

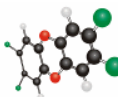


NATIONAL INVENTORY ON MERCURY RELEASES IN NORTH MACEDONIA

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POPs Unit



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INVENTORY OF MERCURY RELEASES IN NORTH MACEDONIA

Project: "Strengthening national capacities to implement the Minamata Mercury Convention with a focus on developing a strategy to identify contaminated sites"

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This inventory was prepared in accordance with UNEP's "Toolkit for identification and quantification of mercury releases Inventory Level 2 (version 1.7, February 2023).

Foreword

This Report has been prepared within the framework of the project “Strengthening national capacities for the Minamata Convention implementation with focus on development of strategy for assessing the sites contaminated by mercury”, implemented by the United Nations Environment Programme (UNEP) and executed by the Ministry of Environment and Physical Planning (MoEPP).

The main goal of this report is to revise and update the initial mercury inventory, through identification of the current sources of mercury releases in the Republic of North Macedonia, quantifying these releases and allocating them to the corresponding output pathways. This is done either by conducting analyses of the raw materials entering the process and analysing the resulting production fractions or by using the default factors provided in the UNEP’s “Toolkit for Identification and Quantification of Mercury Releases”.

The purpose of this document is not to define the environmental risk and health effects of mercury releases on the population. This would require detailed risk assessment analyses identifying exposure pathways and affected receptors, followed by toxicology studies demonstrating the relationship between environmental exposure and health effects.

The National Mercury Inventory Report was prepared by Prof. Dr. Trajce Stafilov, MSc. Marjan Mihajlov and MSc. Simona Domazetovska-Risteska, with the technical assistance and consultations of MSc. Aleksandar Mickovski.

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1 Executive summary

Mercury is a chemical element, also known as quicksilver, of light-silver colour, and the only known metal that is liquid in ordinary temperatures. This chemical is pervasive and persistent pollutant, emitted vastly through various geogenic processes, but also through anthropogenic emissions, which vastly prevail the natural releases. Alongside atmospheric mercury emissions, mercury is found in land and water, as well.

Exposure to mercury in sufficient concentrations, can have deleterious effect on wildlife and humans (Evers, 2018; Clarkson & Magos, 2006). In order to address these issues, the Minamata Convention, a legally-binding multilateral agreement, was developed, on behalf of United Nations Environmental Programme. The main goal of the Minamata Convention on Mercury, which was adopted in 2013, is protection of human health and environment from the anthropogenic emissions and releases of mercury and mercury compounds. The Republic of North Macedonia signed the convention in 2014¹ and ratified it in March 2020.

In 2017, a team of experts have developed an initial national mercury inventory, taking 2013 as a reference year. Inventory Level 2 was selected for the initial inventory, using data from 2013 whenever available. In the initial inventory, the category of Waste deposition/landfilling and waste water treatment was the most significant category contributing with 45% of total mercury releases. Releases to air are the most significant per type of emission, closely followed by those in to land.

The initial inventory has provided experience and grounds for future revisions. Thus, under the implementation of the project entitled *“Strengthening national capacities for the Minamata Convention implementation with focus on development of strategy for assessing the sites contaminated by mercury”*, the team of national experts have developed an updated and improved inventory, choosing 2021 as the reference year, and using the "Toolkit for identification and quantification of mercury releases" (Version 1.7) made available by the Chemicals Branch of the United Nations Environment (UN Environment Chemicals)².

The data in this robust inventory has been taken not only from questionnaires and statistical data, but also 43 samples were taken from pre-defined locations and sent for analysis to an

¹ Signed on 25.07.2014

² <https://www.unep.org/explore-topics/chemicals-waste/what-we-do/mercury/mercury-inventory-toolkit>

accredited foreign laboratory. The data mainly refers to the reference year (2021). In case of lack of such data, the data from the nearest year was used. In all cases, the year in which the data were collected is noted in all categories and sub-categories.

As previously, this inventory was developed on the basis of the Toolkits Inventory Level 2. The Toolkit methodology is based on mass balances for each mercury release source sub-category and consists of a four-step procedure:

- Identification of the main mercury source categories in a country,
- Classification of the main source categories into further sub-categories and gathering of additional qualitative information to identify existing individual activities that are sources of mercury releases.
- Gather detailed quantitative information on the identified sources, and quantify the releases by developing a quantitative inventory
- Apply the method nationwide to establish full inventory and report the results.

The Inventory for releases of priority hazardous substances constitute an important decision-making tool in the process of mitigating environmental impacts from the pollutants in question. The inventory identifies the relevant categories for the country, but should be considered as a first step as further assessment is necessary to confirm the potential priority problems.

This information can be used to determine which release source types are significant and which sources should be addressed through release reduction initiatives.

The national inventory on mercury releases shall present a basis for establishing a national inventory of emissions from relevant sources, which is going to be an obligation for the country no later than five years after the date of entry into force of the Convention, in accordance with Article 8 of the Minamata Convention on Mercury.

Further description of estimations in the relevant source type sections is given below.

1.1 Results and discussion

An aggregated presentation of the results for the main groups of mercury release sources is presented in **Error! Reference source not found.** below.

Table 1. Summary of mercury inventory results

Source category	Calculated Hg output, Kg/y						Total releases by source category	Percent of total releases*3*4
	Air	Water	Land	By-products and impurities	General waste	Sector specific treatment /disposal		
5.1: Extraction and use of fuels/energy sources	277.8	-	-	-	-	62.2	340	29%
5.2: Primary (virgin) metal production	59.9	1.8	66.5	-	-	5.9	134	12%
5.3: Production of other minerals and materials with mercury impurities*1	32.7	-	-	5.1	-	-	38	3%
5.4: Intentional use of mercury in industrial processes	-	-	-	-	-	-	-	0%
5.5: Consumer products with intentional use of mercury (whole life cycle)	14.5	40.8	0.2	-	128.2	5.9	190	16%
5.6: Other intentional product/process use*2	0.9	57.7	7.4	5.5	39.4	34.7	146	13%
5.7: Production of recycled metals	2.4	-	11.1	-	11.1	-	24	2%
5.8: Waste incineration and burning	83.2	-	-	-	-	-	83	7%
5.9: Waste deposition/landfilling and waste water treatment*3*4	59.4	96.1	454.3	-	18.2	2.3	630	12%
5.10: Crematoria and cemeteries	-	-	71.3	-	-	-	71	6%
SUM OF QUANTIFIED RELEASES*3*4	531	157	156	11	197	111	1,163	100%

Notes:

*1 Includes production of cement, pulp and paper, lime and light weight aggregates.

*2 Includes dental amalgam fillings, manometers and gauges, lab chemicals and equipment, Hg use in religious rituals and folklore medicine, and miscellaneous product uses.

*3: The estimated quantities include mercury in products which has also been accounted for under each product category. To avoid double counting, the release to land from informal dumping of general waste has been subtracted automatically in the TOTALS.

*4: The estimated input and release to water include mercury amounts which have also been accounted for under each source category. To avoid double counting, releases to water from waste water system/treatment have been subtracted automatically in the TOTALS.

Figure 1 shows the distribution of releases for each category in each medium, according to the received data, performed analysis and expert opinion. However, when compared, it has to be noted that the Toolkit, when calculating the Total Releases, it deducts the Waste Water system/ treatment release to water from the total releases to water, as well as the releases to

land from the category Informal dumping of general waste. Consequently, the largest releases within inventory come from **Extraction and use of fuels/energy sources**, contributing with 29% of the total mercury releases, as shown in Figure 2.

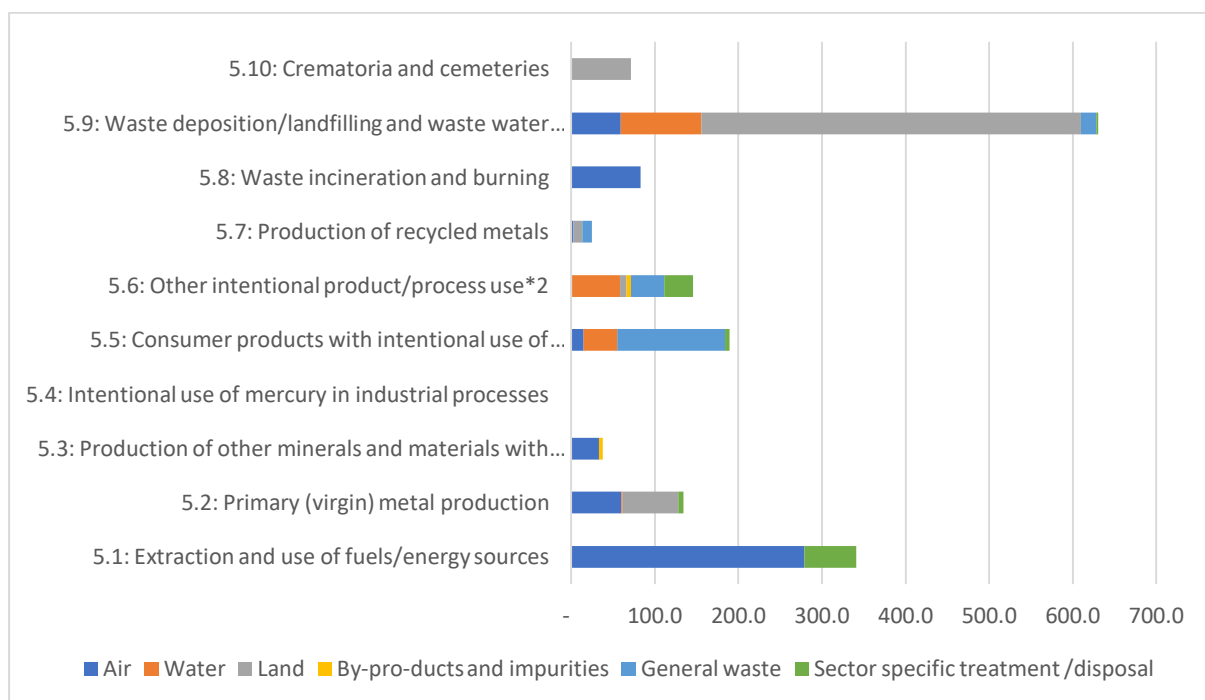


Figure 1. Distribution of releases per category

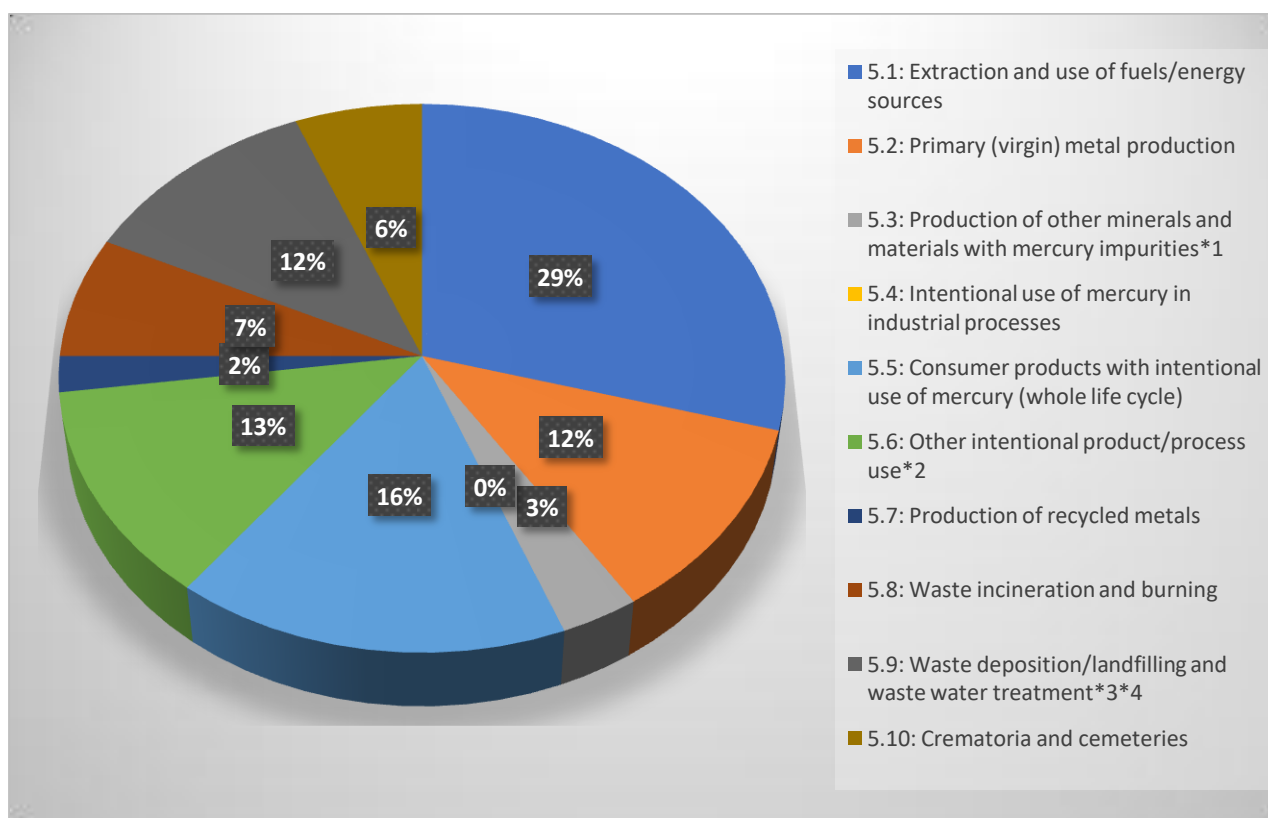


Figure 2. Mercury releases per category

The largest share of releases is in air, followed by general waste, as seen on Figure 3.

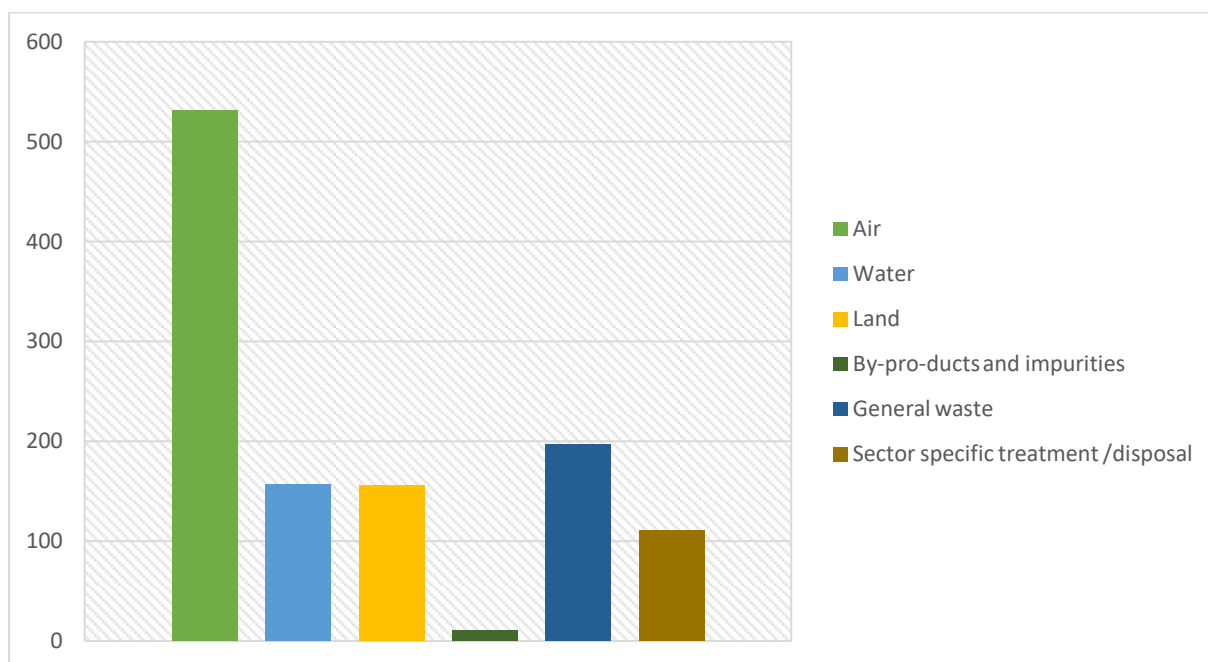


Figure 3. Releases per output

The individual mercury release category contributing the highest mercury releases to the atmosphere was **Extraction and use of fuels/energy sources**, within which the subcategory **Coal combustion in power plants** counts for the highest release.

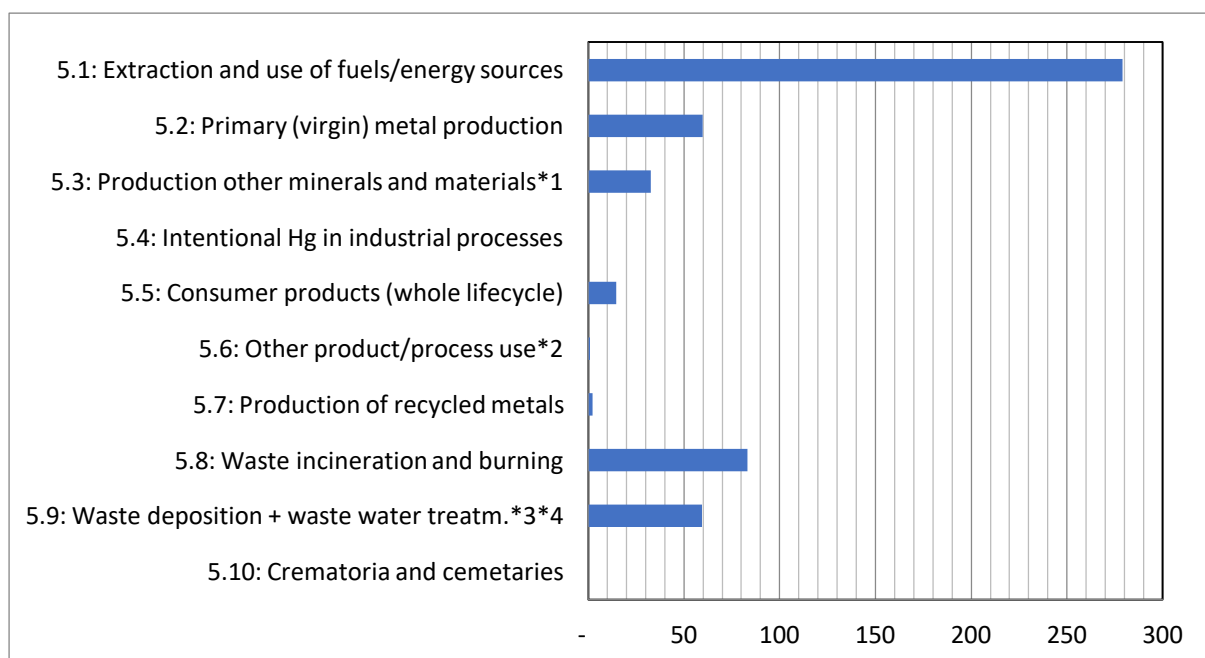


Figure 4. Mercury releases to air (Kg Hg/y)

With regards to releases to water, Figure 5 shows the largest contribution comes from **Waste deposition and waste water treatment**, resulting from sub-category **Waste water system/treatment**.

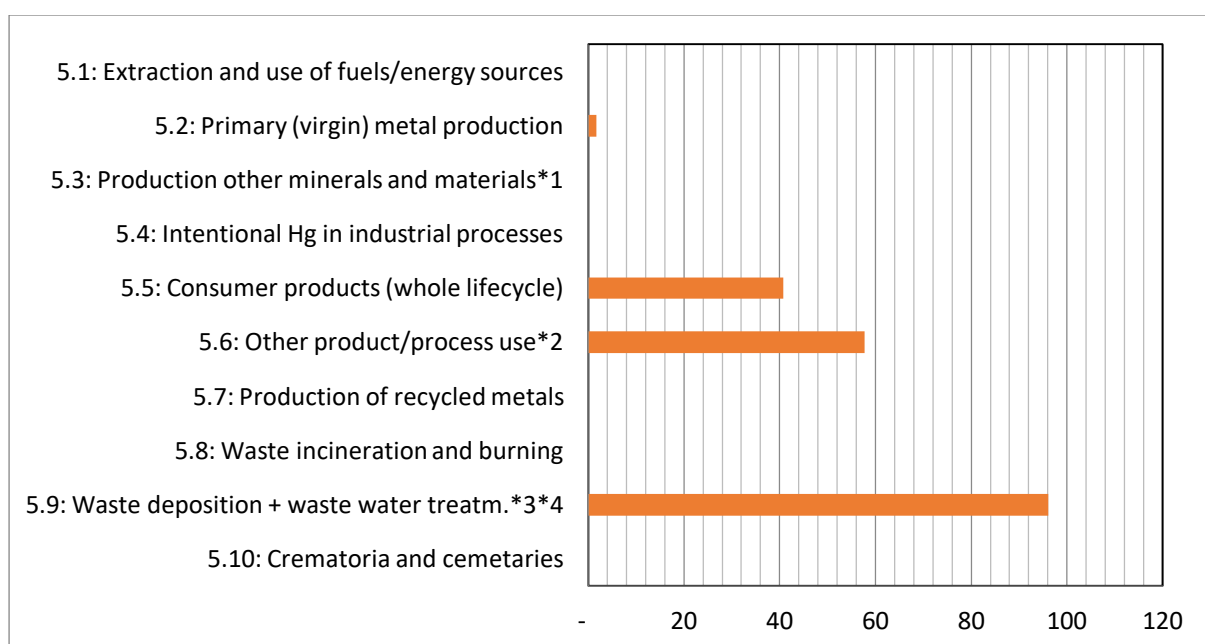


Figure 5. Mercury releases to water (Kg Hg/y)

Furthermore, the category **Waste deposition and waste water treatment**, more specifically sub-category **Informal dumping of general waste** is the largest contributor to releases to land, shown in Figure 6.

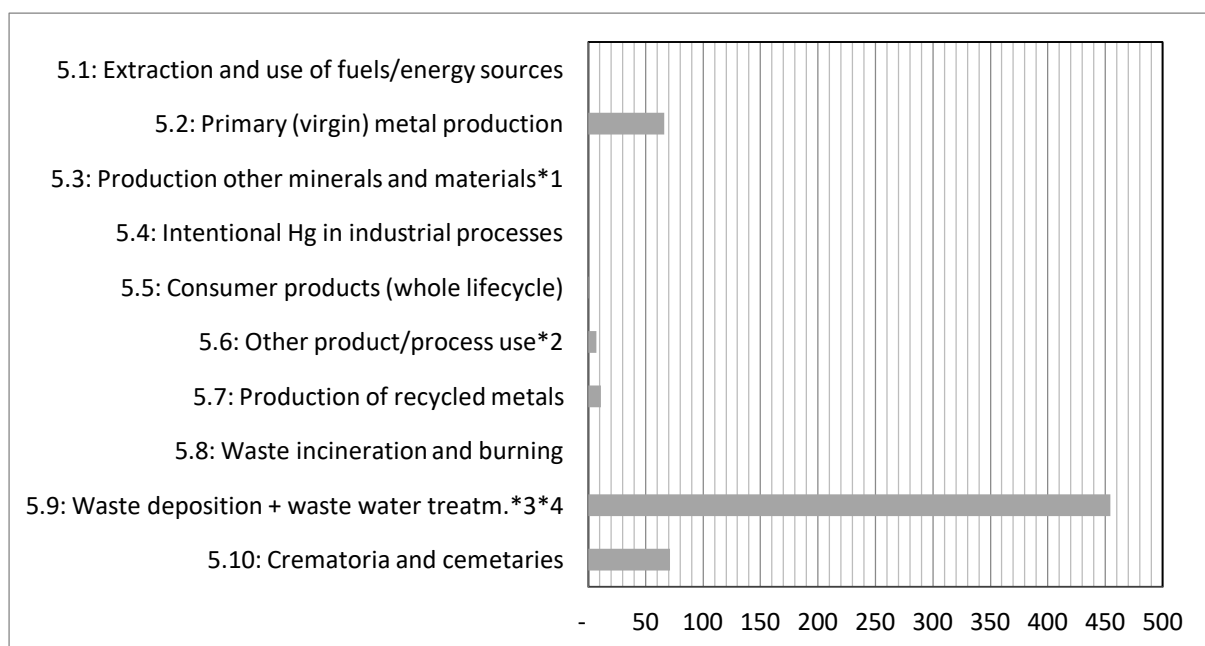


Figure 6. Mercury releases to land (Kg Hg/y)

Dental amalgam fillings from the category **Other Intentional product/process use**, and **Cement cinker producsiton**, from **Production of other minerals and materials with mercury impurities**, are the only contributors to outputs to by-products and impurities, shown in Figure 7.

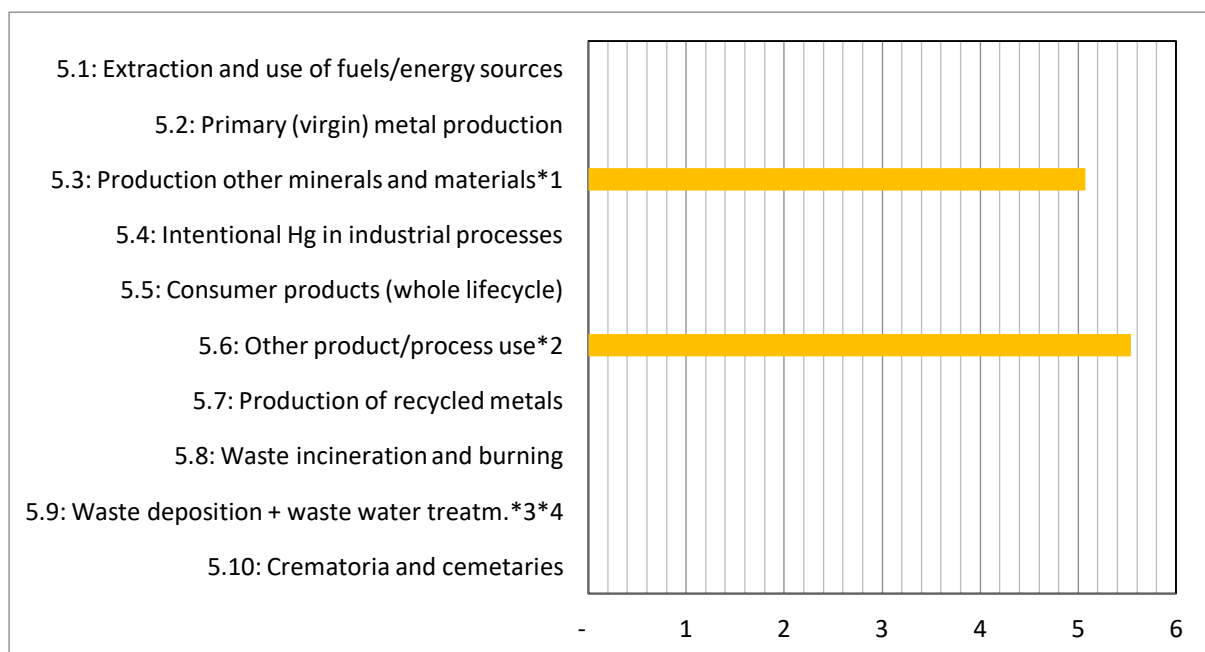


Figure 7. Mercury releases to by-products and impurities (Kg Hg/y)

Largest release to general waste, depicted in Figure 8, comes from the sub-category **Thermometers with mercury**, from **Consumer products with intentional use**.

