposition/landfilling	4.70	336.00
USP	Use and disposal of products with mercury content	9.49	678.00
T	Thermometers	6.55	468.00
ES	Electrical switches and relays with mercury	8.56	633.00
LS	Light sources with mercury	1.09	78.00
B	Batteries with mercury	0.88	63.00
PMC	Polyurethane produced with mercury catalyst	1.90	136.00
MDPG	Medical blood pressure gauges (mercury sphygmomanometers)	12.37	884.00
MG	Other manometers and gauges with mercury	0.32	23.00
LC	Laboratory chemicals	0.63	45.00
LCME	Other laboratory and medical equipment with mercury	2.53	181.00
Cia	Crematoria	0.63	45.10
Cies	cemeteries	0.01	1.00
Total		100	71,174.00

waste treatment and recycling. The following environmental sector more impacted is the one called “general waste”, nonetheless the mercury released only is 1635.10 kg, which represents only 5.16% of the total mercury released in the six factors evaluated. The rest of the sectors have a very a low impact. The quantity of mercury released into them is less than 3.00% regards to the total mercury released.

Figure 3 and **Table 8**, show the percentage distribution of the impact of the mercury sources on the environmental sectors. The “air” sector is almost totally impacted (97.99%) by the source named “waste treatment and recycling”. “Water” sector is influenced (99.44%) because of the mercury output coming from “general consumption of mercury in products”. “Land” is principally affected

Table 7. Release of mercury into different environmental sectors.

STEP	ENVIROMENTAL SECTORS							Total	(%)
	Mercury Released (kg Hg/year)								
	Air	Water	Land	By-products and impurities	General Wastes	Sector specific waste treatment/ disposal			
Step 2: Energy consumption and fuel production	148.70	2.10	0.00	0.00	31.30	0.00	182.10	0.57	
Step 3: Domestic production of metals and raw materials	259.00	0.00	0.00	86.00	86.00	0.00	431.00	1.36	
Step 4: Domestic production and processing with intentional mercury use	0.90	0.40	8.80	0.00	8.80	0.90	19.80	0.06	
Step 5: Waste treatment and recycling	27,591.00	1.29	633.00	0.00	134.00	0.00	28,359.29	89.49	
Step 6: General consumption of mercury in products, as metal mercury and as mercury containing substances	155.00	672.00	63.00	49.00	1375.00	337.00	2651.00	8.37	
Step 7: Crematoria and cemeteries	1.00	0.00	45.10	0.00	0.00	0.00	46.10	0.14	
TOTAL	28,155.60	675.80	749.90	135.00	1635.10	337.10	31,688.29	100	
Percentage (%)	88.85	2.13	2.36	0.42	5.16	0.01	100%	N/A	

(84.41%) by “waste treatment and recycling”. The sector named “by products and impurities” is principally impacted by two sources, the first one is the mercury output from “domestic production of metals and raw materials” with have an impact of 63.70%, and the second one the output of mercury coming from the “general consumption of mercury in products” with have an impact of 36.30%. The mercury release in to sector “general waste”, mainly comes from the source “general consumption of mercury in products” (84.09%). The other sources affecting this sector are “waste treatment and recycling” with only 8.20%, “domestic production of metals and raw materials” with an impact of 5.26% and “domestic production and processing with intentional use” (1.91%). The environment sector denominated “specific waste treatment/disposal”, is entirely affected by the mercury output coming from “general consumption of mercury in products” (99.73%).

The distribution of the mercury emissions from each mercury source in to the

Table 8. Percentage distribution of the impact of mercury sources on the environmental sectors.

Mercury input	Environmental sectors (%)					
	Air	Water	Land	By-products and impurities	General waste	Sector specific waste treatment/disposal
Energy consumption and fuel production	0.53	0.31	0.00	0.00	1.91	0.00
Domestic production of metals and raw materials	0.92	0.00	0.00	63.70	5.26	0.00
Domestic production and processing with intentional mercury use	0.00	0.06	1.17	0.00	0.54	0.27
Waste treatment and recycling	97.99	0.19	84.41	0.00	8.20	0.00
General consumption of mercury in products, as metal mercury and as mercury containing substances	0.55	99.44	8.40	36.30	84.09	99.73
Crematoria and cemeteries	0.00	0.00	6.01	0.00	0.00	0.00
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00