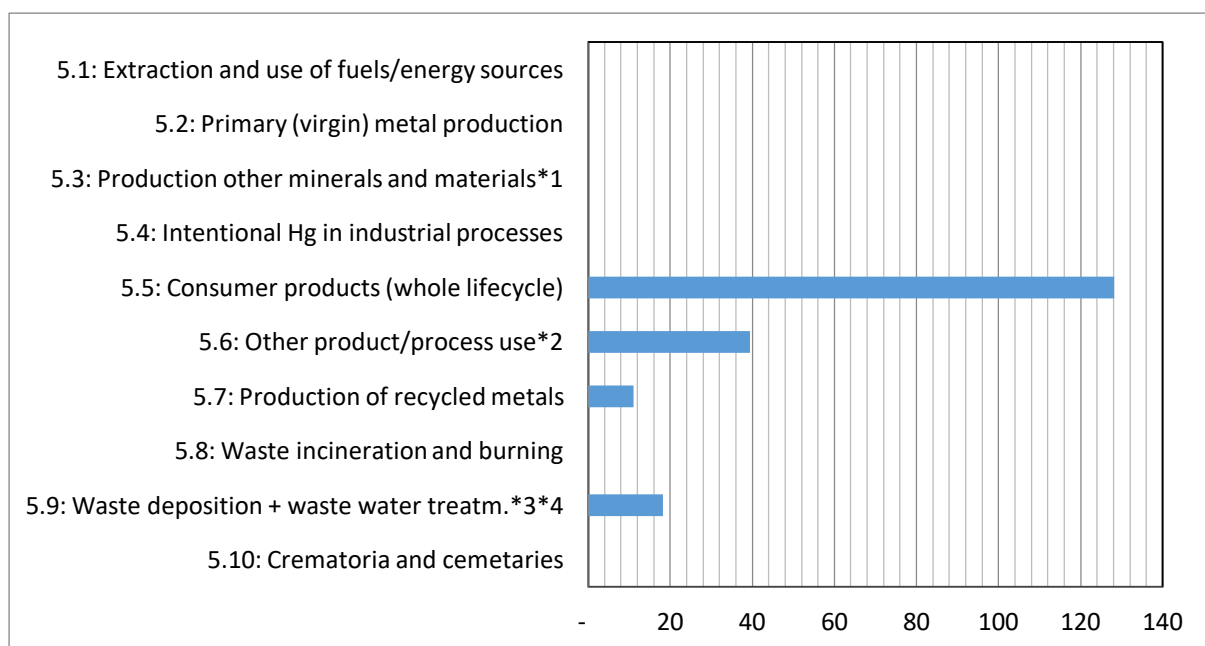


Figure 8. Mercury releases to general waste (Kg Hg/y)

Finally, to sector specific waste treatment/disposal, largest release comes from the category **Extraction and use of fuels/energy sources**, i.e. the sub-category **Coal combustion in power plants**, represented in Figure 9.

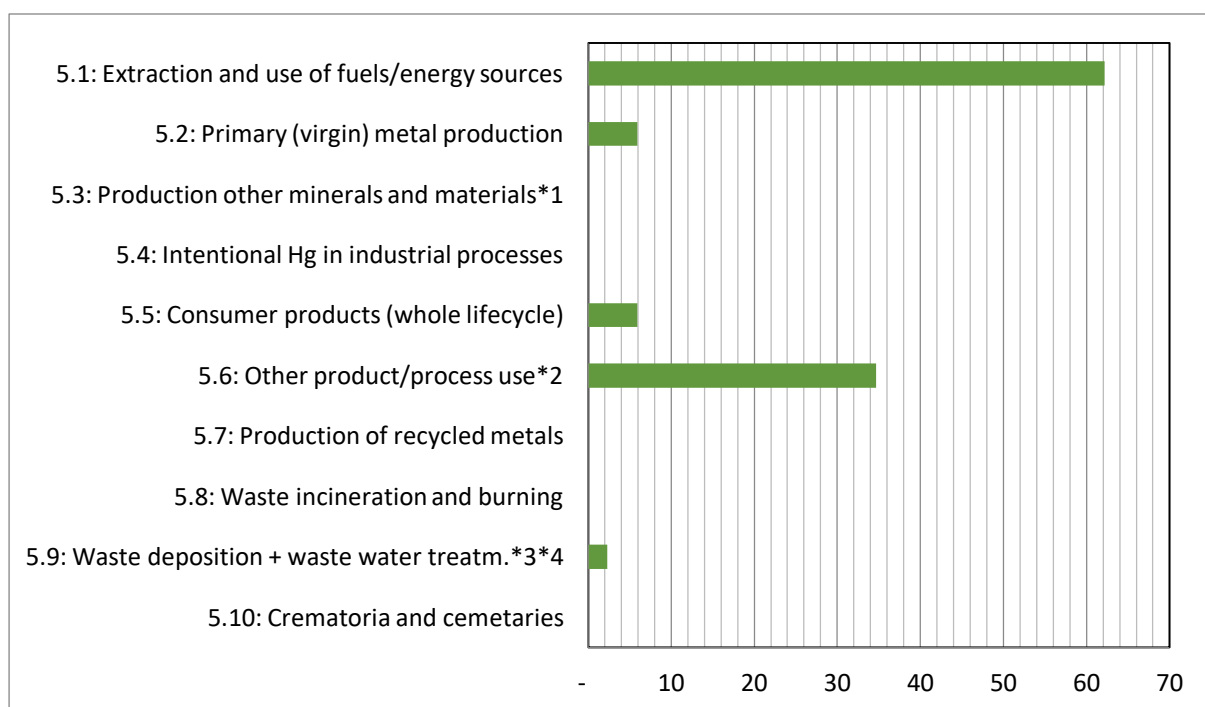


Figure 9. Mercury releases to sector specific waste treatment/disposal (Kg Hg/y)

Since the origin of mercury in waste and waste water produced in the country is mercury in products and materials, waste fractions and waste water do therefore not represent original, or new, mercury inputs to society (except imported waste which is not relevant for this case).

Therefore, individual category contribution with highest inputs of new mercury is by far **Coal combustion in power plants**, followed by **Thermometers with mercury**, as shown in Table 2.

Table 2. Sub-categories contributing with the highest inputs of new mercury

Source category	Calculated Hg input to society	Calculated Hg output, Kg/y					
		Air	Water	Land	By-products and impurities	General waste	Sector specific treatment/disposal
Coal combustion in power plants	285.09	224.08	0.00	0.00	0.00	0.00	61.01
Primary ferrous metal production	62.24	56.32	0.00	0.00	0.00	0.00	5.91
Cement clinker production	37.77	32.69	0.00	0.00	5.08	0.00	0.00
Thermometers with mercury	136.02	13.60	40.81	0.00	-	81.61	0.00
Batteries with mercury	36.98	0.00	0.00	0.00	-	31.06	5.92
Dental mercury-amalgam fillings	56.21	0.00	28.50	7.39	5.54	7.39	7.39
Laboratory chemicals and equipment with mercury	80.24	0.00	26.48	0.00	0.00	26.48	27.28

1.2 Uncertainties and gaps

There were few challenges during the process of updating the mercury inventory:

- There is a lack of background information related to the status for thermometers,
- There is a lack of precise data on the quantities of communal waste water collected and treated,
- There is no data on the mercury content in the input materials (fuels, raw materials, products, etc.).

2 Mercury release source types present

The identified mercury release source types present in the country are shown in **Error! Reference source not found..**

Table 3: Mercury release source types

Cat.no.	Source category	Exists? (y/n/?)
5.1	Source category: Extraction and use of fuels/energy sources	
5.1.1	Coal combustion in power plants	Y
5.1.2.1	Coal combustion in coal fired industrial boilers	Y
5.1.2.2	Other coal use	Y
5.1.3	Mineral oils - extraction, refining and use	Y
5.1.4	Natural gas - extraction, refining and use	Y
5.1.5	Other fossil fuels - extraction and use	Y
5.1.6	Biomass fired power and heat production	Y
5.1.7	Geothermal power production	Y
5.2	Source category: Primary (virgin) metal production	
5.2.1	Mercury (primary) extraction and initial processing (a	N
5.2.2	Gold (and silver) extraction with mercury amalgamation processes	N
5.2.3	Zinc extraction and initial processing	Y
5.2.4	Copper extraction and initial processing	Y
5.2.5	Lead extraction and initial processing	Y
5.2.6	Gold extraction and initial processing by methods other than mercury amalgamation	N
5.2.7	Aluminium extraction and initial processing	N
5.2.8	Other non-ferrous metals - extraction and processing	N
5.2.9	Primary ferrous metal production	Y
5.3	Source category: Production of other minerals and materials with mercury impurities	
5.3.1	Cement clinker production	Y
5.3.2	Pulp and paper production	N
5.3.3	Production of lime and light weight aggregates	N
5.4	Source category: Intentional use of mercury in industrial processes	
5.4.1	Chlor-alkali production with mercury-technology	N
5.4.2	VCM production with mercury catalyst	N
5.4.3	Acetaldehyde production with mercury catalyst	N
5.4.4	Other production of chemicals and polymers with mercury	N
5.4.5	Fire gilding (gold plating) with mercury	N
5.5	Source category: Consumer products with intentional use of mercury	

Cat.no.	Source category	Exists? (y/n/?)
5.5.1	Thermometers with mercury	Y
5.5.2	Electrical switches and relays with mercury	Y
5.5.3	Light sources with mercury	Y
5.5.4	Batteries with mercury	Y
5.5.5	Polyurethane with mercury catalysts	N
5.5.6	Biocides and pesticides with mercury	N
5.5.7	Paints with mercury	N
5.5.6	Pharmaceuticals for human and veterinary uses	N
5.5.9	Cosmetics and related products with mercury	N
5.6	Source category: Other intentional product/process use	
5.6.1	Dental mercury-amalgam fillings (b	Y
5.6.2	Manometers and gauges with mercury	Y
5.6.3	Laboratory chemicals and equipment with mercury	Y
5.6.4.1	Mercury use in traditional Asian medicines	N
5.6.4.2	Mercury use in homeopathic medicines	N
5.6.4	Mercury metal use in religious rituals and other traditional medicines	N
5.6.5	Miscellaneous product uses, mercury metal uses, and other sources	N
5.7	Source category: Production of recycled metals ("secondary" metal production)	
5.7.1	Production of recycled mercury ("secondary production")	N
5.7.2	Production of recycled ferrous metals (iron and steel)	Y
5.7.3	Production of other recycled metals	N
5.8	Source category: Waste incineration*3	
5.8.1	Incineration of municipal/general waste	N
5.8.2	Incineration of hazardous waste	N
5.8.3	Incineration of medical waste	Y
5.8.4	Sewage sludge incineration	N
5.8.5	Informal waste burning	Y
5.9	Source category: Waste deposition/landfilling and waste water treatment	
5.9.1	Controlled landfills/deposits*3	Y
5.9.2	Diffuse disposal under some control	N
5.9.3	Informal local disposal of industrial production waste	N
5.9.4	Informal dumping of general waste*1*3	Y
5.9.5	Waste water system/treatment*2	Y
5.10	Source category: Crematoria and cemeteries	
5.10.1	Crematoria/cremation	N
5.10.2	Cemeteries	Y

*Considering that the same facilities that produce zinc concentrates also produce lead concentrates utilizing the same ore through the same production processes, the sub-categories 6.2.1 “Zinc extraction and initial processing” and 6.2.3 “Lead extraction and initial processing” are merged into one sub-category.

3 Summary of mercury inputs to society

A summary of the estimated mercury inputs to society by life cycle phases is presented in **Error! Reference source not found..**

Table 4. Summary of mercury inputs

Category no.	Source category	Calculated Hg input to society (Kg Hg/y)
5.1	Source category: Extraction and use of fuels/energy sources	
5.1.1	Coal combustion in power plants	285.09
5.1.2.1	Coal combustion in coal fired industrial boilers	26.03
5.1.2.2	Other coal use	0.01
5.1.3	Mineral oils - extraction, refining and use	5.12
5.1.4	Natural gas - extraction, refining and use	0.03
5.1.5	Other fossil fuels - extraction and use	1.24
5.1.6	Biomass fired power and heat production	19.99
5.1.7	Geothermal power production	2.55
5.2	Source category: Primary (virgin) metal production	
5.2.1	Mercury (primary) extraction and initial processing (a	0.00
5.2.2	Gold (and silver) extraction with mercury amalgamation processes	0.00
5.2.3	Zinc extraction and initial processing	32.66
5.2.4	Copper extraction and initial processing	39.22
5.2.5	Lead extraction and initial processing	0.00
5.2.6	Gold extraction and initial processing by methods other than mercury amalgamation	0.00
5.2.7	Aluminium extraction and initial processing	0.00
5.2.8	Other non-ferrous metals - extraction and processing	0.00
5.2.9	Primary ferrous metal production	62.24
5.3	Source category: Production of other minerals and materials with mercury impurities	
5.3.1	Cement clinker production	37.77
5.3.2	Pulp and paper production	0.00
5.3.3	Production of lime and light weight aggregates	0.00
5.4	Source category: Intentional use of mercury in industrial processes	
5.4.1	Chlor-alkali production with mercury-technology	0.00
5.4.2	VCM production with mercury catalyst	0.00
5.4.3	Acetaldehyde production with mercury catalyst	0.00
5.4.4	Other production of chemicals and polymers with mercury	0.00
5.4.5	Fire gilding (gold plating) with mercury	0.00
5.5	Source category: Consumer products with intentional use of mercury	
5.5.1	Thermometers with mercury	136.02
5.5.2	Electrical switches and relays with mercury	2.20

Category no.	Source category	Calculated Hg input to society (Kg Hg/y)
5.5.3	Light sources with mercury	14.44
5.5.4	Batteries with mercury	36.98
5.5.5	Polyurethane with mercury catalysts	0.00
5.5.6	Biocides and pesticides with mercury	0.00
5.5.7	Paints with mercury	0.00
5.5.6	Pharmaceuticals for human and veterinary uses	0.00
5.5.9	Cosmetics and related products with mercury	0.00
5.6	Source category: Other intentional product/process use	
5.6.1	Dental mercury-amalgam fillings (b	56.21
5.6.2	Manometers and gauges with mercury	9.18
5.6.3	Laboratory chemicals and equipment with mercury	80.24
5.6.4.1	Mercury use in traditional Asian medicines	0.00
5.6.4.2	Mercury use in homeopathic medicines	0.00
5.6.4	Mercury metal use in religious rituals and other traditional medicines	0.00
5.6.5	Miscellaneous product uses, mercury metal uses, and other sources	0.00
5.7	Source category: Production of recycled metals ("secondary" metal production)	
5.7.1	Production of recycled mercury ("secondary production")	0.00
5.7.2	Production of recycled ferrous metals (iron and steel)	24.47
5.7.3	Production of other recycled metals	0.00
5.8	Source category: Waste incineration*3	
5.8.1	Incineration of municipal/general waste	0.00
5.8.2	Incineration of hazardous waste	0.00
5.8.3	Incineration of medical waste	8.66
5.8.4	Sewage sludge incineration	0.00
5.8.5	Informal waste burning	74.50
5.9	Source category: Waste deposition/landfilling and waste water treatment	
5.9.1	Controlled landfills/deposits*3	2.61
5.9.2	Diffuse disposal under some control	0.00
5.9.3	Informal local disposal of industrial production waste	0.00
5.9.4	Informal dumping of general waste*1*3	567.89
5.9.5	Waste water system/treatment*2	59.74
5.10	Source category: Crematoria and cemeteries	
5.10.1	Crematoria/cremation	0.00
5.10.2	Cemeteries	71.29

4 Summary of mercury releases

4.1 Methodology for data collection and analyses

The “Toolkit for Identification and Quantification of Mercury Releases” published by UNEP in 2023, providing methodology, as well as the input and output distribution factors, was the basis for the creation of the inventory. Thus, the methodological approach for the inventory was based on using factors developed on the basis of sample analysis done as part of the project activities and default input factors. Similarly, in regard to output distribution, factors derived from sample analysis were used to calculate releases to all media (air, water, land, products and waste) and default factors. The mercury release calculations used in this Toolkit are based on the mass balance principle: all the mercury fed into the system (e.g. an industrial sector) with materials and fuels comes out again, either as releases to the environment or in some kind of product stream. In other words: "Sum of inputs = sum of outputs".

The main parameters used in this methodology for the calculation/estimation of the mercury inputs/outputs are:

- activity rate: amount of feed material processed, or product produced/used/disposed of per unit of time (e.g. tons or pieces per year) that contains mercury.
- input factors: the mercury content (e.g. in grams of Hg) per unit of feed material processed or product produced/used/disposed. For sub-categories with more than one life cycle phase (such as battery production, uses and disposal), the input factor is defined for each phase. For example, the input factor for the production phase is the amount of mercury released per metric ton of batteries produced or product produced (e.g., metric ton or piece).
- output distribution factors: the fraction or part of the mercury input that is released through the particular pathway (air, water, land, product, general waste, or sector specific waste treatment, elaborated in Table 6).

$$\begin{array}{l} \text{Estimated} \\ \text{mercury} \\ \text{release to} \\ \text{pathway X} \end{array} = \text{Activity rate} \times \text{Input factor} \times \text{Output distribution} \\ \text{factor for pathway X}$$

4.1.1 Data collection

The data needed for the determination of the activity rates and where possible the input/output distribution factors were obtained from the following sources:

- *Publications by the State Statistical Office (SSO).* SSO has been considered as primary relevant data source. Valuable data were obtained from the energy balances related to the usage of the different fossil fuels in the industry, transportation, commercial amenities, households, then for the quantities of the collected and landfilled waste, quantities of treated waste water, population and number of buried human corpses;
- *Questionnaires* submitted to relevant stakeholders: separate questionnaires were prepared and submitted to relevant stakeholders: Customs Administration (especially for the imported/exported quantities of the products that contain mercury), Ministry of Environment and Physical Planning (collection rate of the batteries, waste and waste water management), State Statistical Office, thermoelectric power plants, importers (for the estimation of the fraction of the products that may contain mercury), Ministry of Health (fraction of the mercury filled thermometers in the health sector annually disposed), metal production and mining companies, Dental Chamber of Macedonia, Economic Chamber, Ministry of Agriculture, Forestry and Water Economy, Waste Water Treatment Plants, cement production plant, Sanitary landfill, Medical waste incinerators, etc.;
- *Samples analysis:* For inventory improvement purposes, sample analysis was conducted and specific input factors were developed for certain categories. More information is provided below.

4.1.2 Sampling and samples analysis

In order to make improvement to the inventory and provide more precise data, an extended sampling and analysis was conducted. Bearing in mind the previous inventory activities and identifying the room for improvement at some of the category sources, particular activities were identified to determine the presence of mercury.

Total of 16 private companies and communal enterprises were contacted to provide their samples. The samples included:

- Treated waste water and sludge (Communal Waste Water Treatment Plants),

- Filter dust (Metal industry and Cement production),
- Mineral feed (Cement production),
- Ore, concentrates and mining waste (Mining industry),
- Coal (Energy production).

The preparation of the samples included the following steps:

- acidification with hydrochloric acid of the liquid samples
- shredding of samples when necessary
- measurement of weight of the samples, ensuring enough quantity for analysis as specified by the laboratory
- packaging of liquid samples in clean glass bottles, and for the powder samples in plastic bottles
- securing the bottles, labelling and preparation of the package.

The sampling was done in June-July 2023 and the analyzed in August 2023. In total, 43 samples were taken from 18 locations throughout the country, prepared and sent for analysis in accredited laboratory. The specification list and report from the analysis are included in [Annex 1](#) and [Annex 2](#).

4.1.3 Data analyses

The estimation of mercury releases from the various release sources is based preferably on actual data, related to the product, industrial facility or activity under consideration. In a situation where data for more reliable estimations are not available, as the Toolkit recommends default factors were used. It is emphasized that the factors are based on a limited data base and are expert judgements based only on summarized data, i.e. no systematic quantitative approach involved in the development of the factors.

The certainty assessment of the parameters used for the calculations of mercury releases for each sub-category was performed by ranking the strength of the parameters as:

- High level: if the parameters are determined based on specific data from official sources or defined on actual measurements;
- Medium level: if the parameters are determined based on limited data;
- Low level: if the parameters are determined based on the default factors provided in the Toolkit.

Whenever it was possible and sufficient data were available, the inventory report provides different scenarios for the calculation of mercury releases from the same sub-categories and a comparison of these scenarios, thus giving the possibility to evaluate the differences in the calculations of mercury releases using data of different quality and the uncertainties emerging from the non-specific approaches based on limited data. The following scenarios were considered:

- Source-specific scenario. This scenario is related to specific measurements. It is the main and most relevant one and has the highest significance for the mercury release calculations. This is due to the fact that the input and output distribution factors were defined based on the actual analyses of different matrices.
- Semi-conservative scenario. This scenario is based on partial mercury measurements, i.e. the mercury measurements in some of the output pathways, mostly the measurements in the air emissions as part of the regular monitoring campaigns performed by the companies, then some measurements in the ore and the mining concentrates. Afterwards, the total mercury output and consequently the mercury input were calculated using the distribution ratio participation for each of the relevant pathways.
- Conservative scenario: this scenario was used when no data on specific measurements on the mercury content in the processed material/products were available, neither the mercury content in some of the output pathways. In this situation, the default input and output distribution factors provided in the Toolkit were used. Considering that the default factors were derived based on limited data provided from various literature studies and some studies with a partial approach and specific to some particular countries and regions, these default factors could be considered only as indicative ones. Therefore, this scenario is the least relevant one resulting in mercury emission calculations with high level of uncertainty.

The summary of mercury releases by sub-categories is presented in **Error! Reference source not found..**

The category with the highest amount of mercury released in the society in 2021 is **Informal dumping of general waste** with 567.89 kg, followed by **Waste water system treatment** with 538 kg.

Furthermore, as above explained, to avoid double counting, the Toolkit takes into account the lifecycle of the products and therefore deducts 90% of the air, water and land releases of

mercury from some categories (under source categories waste incineration and waste deposition/landfilling and waste treatment), to calculate the mercury input to society.

Table 5. Summary of mercury releases

C	Sub-C	Source category	Exists? (y/n/?)	Calculated. Hg input to society	Calculated Hg output, Kg/y					
					Air	Water	Land	By-products and impurities	General waste	Sector specific treatment/disposal
5.1		Source category: Extraction and use of fuels/energy sources								
	5.1.1	Coal combustion in power plants	Y	285.09	224.08	0.00	0.00	0.00	0.00	61.01
	5.1.2.1	Coal combustion in coal fired industrial boilers	Y	26.03	25.03	0.00	0.00	0.00	0.00	1.01
	5.1.2.2	Other coal use	Y	0.01	0.01	0.00	0.00	0.00	0.00	0.00
	5.1.3	Mineral oils - extraction, refining and use	Y	5.12	4.92	0.00	0.00	0.00	0.00	0.20
	5.1.4	Natural gas - extraction, refining and use	Y	0.03	0.03	0.00	0.00	0.00	0.00	0.00
	5.1.5	Other fossil fuels - extraction and use	Y	1.24	1.24	0.00	0.00	0.00	0.00	0.00
	5.1.6	Biomass fired power and heat production	Y	19.99	19.99	0.00	0.00	0.00	0.00	0.00
	5.1.7	Geothermal power production	Y	2.55	2.55	0.00	0.00	0.00	0.00	0.00
5.2		Source category: Primary (virgin) metal production								
	5.2.1	Mercury (primary) extraction and initial processing (a)	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.2.2	Gold (and silver) extraction with mercury amalgamation processes	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.2.3	Zinc extraction and initial processing	Y	32.66	1.63	0.82	30.21	0.00	0.00	0.00
	5.2.4	Copper extraction and initial processing	Y	39.22	1.96	0.98	36.28	0.00	0.00	0.00
	5.2.5	Lead extraction and initial processing	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.2.6	Gold extraction and initial processing by methods other than mercury amalgamation	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.2.7	Aluminium extraction and initial processing	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.2.8	Other non-ferrous metals - extraction and processing	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.2.9	Primary ferrous metal production	Y	62.24	56.32	0.00	0.00	0.00	0.00	5.91

C	Sub-C	Source category	Exists? (y/n/?)	Calculated Hg input to society	Calculated Hg output, Kg/y					
					Air	Water	Land	By-products and impurities	General waste	Sector specific treatment/disposal
5.3		Source category: Production of other minerals and materials with mercury impurities								
	5.3.1	Cement clinker production	Y	37.77	32.69	0.00	0.00	5.08	0.00	0.00
	5.3.2	Pulp and paper production	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.3.3	Production of lime and light weight aggregates	Y	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.4		Source category: Intentional use of mercury in industrial processes								
	5.4.1	Chlor-alkali production with mercury-technology	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.4.2	VCM production with mercury catalyst	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.4.3	Acetaldehyde production with mercury catalyst	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.4.4	Other production of chemicals and polymers with mercury	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.4.5	Fire gilding (gold plating) with mercury	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.5		Source category: Consumer products with intentional use of mercury								
	5.5.1	Thermometers with mercury	Y	136.02	13.60	40.81	0.00	-	81.61	0.00
	5.5.2	Electrical switches and relays with mercury	Y	2.20	0.22	0.00	0.22	-	1.76	0.00
	5.5.3	Light sources with mercury	Y	14.44	0.72	0.00	0.00	-	13.72	0.00
	5.5.4	Batteries with mercury	Y	36.98	0.00	0.00	0.00	-	31.06	5.92
	5.5.5	Polyurethane with mercury catalysts	N	0.00	0.00	0.00	0.00	-	0.00	0.00
	5.5.6	Biocides and pesticides with mercury	N	0.00	0.00	0.00	0.00	-	0.00	0.00
	5.5.7	Paints with mercury	N	0.00	0.00	0.00	0.00	-	0.00	0.00
	5.5.8	Pharmaceuticals for human and veterinary uses	N	0.00	0.00	0.00	0.00	-	0.00	0.00
	5.5.9	Cosmetics and related products with mercury	N	0.00	0.00	0.00	0.00	-	0.00	0.00
5.6		Source category: Other intentional product/process use								
	5.6.1	Dental mercury-amalgam fillings (b	Y	56.21	0.00	28.50	7.39	5.54	7.39	7.39

C	Sub-C	Source category	Exists? (y/n/?)	Calculated Hg input to society	Calculated Hg output, Kg/y					
					Air	Water	Land	By-products and impurities	General waste	Sector specific treatment/disposal
	5.6.2	Manometers and gauges with mercury	Y	9.18	0.92	2.76	0.00	0.00	5.51	0.00
	5.6.3	Laboratory chemicals and equipment with mercury	Y	80.24	0.00	26.48	0.00	0.00	26.48	27.28
	5.6.4.1	Mercury use in traditional Asian medicines	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.6.4.2	Mercury use in homeopathic medicines	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.6.4	Mercury metal use in religious rituals and other traditional medicines	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.6.5	Miscellaneous product uses, mercury metal uses, and other sources	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.7		Source category: Production of recycled metals ("secondary" metal production)								
	5.7.1	Production of recycled mercury ("secondary production")	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.7.2	Production of recycled ferrous metals (iron and steel)	Y	24.47	2.37	0.00	11.05	0.00	11.05	0.00
	5.7.3	Production of other recycled metals	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.8		Source category: Waste incineration*3								
	5.8.1	Incineration of municipal/general waste	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.8.2	Incineration of hazardous waste	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.8.3	Incineration of medical waste	Y	8.66	8.66	0.00	0.00	0.00	0.00	0.00
	5.8.4	Sewage sludge incineration	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.8.5	Informal waste burning	Y	74.50	74.50	0.00	0.00	0.00	0.00	0.00
5.9		Source category: Waste deposition/landfilling and waste water treatment								
	5.9.1	Controlled landfills/deposits*3	Y	2.61	2.59	0.03	0.00	0.00	0.00	0.00

C	Sub-C	Source category	Exists? (y/n/?)	Calculated Hg input to society	Calculated Hg output, Kg/y					
					Air	Water	Land	By-products and impurities	General waste	Sector specific treatment/disposal
	5.9.2	Diffuse disposal under some control	N	0.00	-	-	-	-	-	-
	5.9.3	Informal local disposal of industrial production waste	N	0.00	0.00	0.00	0.00	-	-	-
	5.9.4	Informal dumping of general waste*1*3	Y	567.89	56.79	56.79	454.31	-	-	-
	5.9.5	Waste water system/treatment*2	Y	59.74	0.00	39.30	0.00	0.00	18.17	2.27
5.10		Source category: Crematoria and cemeteries								
	5.10.1	Crematoria/cremation	N	0.00	0.00	0.00	0.00	-	0.00	0.00
	5.10.2	Cemeteries	Y	71.29	0.00	0	71.29	-	0	0
SUM OF QUANTIFIED INPUTS AND RELEASES *1*2*3*4				1068.09	530.82	157.15	156.44	10.62	197.00	110.99

Table 6. Description of the types of results

Calculation result type	Description
Estimated Hg input, Kg Hg/y	The standard estimate of the amount of mercury entering this source category with input materials, for example calculated mercury amount in the amount of coal used annually in the country for combustion in large power plants.
Air	Mercury emissions to the atmosphere from point sources and diffuse sources from which mercury may be spread locally or over long distances with air masses; for example, from: • Point sources such as coal fired power plants, metal smelter, waste incineration; • Diffuse sources as small-scale gold mining, informally burned waste with fluorescent lamps, batteries, thermometers.
Water	Mercury releases to aquatic environments and to waste water systems: Point sources and diffuse sources from which mercury will be spread to marine environments (oceans), and freshwaters (rivers, lakes, etc.). for example, releases from: • Wet flue cleaning systems from coal fired power plants; • Industry, households, etc. to aquatic environments; • Surface run-off and leachate from mercury contaminated soil and waste dumps
Land	Mercury releases to soil, the terrestrial environment: General soil and ground water. For example, releases from: • Solid residues from flue gas cleaning on coal fired power plants used for gravel road construction; • Uncollected waste products dumped or buried informally • Local un-confined releases from industry such as on-site hazardous waste storage/burial • Spreading of sewage sludge with mercury content on agricultural land (sludge used as fertilizer) • Application on land, seeds or seedlings of pesticides with mercury compounds
By-products and impurities	By-products that contain mercury, which are sent back into the market and cannot be directly allocated to environmental releases, for example: • Gypsum wallboard produced from solid residues from flue gas cleaning on coal fired power plants. • Sulphuric acid produced from desulphurization of flue gas (flue gas cleaning) in non-ferrous metal plants with mercury trace concentrations • Chlorine and sodium hydroxide produced with mercury-based chlor-alkali technology; with mercury trace concentrations • Metal mercury or calomel as by-product from non-ferrous metal mining (high mercury concentrations)
General waste	General waste: Also called municipal waste in some countries. Typically, household and institution waste where the waste undergoes a general treatment, such as incineration, landfilling or informal dumping or burning. The mercury sources to waste are consumer products with intentional mercury content (batteries, thermometers, fluorescent tubes, etc.) as well as high volume waste like printed paper, plastic, etc., with small trace concentrations of mercury.
Sector specific waste treatment /disposal	Waste from industry and consumers which is collected and treated in separate systems, and in some cases recycled; for example. • Confined deposition of solid residues from flue gas cleaning on coal fired power plants on dedicated sites. • Hazardous industrial waste with high mercury content which is deposited in dedicated, safe sites • Hazardous consumer waste with mercury content, mainly separately collected and safely treated batteries, thermometers, mercury switches, lost teeth with amalgam fillings etc. • Confined deposition of tailings and high volume rock/waste from extraction of non-ferrous metals The country-specific waste treatment/disposal method is described for each sub-category in the detailed report sections below.