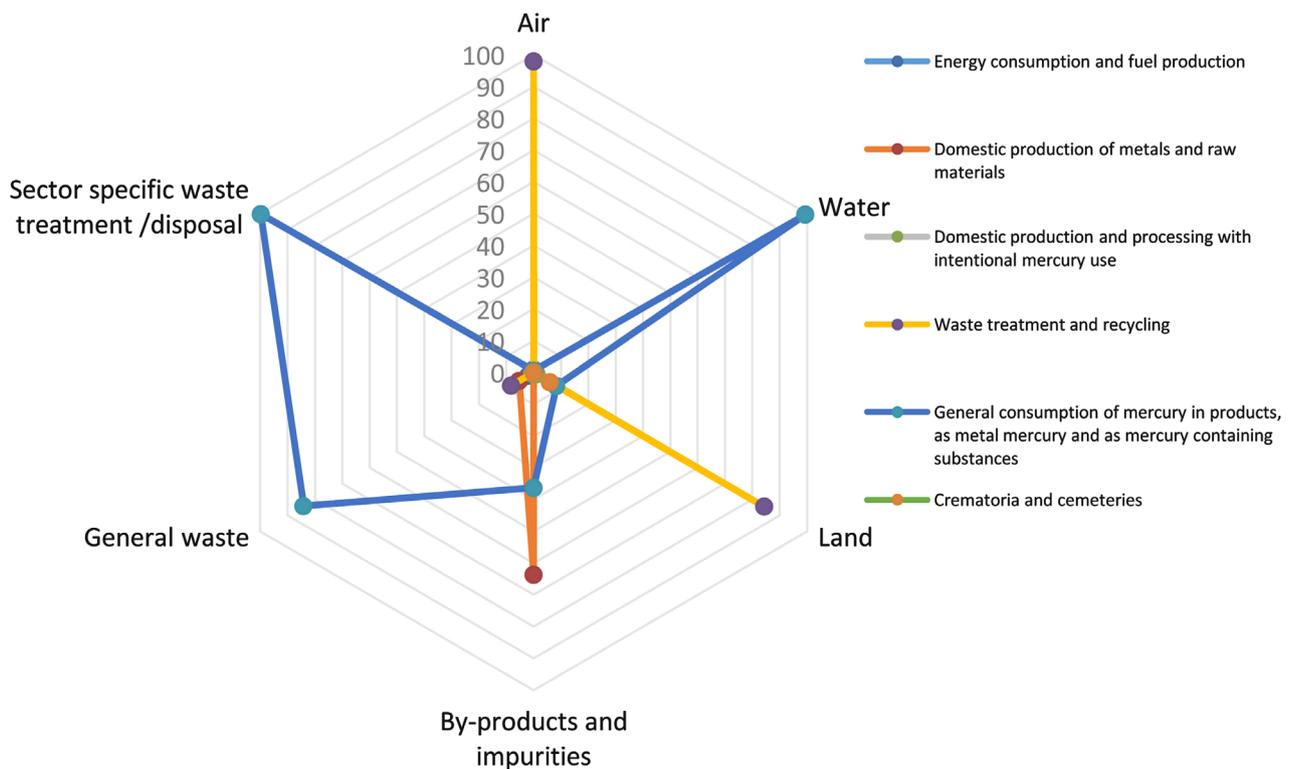


Figure 3. Percentage distribution of the impact of mercury sources on the environmental sectors.

environmental sectors, is shown in **Figure 4** and **Table 9**. Mercury output coming from “energy consumption and fuel production” principally goes to “air” (81.66%), the rest is distributed in the following environmental sectors: in to “general waste” (17.19%) and 1.15% goes to the “land” sector. In the case of the source “Domestic production of metals and raw materials”, its emissions are unloaded as follow: on “air” (60.09%), 19.95% on “by products and impurities”,