5 Identified hot-spots of mercury contamination (contaminated sites)

In North Macedonia, there is no continuous monitoring of mercury in the environment. There are only individual surveys of mercury concentration in different environmental media (air, water, sediments, soils and food). The largest sources of mercury emissions to the environment are fossil fuel combustion processes, thermal power plants (coal burning), ore processing (lead-zinc, copper, arsenic, antimony ores, etc.), metallurgy (steel production from waste sheets, production of nickel, ferrochromium, ferrosilicon, etc.), chemical industry, metal processing, electronics, application of instruments and medical devices, etc.

5.1 Studies on the distribution of mercury in environmental media

5.1.1 Distribution of mercury in air

The first study on the distribution of mercury in the air in North Macedonia was conducted in 2002 as part of the international project "Convention on Long-Range Transboundary Air Pollution (CLRTAP) and International Cooperative Program on Effects of Air Pollution on Natural Vegetation and Crops" by indirectly monitoring the distribution of heavy metals in the air using moss samples as the best biomonitors of air pollution. For this purpose, samples were collected at 72 sites (sample density of 2.8 samples per 1000 km²). The same studies were repeated in 2005, 2010, 2015, and 2020 by collecting moss samples from the same locations (Figure 1).

The results of these studies were published in several articles for each studied period (Barandovski, и др., 2008; Barandovski, и др., 2012; Barandovski, Stafilov, Sajn, Frontasyeva, & Baceva, 2013; Barandovski, Frontasyeva, Stafilov, Sajn, & Ostrovnaya, 2015; Barandovski, Stafilov, Sajn, Frontasyeva, & Baceva Andonovska, 2020), and one article was additionally published on atmospheric deposition of mercury in the country (Stafilov, Barandovski, Sajn, & Baceva Andonovska, 2020). The results for the median, minimum and maximum values are shown in Table 7, while the maps of mercury distribution are shown in Figure 10. Mercury content in moss samples ranged from 0.018 mg/kg to 0.26 mg/kg in 2002, from 0.010 mg/kg to 0.42 mg/kg in 2005, from 0.010 mg/kg to 0.60 mg/kg in 2010, from 0.020 mg/kg to 0.25 mg/kg in 2015, and from 0.035 mg/kg to 0.10 mg/kg in 2020. The

median values indicate some increase in mercury levels from 2002 to 2010 and a decrease in mercury emissions from 2010-2020.

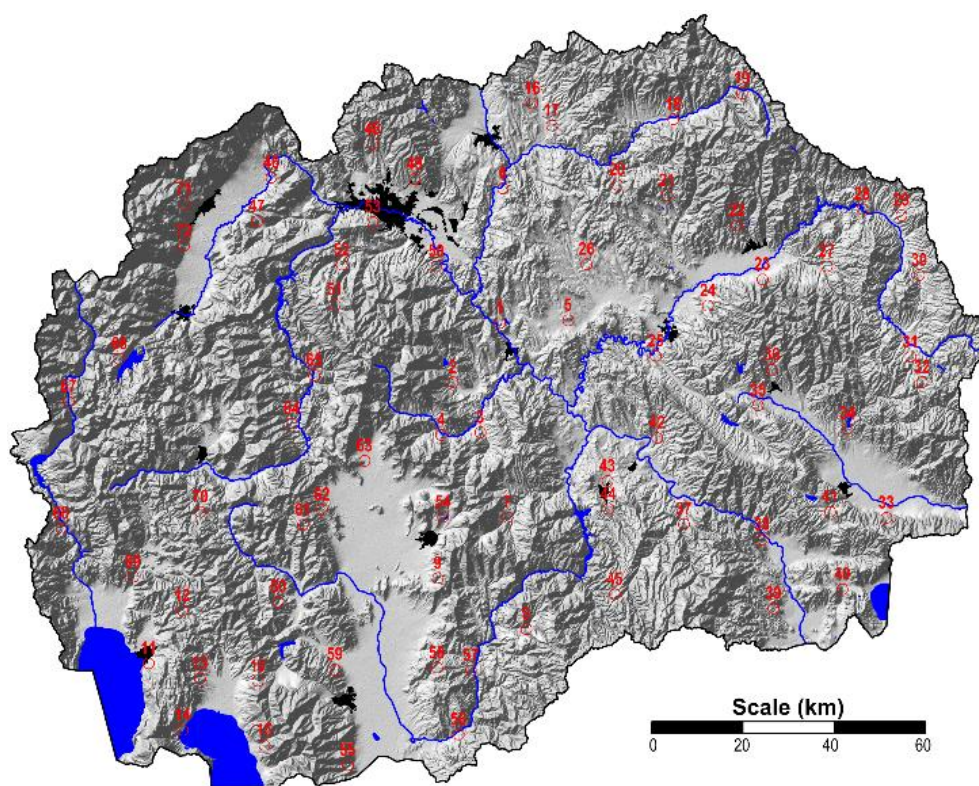


Figure 10. Locations of moss sampling

Maps of the spatial distribution of mercury, Figure 11, show areas with elevated mercury levels, most likely due to anthropogenic influences such as dust emissions from mining and metallurgical activities. Indeed, in Macedonia there is no longer any industry producing and processing mercury and its compounds (in the atmosphere it is present in the form of vapour or in the form of compounds in dust). The presence of mercury in the air in Macedonia is also due to increased transboundary transport from other areas. A comparison of data on Hg content in moss samples in neighbouring countries showed that the highest levels are present in samples collected in Macedonia, Albania, and Italy, countries that are the first to be hit by air currents from the African continent, where mercury is believed to originate (Harmens, et al., 2012).

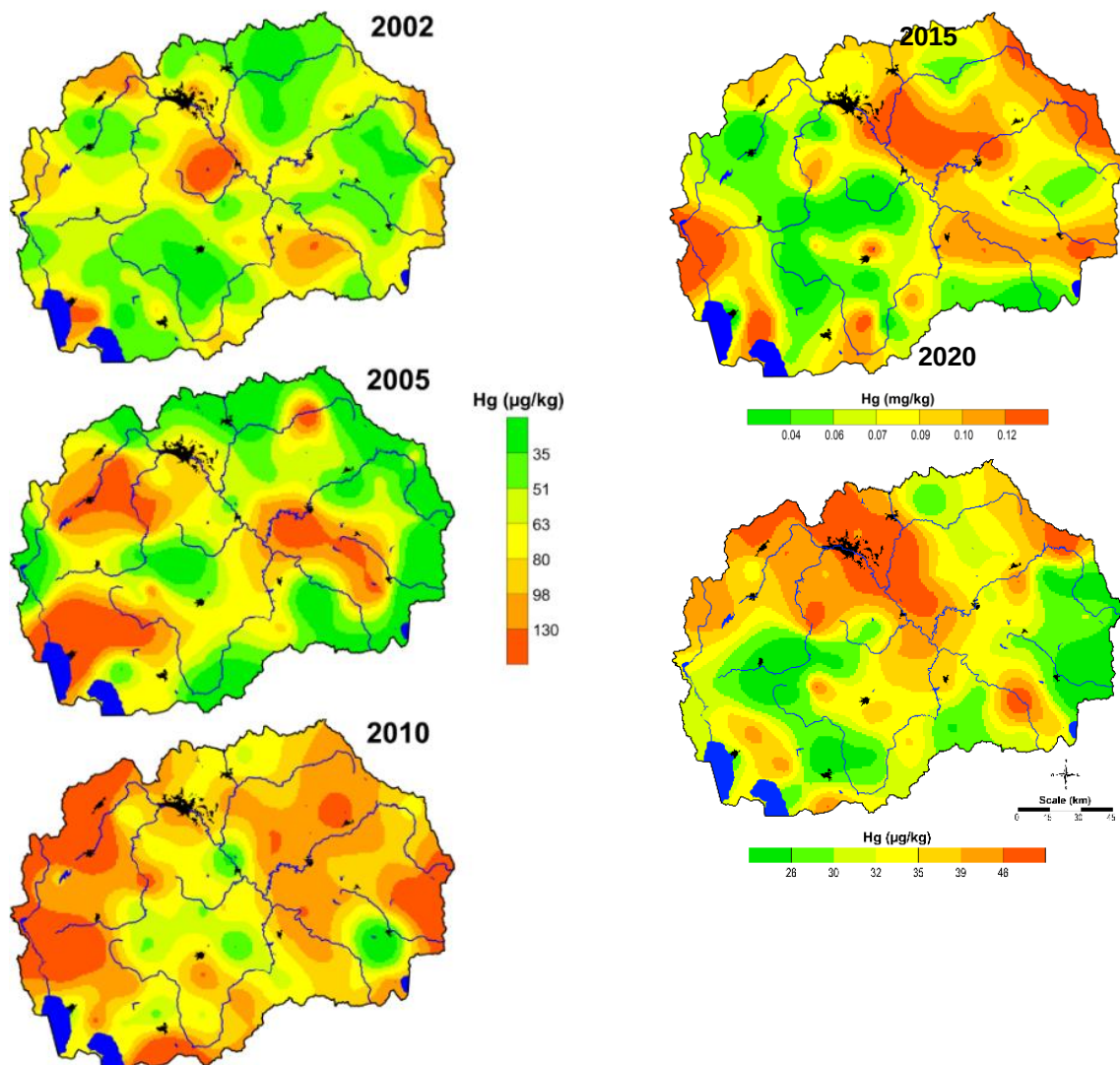


Figure 11. Spatial distribution of HG in moss samples in N. Macedonia (Stafilov, Barandovski, Sajn, & Baceva Andonovska , 2020)

Table 7. Median, minimum and maximum values of mercury content in moss samples from the whole area of N. Macedonia (in mg/kg)

Year	Median	Minimum	Maximum
2002	0.056	0.018	0.26
2005	0.068	0.010	0.42
2010	0.093	0.010	0.60
2015	0.084	0.020	0.25
2020	0.035	0.018	0.10

5.1.2 Distribution in soils

In 2014, a Geochemical Atlas of Europe was published (Reimann, Birke, Demetriades, Filzmoser, & O'Connor, 2014a; Reimann, Birke, Demetriades, Filzmoser, & O'Connor, 2014b) which included the results of mercury analysis in 10 samples of agricultural soils (0-20 cm) and 10 samples of grazing pasture soils (0-10 cm). From the results presented in Figure 12 and Table 8, it is evident that the mercury content in the soils of Macedonia is significantly lower than in the soils of a larger number of countries in Europe. Thus, it was found that the mercury content in Macedonian soils ranges from 0.008 to 0.075 mg/kg with mean values of 0.023 mg/kg and 0.017 mg/kg, which is lower than the mercury content in European soils, where it ranges from 0.003 to 3.10 mg/kg with mean values of 0.030 mg/kg and 0.035 mg/kg.

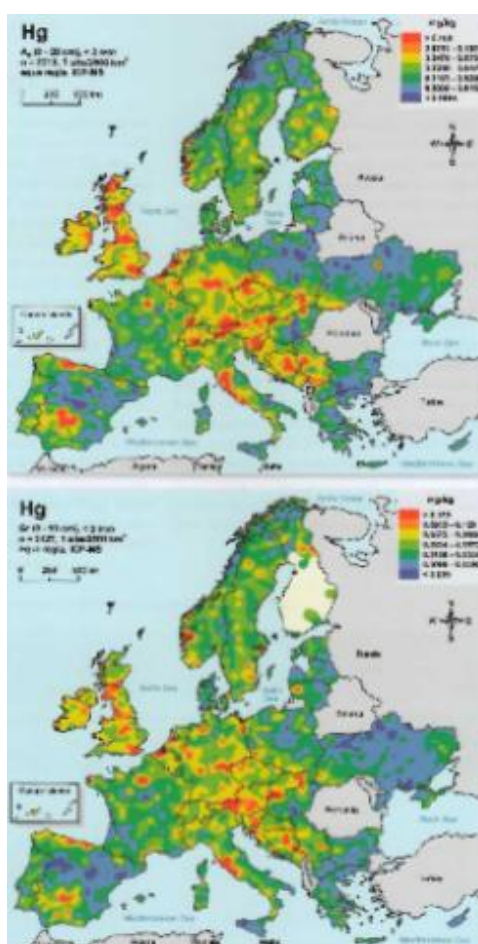


Figure 12. Distribution of Hg in agricultural soils (upper map) and grazing soils (lower map) in Europe (Reimann, Birke, Demetriades, Filzmoser, & O'Connor, 2014a)

Table 8. Mercury content (in mg/kg) in European and Macedonian soils

	Europe		Macedonia	
	Agriculture soil	Grazing soil	Agriculture soil	Grazing soil
Average	0.030	0.035	0.023	0.017
Minimum	<0.003	<0.003	0.008	0.010
Maximum	1.60	3.10	0.068	0.075

In previous studies in Macedonia, higher mercury content was found in the soils of the city of Veles, shown on Figure 13, which are polluted by the work of the lead and zinc metallurgy plant located near the city (Stafilev, et al., 2008a; Stafilev, et al., 2010b). The analysis of 43 elements (including Hg) in about 200 soils showed that the content of elements such as As, Au, Cd, Cu, Hg, In, Pb, Sb, Se, and Zn in the soil samples in the vicinity of the lead and zinc smelter and in the adjacent part of the city of Veles appears to be much higher than in the samples collected in the surrounding areas due to the pollution from the plant.

The Hg average for the cultivable area exceeds the estimated European Hg average for topsoil by a factor of 3.2, for the non-buildable area – by a factor of 3.0, and for the urban area – by a factor of 5.9. In the most polluted area, the average Hg concentration is more than 8 times higher than the European Hg average. It was found that the mercury content in the top-soils in the areas of the lead and zinc smelter and in the cultivated areas in the eastern part of the smelter is very high.

The highest values of mercury content were found in the topsoil around the smelter (between 6.9 and 12 mg/kg), in the topsoil of the Rečani fields (between 1.9 and 6.0 mg/kg) and in two samples from the southern part of the city (2.1 mg/kg and 3.6 mg/kg). These contaminated soils contribute to the pollution of water, sediments and fish from the Vardar River downstream to about 20 km from the town of Veles (Ilic Popov, Stafilev, Sajin, Tánáselia, & Baceva, 2014; Ilic Popov, Stafilev, Sajin, & Tánáselia, 2016).

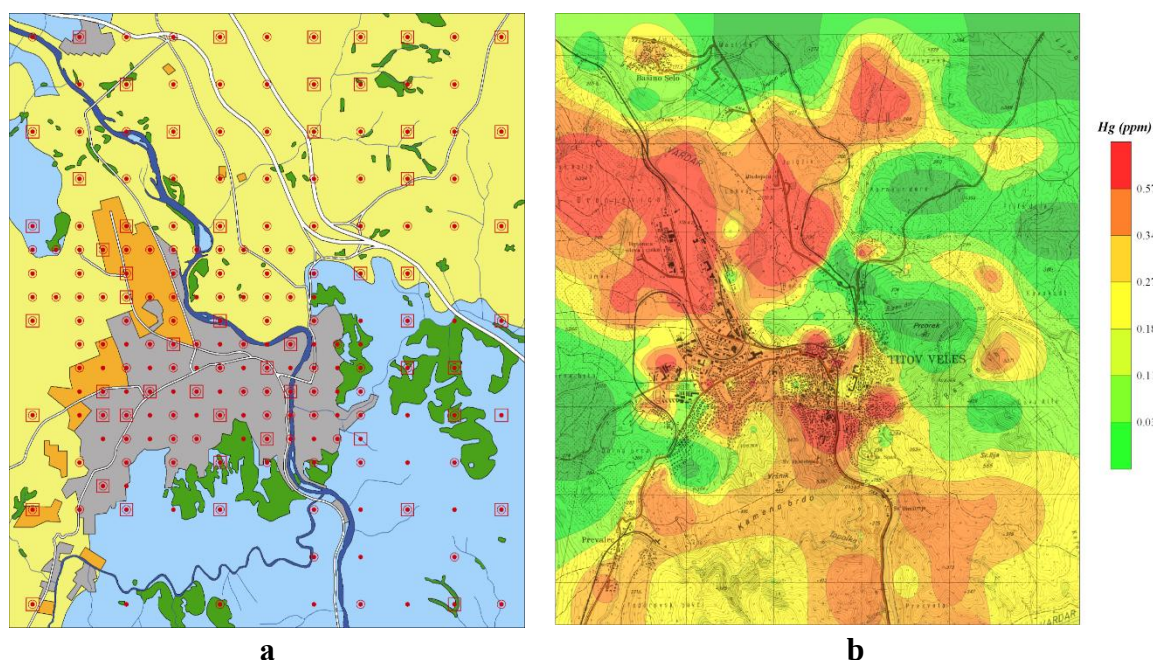


Figure 13. Locations of soil samples in Veles city and its surroundings (a) and map of spatial distribution of mercury content in the region (Stafilov, et al., 2008a)

Both lithogenic and anthropogenic influence on soil mercury contamination was detected in soil samples collected from 174 sites in the Kavadarci area of southern Macedonia, depicted in Figure 14, where a ferronickel smelter has been operating for the past 25 years (Stafilov, et al., 2008b; Stafilov, et al., 2010b). The elevated Hg content in the western part of the study area is due to the lithogenic origin due to the presence of Paleozoic and Mesozoic rocks. However, in some areas along the Vardar River and in the town of Kavadarci, the Hg content was as high as 3.8 mg/kg due to soil and sediment contamination from the Pb-Zn smelter in the town of Veles. Elevated Hg content was also found in the soil samples of the larger settlements (Kavadarci city), which was due to pollution from urban activities shown on Figure 15.

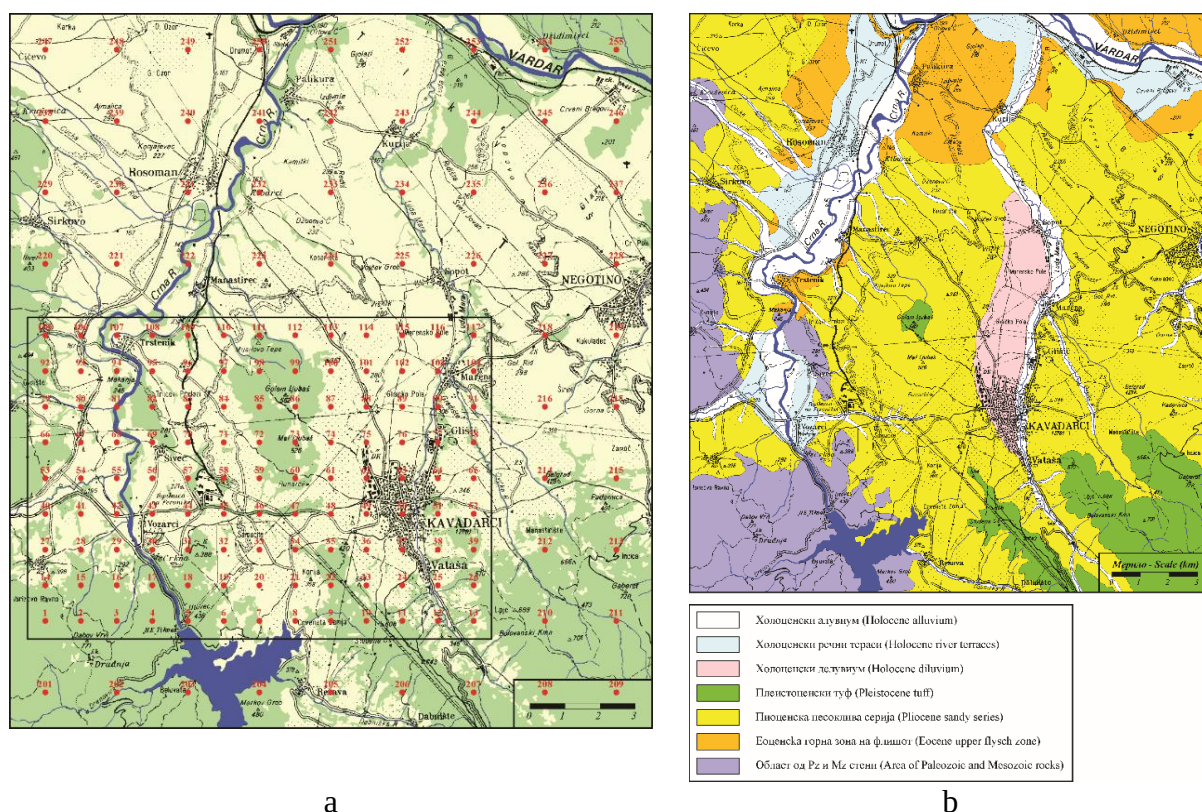


Figure 14. Location of soil sampling (a) and geological map of the Kavadarci region (b) (Stafilov, et al., 2008b)

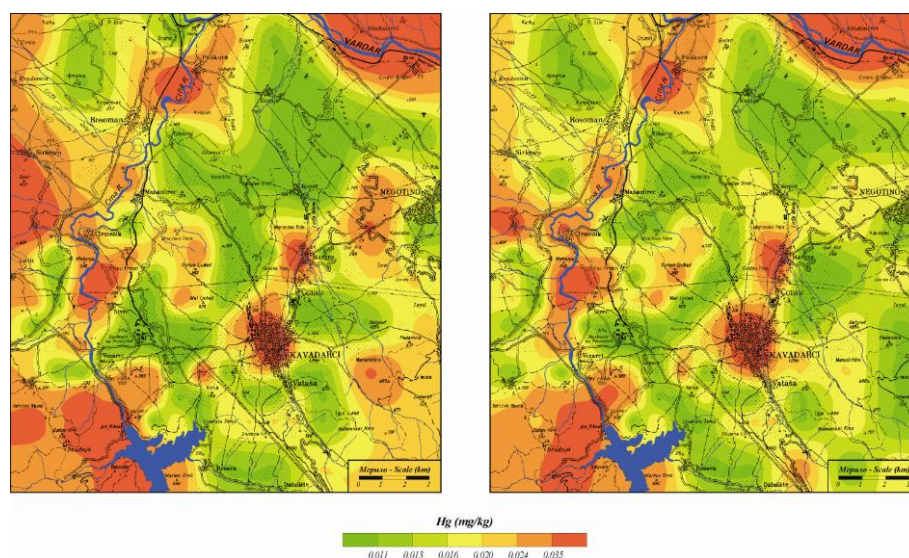


Figure 15. Maps of spatial distribution of mercury content in topsoil (0-5 cm) and subsoil (20-30 cm) of Kavadarci region (Stafilov, et al., 2008b)

Mercury was also analysed in the surface of 230 soils (0-10 cm) from the city of Skopje and its surroundings. It was found, presented on Figure 16, that the soils in the southern (Vodno, Gorno Nerezi, Sopište, Usje) and eastern parts of the study area (Trubarevo, Indžikovo,

Hipodrom) had higher Hg content (Stafilov, Sajin, & Ahmeti, 2017). Some areas in the north are also rich in these elements, as well as the area around the iron and steel plants.

The Hg content is high in the soil of the city centre and the mentioned area, which is probably due to the contamination from the urban activities. According to the geological formations Table 9, higher contents of these elements are observed in the areas with older rocks from the Paleozoic and Quaternary swamp sediments. The lowest contents are found in the areas of Miocene and Pliocene sediments and younger and older Quaternary river terraces. The highest average contents of all elements from this group were found in the soil overlying Quaternary marsh sediments (average value 1.0 mg/kg). There were no major differences in the average contents of these elements in the different types of land use (from 0.12 to 0.25 mg/kg).

Table 9. Average mercury contents in soils from Skopje and its environs by geological formations and land use

Geology	Skopje	Quaternary floodplain	Quaternary swamp sediments	Quaternary young terraces	Quaternary old terraces	Pliocene sediments	Miocene sediments	
Hg, mg/kg	0.17	0.19	1.0	0.16	0.15	0.18	0.12	
Land use	Skopje	Forest	Shrub	Open areas	Cultivated land	Urban area (low build-up)	Urban area (high build-up)	Industrial area
Hg, mg/kg	0.17	0.25	0.13	0.22	0.19	0.18	0.12	0.15

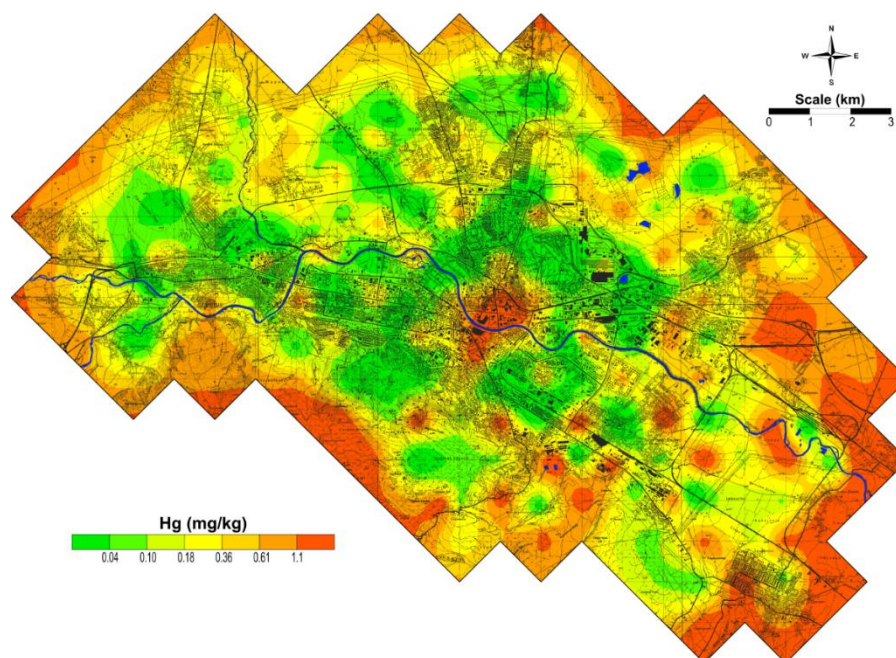


Figure 16. Spatial distribution of the mercury content in the surface soil of the city of Skopje and its environs (Stafilov, Sajn, & Ahmeti, Geochemical atlas of Skopje. Faculty of Natural Sciences and Mathematics, 2017)

5.1.3 Distribution in waters

In order to assess the current situation in the country and/or to prepare a mercury inventory, an analysis of mercury in different environmental samples was carried out in preparation for the Minamata Initial Assessment in the Republic of Macedonia in 2017. For this purpose, a total of 137 samples were collected in Macedonia and analysed in the Laboratory of atomic spectroscopy at the Institute of Chemistry, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University, Skopje. Mercury concentration in the following environmental samples was determined:

- 25 river water samples from the Vardar River Basin, which covers 85% of the country, including the analysis of samples from the Vardar River and tributaries of the Vardar River: Treska, Lepenec, Pcinja, Bregalnica and Crna Reka.
- 25 sediment samples from the Vardar River Basin (covering 85% of the country) including the analysis of samples from the Vardar River and the tributaries of the Vardar River: Treska, Lepenec, Pcinja, Bregalnica and Crna Reka.

- 15 drinking water samples from 15 major cities in Macedonia: Skopje, Gostivar, Kičevo, Ohrid, Bitola, Prilep, Veles, Kavadarci, Gevgelija, Kriva Palanka, Štip, Delčevo, Berovo and Strumica.

The results of the analysis of mercury in sediment samples from the Vardar River basin (15 from the Vardar River and 10 samples and 15 from the main tributaries) are presented in Table 10. From the obtained results, it could be concluded that the mercury concentration in all river water samples from the Vardar River basin (which covers 85% of all water catchment areas in Macedonia) is below the maximum permissible concentrations for classes I and II of 0.2 µg/L according to the Regulation on Classification of Water in the Macedonia (Official Gazzette, R.Macedonia, 1999)

Table 10. The concentration of mercury in river water samples from the Vardar River basin

No	River	Location	Geographic coordinates		Hg conc., µg/L	Class
			N	E		
VV01	Vardar	Vrutok	41°45'53.26"	20°50'14.53"	<0.01	I
VV02	Vardar	Volkovija-Gostivar	41°51'44.58"	20°58'52.86"	<0.01	II
VV03	Vardar	Zelino	41°59'2.18"	21°3'14.25"	0.012	II
VV04	Vardar	Jegunovce	42°5'7.80"	21°7'33.56"	<0.01	II
VV05	Vardar	Rašće-Kondovo	42°0'49.79"	21°16'40.25"	0.053	II
VV06	Vardar	Aerodrom	41°59'38.56"	21°28'2.97"	<0.01	III
VV07	Vardar	Zelenikovo	41°53'14.30"	21°35'24.08"	<0.01	III
VV08	Vardar	Novacani	41°46'7.57"	21°44'16.13"	<0.01	III
VV09	Vardar	Motel Makedonija-Veles	41°41'6.06"	21°49'35.43"	<0.01	III
VV10	Vardar	Gradsko	41°35'21.09"	21°55'58.03"	<0.01	III
VV11	Vardar	Stobi	41°33'46.52"	22°0'44.42"	<0.01	II
VV12	Vardar	Dubrovo TEC Negotino	41°27'48.15"	22°9'40.66"	<0.01	II
VV13	Vardar	Gradec - Udovo	41°23'14.62"	22°22'23.73"	<0.01	II
VV14	Vardar	Miravci	41°18'12.93"	22°28'50.24"	<0.01	II
VV15	Vardar	Gevgelija	41°8'13.50"	22°31'57.59"	<0.01	II
VVTR1	Treska	Sisevo	41°58'23.36"	21°18'27.54"	<0.01	II
VVTR2	Treska	Crcec	41°59'43.38"	21°20'4.18"	<0.01	II
VVLE1	Lepenec	Blace	42°6'21.30"	21°19'27.04"	<0.01	II
VVLE2	Lepenec	Bardovci	42°1'29.82"	21°21'53.87"	<0.01	II
VVPC1	Pcinja	D. Konjari	41°56'54.72"	21°42'11.22"	<0.01	II
VVPC2	Pcinja	Badar	41°52'0.14"	21°41'31.79"	<0.01	II
VVBR1	Bregalnica	Ubogo	41°40'55.73	21°58'4.86"	<0.01	III
VVBR2	Bregalnica	Gradsko	41°37'37.09"	21°56'38.74"	0.072	III
VVCR1	Crna Reka	Ribarci-Rosoman	41°30'24.41"	21°57'0.93"	<0.01	II

No	River	Location	Geographic coordinates		Hg conc., µg/L	Class
			N	E		
VVCR2	Crna Reka	Stobi	41°32'31.43"	21°58'15.72"	<0.01	II
Maximal permitted concentration						
I and II class						0.2
III and IV class						1

The results of the analysis of mercury in sediment samples from the Vardar River basin (15 samples from the Vardar River and 10 samples and 15 samples from the main tributaries) were compared with the Dutch standards since there is no regulation for the maximum permissible concentration of heavy metals in soil and sediments in Macedonia, given in Table 11. From the obtained results, it could be concluded that the Hg content in all tested samples is below the action level of 10 mg/kg according to the Dutch standard and that only two samples from the Polog region (localities near the villages of Želino and Kondovo) are above the optimal value of 0.3 mg/kg of the Dutch standards (Ministerie Van Volkshuisvesting Ruimtelijke Ordening en Milieubeheer, 2023). The results of the analysis of mercury in drinking water samples taken from the tap water of the municipal water supply system of the mentioned cities in Macedonia show that the concentration in all analysed samples is below the maximum permissible concentrations for drinking water of 1.0 µg/L according to Regulation of drinking water (Official Gazette of RM, 2008).

Table 11. The concentration of mercury in sediment samples from the Vardar River basin

No	River	Location	Geographic coordinates		Hg content, mg/kg
			N	E	
VS01	Vardar	Vrutok	41°45'53.26"	20°50'14.53"	0.06
VS02	Vardar	Volkovija-Gostivar	41°51'44.58"	20°58'52.86"	0.08
VS03	Vardar	Zelino	41°59'2.18"	21°3'14.25"	0.79
VS04	Vardar	Jegunovce	42°5'7.80"	21°7'33.56"	0.16
VS05	Vardar	Rasce-Kondovo	42°0'49.79"	21°16'40.25"	0.51
VS06	Vardar	Aerodrom	41°59'38.56"	21°28'2.97"	0.06
VS07	Vardar	Zelenikovo	41°53'14.30"	21°35'24.08"	0.08
VS08	Vardar	Novacani	41°46'7.57"	21°44'16.13"	0.12
VS09	Vardar	Motel Makedonija	41°41'6.06"	21°49'35.43"	0.12
VS10	Vardar	Gradsko	41°35'21.09"	21°55'58.03"	0.09
VS11	Vardar	Stobi	41°33'46.52"	22°0'44.42"	0.07
VS12	Vardar	TEC Negotino	41°27'48.15"	22°9'40.66"	0.17

No	River	Location	Geographic coordinates		Hg content, mg/kg
			N	E	
VS13	Vardar	Gradec - Udovo	41°23'14.62"	22°22'23.73"	0.05
VS14	Vardar	Miravci	41°18'12.93"	22°28'50.24"	0.08
VS15	Vardar	Gevgelija	41°8'13.50"	22°31'57.59"	0.05
VSTR1	Treska	Sisevo	41°58'23.36"	21°18'27.54"	0.05
VSTR2	Treska	Crcec	41°59'43.38"	21°20'4.18"	0.03
VSLE1	Lepenec	Blace	42°6'21.30"	21°19'27.04"	0.05
VSLE2	Lepenec	Bardovci	42°1'29.82"	21°21'53.87"	0.11
VSPC1	Pcinja	D. Konjari	41°56'54.72"	21°42'11.22"	0.03
VSPC2	Pcinja	Badar	41°52'0.14"	21°41'31.79"	0.06
VSBR1	Bregalnica	Ubogo	41°40'55.73	21°58'4.86"	0.05
VSBR2	Bregalnica	Gradsko	41°37'37.09"	21°56'38.74"	0.04
VSCR1	Crna Reka	Ribarci-Rosoman	41°30'24.41"	21°57'0.93"	0.04
VSCR2	Crna Reka	Stobi	41°32'31.43"	21°58'15.72"	0.09
Dutch standards					
Optimal value					0.30
Action value					10

5.1.4 Contaminated sites

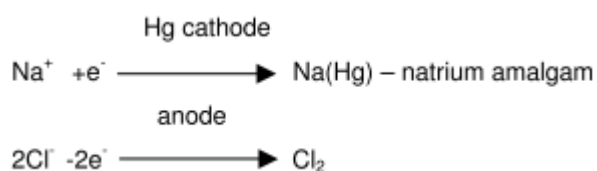
5.1.4.1 OHIS- chlor-alkali production plant

The chlor-alkali plant of the Organic Chemical Industry in Skopje (OHIS) was in operation from 1964 to 1995. It was based on mercury cell electrolysis and designed to produce sodium hydroxide hydrogen, chlorine and hydrochloric acid, shown on Figure 17. However, during the whole period of operation only sodium hydroxide and hydrochloric acid were produced.



Figure 17. Location of the electrolysis plant in relation to the city of Skopje (left) and Former electrolysis plant and mercury impacted area (right)

The mercury from the electrolysis plant is the main source of contamination. In this plant, mercury has been used as a cathode in the process of electrolysis of NaCl – sodium chloride salt. The previously decomposed NaCl, and cleaned from supplements such as Ca, Mg etc., as a pure electrolyte get in the electrolytic cell. The process is carried out in an electrolytic cell consisting of separated positive and negative electrodes (anode and cathode, respectively) immersed in a NaCl electrolyte solution. The chemical reactions that are running after the electric current enters are as follows:



After those reactions, both ions become neutral molecules. After that, the Na(Hg) goes in the device for decomposition. At the end mercury comes out pure, and is recycled and circles in the process (reused in the electrolytic cell for NaCl electrolysis).

Within the facility, drops of metallic Hg are spread over a large part of the floor and the equipment, resulting in a rough estimation of 400 Mg of metallic Hg. Large amounts of Hg might also be trapped in underground crawl spaces or inactive drain pipes.

The mercury cell process for chlorine production results in several types of waste such as: brine sludge, waste water solids (wastewater sludge if a wastewater plant is operated), carbon sludge and decomposer carbon etc. All the wastes arising from this process contain mercury shown in Figure 18. In addition, substantial amounts of mercury have been found in the

surrounding soil and in the cell building. It is possible that part of the mercury containing waste have been disposed of onto the mixed waste dump.

Major part of the mercury has been lost as a liquid metal through spillages or during maintenance.



Figure 18. Former electrolysis plant (view from NE towards SW) (left) and former electrolysis plant – inside, massive Hg spillage (right)

Broader, located area of 6,200 m² is contaminated with mercury, because of the fact that during the production approximate 400 tons of mercury where lost in the environment. It could to be assumed that main mercury is on the plant location as outside. Migration ways of mercury are only in deeper layers (layer between alluvial and Pliocene ~ 20 m) and outside the plant. Close to the plant are traces of surface contamination due to the ongoing dismantling of the plant, while east of the electrolysis plant shows mercury contamination ranges from a depth of 7 m – 15 m. The surface pollution reduces with the distance to the electrolysis building (EPITSA, 2007a). Maximal mercury content in soil exceeds the Dutch Intervention Limit 98 times (Deconta, 2009).

Local groundwater contamination by mercury in the vicinity of the former electrolysis plant (0.006 mg/l) was found, exceeding respective Dutch Intervention Values by 20 times (Deconta, 2009). Mercury contaminated soil was found under the floor of the electrolysis building as well as outside the building. Generally, Hg concentration increases with depth in most of the borings of this sector.

Of the monitored metals in the former electrolysis plant, only elevated concentration of mercury was determined. Mercury contaminated soil was found under the floor of the electrolysis building as well as outside the building. Generally, Hg concentration increases

with depth in most of the borings of this sector. Maximal mercury content in soil exceeded the Dutch Intervention Limit by 98 times.

Results of an Investigation of Contamination of Construction Materials Laboratory analysis for samples taken inside and outside the former electrolysis building, found high concentrations of mercury in the mortar, masonry as well as in concrete constructions. Concentrations of mercury in most samples exceeded 10 mg/kg (except for an annex building in the switch room). Maximum concentrations were found in concrete construction materials on the ground floor (up to 80,300 mg/kg). On average, concentrations of mercury in concrete, mortar and masonry vary in order of hundreds up to thousands of mg/kg in both floors of the former electrolysis building. High content of mercury in order of tens up to hundreds of mg/kg were found also in sewer sediment and in the concrete ramp in front of the building next to the railway siding.

In the investigation of environmental pollution in the area of the industrial complex in the city of Skopje OHIS (Organic Chemical Industry Skopje), numerous studies have been conducted. The first feasibility study was conducted in 2007 (European Agency for Reconstruction & Ministry of Environment and Physical Planning, 2007) and it was found that, in general, there is a hazard and a moderate-high potential health risk from stored hexachlorocyclohexane (HCH) isomers in enormous quantities for the workers and the population in Skopje, as well as a potential local mercury pollution of groundwater and soil.

The previous study conducted under the National Solid Waste Management Plan and Feasibility Studies (EAR & MOEPP, 2006) shows that the groundwater is extremely polluted with mercury, especially in the area of the chlor-alkali plant for the production of chlorine, where the concentration ranges from 0.11 to 1.1 µg/L, while the maximum allowable level is 0.2 µg/L. It was also found that the Hg content in the soil near the plant is extremely high (7.0 mg/kg), although the target value is 0.3 mg/kg and the intervention value is 10 mg/kg.

The studies conducted as part of the Feasibility Study Development of Remediation Plans with Financial Requirements for the Elimination of Industrial Hotspots, Feasibility Study – Volume I – OHIS Plant (EPITSA, 2007a) found that the Hg content in soil near the chlorine plant ranged from 0.1-0.7 mg/kg and in groundwater from 2.3-2.7 µg/l.

Another study in the OHIS plant area (OHIS Site Remediation Project Conceptual Design (D'APPOLONIA, 2010) found that the average Hg content in 38 soil samples from the area was 28.8 mg/kg (ranging from 0.15 mg/kg to 336 mg/kg) and that Hg concentrations in groundwater ranged from 28 to 38 µg/L.

The data from the latest study on OHIS factory (Polyeco, 2018) show that the huge area of groundwater in the factory and nearby Lisiče settlement is above the Dutch intervention concentration of 0.3 µg/L, Figure 19

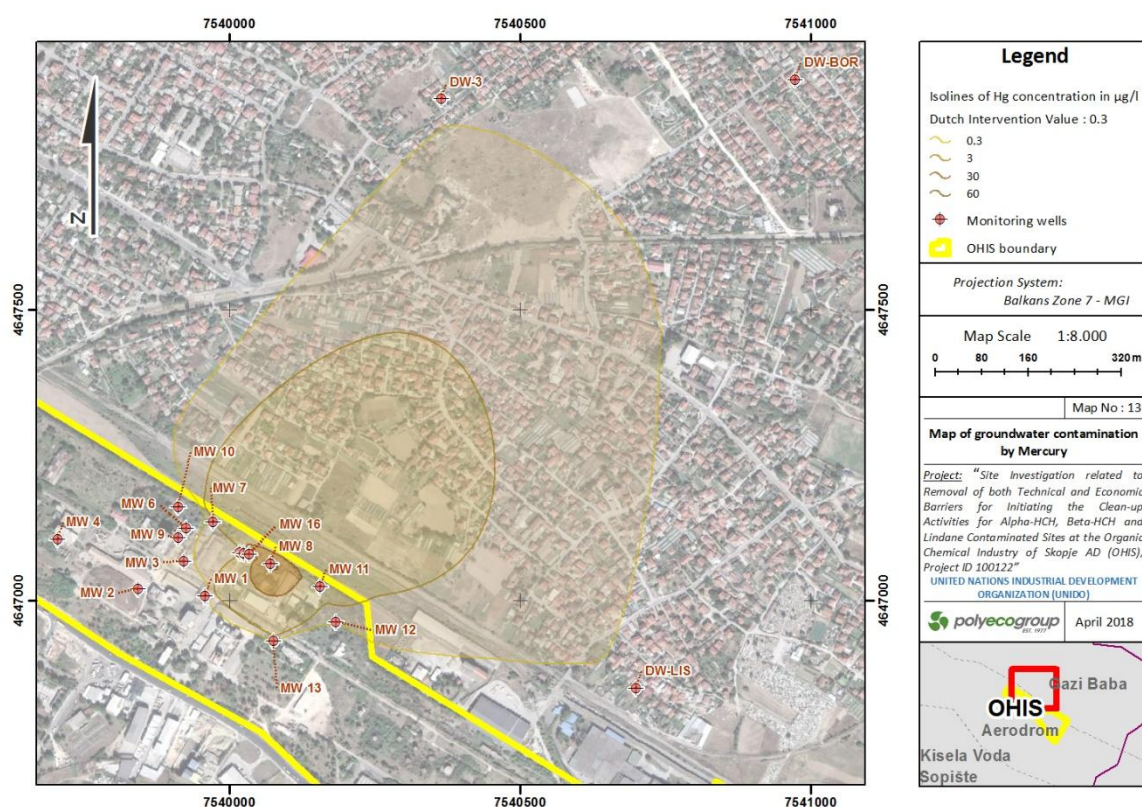


Figure 19. Distribution of the concentration of mercury in groundwaters in the area of the OHIS factory and the Lisiče settlement

Based on the results of previous soil and groundwater investigations and results of the site reconnaissance, the following contamination sources were identified in the area of the former electrolysis plant in OHIS:

1. Current draw of the interior technology caused massive spreading of contamination by mercury over the outdoor paved areas;

2. Concrete floors in the hall of the former electrolysis plant do not prevent mercury seepage – as demonstrated by high concentration of Hg in deeper soil layers.

The collection system of cooling water and especially underground settling sumps were identified as potential Hg contamination sources. Under the current land use the potential risk acceptors are associated with the following:

- Contaminated top soil horizon. It includes the contact (inhalation of dust / fine particles generated from unpaved areas) with contaminated soil during a routine walkover by on-site workers;
- Contaminated soil to a depth of approximately 2m below surface. It includes the contact with contaminated soil during the temporary excavation activities at the site carried out by external workers;
- Contaminated construction material - it includes the inhalation of dust and fine particles released from construction material by on-site workers during routine activities;
- Contaminated soil gas – it includes the excavation activities and vapors intrusion into on-site buildings and their subsequent inhalation by on-site workers;
- Contaminated soil in gardens and small fields off-site – it includes the contact with soil impacted by dust originated from the site during gardening;

Risks related to indoor or outdoor inhalation of mercury vapors could not be assessed due to the absence of data on mercury concentration in the soil gas.

5.1.4.2 Additional contaminated sites

According to the studies conducted so far, North Macedonia has a large number of landfills with industrial waste, mainly from mines, ore processing and metallurgical smelters (EAR & MOEPP, 2006; Deconta, 2009; EPITSA, 2007a; EPITSA, 2007b; EPITSA, 2007c; EPITSA, 2007d; Golomeov, Krstev, Golomeova, & Kostadinov, 2012; RIS-RECOVER, 2020; Sajin, et al., 2020; Sijakova-Ivanova, Zajkova Panova, Stefanova, & Stojanova, 2017). The available data were used to estimate the quantities of deposited material, which are listed in Table 12. As part of the preparation of this study, samples were taken from these landfills and analysed for mercury.

Table 12. Estimated amounts of mercury in the industrial waste dam sites in North Macedonia

No.	Name of company	Type of deposit	Amount, million t		
			(estimated)	Hg, g/t	Hg, kg
1	Zletovo-Probištip	Pb-Zn flotation tailings	25	0.208	5,200
2	Bučim, Radoviš	Cu flotation tailings	150	0.012	1,800
3	REK Bitola	Fly ash and slag	35	0.044	1,540
4	Smelter, Veles	Pb-Zn slag	1.8	0.117	211
5	REK Oslomej, Kičevo	Fly ash and slag	5	0.033	165
6	Sasa, M. Kamenica	Pb-Zn flotation tailings	22	0.005*	110
7	Toranica, K. Palanka	Pb-Zn flotation tailings	10	0.005*	50
8	Jugohrom, Jegunovce	Cr slag	2	0.027	54
9	Makstil, Skopje	Filter dust	0.005	5.84	29.2
10	Lojane	As-Sb flotation tailings	0.45	0.025	11.2
11	Lojane	As concentrate	0.015	0.417	6.3
Total					9,176

* The numerical value was defined as a half of the limit detection value which was <0.010 g Hg/t

Based on the data obtained, it is estimated that industrial waste contains approximately 9,000 tons of mercury (Table 12).

The largest amount of it is contained in the landfill for flotation residues from the processing of Pb-Zn ore in the town of Probištip, where about 25 million tons of flotation residues with a mercury content of 0.208 g/t were deposited, which corresponds to a total amount of about 5,200 kg of mercury. This is followed by the landfill for flotation tailings from the processing of copper ore in the Bučim mine near Radoviš, where about 150 million tons of residues with a mercury content of 0.012 g/t were deposited, which correspond to a total amount of about 1,800 kg.

Landfills with large amounts of mercury include the ash and slag landfill of the REK Bitola thermal power plant near the city of Bitola, where about 35 million tons of ash with a mercury content of 0.044 g/t and a total amount of about 1,540 kg of mercury were deposited. Corresponding quantities of mercury are also contained in the industrial waste from the country's other hotspots. Thus, 211 kg of Hg are accumulated in the slag deposit from the Pb-Zn smelter in Veles, where the Hg content is 0.117 mg/kg. The amount of 165 kg Hg is present in the fly ash landfill of the Oslomej thermoelectric power plant near Kičevo. Further quantities of mercury are contained in the flotation slags of the Pb-Zn mines in Sasa (approx. 100 kg) and Toranica (approx. 50 kg), in the ferrochromium slag deposit in Jegunovce (54

kg), in the steelworks in Skopje (approx. 29 kg) and in the As-Sb mine and flotation plant in Lojane (approx. 17 kg).

6 Evaluation of the sources of the mercury releases

6.1 Extraction and use of fuels/energy sources

Different fuel/energy sources such as fossil fuels, biomass and geothermal energy, in North Macedonia are used for electricity production, transportation, industry, commercial amenities, households etc. Table 13 represents the relevant sub-categories within the main category.

Table 13: Relevant sub-categories related the main category

Chapter	Sub-category
6.1.1	Coal combustion in large power plants
6.1.2	Other coal combustion
6.1.3	Extraction, refining and use of mineral oil
6.1.4	Extraction, refining and use of natural gas
6.1.5	Extraction and use of other fossil fuels
6.1.6	Biomass fired power and heat production
6.1.7	Geothermal power production

6.1.1 Coal combustion in large power plants

In North Macedonia, coal is used for the production of heat and electricity in different sectors with varying combustion technology. Mercury, as well as arsenic and other metals are found in trace amounts in coal and may thermally release during the combustion (UNEP, 2023).

There are two thermoelectric power plants in the Republic of North Macedonia using coal as a fuel: REK Bitola and REK Oslomej.

REK Bitola

The thermoelectric power plant REK Bitola is located in the southern part of Macedonia, in Pelagonia plain. It has been built on the basis of the finds of coal-lignite, at around 15 km eastwards of the City of Bitola.

REK Bitola has 3 boilers, i.e. blocks each with capacity of 225 MW or total installed capacity of 675 MW and used to provide an average annual generation of 4.125 million MWh electricity during period 2011-2014, and during the period from 2015-2018 the average generation was 2.946 million MWh. REK Bitola has a share of over 72% in the total energy production of the Macedonian energy system. However, during 2021, the generation of electricity has substantially declined in REK Bitola to 1.864 million MWh, due to several defects, reduction of coal mining, as well as the quality of coal (Energy and water services regulatory commission of the Republic of North Macedonia, 2022)

REK Oslomej

The thermoelectric power plant REK Oslomej is located in the west central part of Macedonia, approximately 9 km north of the town Kicevo.

REK Oslomej has one boiler, i.e. block with installed capacity of 125 MW and currently REK Oslomej accounts for about 10% in the total energy production of the Macedonian energy system. The data has shown increase of generation of electricity in REK Oslomej in 2021, doubling generation to 213,9 GWh compared to previous years (Energy and water services regulatory commission of the Republic of North Macedonia, 2022).

Mercury releases estimation

Activity rate

REK Bitola uses lignite coal as a fuel from two pits located in Suvodol and Brod Gneotino. The coal consumption for 2021 of this plant was 4,248,420 tons³. The lignite from Suvodol, with a calorific value of 6,612 KJ/kg (Reserve, 2023) contributed with 3,404,469 tons of the total consumption in 2021, while the lignite from Brod Gneotino, with calorific value of 8,437 KJ/kg (Reserve, 2023) contributed 843,951 tons. The coal was not pre-treated, i.e. pre-washed prior to combustion.

³ Data provided by REK Bitola upon previously submitted questionnaire and the same was cross-checked with the official statistical data.

REK Oslomej uses domestic lignite coal as a fuel from a pit located in Oslomej basin, but also imported coal from Kosovo. The coal consumption for 2021 of this plant was 353,428 tons⁴ (EB, 2014), from which 287,003 tons were imported. The lignite coal has a calorific value, 7,600 kJ/kg and contains a moisture content of 48% and ash from 17% (Reserve, 2023). The coal was not pre-treated, i.e. pre-washed prior to combustion.

Input factor

Initially, from the delivered questionnaires, no information about the mercury content in the lignite originated from the two pits exploited by REK Bitola and from the pit exploited by REK Oslomej, was provided. Therefore, samples from the coal and the fly ash from both REK Oslomej and REK Bitola were requested and delivered. Thus, providing data on the mercury content in the lignite. In order to calculate/estimate the mercury input/releases, two scenarios were developed and compared: one main (presented below) and one alternative (presented in the [Annex 3](#)) and same were compared.

The first scenario, includes results from the laboratory analysis, hence this scenario is related to specific measurements and has the highest accuracy for the mercury release calculations. Namely, that the input and output distribution factors were defined based on the actual analyses of different matrices: the coal and the fly ash. The analyses demonstrated that the mercury content in the coal originated from Suvodol is 0.062 g/ton, from Brod Gneotino is 0.04 g/ton.

In the previous inventory, the input factor for mercury content was taken as an average of the mercury content of the lignite from the two pits, however, in this inventory, each pit was defined as a separate entity. Thus, using the quantity of lignite from Suvodol, as well as the mercury content in the lignite from Suvodol, as shown in the laboratory analysis, to receive an annual mercury input of 211.08 kg. The annual mercury input from Gneotino was calculated to be 33.76 kg.