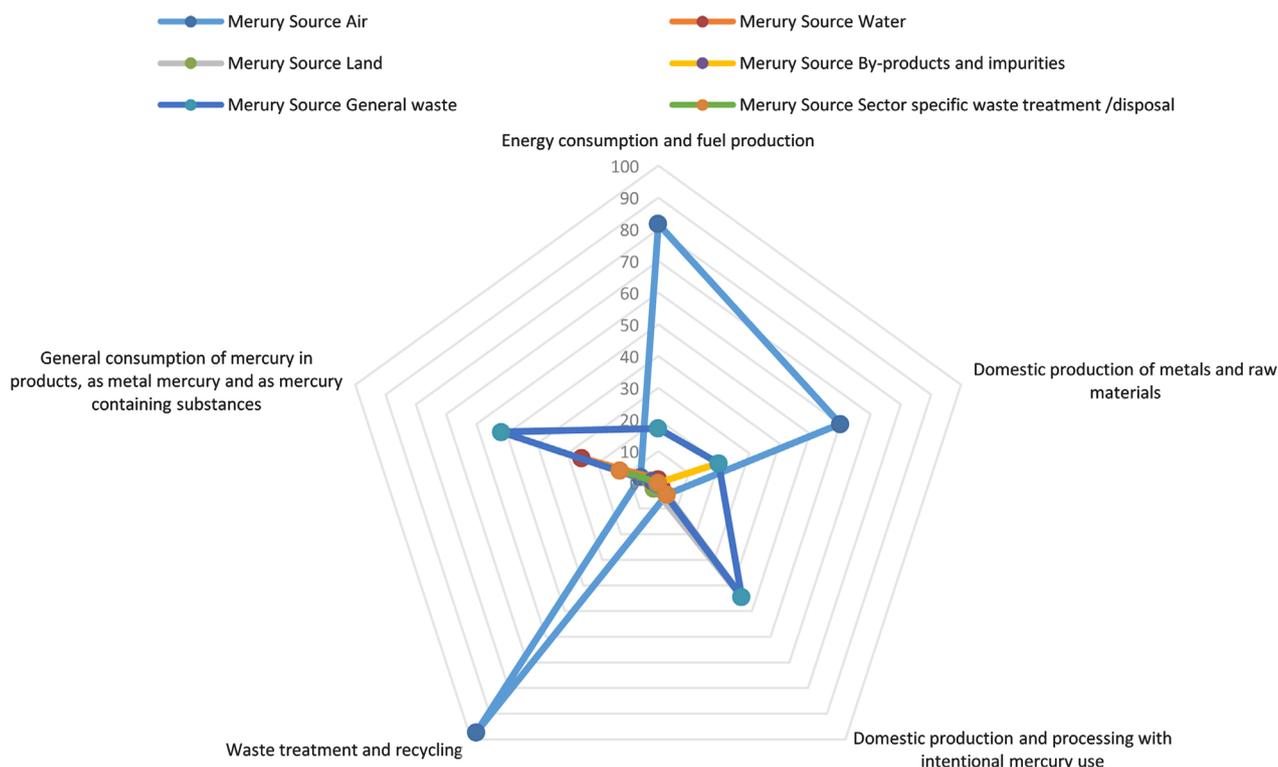


Figure 4. Percentage distribution of mercury emissions on each environmental sector.

Table 9. Percentage distribution of mercury emissions on each environmental sector.

Mercury source	Environmental sectors (%)						TOTAL
	Air	Water	Land	By-products and impurities	General waste	Sector specific waste treatment/disposal	
Energy consumption and fuel production	81.66	1.15	0.00	0.00	17.19	0.00	100.00
Domestic production of metals and raw materials	60.09	0.00	0.00	19.95	19.95	0.00	100.00
Domestic production and processing with intentional mercury use	4.55	2.02	44.44	0.00	44.44	4.55	100.00
Waste treatment and recycling	97.29	0.00	2.23	0.00	0.47	0.00	100.00
General consumption of mercury in products, as metal mercury and as mercury containing substances	5.85	25.35	2.38	1.85	51.87	12.71	100.00
Crematoria and cemeteries	2.17	0.00	97.83	0.00	0.00	0.00	100.00

and 19.95% on “general waste”. The source named “domestic production and processing with intentional use” affect 5 of the 6 environmental sectors, the most influenced sectors are “land” (44.44%) and “general waste” (44.44%). In the case of the mercury emissions coming from “waste treatment and recycling”, almost 100.00% of the emissions are released on “air”. **Figure 4** and **Table 9** also show that all the environmental sectors are affected by the mercury output coming from the source “general consumption of mercury in products, as metal mercury and as mercury containing substances”. In this case, the more impacted environmental sectors are the following: “general waste” (51.87%) and “water” (25.35%). Finally, the distribution of the mercury coming from “crematoria and cemeteries” indicate that 97.83% of the mercury emissions goes to the land and only 2.17% is released to “air”.

4. Conclusions

The study was developed in Costa Rica during the year 2008, for that period the population was close to 5 million. The main economic sectors were: trade, service, agricultural, hotels and restaurants, transport and communication, building, industry, real estate, public administration and education and financial.

The standard estimation of total mercury input (by using the Toolkit level I) is 7174.00 kg/year. The share of this mercury input are due to 3189.00 kg Hg (44.62%) from the Step named general consumption of mercury in products (as metal mercury and as mercury containing substances), 308,600.00 kg Hg (43.17%) from the Step called waste treatment and recycling, 432.00 kg Hg (6.05%) from domestic production of metals and raw materials, 306.00 kg Hg (4.28%) coming from the Step named energy consumption and fuel production, 88 kg Hg (1.00%) because of the Step domestic production and processing with intentional mercury use, and finally a total of 46.00 kg Hg (1.23%) from Step crematoria and cemeteries.

For the year of study, the total mercury released coming from the different Steps evaluated is 31689.29 kg/year. The share of mercury released from each Step is the following: 182.10 kg/year (0.87%) from the Step named energy consumption and fuel production, 431.00 kg/year (1.36%) from the Step called domestic production of metals and raw materials, 19.80 kg/year (0.06%) coming from the Step named domestic production and processing with intentional mercury use, a total of 28,359.29 kg/year (89.49%) because of the Step waste treatment and recycling, an amount of 2651.00 kg/year (8.37%) from the Step named general consumption of mercury in products (as metal mercury and as mercury containing substances), and finally 46.10 kg Hg (0.14%) from crematoria and cemeteries.

Air is the main impacted environmental sector due to the different mercury emissions. A total of 28,155.60 kg/year (88.55%) is released in this media.

The total mercury inputs do not equal the total mercury outputs due to corrections for double counting. This correction with the rest of the mercury inputs and outputs leads to a total input of mercury for year 2008 of 7147.00 kg and a

total output of 31,688.29 kg.

In order to compare the results of this investigation with nowadays data, a new project is being actualized with the inputs and outputs of mercury for year 2014.

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