With reference to Oslomej, the laboratory analyses showed that the mercury content in the coal originated from the Oslomej basin is 0.269 g/ton, while the imported coal had a mercury presence of 0.078g/t. The calculations were made separately for the quantities of domestic

⁴ Data provided by REK Oslomej upon previously submitted questionnaire and the same was cross-checked with the official statistical data.

lignite and the results for mercury content of the domestic lignite, as well as for the imported quantity of lignite used in REK Oslomej with the respective mercury content value. The annual mercury input from the domestic lignite was 17.87 kg, whereas for the imported it was 22.39 kg.

The total mercury input for 2021 for the coal combustion in power plants was calculated by the multiplication of the activity rates (annual quantities of combusted coal) and the input factors (mercury content in the coal) for the both power plants. Summarized, the annual mercury input from REK Bitola was 244.84 kg, whereas from REK Oslomej the annual input, both from imported coal and domestic coal was 40.25 kg.

The total annual mercury input from this sub-category is 285.10 kg.

Output distribution

REK Bitola is equipped with electrostatic precipitators for the collection of the exhaust gaseous and the particles generated during the coal combustion in the boilers. There are two-point sources (stacks), i.e. the outlets of the air emissions from the coal combustion. Two boilers are connected to one stack and the third boiler to the second one. The dimensions of the two stacks are: height 250 meters, inner diameter 8.4 meters and outer diameter 9.4 meters. The electrostatic precipitator collects 99.84% of the generated fly ash (IPPC, Bitola, 2007). The fly ash is deposited in a depot located within the premises of the power plant. One part of the fly ash is sold as a raw material for the cement production to the cement plant USJE located in the city of Skopje.

REK Oslomej is equipped with an electrostatic precipitator for the collection of the exhaust gaseous and the particles generated during the coal combustion in the boiler. The dimensions of the stack are: height 185 meters and diameter 6 meters. The effectiveness of the electrostatic precipitator in the ash collection is 98.5% (IPPC, Oslomej, 2007). The fly ash is deposited in a depot located in a former coal pit, in the form of a dense mud.

For the definition of the mercury output distribution factors, analyses of the mercury presence in the landfilled fly ash (1,328,475 tons for 2021 from REK Bitola and 75,000 tons from REK Oslomej) was performed resulting in mercury concentration of 0.044 g Hg/ton of fly ash generated by REK Bitola and 0.033 g Hg/ton of fly ash generated by REK Oslomej.

REK Bitola

$$MO_{SS(RB)} = Q_{FA(RB)} \times FA_{RB} = 1,328,475 \times 0.044 = 58,452.9 \frac{g \text{ Hg}}{y} = 58.5 \text{ kg Hg/y}$$

$$MO_{A(RB)} = MI_{RB} - MO_{SS(RB)} = 244.84 - 58.5 = 186.34 \text{ kg Hg/y}$$

REK Oslomej

$$MO_{SS(RO)} = Q_{FA(RO)} \times FA_{RO} = 75,000 \times 0.033 = 2,475 \frac{g \text{ Hg}}{y} = 2.5 \text{ kg Hg/y}$$

$$MO_{A(RO)} = MI_{RO} - MO_{SS(RO)} = 40.25 - 2.5 = 37.75 \text{ kg Hg/y}$$

where:

MO_{SS} – mercury output in sector specific (kg Hg/y)

Q_{C(RB)} – quantities of generated fly ash for REK Bitola (ton)

FA_{RB} – mercury concentration in fly ash from REK Bitola (g Hg/ton)

Q_{C(RO)} – quantities of generated fly ash for REK Oslomej (ton)

FA_{RO} – mercury concentration in fly ash from REK Oslomej (g Hg/ton)

MO_A – mercury output in air (kg Hg/y)

MI – mercury input (kg Hg/y)

The output distributions given in the Toolkit, do not correspond to the calculations above, which are based on the mercury content in the fly ash. Therefore, modifications have been made:

- for REK Bitola, the mercury output to air factor from 0.98 was modified to 0.761, whereas the mercury output distribution to sector specific was modified from 0.02 to 0.239,

- for REK Oslomej, the mercury output to air factor from 0.98 was modified to 0.938, whereas the mercury output distribution to sector specific was modified from 0.02 to 0.062.

The mercury releases are distributed as 224,09 kg to the air and 61,01 kg to the ash.

The mercury input and output calculations for the Scenario 1 are presented in Table 14.

Table 14: Mercury input and output calculations for the coal combustion in power plants (Scenario 1)

Source	Activity rate (t/y)	Input factor (g Hg/t)	Mercury input (kg/y)	Pollution abatement system	Mercury output (kg/y)		Stack height (m)
					Air	Sector Specific	
REK Bitola	4,248,420		244.84				
Suvodol	3,404,469	0.062	211.08	ESP	186.34	58.52	250
Gneotino	843,951	0.04	33.76				
REK Oslomej	353,428		40.26				
domestic lignite	66,425	0.269	17.87	ESP	37.76	2.50	185
imported lignite	287,003	0.078	22.39				
TOTAL	4,601,848.00		285.10		224.10	61.02	

In comparison with the conservative scenario, presented in [Annex 3](#), using default input factors, the mercury input, therefore output is more than 2,5 times larger than the above elaborated scenario, using input factors derived from sample analysis.

Evaluation of the estimation certainty

The evaluation of the estimation certainty was made by assessing the level of validity and the strength of the different parameters used in the mercury release calculations.

The certainty assessment of the calculations related to the Scenario 1 is presented in Table 15.

Table 15: Certainty assessment for the coal combustion in power plants (Scenario 1)

Parameter	Level	Description
Activity rate	HIGH	The quantities of the combusted coal were provided by the thermo power plants, and the results were cross-checked with the official state statistics data.
Input factor	HIGH	The content of the mercury in the coal was determined based on the actual measurements of the coal from the pits used by the thermo power plants.
Output distribution factors	HIGH	The amount of the mercury released in the “Sector specific treatment/disposal” output fraction was derived based on actual measurements of the Hg presence in the fly ash, while for the emissions in the air the mass balance of the mercury was taken into consideration, i.e. the difference between the mercury quantities that enters into the process as mercury content in the coal (input factor) and the mercury content in the fly ash.

6.1.2 Other coal combustion

Other uses of coal in R. North Macedonia, besides generation of electricity, include the generation of heat in the heat production plants, as a reduction agent in steel production plants, and for heating purposes in the households, agriculture, etc.

This category comprises from two groups: a) Coal fired industrial boilers and b) Other coal uses (coking as well as combustion). The activity rates are summarized in one section, whereas the input and output are analysed in separate sections.

Mercury releases estimation

Activity rate

The quantities of coal consumption in sectors other than the electricity production, are obtained from the energy balances for 2021 published by the State Statistical Office. In accordance with the Energy Balances report (State Statistical Office, 2023), the total coal consumption by different types of coal and different sectors of use is presented in Table 16.

Table 16: Coal consumption in non-electricity sector for 2021

Sector	Coal consumption (t)
--------	----------------------

	Hard coal	Coke	Sub-bituminous coal	Lignite
Heat and power production plants				
Steel production industry	1,012	590	107,042	41,141
Industry for building material, glass and ceramics	37,021			601
Textile, leather and clothing industry				3,416
Engineering and other metal industry				531
Households				843
Agriculture	1,020			1,006
Other				1,895
Total:	39,053	590	107,042	49,433

The total amount of coal used in the non-electricity sector for 2021 is 196,118 tons, out of which 76.4% (149,785 tons) are consumed by the metal production industry. All of the quantities of the different types of coal consumed in this sector were imported.

a) Coal fired industrial boilers

Input factor

The data for estimation of the activity rate was taken from the Energy Balance of the Republic of North Macedonia (State Statistical Office, 2023). For the mercury content, in the initial inventory, FENI, (a ferronickel production plant), which coal was used as a reduction agent in the ferronickel production process, provided laboratory results where mercury presence in the lignite is 0,08 mg/kg and this figure was used as the input factor for the quantities of lignite used in the steel industry. For the rest, since no information was provided on the mercury content of any of the coal types, nor the country of origin was reported, the input factor for hard coal and sub-bituminous coal was taken to be within the range 0.05-0.5 (0.15) g Hg/t, and for the lignite consumed in the other sectors 0.05-0.2 (0.1) g Hg/t as given in the Toolkit.

The total mercury input for this sub-category is within the range 11.0 - 78.00 (26.044 as an intermediate value) kg.

In order to avoid double accounting, the quantities of the coal used by the steel production industry were not taken into consideration when calculating the mercury emissions from the primary metal production facilities, having in mind that these estimations are already included in this chapter.

Output distribution

All of the metal production plants (see the details in the chapter “Primary metal production”) are equipped with electrostatic precipitators as an air pollution reduction measure. Therefore, the output distribution factors for the coals consumed in the steel production plants utilized the suggested value in the Toolkit, i.e. for the hard coal 75% to air and 25% to ash and for the sub-bituminous coal and the lignite 95% to air and 5% to ash. For the combusted lignite and hard coal in the other sectors, it is considered that the entire mercury input is distributed to air.

The mercury output was distributed as follows: to air the distribution is within the range 10.61-75.08 (25.08 as an intermediate value) kg, whereas to sector specific the distribution is within the range of 0.43-2.91 (0.99 as an intermediate value) kg.

b) Other coal uses

Input factor

In R. North Macedonia, quantity of 590 tons of coke were reported as consumed by the steel production industry. Since this is not a coke production, it is calculated under section other coal combustion. As suggested in the Toolkit the input factor was taken to be 0.01.

The total mercury input for this sub-category is 0.006 kg.

Output distribution

As above, considering that no data was available, the worst case-scenario was considered that entire mercury is distributed to air.

Entire mercury input, of 0.006 kg is distributed to air.

The mercury input and output calculations for the sub-category “Other coal combustion are presented in Table 17.

Table 17: Mercury input and output calculations for the other coal combustion

Source		Activity rate	Input factor	Mercury input	Pollution abatement system	Mercury output (kg/y)	
		(t/y)	(g Hg/t)	(kg/y)		Air	Sector specific
Hard coal	for steel industry	1,012	0.05-0.5 (0.15)	0.05-0.51 (0.15)	ESP	0.04-0.38 (0.11)	0.01-0.13 (0.04)
	other uses	38,041	0.05-0.5 (0.15)	1.90-19.02 (5.71)	/	1.90-19.02 (5.71)	0
Sub-bituminous coal		107,042	0.05-0.5 (0.15)	5.35-53.52 (16.06)	ESP	5.08-50.84 (15.25)	0.27-2.68(0.80)
Lignite	for steel industry	41,141	0.08	3.29	ESP	3.13	0.16
	other uses	8,292	0.05-0.2 (0.1)	0.41-1.66 (0.83)	/	0.41-1.66 (0.83)	0
Coke		590	0.006		/		
Coke				0.006		0.06	0
TOTAL		196,118		11.006 - 78.006 (26.05)		10.62-75.09(25.09)	0.44-2.97 (1)

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Other coal combustion” is presented in Table 18.

Table 18: Certainty assessment for the “Other coal combustion” sub-category

Parameter	Level	Description
Activity rate	HIGH	The quantities of the combusted coal were provided by the official state statistics data.

Input factor	LOW	The content of the mercury in the coal was taken from the measurements provided in the Toolkit (which are only indicative ones) of the mercury content in the different types of coal originated from different countries.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

6.1.3 Extraction, refining and use of mineral oil

Like other natural materials, mineral oil contains small amounts of natural mercury impurities, which are mobilised to the biosphere by extraction and use. Thus, mercury concentrations could be found in a variety of refined oil products (including gasoline/petrol, diesel, jet fuel, kerosene, liquefied petroleum gas (such as propane), distillates (diesel, petrol and jet fuels), and "residuals" (UNEP, 2023).

There is no extraction and refining of the mineral oil in North Macedonia. There was one refinery "OKTA" that stopped with the production process at the beginning of 2013. The estimates for the mercury releases were based only on the usage of the crude oil, distillates and residual oil utilized in different sectors (transportation, residential heating, as a fuel in the industrial facilities, and other combustion facilities).

Mercury releases estimation

Activity rate

According to the *EB, 2022* the total consumption of the crude oil, distillates and residual oil in different sectors is presented in Table 19.

Table 19: Mineral oil consumption in 2021

Sector	Mineral oil consumption (t)						TOTAL	
	LPG	Petrol	Diesel	Kerosene	Heating and other gasoil	Residual fuel oil		Petroleum coke
Industry	12,710		27,276		13,417	43,195	123,276	219,874
Transport	43,945	84,417	579,847	16,019				724,228

Households, commerce, etc.	10,255	415.00	25,742	40	18,356	4,589	1,832	61,229
TOTAL	66,910	84,832	632,865	16,059	31,773	47,784	125,108	1,005,331

In the 2021, the total consumption of mineral oil is 1,005,331 tons, out of which 72% belongs to transport sector, 22% to industrial and 6% to households and the commercial sector.

Input factor

For the use of heavy oil and petroleum coke, more specifically for the oil combustion facilities, the activity rate was defined as a sum of the quantities for petroleum coke and residual fuel oil. Since no data on the mercury content was available, as advised by the Toolkit, the input factor is within the range 10-100 (20 as default factor).

With regards to the use of other oils, in the transportation and other uses than residential heating and other oil combustion facilities, the quantities of used LPG, diesel, petrol and kerosene were taken in calculation of the activity rate. As for residential heating, the activity rate was 31,773t/y. For this two groups, the Toolkit suggests input factor between the range 1-10 (2 as default).

The total mercury input for this sub-category is 2.54-25.63 (5.11 as an intermediate value) kg.

Output distribution

As no other information was available, since the companies Euronickel and Titan have reported quantities of used petroleum coke, as well as taking into consideration they have some emissions control, their quantities have an output distribution of 90% to air and 10% to specific treatment/disposal. For the remaining, worst-case scenario was assumed, namely that there is no control of the emissions and that the entire mercury input is distributed to air.

The mercury releases are distributed as 2.44-24.61 (4.91 as an intermediate value) kg to the air and 0.1-1.01 (0.20 as an intermediate value) kg to sector specific treatment/disposal.

The mercury input and output calculations for the sub-category “Extraction, refining and use of mineral oil” are presented in Table 20.

Table 20. Mercury input and output calculations for the “Extraction, refining and use of mineral oil”

Source	Activity rate (t/y)	Input factor (mg Hg/t)	Mercury input (kg/y)	Pollution abatement system	Mercury output (kg/y)	
					Air	Sector specific
Uses (petroleum coke by Euronickel+Titan)	101,227	10-100 (20)	1.01-10.12 (2.02)	/	0.91-9.11 (1.82)	0.1-1.01 (0.2)
Oil combustion facilities (petroleum coke and residual fuel oil)	71,664.8	10-100 (20)	0.7- 6.98 (1.4)	/	0.7-6.98(1.4)	
Transportation and other uses other than combustion (LPG, motor spirit, kerosine,jet fuels, road diesel)	800,666	1-10 (2)	0.8-8.01 (1.60)	/	0.8-8.01 (1.60)	
Residential heating with no control	31,773	1-10 (2)	0.03-0.32 (0.06)	/	0.03-0.32 (0.06)	
Total	1,005,331		2.54-25.63 (5.11)		2.44-24.61 (4.91)	0.1-1.01 (0.20)

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Extraction, refining and use of mineral oil” is presented in **Error! Reference source not found.** Table 21.

Table 21: Certainty assessment for the “Extraction, refining and use of mineral oil” sub-category

Parameter	Level	Description
Activity rate	HIGH	The quantities of the consumed mineral oil derivatives were

		provided from the official state statistics data.
Input factor	LOW	The content of the mercury in the mineral oil derivatives was taken from the measurements provided in the Toolkit (which are only indicative ones), except for the petroleum coke which are based on the laboratory analysis.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones, and the mercury releases are expected to be emitted in the air.

6.1.4 Extraction, refining and use of natural gas

Natural gas, as a fossil fuel, mainly used for generation of heat and electricity, contains small amounts of natural mercury impurities, which are mobilized to the biosphere during extraction, refining and combustion (UNEP, 2023).

No extraction and refining of the raw natural gas exist in the country, the mercury emissions from this sub-category come from the usage/combustion of pipeline gas used mainly for heat generation.

Mercury releases estimation

Activity rate

The State Statistical Office, has reported, through the Energy Balance for 2021, the total consumption of natural gas in the Republic of North Macedonia was 432,262,721 Nm³. Largest share was by heat production plants, and a smaller portion within industry, households, commerce, etc.

Input factor

There was no information on the mercury content in the imported pipeline gas. Considering that all pipeline gas originated from the Russian Federation, the default input factor indicated in the Toolkit, with a range between 0.03-0.1 µg Hg/Nm³ (0.065 µg Hg/Nm³ mean value), was used for the mercury releases calculation.

The total mercury input for this sub-category is within the range 0.01-0.04 (0.03 as an intermediate value) kg.

Output distribution

The entire mercury input is distributed to air.

The entire mercury input within the range 0.01-0.04 (0.03 as an intermediate value) kg is distributed in air.

The mercury input and output calculations for the sub-category “Extraction, refining and use of natural gas” are presented in Table 22.

Table 22: Mercury input and output calculations for the “Extraction, refining and use of natural gas”

Source	Activity rate	Input factor	Mercury input	Pollution abatement system	Mercury output (kg/y)	
	(Nm ³ /y)	(mg Hg/Nm ³)	(kg/y)		Air	Sector specific
Pipeline gas	432,262,721	0.03-0.1 (0.065)	0.01-0.04 (0.03)	/	0.01-0.04 (0.03)	

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Extraction, refining and use of natural gas” is presented in Table 23.

Table 23: Certainty assessment for "Extraction, refining and use of natural gas" sub-category

Parameter	Level	Description
Activity rate	HIGH	The quantities of the consumed pipeline gas were provided from the official state statistics data.
Input factor	MEDIUM	The content of the mercury in the pipeline gas was taken from the default Toolkit values for the specific country of origin.

Parameter	Level	Description
Output distribution factors	MEDIUM	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones, but having in mind the nature of the usage of the mineral oil distillates the majority of the mercury releases are expected to be emitted in the air.

6.1.5 Extraction and use of other fossil fuels

Like other fossil and non-fossil fuels, peat and oil shale may contain traces of mercury, which can be mobilized by extraction and combustion (UNEP, 2023)

There is usage of peat in North Macedonia and majority of the quantities were consumed by the heat production plants, and a small portion in industry, households, commerce, etc.

Mercury releases estimation

Activity rate

The annual consumption of peat in North Macedonia was 10,625.81 tons⁵ for 2021 and the entire quantity was obtained by import.

Input factor

There was no information on the mercury content in the imported peat. The Toolkit has a default input factor that uses a mercury concentration range between 40-193 mg Hg/ton of dry weight (117 mg Hg/t dry weight as a mean value).

The total mercury input for this sub-category is 0.43-2.05 (1.24 as an intermediate value) kg.

Output distribution

⁵ Data provided by the Customs Administration, under the Ministry of Finance, upon previously submitted questionnaire

Since there was no clear indication about the sectors of usage of the peat (whether as a fuel in industries, households, or agriculture, etc.), the entire mercury input within the range 0.43-2.05 (1.24) is assumed to be released to air.

The entire mercury input within the range 0.43-2.05 (1.24 as an intermediate value) kg is distributed in air.

The mercury input and output calculations for the sub-category “Extraction and use of other fossil fuels” are presented in Table 24.

Table 24: Mercury input and output calculations for the “Extraction and use of other fossil fuels”

Source	Activity rate (t/y)	Input factor (mg Hg/t)	Mercury input (kg/y)	Pollution abatement system	Mercury output (kg/y) Air	Sector specific
Peat	10,626	40-193 (117)	0.43-2.05 (1.24)	/	0.43-2.05 (1.24)	

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Extraction and use of fossil fuels” is presented in Table 25.

Table 25: Certainty assessment for the “Other fossil fuel “use sub-category

Parameter	Level	Description
Activity rate	HIGH	The quantities of the consumed peat were provided from the official state statistics data.
Input factor	LOW	The content of the mercury in the peat was taken from the default Toolkit values which were derived based on limited studies.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones, considering only emissions to air as there was no information on the sectors of the usage of the peat.

6.1.6 Biomass fired power and heat production

Biomass is the oldest renewable energy source, including leftovers from municipal and industrial waste, residues from agricultural production and forestry. With regards to mercury in biomass, it can be naturally present, but also from anthropogenic emissions. In R. North Macedonia, this includes biomass but also pellets, briquettes and wood residues, mainly used for residential heating and cooking.

Mercury releases estimation

Activity rate

In total biomass and pellets, briquettes and wood residues amount to 1,145,085 m³ for 2021. The following assumptions were taken into consideration for the calculation of the weight of the combusted wood and pellets:

- the moisture content of 30% for the wood⁶ and 10% for the pellets⁷
- density of the wood in average amount of 775 kg/m³ (density of beech 700-900 kg/m³ and of oak 600-900 kg/m³)⁸ and of 650 kg/m³ for the pellets⁶

To calculate the weight of the combusted biomass, following equations were used:

$$BC_{DW} = WC_V \times WC_D / WC_{MC} + PC_w \times PC_D / PC_{MC}$$
$$BC_{DW} = \frac{1,029,772 \times 0.755}{1.3} + \frac{115,313 \times 0.650}{1.1} = 666,199.392 \text{ tons}$$

where:

BC_{DW} - biomass combustion- dry weight (t)

WC_V - wood combustion-volume (m³)

WC_D - wood combustion- density (t/m³)

WC_{MC} - wood combustion-moisture content (%)

⁶ Data provided by limited measurements performed by the State Environmental Inspection

⁷ http://www.seai.ie/Renewables/Bioenergy/Sources/Wood_Energy_and_Supply_Chain/Wood_Pellets/

⁸ http://www.engineeringtoolbox.com/wood-density-d_40.html

PC_W - pellet combustion- weight (t)

PC_D - pellet combustion- density (t/m³)

PC_{MC} - pellet combustion-moisture content (%)

The weight of the combusted biomass is calculated to 666,199.392 tons.

Input factor

Since there was no information on the mercury content in combusted wood and pellets, the default input factor recommended in the Toolkit in a range between 0.007-0.07 g Hg/t of dry weight (0.03 g Hg/t dry weight as a mean value) was used.

The total mercury input for this sub-category is 4.66–46.63 (19.99 as an intermediate value) kg.

Output distribution

The entire mercury input is considered to be released to air.

The entire mercury input for this sub-category, that is within the range 4.66– 46.63 (19.99 as an intermediate value) kg, is distributed to air.

The mercury input and output calculations for the sub-category “Biomass combustion” are presented in Table 26.

Table 26: Mercury input and output calculations for the “Biomass combustion”

Source	Activity rate	Input factor	Mercury input	Pollution abatement	Mercury output (kg/y)	
	(t/y)	(mg Hg/t)	(kg/y)	system	Air	Sector specific
Biomass + briquettes, pellets and wood residues	666,199.392	0.007-0.07 (0.03)	4.66– 46.63 (19.99)	/	4.66– 46.63 (19.99)	

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Biomass combustion” is presented in **Error! Reference source not found.** Table 27.

Table 27: Certainty assessment for the "Biomass combustion" sub-category

Parameter	Level	Description
Activity rate	MEDIUM	The quantities of the combusted biomass were provided from the official state statistics data. Approximate values for the density and the moisture content.
Input factor	LOW	The content of the mercury in the biomass was taken from the default Toolkit values which are only indicative ones.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones, considering only emissions to air.

6.1.7 Geothermal power production

The mercury releases from geothermal power plants are caused by human mobilization of mercury in naturally occurring in areas with geothermal activity, sometimes in areas with volcanic activity (UNEP, 2023).

North Macedonia is characterized with low-temperature geothermal energy utilization, while the medium and high-temperature potentials are still not explored. There are 18 known geothermal fields in the country represented by more than 50 thermal springs, boreholes and wells with hot water, with temperatures between 20-79°C used for the heating of the greenhouses complexes and in spas (Popovska-Vasilevska & Stavreva, 2022).

In the country there are no geothermal power generation plants.

Mercury releases estimation

Activity rate

According the State Statistical Data (State Statistical Office, 2023), the total geothermal energy consumption in the country for 2021 is 4,388 tons oil equivalent, resulting in the production of 51,032.44 MWh/year.

Input factor

The Toolkit does not provide default input factors for the direct usage of geothermal energy, but only for the geothermal power plants. Moreover, there are some emissions factors for off-gas ejectors and for cooling towers based on limited emissions data. For the mercury

emissions calculations, the emission factor for cooling towers in a range between 0.026-0.072 g Hg/ MWh (0.05 g Hg/ MWh mean value) was used as the input factor.

The total mercury input for this sub-category is estimated within the interval 1.33-3.67 (2.55 as an intermediate value) kg for 2021.

Output distribution

The entire mercury input is considered to be released to air.

The total mercury input for this sub-category is estimated within the interval 1.33-3.67 (2.55 as an intermediate value) kg is distributed to air.

The mercury input and output calculations for the sub-category “Geothermal power production” are presented in Table 28.

Table 28: Mercury input and output calculations for the “Geothermal energy production” sub-category.

Source	Activity rate	Input factor	Mercury input	Pollution abatement	Mercury output (kg/y)	
	(MWh/y)	(mg Hg/MWh)	(kg/y)	system	Air	Sector specific
Geothermal	51,032	0.026-0.072 (0.05)	1.33-3.67 (2.55)	/	1.33-3.67 (2.55)	

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Extraction and use of fossil fuels” is presented in Table 29.

Table 29: Certainty assessment for the geothermal power production sub-category

Parameter	Level	Description
Activity rate	MEDIUM	The quantities of the combusted biomass were provided from the official state statistics data. Approximate values for the density and the moisture content.

Input factor	LOW	The content of the mercury in the biomass was taken from the default Toolkit values which are only indicative ones.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones, considering only emissions to air.

Summary of the category

Within this category, Coal combustion in large power plants, has by a great amount, the largest mercury input, therefore output to air and to sector specific treatment/disposal, shown in Table 30.

Table 30. Summary of the input and output calculations for the main source category “Extraction and use of fuels/energy sources” for 2021

Sub-category	Mercury input		Mercury output (kg)				
	(kg)	Air	Water	Land	Product	General waste	Sector specific treatment/disposal
Coal combustion in large power plants	285.10	224.10	0	0	0	0	61.02
Other coal combustion	11.006 - 78.006 (26.05)	10.62-75.09(25.09)	0	0	0	0	0.44-2.97 (1)
Extraction, refining and use of mineral oil	2.54-25.63 (5.11)	2.44-24.61 (4.91)	0	0	0	0	0.1-1.01 (0.20)
Extraction, refining and use of natural gas	0.01-0.04 (0.03)	0.01-0.04 (0.03)	0	0	0	0	0
Extraction and use of other fossil fuels	0.43-2.05 (1.24)	0.43-2.05 (1.24)	0	0	0	0	0

Biomass fired power and heat production	4.66– 46.63 (19.99)	4.66– 46.63 (19.99)	0	0	0	0	0
Geothermal power production	1.33-3.67 kg (2.55)	1.33-3.67 kg (2.55)	0	0	0	0	0
TOTAL	305.08-441.126 (340.07)	242.44-382,53 (278.34)					61.48-65,23 (62.25)

6.2 Primary (virgin) metal production

This category in the Republic of North Macedonia is represented by the production of zinc, copper and lead concentrates from the mining and processing of the metal reach ores, as well as the production of ferrous metals.

Considering that the same facilities that produce zinc concentrates also produce lead concentrates utilizing the same ore through the same production processes, the sub-categories “Zinc extraction and initial processing” and “Lead extraction and initial processing” are merged into one sub-category.

The relevant sub-categories within this main source category are presented in Table 31.

Table 31: Relevant sub-categories related to the main category

Chapter	Sub-category
6.2.1	Zinc/lead extraction and initial processing
6.2.2	Copper extraction and initial processing
6.2.3	Primary ferrous metal production

6.2.1 Zinc/lead extraction and initial processing

Zinc, copper and lead production are significant sources of mercury emissions, with zinc taking almost half of the emissions in this group (Hylander & Herbert, 2008). In the process of extracting the zinc/lead from the ore, processes are used which release mercury from the rock material. This mercury may evaporate and follow the gaseous streams in the extraction processes (in most cases) or follow wet (liquid) process streams, depending on the extraction technology used (UNEP, 2023).

The waste rock and tailings may, just like the generated concentrates, contain trace amounts of mercury. This material is much more susceptible to weathering than the original deposits, due to the reduced particle sizes and higher accessibility to air and precipitation.

In North Macedonia, three mining capacities exist that extract zinc/lead ores producing zinc/lead concentrates. These concentrates are all exported, so there is no factual production of zinc/lead.

Sasa

The Sasa Mine is located near the town of Makedonska Kamenica, in the North-East part of Macedonia's Osogovo Mountain Massif (2,252 m), near the border with Bulgaria, approximately 150 km east of the capital of Skopje. It is one of the largest zinc/lead/silver mines in Europe. After grinding and milling, the zinc/lead fractions from the ore are separated by floatation. There is no extraction of the zinc/lead from the concentrates, but all quantities of produced concentrates are exported.

Toranica

The Toranica mine is located in the North-East part of North Macedonia, 24 km from the town Kriva Palanka, and 150 km to the east of the capital of Skopje, near the border with Bulgaria. The technological process includes: grinding and milling of the ore, preparation of the zinc/lead concentrates by floatation, thickening and filtering of the floatation concentrate, dewatering and disposal of the floatation waste, i.e. the reject material. There is no extraction of the zinc/lead from the concentrates, but all quantities of produced concentrates are exported.

Zletovo

The Zletovo mine is located between the towns Kratovo and Zletovo in the western part of the Macedonia's Osogovo Mountain Massif around 120 km east of the capital of Skopje. The process of preparation and concentration of the ore includes: grinding, milling, floatation, thickening and filtering of the floatation concentrate. There is no extraction of the zinc/lead from the concentrates, but all quantities of produced concentrates are exported.

Mercury releases estimation

Activity rate

The quantities of the zinc/lead ore mined and concentrated in 2021, as well as the generated waste deposited in the tailings ponds is presented in Table 32.

Table 32. Zinc/lead ore mining and concentrating in 2021

Sector	Zinc/lead ore processed (t/y)	Concentrate produced (t/y)		Reject material (t/y)
		Zinc concentrate	Lead concentrate	
SASA	818,609	44,383	37,893	736,333*

Toranica	285,499	8,641	9,877	284,926
Zletovo	152,620	2,696	9,341	139,163
Total:	1,256,728	55,720	57,111	1,160,422

*SASA have reported 748,432 tons of reject material, however that is the quantity of wet reject material. The value of 736,333 is calculated as a difference between the processed ore and the concentrate.

The total amount of zinc/lead ore processed in 2021 is 1,256,728 tons, producing 55,720 tons of zinc concentrates and 57,111 tons of lead concentrates, and generating 1,160,422 tons of reject material (waste rocks and tailings). In order to calculate/estimate the mercury releases, the sampling and analyses of the ore, concentrates and reject material from the three mines was performed, and the calculation on the mercury input from all three materials is included in [Annex 4a](#).

As suggested in the Toolkit, and taking into consideration that all of the concentrate produced is exported (therefore not relevant to this inventory), for the activity rate the quantity of floatation tailing is taken into account.

Input factor

For the input factor, the laboratory analysis of the floatation tailings samples, has provided values that were considered as input factors in the Toolkit.

The total mercury input for this sub-category is 32.65 kg for 2021.

Moreover, semi-conservative approach was considered as well, and compared with the mercury specific calculation approach included in [Annex 4b](#).

Output distribution

The distribution of the mercury releases from the reject material is considered to be 5% to air, 2.5% to water and 92.5% to land and the same is an expert assumption based on previous studies and analysis on similar heavy metals.

The mercury releases are distributed as 1.63 kg to the air, 0.82 kg to the water and 30.22 kg to the land.

The mercury input and output calculations for the sub-category “Zinc/lead extraction and initial processing” are presented in Table 33.

Table 33: Mercury input and output calculations for the zinc/lead extraction and initial processing

Source	Activity rate (t/y)	Input factor (g Hg/t)	Mercury input (kg/y)	Mercury output (kg/y)		
				Air	Water	Land
SASA	736,333	0.005*	3.68	0.1840	0.0920	3.4100
Toranica	284,926	0.005*	1.42	0.0712	0.0356	1.3178
Zletovo	139,163	0.198	27.55	1.3777	0.6889	25.4877
Total:	1,160,422		32.65	1.63	0.82	30.22

* The numerical value for SASA and Toranica was defined as a half of the limit detection value of <0.010 g Hg/t

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “zinc/lead extraction and processing” is presented in **Error! Reference source not found.** Table 34.

Table 34: Certainty assessment for the “Zinc/lead extraction and initial processing” sub-category

Parameter	Level	Description
Activity rate	HIGH	The quantities of the generated reject material were provided by the mining companies.
Input factor	HIGH	The content of the mercury in the reject material was determined based on the actual measurements.
Output distribution factors	MEDIUM	The output distribution factors were derived based on consultant’s assumptions.

6.2.2 Copper extraction and initial processing

Similar to the processing for the zinc/lead, the ore for the extraction of copper can contain trace amounts of mercury which can be released from the rock material in the process of mining, production of concentrates and extraction of the copper from the concentrates (UNEP, 2023).

The waste rock and tailings may, just like the generated concentrates, contain trace amounts of mercury. This material is much more susceptible to weathering than the original deposits, due to the reduced particle sizes and higher accessibility for air and precipitation.

There is one copper mine in North Macedonia.

Bucim

The Bucim mine is located in the Central-East part of North Macedonia on the mountain Plackovica, 16 km from the town Radovis, and approximately 120 km to the south-east of the capital of Skopje. The process of preparation and concentration of the ore includes: grinding, milling, floatation, thickening and filtering of the floatation concentrate. There is no extraction of the copper from the concentrates, but all quantities of produced concentrates are exported.

Mercury releases estimation

Activity rate

According to the data provided by Bucim, the quantities of the copper ore mined and concentrated in 2021 were 3,297,500 tons, generating reject material of 3,268,685 tons which is deposited in the tailings ponds, and producing copper concentrate of 28,866 tons.

Input factor

Similarly, as for the zinc/lead extraction and initial processing sub-category, the Toolkit provides input factors only for the process related to the production of copper from concentrates, but not for the process related to the mining and concentrating of the copper ore and consequently for the deposition of the waste rocks and the tailings (the floatation waste). As suggested in the Toolkit, this mercury source category should not be neglected due to the enormous amounts of materials handled in mining operations.

In order to calculate/estimate the mercury releases from the reject material, the sampling and analyses of the ore, concentrate and reject material from the Bucim mine was performed and the analyses demonstrated that the mercury content in the reject material is 0.012 g Hg/t reject material. Quantities of ore, concentrate and floatation tailing is included in Table 35.

Calculation on the mercury input from all three materials is included in [Annex 5a](#).

Table 35: Ore, concentration and floatation tailings quantities from Bucim

Mine	Ore (t)	Concentrate (t)	Floatation tailings (t)
Bucim	3,297,500	28,866	3,268,685

The total mercury input for this sub-category is estimated to 39.22 kg for 2021.

Moreover, conservative approach was considered as well, and compared with the mercury specific calculation approach (see [Annex 5b](#)).

Output distribution

Similar to the zinc/lead extraction sub-category, the distribution of the mercury releases from the reject material is considered to be 5% to air, 2.5% to water and 92.5% to land.

The mercury releases are distributed as 1.96 kg to the air, 0.98 kg to the water and 36.28 kg to the land.

The mercury input and output calculations for the sub-category “Copper extraction and initial processing” are presented in **Error! Reference source not found.** 36.

Table 36: Mercury input and output calculations for the copper extraction and initial processing

Source	Activity rate	Input factor*	Mercury input	Mercury output (kg/y)		
	(t/y)	(g Hg/t)	(kg/y)	Air	Water	Land
Bucim	3,268,685	0.012	39.22	1.96	0.98	36.28

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “copper extraction and processing” is presented in **Error! Reference source not found.** Table 37.

Table 37. Certainty assessment for the copper extraction and initial processing sub-category

Parameter	Level	Description
Activity rate	HIGH	The quantities of the generated reject material were provided by the mining company.
Input factor	HIGH	The content of the mercury in the reject material was determined based on the actual measurements.
Output distribution factors	MEDIUM	The output distribution factors were derived based on consultant's assumptions.

6.2.3 Primary ferrous metal production

Similar to the processing for zinc/lead and copper, the iron ore used to produce pig iron can contain trace amounts of mercury which can be released from the rock material during the process of sintering and blast furnace processes. These two processes are treated as one process with pig-iron as the output. The subsequent basic oxygen process is not considered a significant mercury source (UNEP, 2023).

There are three facilities within this category in the country that produces ferro-alloys: Euronickel, SILMAK and SKOPSKI LEGURI. SKOPSKI LEGURI did not have any production in 2021.

EURONICKEL

Euronickel is a pyro-metallurgical ferronickel producing plant, located in the central part of the country, near the town of Kavadarci, and approximately 80 km to the south of the capital of Skopje. The nickel ore is crushed, dried, milled and pre-reduced in a rotary kiln and then fed into an electric furnace for complete reduction into a molten nickel/iron alloy. The nickel/iron alloy is then placed into an oxygen converter and blown with oxygen to reduce the iron content, thereby increasing the nickel content. The ferronickel is then transported to a holding furnace where the temperature is raised to cast the metal, in the form of granules.

The rotary kilns are equipped with burners that operate on fuel oil and petroleum coke. For heating the rotary kilns solid fuels, except lignite which is required for reduction, biomass and rubber chips are added.

Mercury releases estimation

Activity rate

According to the data provided by Euronickel, the quantities of the nickel ore processed in 2021 were 1,352,988 tons, resulting in 16,779 tons of ferro-nickel produced and 851,487 tons of sludge generated (767,474 tons from the electro-furnaces and 84,013 tons from the converter). The ore originated from different places with different quality, mostly from Ivory Coast, Guatemala, Turkey and Albania.

Input factor

Euronickel provided data on mercury content in the ores originated from the different countries. Using the given values, the input factor was determined to be 0.046 g Hg/t of processed ore, as an average of the mercury concentration in the ore from different countries of origin (see Table 38).

Table 38: Mercury content in the processed ores

Origin of ore	Quantity (t)	Mercury (g/t)
Guatemala	80,918	0.054
Turkey	1,020	0.154
Albania	331,697	0.031
Ivory coast	939,353	0.05*
Total:	1,352,988	

* The numerical value was defined as a half of the limit detection value of <0.1 g Hg/t

$$IF = \frac{\sum Q \times C}{\sum Q} = \frac{61,776.9}{1,352,988} = 0.046 \text{ g Hg/t}$$

where,

IF – input factor (g Hg/t)

Q – Quantity of the processed ore (t)

C – mercury content in the ore (g Hg/t)

The total mercury input for this sub-category is estimated to 62,24 kg for 2021.

Moreover, a conservative approach was considered as well, and compared with the mercury specific calculation approach (see [Annex 6](#)).

Output distribution

There are five-point sources (stacks), two for both electro-furnaces with a height of 46 meters and one for the convertor with a height of 52 meters equipped with dry PM retention.

In the previous inventory, analysis of the sludge (from both the electro furnaces and from the convertor), was performed, leading to conclusion that in the process of the ferro-nickel production 90.5% of the mercury is emitted in the air and 9.5% is released in the sector specific treatment/disposal output. Applying these input factors, it comes out that the annual emissions to air for 2021 are 56.32 kg and to the sector specific treatment/disposal 5.91 kg.

The mercury releases are distributed as 56.32 kg to the air and 5.91 kg to the sector specific treatment/disposal.

The mercury input and output calculations for the sub-category “Primary ferrous metal production” are presented in Table 39.

Table 39: Mercury input and output calculations for the primary ferrous metal production sub-category

Source	Activity rate (t/y)	Input factor* (g Hg/t)	Mercury input (kg/y)	Mercury output (kg/y)	
				Air	Sector specific treatment/disposal
Euronickel	1,352,988	0.046	62.24	56.32	5.91

Compared to the conservative scenario, the input factor is only slightly higher, and therefore the mercury input in the conservative scenario is slightly higher.

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “primary ferrous metal production” sub-category is presented in **Error! Reference source not found.** Table 40.

Table 40: Certainty assessment for the primary ferrous metal production sub-category

Parameter	Level	Description
Activity rate	HIGH	The quantities of the processed ore were provided by the ferro-nickel production plant.
Input factor	HIGH	The content of the mercury in the ore was determined based on

		the actual measurements.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

Summary of the category

Within the category Primary (virgin) metal production, the subcategory with the highest mercury releases is Primary ferrous metal production with 58.69 kg of mercury released in 2021, shown in Table 41.

Table 41. Summary of the input and output calculations for the main source category “Primary (virgin) metal production” for 2021

Sub-category	Mercury input	Mercury output (kg)			Sector specific
	(kg)	Air	Water	Land	
Zinc/lead extraction and initial processing	32.65	1.63	0.82	30.22	
Copper extraction and initial processing	39	1.96	0.98	36.28	
Primary ferrous metal production	62.24	56.32			5.91
TOTAL:	134.11	59.91	1.80	66.50	5.91

6.3 Production of other minerals and materials with mercury impurities

This category in North Macedonia is represented by the production of cement only.

The relevant sub-categories within this main source category are presented in Table 42.

Table 42: Relevant sub-categories related to the main category

Chapter	Sub-category
6.3.1	Cement production
6.3.2	Lime production

6.3.1 Cement production

The raw materials used for the production of cement contain trace concentrations of mercury. The origin of this mercury is naturally present in the raw materials used (lime, coal, oil etc.), in mercury content in solid residues from other sectors (e.g. fly-ashes and gypsum from combustion of coal) in which mercury content may be elevated compared to virgin materials, and in waste sometimes used as fuels in cement manufacturing. The mercury can be released in the thermal processes involved in the cement production: calcination (a heating process in which calcium oxide is formed), and burning-sintering (clinker production) (UNEP, 2023).

There is one cement production plant in the country.

TITAN-USJE

The TITAN-USJE cement plant is located in the south-west part of the capital of Skopje. The raw materials used in the cement production are: marlstone, limestone, sand, iron ore, gypsum and the fly ash from the thermo power plant, REK Bitola. The main fuel type used is brown coal, followed by lignite, then petroleum coke and residual fuel oil. There is no usage of waste as an alternative fuel.

Mercury releases estimation

Activity rate

In 2021, 1,015,244 tons of cement were produced using:

- 821,402 of marl
- 487,680 of limestone

- 102,062 of other materials (1,075 of sand, 58,377 of pozzolan, 42.610 gypsum).

Input factor

Since no data could be provided, analysis of the cement and raw materials: marl and limestone, was performed. Results are shown in Table 43.

Table 43: Mercury content in the raw materials for cement production

Source	Quantity (t)	Mercury content (g/t)
Marlstone	821,402	0.018 - 0.034 (0.026)
Limestone	487,680	0.028
Other	102,062	0.027*
Cement	1,015,244	<0.010

*calculated as average from the mercury content of marlstone and limestone

$$MI = \sum Q \times C = 37.77$$

$$IF = \frac{MI}{Q_c} = 0.0372 \text{ gHg/t}$$

where,

MI – mercury input (kg/y)

Q – quantity of the raw materials (t)

IF – input factor (g Hg/t)

C – mercury content in the raw materials (g Hg/t)

Q_c – quantity of the produced cement (t/y)

The input factor was determined to be 0.0372 g Hg/t for produced cement and was derived as average figure of the mercury concentration in the different raw materials that enters into the process.

The total mercury input for this sub-category is 37.77 kg for 2021.

Moreover, a conservative and semi-conservative approach were considered as well, and compared with the mercury specific calculation approach (see [Annex 7](#))

Output distribution

With regards to the output distribution factors, the Toolkit offers several default output distributions based on studies. TITAN-USJE is equipped with an electrostatic precipitator and bag filters for the collection of the exhaust gaseous and the particles generated during the clinker production. There are two stacks, i.e. outlets for the air emissions from the two rotary kilns. The dimensions of the two stacks are: height 60 meters and diameter 2.9 meters. The dust collected from the filtering systems is reintroduced back in the raw materials used for the clinker production. Therefore, for the filtration they have (Optimized particle control (FF+SNCR / FF+WS / ESP+FGD / optimized FF), the Toolkit offers default factors of: 40% to air, 20% to products and 40% to sector specific treatment/disposal.

However, since an analysis of the cement was performed, as shown in Table 90 the concentrations were below limit detection value (<0.01 mg Hg/kg). Therefore, half of the limit detection value was taken into consideration. Since cement is the product, by multiplication of the mercury content of cement and the quantity of produced cement in 2021, the mercury output to product was calculated to be 5.08 kg. Furthermore, the output distributions to air were derived to be 32.69 kg Hg/y.

$$MO_P = Q_C \times C_C = 5.08 \text{ kg Hg/y}$$

$$MO_A = MI - MO_P = 37.77 - 5.08 = 32.69 \text{ kg Hg/y}$$

Where,

MO_P – Mercury output in product (kg/y)

Q_C – Quantity of produced cement (t/y)

C_C – Mercury content of cement (g Hg/t)⁹

MO_A – Mercury output in air (kg/y)

MI – Mercury input (kg/y)

Therefore, the distributions were modified to be 13.5% to product and 86.5% to air.

The mercury releases are distributed as 32.69 kg to the air and 5.08 kg to the product.

⁹ The mercury content of cement is half of limit detection value (0.005)

The mercury input and output calculations for the sub-category “Cement production” are presented in Table 44.

Table 44: Mercury input and output calculations for the cement production

Source	Activity rate	Input factor	Mercury input	Pollution abatement	Mercury output (kg/y)	
	(t/y)	(g Hg/t)	(kg/y)	system	Air	Product
TITAN-USJE	1,015,244	0.0372	37.77	ESP/FF	32.69	5.08

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “cement production” is presented in Table 45.

Table 45: Mercury input and output calculations for the cement production

Parameter	Level	Description
Activity rate	HIGH	The quantities of the raw materials used and the produced cement were provided by the cement production company.
Input factor	HIGH	The content of the mercury in the raw materials was determined based on the actual measurements.
Output distribution factors	HIGH	The output distribution factors were derived based on actual measurements of the Hg presence in the cement, i.e. the output “Product”, while for the emissions in the air the mass balance of the mercury was taken into consideration, i.e. the difference between the mercury quantities that enters into the process as mercury content in the raw materials (input factor) and the mercury content in the cement.

6.3.2 Lime production

The only company registered for producing lime in the country, Tehno Paver, have reported that they have not produced lime in 2021.

6.4 Consumer products with intentional use of mercury

This category covers mercury uses in thermometers, mercury switches and relays, light sources and batteries.

The relevant sub-categories within this main source category are presented in Table 46.

Table 46: Relevant sub-categories related to the main category

Chapter	Sub-category
6.4.1	Thermometers with mercury
6.4.2	Electrical and electronic switches, contacts and relays with mercury
6.4.3	Light sources with mercury
6.4.4	Batteries containing mercury

6.4.1 Thermometers with mercury

Mercury has been traditionally used in thermometers for most medium temperature range measurements. Today they are increasingly substituted by electronic and other thermometer types, but the degree of substitution probably varies among countries.

There is no production of thermometers in North Macedonia. The mercury filled thermometers are represented by the medical thermometers (in hospitals and households), ambient air thermometers, and in industrial equipment, laboratories, etc. Moreover, in accordance with the List of Restrictions and Bans for the Chemical Applications (Official Gazette of the Republic of Macedonia no. 57/11, 31/14) it is forbidden to place thermometers, manometers, barometers, etc. on the market that contain mercury.

Mercury releases estimation

Activity rate

The calculation of the mercury releases from the mercury filled thermometers refers to the mercury releases/mobilization during the usage (by breakage or loss of the thermometers) and during the disposal (depends on the efficiency of the waste collection procedures).

Table 47. shows the consumption of thermometers (import minus export quantities) for 2021, as provided by the Customs Administration.

Table 47: Consumption of thermometers for 2021

HS code	Description	Consumption (pieces)
9025 11 20 00	Clinical or veterinary thermometers, liquid-filled, for direct reading	11,212
9025 11 80 00	Other thermometers, liquid-filled, for direct reading, not combined with other instruments (excl. clinical or veterinary thermometers)	93,906
9025 19 00 00	Thermometers and pyrometers, not combined with other instruments (excl. liquid-filled thermometers for direct reading)	107,517
Total:		212,635

For this sub-category, it is relevant to determine the number of thermometers broken or disposed of, which can result in mercury releases. For the estimation of the number of the mercury thermometers that were broken or disposed of in 2021, the annual consumption of thermometers was used. Moreover, to make more appropriate estimations the consumption of the thermometers was divided into the following sectors: hospitals, households, industry and laboratories, by taking into consideration the different representation of the mercury filled thermometers in these sectors.

Upon consultation with the suppliers of the thermometers and the health workers, that around 90% of the total annual consumption (or 191,372 thermometers) is used for replacement of the damaged and disposed thermometers, while the remaining 10% are to cover the purchase of new thermometers based on increased needs.

Medical thermometers

With regards to the usage in health centers, and in accordance with consultations made with the Clinical Centre in Skopje, along with a survey of the usage/disposal of mercury filled thermometers in the public health centers, it was determined that a majority of the mercury filled thermometers have already been replaced with electronic ones. Therefore, the annual supply of clinical thermometers is primarily intended for the replacement of the

damaged/disposed thermometers, meaning 90% or 10,091¹⁰ pieces from the medical thermometers. From those it is assumed that 2% or 202 pieces are considered to be used as a replacement for mercury filled ones.

However, uses other than in hospitals or other health centres, need to be considered. As above, the disposal rate of 90%¹¹ is calculated, to amount to 94,606 thermometers. Based on the consultations with the suppliers of the thermometers and the pharmacies, it could be estimated that the participation of the mercury filled thermometers in the household sector is around 40% and this percentage is applied as a disposal rate, i.e. to calculate the part of the annual supply of the clinical and other thermometers that are used to replace the mercury filled ones within the population, resulting in 37,843 pieces.

In total, the activity rate for the medical thermometers amounts to 38,044 thermometers.

Ambient air thermometers, industrial and special thermometers, and other glass thermometers

As before, first 90%¹² (96,765 thermometers) of the thermometers are assumed to be used for replacement of damaged or disposed there is no valid data from the industry/laboratory sector about the usage of the mercury filled thermometers, but based on the indications from the industry sector, a disposal rate for the mercury filled thermometers of 5% (4,838 thermometers) was used for the calculation of the mercury releases in this sector. There was no sufficient data that will enable distribution of the disposed mercury filled thermometers within the categories specified in the Toolkit, i.e. to the ambient air thermometers, industrial and special thermometers and the other glass Hg thermometers including the laboratories. Based on consultants' assumption the following distributions were decided upon

- 50% (2,419 pieces) of the of the disposed mercury filled thermometers are distributed in the category of ambient air thermometers,
- 10% (484 pieces) to the industrial and special thermometers and
- 40% (1,935 pieces) to the other glass Hg thermometers.

Input factor

¹⁰ From quantities of Clinical or veterinary thermometers, liquid-filled, for direct reading

¹¹ From the sum of Clinical or veterinary thermometers, liquid-filled, for direct reading and Other thermometers, liquid-filled, for direct reading, not combined with other instruments (excl. clinical or veterinary thermometers)

¹² From quantities of Thermometers and pyrometers, not combined with other instruments (excl. liquid-filled thermometers for direct reading)

There was no information about the mercury content in the thermometers. Therefore, the default input factors for the different types of thermometers provided in the Toolkit were used, i.e. 0.5-1.5 (1) g Hg/item for the medical thermometers, 2-5 (3.5) g Hg/item for the ambient air thermometers, 5-200 (103) g Hg/item for the industrial thermometers and 1-40 (20.5) g Hg/item for the other glass Hg thermometers in laboratories.

The total mercury input for this sub-category within the range 28.21- 243.34 (136.02 as an intermediate value) kg for 2021.

Output distribution

The current waste management practices show that there is no separate collection system established for the disposed thermometers, which means that all mercury filled thermometers ends up in the general waste deposited in the landfills.

The Toolkit recommends output distributions factors related to the publicly controlled waste collection services as of 10% to the air, 30% to water and 60% to general waste.

The mercury releases are distributed as 2.82-24.33 (13.6 as an intermediate value) kg to air and 8.46-73.00 (40.81 as an intermediate value) kg to water and 16.93-146.00 (81.61 as an intermediate value) kg to general waste.

The mercury input and output calculations for the sub-category “Use/disposal of thermometers” are presented in Table 48.

Table 48: Mercury input and output calculations for the use/disposal of the thermometers

Source	Activity rate (items)	Input factor (g Hg/item)	Mercury input (kg/y)	Waste management practices	Mercury output (kg/y)		
					Air	Water	General waste
Medical thermometers	38,044	0.5-1.5 (1)	19-57.07	No separate collection.	1.90-5.71	5.71-	11.41-
			(38.04)		(3.8)	17.12	34.24
Ambient air thermometers	2,419	2-5 (3.5)	4.84-	Waste handled controlled	0.48-1.21	1.45-	2.90-7.26
			12.10			3.63	(5.08)
Industrial and special	484	5-200 (103)	2.42-		0.24-9.68	0.73-	1.45-58.06
			96.77			29.03	(29.9)

thermometers			(49.83)		(14.95)
Other glass Hg thermometers including the laboratories	1,935	1-40 (20.5)	1.94- 77.41 (39.67)	0.19-7.74 (3.97)	0.58- 23.22 (11.9)
			28.21-	2.82-	8.46-
TOTAL:	42,883		243.34 (136.02)	24.33 (13.6)	73.00 (40.81)
					16.93- 146.00 (81.61)

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “use/disposal of thermometers” is presented in **Error! Reference source not found. 49**.

Table 49: Certainty assessment for the use/disposal of thermometers sub-category

Parameter	Level	Description
Activity rate	MEDIUM	The quantities of the different types of imported/exported thermometers were obtained from the Customs Department. Assumption was used for the determination of the disposal rate.
Input factor	LOW	The content of the mercury in the thermometers was taken from the default Toolkit values which are only indicative ones.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

6.4.2 Electrical and electronic switches, contacts and relays with mercury

Mercury has been used (and continues to be used) in a variety of electrical switches and relays. In some countries mercury in electrical components have been under substitution during the last two decades and non-mercury substitutes are being used for most or all of these applications in some countries today (UNEP, 2023)

There is one company in the North Macedonia, Rade Koncar - Kontaktori i Relei, producing switches, contactors and relays. The company stated that they do not use mercury in any of

their products. Since there is no usage of mercury in the production process of electrical devices, the main releases refer to the mercury mobilization during usage and disposal.

Mercury releases estimation

Activity rate

Since no data for the production, import or export was provided, the Toolkit recommends to use as activity rate the number of inhabitants, which according to State Statistical Office for 2021 was 1,836,713.

Input factor

The Toolkit provides a default input factor of 0.0012 g mercury per inhabitant, taking into account that the whole population has access to electricity¹³.

The total mercury input for this sub-category is 2.20 kg for 2021.

Output distribution

The instruments and devices within this sub-category are usually components of other electric/electronic equipment, and are usually disposed of when the equipment is discarded. The management of the electric/electronic waste is regulated by the “Law on Electrical and Electronic Equipment and Waste Electrical and Electronic Equipment Management”, according to which a scheme for the collection, treatment and disposal of electric/electronic waste is established. This results in partial separate collection of the EEW. But, having in mind that the thermostats, manostats, and the other control devices are not of particular interest to the waste management companies, it is likely that these devices end up in landfills, thus it can be considered that there is no separate collection of these devices.

The Toolkit recommends output distributions factors related to the publicly controlled waste collection services as of 10% to the air, 10% to land and 80% to general waste.

The mercury releases are distributed as 0.22 kg to air, 0.22 kg to land and 1.76 kg to general waste.

The mercury input and output calculations for the sub-category “Use/disposal of thermometers” are presented in Table 50.

¹³ https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=MK&name_desc=false

Table 50: Mercury input and output calculations for the use/disposal of the switches, contacts and relays with mercury

Source	Activity rate (inhabitants)	Input factor (g Hg/item)	Mercury input (kg/y)	Waste management practices	Mercury output (kg/y)		
					Air	Land	General waste
Population with access to electricity	1,836,713	0.0012	2.2	No separate collection. Waste handled controlled	0.22	0.22	1.76

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “use/disposal of switches, contacts and relays with mercury” is presented in Table 51.

Table 51: Certainty assessment for the use/disposal of switches, contacts and relays with mercury sub-category

Parameter	Level	Description
Activity rate	HIGH	The number of inhabitants obtained by the State Statistical Office.
Input factor	LOW	The content of the mercury in the control units was taken from the default Toolkit values which are only indicative ones.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

6.4.3 Light sources with mercury

Mercury is used in small amounts in a number of different types of discharge lamps, with fluorescent tubes and compact fluorescent lamps (CFLs) as the most common examples. Significant progress has been made by some producers to reduce the amount of mercury per lamp, with reductions of about a factor 10 achieved in newer mercury-lamps as compared to traditional types (UNEP, 2023).

There is no production of light sources in North Macedonia. The mercury containing light sources are represented by the fluorescent tubes (double end), compact fluorescent lamp (CFL

single end), high-pressure sodium lamps, ultra violet and infrared lamps and metal halide lamps.

Mercury releases estimation

Activity rate

The calculation of the mercury releases from the mercury containing light sources refers to the mercury releases/mobilization during the usage (by breakage of the lamps) and during the disposal (depends on the efficiency of the waste collection/recycling procedures). To estimate the disposed, data from 5-10 years before 2021 was requested. The Customs Administration from North Macedonia, have provided data for the period 2013-2016, shown on Table 52. When compared, the data from 2021 is showing significant decrease in import, which is highly likely a result from the Covid pandemics. Therefore, an average data from the period 2013-2016 and 2021 was taken activity rate, presenting the replacement need for light sources on the market

Table 52. Consumption of light sources

HS code	Description	Consumption (pieces)					Average (for the period 2013-2016 and 2021)
		2021	2013	2014	2015	2016	
8539 31 10 00	Fluorescent tubes (double end)	84,052	760,492.00	546,175.00	449,651.00	602,603.00	488,595
8539 31 90 00	Compact fluorescent lamp (CFL single end)	19,474	1,343,259.00	1,379,762.00	849,784.00	641,374.00	846,731
8539 32 20 00	High-pressure mercury/sodium lamps	8,000	402,852.00	185,795.00	142,548.00	185,018.00	184,843

8539 49 00 00	Ultra violet and infra red lamps	17,062	31,076.00	54,745.00	31,160.00	67,894.00	40,387
8539 32 90 00	Metal halide lamps	10,352	10,449.00	7,975.00	9,098.00	11,928.00	9,960
TOTAL		138,940	2,548,128	2,174,452	1,482,241	1,508,817	1,570,516

Input factor

Since there was no information on mercury content in the different light sources, the default input factors provided in the Toolkit were used, i.e. 2-15 mg Hg/item for the fluorescent tubes double end, 1.4-4 mg Hg/item for the compact fluorescent lamp single end, 15-70 mg Hg/item for the high pressure mercury vapour lamps, 10-30 mg Hg/item for the high-pressure sodium lamps, 5-25 mg Hg/item for the ultra violet and infra-red lamps and 5-150 mg hg/item for the metal halide lamps. Considering the fact that high pressure mercury vapour lamps and high-pressure sodium lamps were reported together, the input factor 15-70 mg hg/item, was taken due to the larger high-end value, to have worst-case scenario option considered.

The total mercury input for this sub-category within the range 5.19-26.16 (14.44 as intermediate value) kg for 2021.

Output distribution

The current waste management practices show that there is no separate collection/recycling system established for the disposed light sources, which means that all mercury containing light sources ends up in the general waste deposited in the landfills.

The Toolkit recommends output distributions factors related to the publicly controlled waste collection services as of 5% to the air and 95% to general waste.

The mercury releases are distributed as 0.26-1.31 (0.72 as intermediate value) kg to air and 4.93-24.85 (13.72 as an intermediate value) kg to general waste.

The mercury input and output calculations for the sub-category “Use/disposal of light sources” are presented in Table 53.

Table 53. Mercury input and output calculations for the use/disposal of the light sources

Source	Activity rate	Input factor	Mercury input	Waste management	Mercury output (kg/y)
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	(items)	(mg Hg/item)	(kg/y)	practices	Air	General waste
Fluorescent tubes (double end)	488,595	2-15 (8)				
Compact fluorescent lamp (CFL single end)	846,731	1.4-4 (2.7)				
High-pressure mercury/sodium lamps*	184,843	15-70 (40)	5.19-26.16 (14.44)	No separate collection. Waste handl. controlled	0.26-1.31 (0.72)	4.93-24.85 (13.72)
Ultra violet and infra red lamps	40,387	5 - 25 (15)				
Metal halide lamps	9,960	5-150 (25)				
TOTAL:			5.19-26.16 (14.44)		0.26-1.31 (0.72)	4.93-24.85 (13.72)

*Macedonian customs codification system does not separate the high-pressure mercury and sodium vapour lamps

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “use/disposal of light sources” is presented in Table 54.

Table 54. Certainty assessment for the “Light sources” sub-category

Parameter	Level	Description
Activity rate	MEDIUM	The quantities of the different types of imported/exported light sources were obtained from the Customs Department.
Input factor	LOW	The content of the mercury in the light sources was taken from the default Toolkit values which are only indicative ones.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

6.4.4 Batteries containing mercury

The use of mercury in various types of batteries has been extensive and it has been among the largest product uses of mercury. Mercury has mainly, or perhaps solely, been used in primary, non-rechargeable batteries (UNEP, 2023)

There is no production of batteries in North Macedonia. The mercury containing batteries are represented by the manganese dioxide batteries and cells (alkaline and non-alkaline, in the form of cylindrical or button shape), silver oxide, lithium, air-zinc batteries and cells in cylindrical or button shape, and dry zinc-carbon batteries.

Mercury releases estimation

Activity rate

The calculation of the mercury releases from the mercury containing batteries and cells refers to the mercury releases/mobilization during their disposal, which depends on the efficiency of the waste collection/recycling procedures. Since the life span of batteries is in the range from a few months to a few years, the annual consumption for 2021 was taken into consideration as the average figure for the calculations.

In order to calculate the quantities of the batteries and cells that might contain mercury, the main suppliers of the batteries and cells were contacted and it was revealed that around 70% of the consumed batteries and cells were mercury free. Therefore, the remaining 30% of the consumed batteries and cells were used for the estimation of the annual mercury input.

The annual consumption (import-export) of the different types of batteries and cells for 2021 and the assumed quantities the mercury containing batteries is presented in Table 55¹⁴. There is no consumption of the mercury oxide batteries and cells.

Table 55: Consumption of batteries and cells for 2021

HS code	Description	Consumption (kg)	Mercury containing (kg)
8506 10 11 00	Manganese dioxide cells and batteries, alkaline, in the form of cylindrical cells (excl. spent)	95,072	28,521

¹⁴ Data provided by the Customs Department

8506 10 18 00	Manganese dioxide cells and batteries, alkaline, in the form of button cells (excl. spent)	17,568	5,271
8506 10 91 00	Manganese dioxide cells and batteries, non-alkaline, in the form of cylindrical cells (excl. spent)	14,634	4,390
8506 10 98 00	Manganese dioxide cells and batteries, non-alkaline, in the form of button cells (excl. spent)	3,464	1,039
8506 40 00 00	Silver oxide cells and batteries, in the form of cylindrical and of button cells (excl. spent)	48.4	15
8506 50 10 00	Lithium cells and batteries, in the form of cylindrical cells (excl. spent)	509.759	153
8506 50 30 00	Lithium cells and batteries, in the form of button cells (excl. spent)	1,417	425
8506 50 90 00	Lithium cells and batteries (excl. spent, and in the form of cylindrical or button cells)	4,470	1,341
8506 60 00 00	Air-zinc cells and batteries, in the form of cylindrical and of button cells (excl. spent)	366.654	110
8506 80 05 00	Dry zinc-carbon batteries of a voltage of $\geq 5,5$ V but $\leq 6,5$ V (excl. spent)	8,063	2,419
TOTAL:		145,612	43,684

Input factor

The Toolkit provides default input factors for the following types of batteries: 12 kg Hg/t for the zinc air button cells, 5 kg Hg/t for the alkaline button cells, 4 kg Hg/t for the silver oxide button cells, 0.25 kg Hg/t for the alkaline, other than button cell shapes. The Toolkit does not provide any suggestions for the mercury content in the lithium, air-zinc, dry zinc-carbon

batteries, and non-alkaline cylindrical/button shape cells¹⁵, regardless of the fact that these types of batteries are mentioned as potentially containing mercury.

During the preparation of the initial inventory analyses of the mercury presence in the batteries with the highest participation were performed. The following types of batteries were analysed: three alkaline batteries of cylindrical form from different countries of origin, one non-alkaline battery of cylindrical form, and one non-alkaline battery in form of button shape. The laboratory results showed that mercury concentration in all types of batteries is below the limit of detection of <0.05 g Hg/ton.

Therefore, as previously, for these types of batteries half of the limit detect value will be used.

The total mercury input for this sub-category is 36.97kg for 2021.

Output distribution

A system for the collection of waste batteries has been established, where the collected waste batteries are exported. According to Annual report from the Ministry of Environment and Physical Planning, 23,598 kg were collected. Taking into consideration the number of imported quantities, amounting to 145,612 kg, and the quantity collected, it can be concluded that approximately 16% of the waste batteries are properly handled, whereas the rest ends up as household waste in the landfills.

Therefore, the distribution is taken as 16% to sector specific treatment/disposal, where as the rest to general waste.

The mercury releases are distributed as 31.06 kg to general waste and 5.92 kg to sector specific

The mercury input and output calculations for the sub-category “Batteries containing mercury” are presented in Table 56.

¹⁵ There some data indicating that these types of batteries are mercury free:
http://www.newmoa.org/prevention/mercury/imerc/factsheets/batteries_2015.pdf;
http://www.zendergroup.org/docs/battery_table.pdf

Table 56: Mercury input and output calculations for the disposal of the batteries

Source	Activity rate	Input factor	Mercury input	Waste management practices	Mercury output (kg/y)	
	(kg)	(g Hg/t)	(kg/y)		General waste	Sector specific treatment/disposal
Zinc-air button cells	147	12	1.76			
Alkaline button cells	7,027	5	35.14			
Silver oxide button cells	19	4	0.08			
Alkaline, other than button cell shapes	38,029	0.025*	0***	No separate collection. Waste handled controlled		
Dry zinc-carbon batteries**	3,223				31.06	5.92
Lithium cells and batteries**	2,558					
Non-alkaline button cells	1,386	0.025*	0***			
Non-alkaline, other than button cell shape	5,854	0.025*	0***			
Total:	58,243		36.98		31.06	5.92

* The numerical value was defined as a half of the limit detection value

** These types of batteries were not taken into consideration for the mercury calculation since there is indication that these types of batteries are mercury free ones

*** Insignificant value

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “use/disposal of light sources” is presented in Table 57

Table 57: Certainty assessment for the use/disposal of thermometers sub-category

Parameter	Level	Description
Activity rate	MEDIUM	The quantities of the different types of imported/exported light sources were obtained from the Customs Department.
Input factor	LOW	The content of the mercury in the light sources was taken from the default Toolkit values which are only indicative ones.
Output distribution	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

factors		
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Summary of the category

Within the category Consumer products with intentional use of mercury, the subcategory with the highest representation is Thermometers with mercury with 136.02 kg of mercury released in 2021, followed by Batteries containing mercury, with input of 36.97 kg, shown on Table 58.

Table 58. Summary of the input and output calculations for the main source category “Consumer products with intentional use of mercury” for 2021

Sub-category	Mercury input	Mercury output (kg)					
	(kg)	Air	Water	Land	Product	General waste	Sector specific treatment/disposal
Thermometers with mercury	28.21-243.34 (136.02)	2.82-24.33 (13.6)	8.46-73.00 (40.81)			16.93-146.00 (81.61)	
Electrical and electronic switches, contacts and relays with mercury	2.2	0.22		0.22		1.76	
Light sources with mercury	5.19-26.16 (14.44)	0.26-1.31 (0.72)				4.93-24.85 (13.72)	
Batteries containing mercury	36.97					31.06	5.92
TOTAL	67.82-286.39 (176,75)	3,06-24,74 (13.9)	8.46-73.00 (40.81)	0.22		50.16-182.5 (115.91)	5.92

6.5 Other intentional products/process uses

This category covers mercury uses in dental fillings, thermometers, manometers and gauges and laboratory chemicals and equipment.

The relevant sub-categories within this main source category are presented in Table 59.

Table 59: Relevant sub-categories related to the main category

Chapter	Sub-category
6.5.1	Dental mercury-amalgam fillings
6.5.2	Manometers and gauges
6.5.3	Laboratory chemicals and equipment

6.5.1 Dental mercury-amalgam fillings

Dental amalgam fillings consist of an alloy of mercury, silver, copper and tin (typically about 44-51% mercury by weight). The alloy is typically supplied to the dentists either: 1) as pure mercury along with a powder mix of the other metals, which are weighed and mixed in an agitator in the clinic; or 2) as small capsules where mercury and the metal powder are present in the right formula and only need to be mixed (in the capsule before opening) in the clinic, prior to filling the cavity in the tooth (UNEP, 2023)

The calculation of the mercury releases from the dental-amalgam fillings refers to the introduction of the mercury into the air, water and wastes during the preparation of the fillings, and use and disposal of the amalgam fillings (such as following the removal of fillings or teeth containing fillings during medical/dental procedures, or through lost teeth). Also, releases can occur at the end of the life of a person with fillings.

Preparation of fillings

As the preparation of amalgam fillings is restricted in the country, we got an estimation upon consultation with the Faculty of Medicine, that they have used 11 packages, which amounts to approximately 220g Hg, which amount is negligible. Therefore, we will not include it in the calculations.

Use - from fillings in the mouth

Input factor

This category encompasses excretions of mercury through feces and urine. In order to estimate the mercury releases from the use of amalgam fillings, it was needed to estimate the mercury excretion per capita per year. Since there were no such estimates in the country, the excretion rate of 60 µg Hg/day/person presented in the Toolkit and derived from a study from Stockholm was taken into consideration.

The total mercury input for this sub-category is estimated to 40.22 kg for 2021.

Output distribution

The estimations indicate that the mercury input from this phase related to the usage of the amalgam fillings is 40.22 kg per year and the Toolkit suggests 2% are distributed to water through excretion with feces and urine.

The mercury output of 0.8kg is distributed to water.

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Dental amalgam/use of fillings” is presented in Table 60.

Table 60: Certainty assessment for the “Dental amalgam/use” sub-category

Parameter	Level	Description
Activity rate	HIGH	The population data was taken from the State Statistical Office
Input factor	LOW	The data is based on the limited study performed in a country with different dental care conditions
Output distribution factors	HIGH	The entire quantities are distributed in one output pathway, i.e. the waste water

Disposal

Input factor

Since no data on the quantity of mercury fillings for 10-20 years ago, is available, to calculate mercury release an estimation of the amalgam fillings still in the alive population, lifetime of amalgam and the mercury consumption was made.

In communication with the Dental Chamber and State Statistical the following was concluded:

- 10% of the population with age less than 20 years (41,538 inhabitants) has amalgam fillings,
- 23% of the population between 20-29 years (51,221 inhabitants) has amalgam fillings and
- 50% of the population older than 29 years of age (599,317 inhabitants) has amalgam fillings,

In total, 692,075 have amalgam fillings, as shown in Table 61.

Table 61: Share of population with dental amalgam fillings

Population	1,836,713	Share with amalgam (%)	Inhabitants with amalgam fillings
< 20 years	415,382	10%	41,538
20-29 years	222,698	23%	51,221
> 20 years	1,198,633	50%	599,317
Total			692,075

Moreover, the estimation took into account two amalgam fillings average per person, in the previous inventory. However, since amalgam fillings are officially not in use for several years, 1.5 amalgam fillings per person are considered now, amounting to 1,038,112 amalgam fillings within the population.

The Toolkit recommends the lifetime of the amalgam fillings between 10-20 years (taking 15 as average), resulting in annual disposal rate of 6.67% or 69,242 amalgam fillings disposed annually. The average mercury consumption per filling was set to 0.8 g Hg/filling as provided in the Toolkit and in accordance with data related to a study performed in Denmark.

The mercury input from this category is estimated to 55.39 kg per year.

The total mercury input for this sub-category is estimated to 55.39 kg for 2021.

Output distribution

The output distribution depends on the filtering collecting systems implemented in the dental clinics. Based on the data provided by the Dental Chamber, it is assumed that most of the dental chairs are equipped with filters/strainers for the retention of the disposed amalgam fillings. The quantities of the wastes collected by the filters are disposed of in landfills as a general waste (there are no waste selection services available at this time). The output distribution factors provided by the Toolkit reflect only about 60% of the original supplies, i.e. the quantity of the mercury that was built into the fillings when they were made.

The annual output distribution of the mercury input related to the usage of filters/strainers as mercury retention measure is provided in the Toolkit as follows: 28% to water, 8% to land, 6% to product, i.e. the mercury remaining in fillings by the time of the person's death, 8% to general waste and 8% to sector specific treatment/disposal. But, having in mind that the quantities of the disposed amalgam fillings have been estimated using the number of the amalgam fillings within the population and the respective disposal rate, the output distribution should reflect the entire mercury input resulting in annual output distribution pathways as 27.70 kg to water, 7.39 kg to land, 5.54 kg to products, i.e. the mercury remaining in the death persons, 7.39 kg to general waste and 7.39 kg to sector specific treatment/disposal.

The mercury releases are distributed as 27.70 kg to water, 7.39 kg to land, 5.54 kg to products, i.e. the mercury remaining in the death persons, 7.39 kg to general waste and 7.39 kg to sector specific treatment/disposal.

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Dental amalgam fillings/disposal” is presented in Table 62.

Table 62: Certainty assessment for the “Dental amalgam/disposal” sub-category

Parameter	Level	Description
Activity rate	MEDIUM	The data were derived based on assumptions by the dental institutions
Input factor	MEDIUM	The average mercury consumption per filling was determine based on the data provided by the Dental Chamber and the study presented in the Toolkit
Output distribution factors	LOW	The retention efficiency of the dental chairs is not known and the output distribution factors are based on the Toolkit default ones which are only indicative.

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The mercury input and output calculations for the sub-category “Dental mercury-amalgam fillings” are presented in Table 63.

Table 63: Mercury input and output calculations for the dental mercury amalgam fillings

Source	Activity rate	Input factor*	Mercury input	Mercury output (kg/y)					
	(t/y)	(g Hg/t)	(kg/y)	Air	Water	Land	Products	General waste	Sector specific
Use -from fillings in the mouth	1,836,713	0.06	40.22		0.8	0	0		
(population*µg Hg (day*person) Disposal (estimation of amalgam fillings and suggested concentration)	69,242	0.8	55.39		27.7	7.39	5.54	7.39	7.39
TOTAL			95.61		28.5	7.39	5.54	7.39	7.39

6.5.2 Manometers and gauges

Blood pressure gauges, industrial and meteorological manometers, and pressure valves can contain mercury, which may be supplied in the product or separately, and may be supplemented during the use period for all types mentioned (UNEP, 2023).

There is no production of manometers, barometers and gauges in the Republic of North Macedonia. The main releases of the mercury from this sub-category refer to the mercury mobilization during usage and disposal of the mercury containing instruments.

Mercury releases estimation

Activity rate

The import and export quantities for 2021 were obtained by the Customs Department. The total annual consumption (import minus export) for this kind of equipment in 2021 was 40,491 pieces, shown in Table 64.

Table 64: Consumption of manometers, barometers and gauges for 2021

HS code	Description	Consumption (pieces)
9025 80 20 00	Barometers, not combined with other instruments	67
9026 20 20 00	Instruments and apparatus for measuring and controlling of pressure, electronic	n/a
9026 20 40 00	Spiral or metal diaphragm type pressure gauges	9,439
9026 20 80 00	Instruments and apparatus for measuring or checking pressure of liquids or gases, non-electronic (excl. spiral or metal diaphragm type pressure gauges, and regulators)	30,985
Total:		40,491

Due to lack of data on stock of mercury filled devices, estimation of annual disposal rate and replacement need were burdensome to estimate. Therefore, the suggested input factor and activity rate in the Toolkit were used. As the activity rate for the use/disposal of other manometers the number of inhabitants was used, which for 2021 was 1,836,713. There is no such suggestion for the estimation of the mercury releases related to the use/disposal of the medical blood pressure gauges, therefore we were unable to derive some reliable estimation on mercury releases from this type of devices.

Input factor

Recommended input factor, by the Toolkit, is 0.005 g mercury per inhabitant, adjusted for the percent of population with access to electricity. According World bank, in North Macedonia, 100% of the population has access to electricity¹⁶. Using the recommended activity rate of 1,836,713 inhabitants, the mercury input for 2021 is 9.18 kg.

The total mercury input for this sub-category is estimated to 9.18 kg for 2021.

¹⁶ https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=MK&name_desc=false

Output distribution

From the experience in this field, the experts assume no separate collection system established for the disposed manometers, barometers and gauges, which means that all mercury filled devices ends up in the general waste deposited in the landfills.

The Toolkit recommends output distributions factors related to the publicly controlled waste collection services as of 10% to the air, 30% to water and 60% to general waste.

The mercury releases are distributed as 0.92 kg to the air, 2.76 kg to the water and 5.51 kg to general waste.

The mercury input and output calculations for the sub-category “Use/disposal of manometers, barometers and gauges” are presented in Table 65.

Table 65: Mercury input and output calculations for the use/disposal of the manometers, barometers and gauges

Source	Activity rate (inhabitants)	Input factor (g Hg/ inhabitant)	Mercury input (kg/y)	Waste management practices	Mercury output (kg/y)		
					Air	Water	General waste
Other manometers and gauges	1,836,713	0.005	9.18	No separate collection. Waste handled controlled	0.92	2.76	5.51

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Use/disposal of manometers, barometers and gauges” is presented in Table 66.

Table 66: Certainty assessment for the “Manometers, barometers and gauges” sub-category

Parameter	Level	Description
Activity rate	MEDIUM	The data on the population was obtained by the State Statistical Office. The usage of the number of inhabitants as activity rate is a very general, conservative approach.

Input factor	LOW	The content of the mercury in the manometers was taken from the default Toolkit value which was based on the on limited study and is only indicative.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

6.5.3 Laboratory chemicals and equipment

As mercury is used in laboratories in instruments, reagents, preservatives, and catalysts, this sub-category includes the releases of mercury mobilization during their usage. According to the Toolkit, some of this mercury is released to air, primarily through lab vents, while most of the mercury may be released in wastewater or disposed of as hazardous or municipal waste.

Mercury releases estimation

Laboratory chemicals containing mercury

As reported by the Customs Administration, the total import of mercury was 6,77 kg, for 2021. Having in mind that there was no possibility to define the types of the mercury compounds, the entire imported amount is considered as mercury input.

The total mercury input for this sub-category is 6.77 kg for 2021.

The mercury input as suggested by the Toolkit is distributed to the following output pathways: 33% to water, 33% to general waste (2.23 kg) and 34% to the sector specific treatment/disposal (2.3 kg).

The mercury releases are distributed as 2.23 kg to the water, 2.23 kg to the general waste and 2.30 to sector specific treatment/disposal.

The Toolkit provides a conservative approach, included in [Annex 8](#), (in the absence of reliable data) for the estimation of the mercury releases from the usage of the laboratory chemicals.

The estimation certainty of the activity rate is given in Table 67 below.

When comparing the two approaches (using import data as activity rate as opposed to using number of inhabitants with a default factor provided in the toolkit) for the estimations of the mercury releases, the mercury input calculated using the real data on import of the mercury compounds is three times lower than the conservative approach.

Table 67: Certainty assessment for the “Laboratory chemicals” sub-category

Parameter	Level	Description
Activity rate	HIGH	The data on import of the compounds of mercury were obtained from the official statistics.
Input factor	LOW	Since the input factor is based on the on limited study presented in the Toolkit.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

Laboratory equipment

Due to the lack of data, it was very difficult to estimate the number of the instruments with mercury in the laboratories and consequently the quantities of mercury needed for measurements purposes. Where no data for reliable estimations are available, the Toolkit recommends to use as an activity rate for the instruments in laboratories based on the number of inhabitants with an input factor 0.04 g Hg per inhabitant per year, resulting in mercury input of 73.47 kg.

The total mercury input for this sub-category is 73.47 kg for 2021.

The mercury input is distributed using the Toolkit distribution factors to the following output pathways: 33% to water, 33% to general waste and 34% to the sector specific treatment/disposal.

The mercury releases are distributed as 24.24 kg to the water, 24.24 kg to the general waste and 24.98 to sector specific treatment/disposal.

The estimation certainty is given in the Table 68, below.

Table 68: Certainty assessment for the “Laboratory equipment” sub-category

Parameter	Level	Description
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Parameter	Level	Description
Activity rate	LOW	The data on the population was obtained by the State Statistical Office and the usage of the number of inhabitants as activity rate is very general, conservative approach.
Input factor	LOW	Since the input factor is based on the on limited study presented in the Toolkit.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

The mercury input and output calculations for the sub-category “Laboratory chemicals and equipment” are presented in Table 69.

Table 69: Mercury input and output calculations for the laboratory chemicals and equipment sub-category

Source	Activity rate (inhabitants)	Input factor (g Hg/ inhabitant)	Mercury input (kg/y)	Mercury output (kg/y)		
				Water	General waste	Sector specific
Laboratory chemicals containing mercury			6.77	2.23	2.23	2.3
Laboratory equipment	1,836,713	0.04	73.47	24.24	24.24	24.98
Total:			80.24	26.48	26.48	27.28

Summary of the category

Within the category “Other intentional products/process”, as seen on Table 70, the subcategory with the highest representation is “Dental mercury amalgam fillings” with the mercury output of 95.61 kg, followed by “Laboratory chemicals and equipment” with the output of 80.24 kg (see **Error! Reference source not found.**). Note that the mercury input for the sub-category “Dental mercury amalgam fillings” is not equal to the mercury output due to the fact that only minor part of the mercury fillings is excreted with the feces and urine in the water output pathway

Table 70: Summary of the input and output calculations for the main source category “Other intentional products/process uses” for 2021

Sub-category	Mercury input	Mercury output (kg)					Sector specific treatment/ disposal
	(kg)	Air	Water	Land	Product	General waste	
Dental mercury-amalgam fillings	95.61	0	28.5	7.39	5.54	7.39	7.39
Manometers and gauges	9.18	0.92	2.76			5.51	
Laboratory chemicals and equipment	80.24		26.47			26.47	27.28
TOTAL:	185.03	0.92	57.73	7.39	5.54	39.37	34.67

6.6 Production of recycled metals

This category in the Republic of North Macedonia is represented by the production of recycled ferrous metals.

6.6.1 Production of recycled ferrous metals (iron and steel)

Scrap metal is used to produce iron and steel. During this production process, the recycled metals/materials may contain mercury from natural mercury impurities but also as a result of anthropogenic emissions, through use of mercury (e.g. mercury switches in cars going to iron/steel recycling), which is considered to have larger impact. The major pathway of releases is expected to be to air via stack emissions from the iron and steel facility furnaces. Mercury releases to air, land and water may also occur at other points during process, such as during storage, shredding and dismantling activities (UNEP, 2023)

There is one facility in the country for the production of steel from ferrous scrap.

MAKSTIL

MAKSTIL AD is a steel-works with electric furnace which processes the preparation of scrap and other charging materials for the production of liquid steel, casting of slabs, and the production of plates. The two main phases of MAKSTIL AD plants are: Steel Making Plant with an electric furnace for production of liquid steel and three Continuous Casting machine lines to transform liquid steel into slabs, and Quarto Plate Mill for rolling the slabs into hot rolled plates with the finishing line with facilities for shot blasting and priming of plates.

Activity rate

The Toolkit recommends using the number of vehicles/appliances recycled annually to determine the estimated activity rate. Since there was no such record keeping in the companies, the activity rate was based on the quantities of recycled scrap metal.

According to the data provided by the company, the quantities of the recycled scrap metal for MAKSTIL in 2021 were 348,417.25 tons. Even though, the Toolkit recommends using the number of vehicles/appliances recycled annually to determine the estimated activity rate, the activity rate was based on the quantities of recycled scrap metal.

Input factor

The Toolkit provides an input factor within a range of 0.2-2 g Hg/vehicle. As advised, using more exact data is preferable. Therefore, the input factor was derived considering the following information

- Filter dust quantity in 2021 was 1,892.7 tons
- Samples from the filter dust were analyzed concluding mercury concentration of 5.84 mg/kg.
- Makstil reported mercury measurements in the air performed during two monitoring campaigns in 2021 resulting in 0.0007 mg Hg/Nm³ and <0.001¹⁷ mg Hg/Nm³. The average was estimated 0.0006 mg Hg/Nm³, including the mercury emissions from the used fuel which have been already calculated in the category “Extraction and use of fuel/energy sources”. Therefore, the mercury emissions from this source (burning of the coke and the natural gas) in amount of 0.008 kg/y should be excluded from the measured/calculated emissions. However, having in mind the negligible amount of mercury emitted from the burning of the fuel, the measured emission values remain the same.
- During the same campaigns the flow of the exhaust gasses was measured to be 1,286,821.7 m³/h and 935,743.86 m³/h, amounting to an average of 1,111,282.78.

Using this information and considering the assumption, provided by experts working on this inventory, that the output distribution to land is the same as to general waste, the following calculations were performed to estimate the input factor:

Mercury distribution in air,

$$MO_A = \frac{MI_{EG1} + MI_{EG2}}{2} \times \frac{EG_1 + EG_2}{2} \times \text{working hours}$$

$$MO_A = 0.0000000006 \times 1,111,282.78 \times 3551.9 = 2.37 \text{ kg Hg/y}$$

Mercury distribution in general waste,

$$MO_{GW} = MI_{FD} \times FD$$

$$MO_{GW} = 0.00584 \times 1,892.7 = 11.05 \text{ kg Hg/y}$$

¹⁷ It is a general expert approach that when a sample analysis result is below the detection value, half of the limit value is taken (0.0005).

Mercury distribution in land,

$$MO_L = MO_{GW}$$

Mercury input from this sub-category,

$$MI = MO_A + MO_L + MO_{GW} = 24.47 \text{ kg HG/y}$$

The input factor can be determined as follows:

$$IF = \frac{MI \times 1000}{AR} = 0.07 \text{ g Hg/t}$$

where,

MO_A -mercury output distribution to air (kg Hg/y)

MO_{GW} - mercury output distribution to general waste (kg Hg/y)

MO_L - mercury output distribution to land (kg Hg/y)

MI – mercury input (kg HG/y)

IF_{FD} – input factor in filter dust (kg HG/y)

IF_{EG1} – input factor in exhaust gases campaign 1(kg HG/y)

IF_{EG2} – input factor in in exhaust gases campaign 2 (kg HG/y)

EG₁ – flow of exhaust gases campaign 1 (m3/h)

EG₂ - flow of exhaust gases campaign 2 (m3/h)

FD – filter dust quantity (t)

IF – input factor (g Hg/t)

The total mercury input for this sub-category is 24.47 kg for 2021.

Conservative approach is included in [Annex 9](#).

Output distribution

According the calculations above, the calculated output distributions are 9.6% to air, 45.2% to land and 45.2% to general waste.

The mercury releases are distributed as 2,37 kg to air, 11.05 kg to land and 11.05 kg to general waste.

The mercury input and output calculations for the subcategory “Production of recycled ferrous metals” are presented in Table 71

Table 71: Mercury input and output calculations for the alternative approach for the “Production of recycled ferrous metals” sub-category

Source	Activity rate	Input factor	Mercury input	Pollution abatement	Mercury output (kg/y)		
	(t/y)	(g Hg/t)	(kg/y)	system	Air	Land	General waste
MAKSTIL	348,417.25	0.07	24.47	Filter bags	2.37	11.05	11.05

The certainty assessment of the calculations related to the sub-category “Production of recycled metals” is presented in Table 72.

Table 72: Certainty assessment for the “Production of recycled ferrous metals” sub-category

Parameter	Level	Description
Activity rate	HIGH	The quantities of the recycled ferrous metals were provided by the steelwork company.
Input factor	HIGH	The input factor derived from calculated output distributions, based on measured data, provided by the company.
Output distribution factors	HIGH	The output distribution factors are based on measured data provided by the company.

6.7 Waste incineration

This category of mercury source releases in North Macedonia is represented by the incineration of medical waste and informal waste/open burning.

The relevant sub-categories within this main source category are presented in Table 73.

**Table 73: Relevant sub-categories related to the main category
“Waste incineration”**

Chapter	Sub-category
6.7.1	Incineration of medical waste
6.7.2	Informal waste/open burning

6.7.1 Incineration of medical waste

The term “medical waste” encompasses both infectious and non-infectious wastes generated by a variety of medical, veterinary or research institutions and facilities (incl. hospitals, clinics, doctors' and dentists' offices, nursing homes, veterinary clinics and hospitals, medical laboratories, medical and veterinary schools and research units). The mercury content in the medical waste stream originates primarily from intentionally used mercury in discarded products and process waste (UNEP, 2023)

In the reference year (2021), there was one facility in the country for the incineration of the medical waste.

DRISLA

The incinerator is located at the landfill Drisla. The incinerator works with a capacity of 200 kg per hour and at the temperature of 750°C for the incineration of infectious, toxic solid waste materials are burnt. Between 1 to 1.5 tons of waste is burned every day (it works 12 hours daily) and heating gasoil is used as a fuel. The public enterprise DRISLA organizes the collection of medical waste from medical institutions in Skopje.

Mercury releases estimation

Activity rate

The quantity of medical waste incinerated in 2021 in DRISLA was 1,153,770 kg.

Input factor

In order to estimate the input factor, a study from 2011, that provided the air emissions of mercury from DRISLA in 2011 was taken into consideration and the same, were 3.53 kg/y¹⁸, including the mercury emissions from the used fuel, i.e. the heating gasoil in amount of 20 tons which have been already calculated in the category “Extraction and use of fuel/energy sources”. Having in mind the negligible amount of mercury emitted from the burning of the fuel, i.e. the heating gasoil, the measured emission value of 3.53 kg/y remain the same¹⁹.

According the Toolkit, Hg releases in the air are 100% if there are no air emission reduction measures implemented. However, the Toolkit suggests that small quantities of mercury may be contained in the fugitive PM emissions from ash handling operations.

The input factor (i.e. the mercury content in the medical waste) was derived by dividing the total amount of mercury output of 3.53 kg with the quantities of the incinerated medical waste in 2011 of 470 tons²⁰, which gave 7.51 g Hg/t in the incinerated medical waste.

$$IF = \frac{MO_{2011}}{AR_{2011}} = \frac{3.53}{470} = 7,51 \text{ g Hg/t} = 0.00751 \text{ kg Hg/t}$$

Where,

IF - input factor (g Hg/t)

MO₂₀₁₁ - mercury output measured in 2011 (kg Hg/y)

AR₂₀₁₁ – activity rate in 2011 (t)

This input factor was applied for the relevant activity rate for 2021 of 1,153.77 tons resulting in annual mercury input for 2021 of 8.66 kg.

The total mercury input for this sub-category is 8.66 kg for 2021.

¹⁸ Tehnolab, 2011

¹⁹ More recent data has not been identified.

²⁰ Data provided by DRISLA

Conservative approach, using default input factors was undertaken as well, and the calculations are shown in [Annex 10](#). In comparison, the semi-conservative approach of using measurements for the emissions in air, taken in 2011, shows much lower mercury input than the conservative approach with default factors given in the Toolkit.

Output distribution

The medical waste incinerator is not equipped with some filtering system for reduction of the air emissions. The Toolkit in such situation provides the distribution of the mercury releases as 100% to the air.

The entire mercury input of 8,66 kg is released to air.

The mercury input and output calculations for the subcategory “Incineration of medical waste” are presented in Table 74.

Table 74: Mercury input and output calculations for the “Incineration of medical waste” sub-category

Source	Activity rate (t/y)	Input factor (g Hg/t)	Mercury input (kg/y)	Pollution abatement system	Mercury output (kg/y) Air
DRISLA	1,153.70	7.51	8.66	/	8.66

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Incineration of medical waste” is presented in Table 75.

Table 75: Certainty assessment for the “Incineration of medical waste” sub-category

Parameter	Level	Description
Activity rate	HIGH	The quantities of the incinerated medical waste were provided by the incinerators.
Input factor	MEDIUM	The content of the mercury in the incinerated medical waste was estimated based on the measurements of the annual Hg releases in the air applying the Toolkit distribution of the

		output releases.
Output distribution factors	MEDIUM	The entire quantities are distributed in one output pathway, i.e. in the air, but as mentioned in the Toolkit, small quantities of mercury may be contained in the fugitive PM emissions from ash handling operations.

6.7.2 Informal waste/open burning

Waste incineration performed at informal conditions (including incineration in barrels, containers or on landfills, forests, grasslands) not including any kind of flue gas control, nor control on spread of residues on land, is encompassed in this sub-category. Mercury, if present in the incinerated waste, will be partially released to air and the other part will remain in the residues, potentially released to air, ground water and surface waters. Moreover, trees (especially needles and leaves) absorb mercury from the atmosphere overtime. This mercury is readily released mostly to air when the wood and other biomass are burned (UNEP, 2023).

Therefore, this source group comprises two source categories of open burning (i.e., combustion with no equipment or containment present) with the following materials:

- Waste (mainly domestic or municipal solid waste burned in official landfills, other dumps or private backyards; vehicles, buildings and factories burned in accidental fires; and construction/demolition waste) and
- Biomass (forests, savannahs, grasslands, agricultural crop residues, including sugarcane).

Mercury releases estimation

Activity rate

In North Macedonia, there are approximately 54 informal, i.e. non-compliant landfills, without any standard landfill operational practices, which results in the occurrence of accidental or intentional fires. To calculate the waste burned, the generated communal waste was taken into consideration. According the State Statistical Office, 896,060 tons of

communal waste were generated in 2021. From these, 258,770²¹ tons were deposited on the landfill Drisla. According experts opinion, one-third of the remaining quantities, i.e. 69,400.8 tons are informally incinerated.

With regards to the forest fires, 482,106 m³ is the volume of burned wood, or expressed in mass of 169,833 kg. For calculating the weight, the same parameters were used as for the biomass burned as a fuel presented in Chapter 6.1.6, except for the wood burned in forest fires, a moisture content of 120%²² was used.

Input factor

The input factor for the informal burning of waste recommended in the Toolkit for the municipal waste incineration was used within the interval of 1-10 g Hg/t of waste burned (5 g Hg/t mean value).

For the input factor for the forest fires, the recommended estimate in the Toolkit in a range between 0.007-0.07 g Hg/t of dry weight (0.03 g Hg/t dry weight as a mean value) was used.

The total mercury input for this sub-category within the range 15.07 -289.49 (74.49 as an intermediate value) kg for 2021.

Output distribution

The entire mercury input is considered to be released to air.

The entire mercury input for this sub-category within the range 15.07 -289.49 (74.49 as an intermediate value) kg is released to air.

The mercury input and output calculations for the sub-category “Informal waste/open burning” are presented in Table 76.

Table 76: Mercury input and output calculations for the informal waste/open burning

Source	Activity rate (t/y)	Input factor (g Hg/t)	Mercury input (kg/y)	Pollution abatement	Mercury output (kg/y)
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²¹ <https://drisla.mk/tretman-na-neopasen-otpad/>

²² Data provided by Makedonski šumi

				system	Air
Waste (open burning)	69,400.88	0.2-4 (1)	13.88-277.6 (69.4)	/	13.88-277.6 (69.4)
Wood (forest fires)	169,833	0.007-0.07 (0.03)	1.19-11.89 (5.09)	/	1.19-11.89 (5.09)
TOTAL:			15.07 -289.49 (74.49)		15.07 -289.49 (74.49)

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Waste incineration” is presented in Table 77.

Table 77: Certainty assessment for the “Waste incineration” sub-category

Parameter	Level	Description
Activity rate	MEDIUM	The quantities of the combusted waste/biomass were provided from the official state statistics data. Uncertainty resulted from the estimated quantities of burned waste/biomass and approximate values for the density and the moisture content.
Input factor	LOW	The content of the mercury in the waste and the biomass was taken from the default Toolkit values which are only indicative ones.
Output distribution factors	MEDIUM	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones, considering only emissions to air.

Summary of the category

Within the category “Waste incineration”, the subcategory with the highest representation is “Informal waste/open burning” (see Table 78)

Table 78: Summary of the input and output calculations for the main source category “Waste incineration” for 2021

Sub-category	Mercury input (kg)	Mercury output (kg) Air
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Incineration of medical waste	8.66	8.66
Informal waste/open burning	15.07 -289.49 (74.49)	15.07 -289.49 (74.49)
TOTAL:	23.73-298.15 (83.15)	23.73-298.15 (83.15)

6.8 Waste deposition/landfilling and waste water treatment

This category of mercury source releases in the Republic of North Macedonia is represented by the controlled landfills/deposits, informal dumping of general waste and waste water system/treatment.

The relevant sub-categories within this main source category are presented in Table 79.

**Table 79: Relevant sub-categories related to the main category
“Waste deposition/landfilling and waste water treatment”**

Chapter	Sub-category
6.8.1	Controlled landfills/deposits
6.8.2	Informal dumping of general waste
6.8.3	Waste water system/treatment

6.8.1 Controlled landfills/deposits

Mercury content in the general waste stream originates from three main groups: 1) intentionally used mercury in spent products and process waste; 2) natural mercury impurities in bulk materials (plastics, tin cans, etc.) and minerals, and; 3) mercury as an anthropogenic trace pollutant in bulk materials (UNEP, 2023)).

There is one sanitary landfill in the country.

DRISLA

DRISLA landfill is the only sanitary landfill in the country and is located in the south-eastern part of the capital city of Skopje at a distance of 14 km from the city centre. It covers an area of 76 ha with a project capacity of 26 million m³ of deposited waste. The purification of the waste takes place as a result of their bio-thermal anaerobic decomposition by separating the filtrate (it contains increased amounts of filtrate, chlorides and sulphates), gases (methane, hydrogen, hydrogen sulphide) and a certain amount of heat. The amount of the filtrate varies from 10 to 15% of total rainfalls, but it is dangerous in a sanitary sense, since its pollution is 5 to 10 times greater than the pollution of the domestic waters. The received waste is compressed, covered with inert material and then with humus. The leachate water from the landfill is collected in two concrete basins and reintroduced back to the landfill together with the generated sludge.

Mercury releases estimation

Activity rate

The quantities of household waste deposited in the landfill for 2021 were 258,770 tons, while the total weight of the deposited waste by the end of 2021 was 4,549,290 ²³tons.

Input factor

Since there were no indications available on the mercury concentrations in municipal waste, estimations were made using the default input factors given in the Toolkit in a range between 0.2-4 g Hg/t of waste deposited, (1 g Hg/t). The low-end input factor is expected to be relevant for a situation where substantial parts of the waste products with high mercury concentration (thermometers, batteries, dental amalgam wastes, switches etc.) have been sorted out of the waste for separate treatment and will therefore be present in lower numbers in the municipal waste. The high-end input factor is expected to be relevant for situations where no such sorting takes place and most of the product waste with high mercury concentrations is therefore present in the municipal waste (UNEP, 2023).

The total mercury input for this sub-category within the range 51.75-1,035.08 (258.77) kg for 2021.

Output distribution

The largest "release" of mercury is the actual accumulation of waste to land. However, in the latest version of the Toolkit, emissions to air and via leachate water are calculated only. The limited data available indicate that mercury air emissions from landfills may be relatively modest compared to major mercury sources such as coal fired power plants, etc. However, they are still relevant mercury release source, the Toolkit set artificial output factors for the mercury releases to air as 1% of the waste landfilled and 0,01% of the landfilled waste to the water (via leachate).

The mercury releases are distributed as 0.52-10.35 (2.59 as an intermediate value) kg to air and 0.01-0.1 (0.03 as an intermediate value) kg to water.

²³ <https://drisla.mk/wp-content/uploads/2023/06/jpg-neopasen.png>

The mercury input and output calculations for the sub-category “Controlled landfills/deposits” are presented in **Error! Reference source not found.** 80.

Table 80. Mercury input and output calculations for the controlled landfills/deposits

Source	Activity rate (t/y)	Input factor (g Hg/t)	Mercury input (kg/y)	Pollution abatement system	Mercury output (kg/y)	
					Air	Water
DRISLA	258,770	0.2-4 (1)	51.75-1,035.08 (258.77)	/	0.52-10.35 (2.59)	0.01-0.1 (0.03)

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Controlled landfills/deposits” is presented in **Error! Reference source not found.** Table 81.

Table 81: Certainty assessment for the “Controlled landfills/deposits” sub-category

Parameter	Level	Description
Activity rate	HIGH	The quantities of the landfilled waste were provided by the sanitary landfill
Input factor	LOW	The content of the mercury in the waste was taken from the default Toolkit values which are only indicative ones.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

6.8.2 Informal dumping of general waste

Informal dumping of waste is defined as waste dumping undertaken under informal conditions with no safeguards to minimise releases of pollutants to the surroundings. If mercury is present in the waste, it represents a potential for mercury releases to soil, air, ground water and surface waters. This waste disposal method may pose an immediate risk for

the local community in which it takes place, because mercury (and other contaminants) may cause contamination of the local ground water (UNEP, 2023).

As stated above, in North Macedonia, there are 54 municipal landfills categorized, according to the assessment of their environmental risk, as informal and non-compliant where waste (including hazardous components) is deposited on open dumps with no engineered containment or pollution control techniques.

Mercury releases estimation

Activity rate

According the data provided by the State Statistical Office, the quantities of the generated waste in 2021 were 896,060 tons, out of which it is assumed that 99.8% are landfilled. If we exclude the quantities of the waste that are deposited in the sanitary landfill DRISLA of 258,770 tons, as well as the quantities of informally incinerated waste, then the quantities of the informal dumped waste for 2021 were 567,890 tons.

Input factor

The input factor used for the sub-category “Controlled landfills/deposits”, with a range between 0.2-4 g Hg/t of waste deposited (1 g Hg/t as mean value), was used considering that there are likely common characteristics of the wastes that are deposited in the both types of landfills. Similar to the sub-category “Controlled landfills/deposits”, the usage of the lower/upper end input factors depends on the management practices related to the product waste with high mercury concentrations.

The total mercury input for this sub-category within the range 113.58-2,271.56 (567.9 as an intermediate value) kg for 2021.

Output distribution

The Toolkit provides output distribution factors, but these factors should serve only as a signal that these releases may be significant. These default factors are formed on a basic assumption that most of the mercury is released to land, while minor fractions may be lost to air via evaporation, and to water via surface run-off of precipitation. Therefore, the mercury input is distributed to the following pathways: land 80%, air 10% and water 10%.

The mercury releases are distributed as 11.36-227.16 (56.79 as an intermediate value) kg to air, 11.36-227.16 (56.79 as an intermediate value) kg to water and 90.86-1,817.25 (454.31) kg to land.

The mercury input and output calculations for the sub-category “Informal dumping of general waste” are presented in Table 82.

Table 82: Mercury input and output calculations for the informal dumping of general waste

Source	Activity rate (t/y)	Input factor (g Hg/t)	Mercury input (kg/y)	Pollution abatement system	Mercury output (kg/y)		
					Air	Water	Land
Informal dump yards	567,890	0.2-4 (1)	113.58-2,271.56 (567.9)	/	11.36-227.16 (56.79)	11.36-227.16 (56.79)	90.86-1,817.25 (454.31)

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Informal dumping of general waste” is presented in Table 83.

Table 83: Certainty assessment for the “Informal dumping of general waste” sub-category

Parameter	Level	Description
Activity rate	MEDIUM	The quantities of the landfilled waste were provided by the State Statistical Office, based on estimated amount on communal waste annually generated per capita and the estimated waste collection rate.
Input factor	LOW	The content of the mercury in the waste was taken from the default Toolkit values which are only indicative ones.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

6.8.3 Waste water system/treatment

In general, waste water can contain mercury from two source groups: 1) intentionally used mercury in products and processes (such as from dental amalgams, spillage from thermometers and other devices, and industrial discharges); and 2) atmospheric mercury washed out by precipitation that goes into waste water systems (originating from both anthropogenic and natural sources). As such, waste water treatment is an intermediate mercury release source where mercury inputs from original mercury contamination is

distributed on the output pathways water (with treated water), land (through the application of sludge as fertiliser) and air (through sludge incineration and sludge application). In addition, some sludge is disposed of in landfills (UNEP, 2023)

Mercury releases estimation

Activity rate

In 2021, 19²⁴ Waste Water Treatment Plants (WWTP) were operational, covering 38%²⁵ of the entire quantity of communal waste water generated in the country. Namely, the total amount of the generated waste water quantities for 2021 are estimated at 102,648,000 m³, out of which 63,620,000 m³ were directly released without any treatment, whereas 39,028,000 m³ to mechanical and biological treatment with no land sludge application.

Input factor

Chemical analysis of waste water samples taken from 5 operational waste water treatment plants (Novo Selo/Skopje, Kumanovo, Radovis, Kocani and Strumica) were made. The results from the analysis are beyond the measurement threshold, i.e. <0.0538. The sludge was also analysed, with concentrations of mercury ranging from 0.322-0.605mg Hg/kg. Upon analysis and calculations, as shown below, the input factor of 0.582 was derived.

The calculations to derive the input factor, are as follows²⁶

$$MQ_{WW} = WW_{NS} \times MC_{WWNS} + WW_K \times MC_{WWK} + WW_{KO} \times MC_{WWKO} + WW_{ST} \times MC_{WWST}$$

$$MQ_{WW} = 0.72 \text{ kg Hg/y}$$

$$MQ_S = SQ_{NS} \times MC_{SNS} + SQ_K \times MC_{SK} + SQ_{KO} \times MC_{SKO} + SQ_{ST} \times MC_{SST}$$

$$MQ_S = 14.89 \text{ kgHg/y}$$

$$IF_{ww} = \frac{(MQ_{WW} + MQ_S)}{\Sigma WW} = 0.582 \text{ mg Hg/m}^3$$

Where,

MQ_{ww} – mercury quantity in waste water (kg Hg/y)

WW_{NS} – waste water in Novo Selo (m³)

²⁴ Energy and water services regulatory commission of the Republic of North Macedonia, 2022

²⁵ State Statistical Office, 2022

²⁶ It has to be noted, as the quantity of treated waste water from the WWTP in Radovish was not reported, this was not taken into account for performing the calculations

MC_{WWNS} – mercury concentration in waste water in Novo Selo ($\mu\text{g/l}$)

WW_K – waste water in Kumanovo (m^3)

MC_{WWK} – mercury concentration in waste water in Kumanovo ($\mu\text{g/l}$)

WW_{KO} – waste water in Kocani (m^3)

MC_{WWKO} – mercury concentration in waste water in Kocani ($\mu\text{g/l}$)

WW_{ST} – waste water in Strumica (m^3)

MC_{WWST} – mercury concentration in waste water in Strumica ($\mu\text{g/l}$)

MQ_S – mercury quantity in sludge

SQ_{NS} – sludge quantity in Novo Selo (m^3)

MC_{SNS} – mercury concentration in sludge in Novo Selo (mg/kg)

SQ_K – sludge quantity in Kumanovo (m^3)

MC_{SK} – mercury concentration in sludge in Kumanovo (mg/kg)

SQ_{KO} – sludge quantity in Kocani (m^3)

MC_{SKO} – mercury concentration in sludge in Kocani (mg/kg)

SQ_{ST} – sludge quantity in Strumica (m^3)

MC_{SST} – mercury concentration in sludge in Strumica (mg/kg)

IF_{WW} – input factor for waste water

This input factor was considered for all of the waste water quantities (both treated and waste water released without any treatment).

The total mercury input for this sub-category is 59.74 kg for 2021.

Output distribution

The Toolkit provides output distribution factors and pathways based on different waste water management practices implemented, i.e. the type of treatment, whether waste water was treated before discharging into waterways or directly discharged in the aquatic environment. For the waste water that is not being treated the entire output is to water. However, for the

treated water, taking into consideration the laboratory results (from the sludge) and from the common practices shared by the waste water plants with regards to the sludge, it was decided to use the following distributions: 10% to water, 80% to general waste and 10% to sector specific disposal.

The total mercury releases from treated and waste water not treated are distributed as 39.3 kg to water 18.17 kg to general waste and 2.72 kg to sector specific.

The mercury input and output calculations for the sub-category “Waste water system/treatment” are presented in Table 84.

Table 84: Mercury input and output calculations for the waste water system/treatment for 2021

Source	Activity rate	Input factor	Mercury input	Mercury output (kg/y)		
	(m ³)	(mg Hg/m ³)	(kg)	Water	General waste	Sector specific
Direct release	63,620,000	0.582	37.03	37.03		
Mechanical and biological treatment; no land application of sludge	39,028,000	0.582	22.71	2.27	18.17	2.27
TOTAL:	102,648,000		59.74	39.30	18.17	2.27

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Waste water system/treatment” is presented in Table 85.

Table 85: Certainty assessment for the “Waste water system/treatment” sub-category

Parameter	Level	Description
Activity rate	MEDIUM	The quantities of the generated waste water were provided by the State Statistic Office, based on the estimated amounts on communal waste water annually generated per capita. The quantities of the treated waste waters were provided directly by the WWTP.
Input factor	MEDIUM	The content of the mercury in the waste water was calculated from the results of the laboratory analysis of the waste water and sludge

Output distribution factors	MEDIUM	The output distribution factors are based on the laboratory results and shared common practices among WWTP
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Summary of the category

Within the category “Waste deposition/landfilling and waste water treatment”, the sub-category with the highest representation is “Informal dumping of general waste”, followed by “Controlled landfills/deposits”, shown on Table 86.

Table 86: Summary of the input and output calculations for the main source category “Waste deposition/landfilling and waste water treatment” for 2021

Sub-category	Mercury input	Mercury output (kg)				Sector specific treatment/disposal
	(kg)	Air	Water	Land	General waste	
Controlled landfills/deposits	51.75-1,035.08 (258.77)	0.52-10.35 (2.59)	0.01-0.1 (0.03)	0	0	0
Informal dumping of general waste	113.58-2271.56 (567.9)	11.36-227.16 (56.79)	11.36-227.16 (56.79)	90.86-1,817.25 (454.31)	0	0
Waste water system/treatment	59.74	0	39.30	0	18.17	2.27
TOTAL:	225.34-3,366.38 (886.41)	11.88-237.51(59.38)	50.67-266,56 (96.12)	90.86-1,817.25 (454.31)	18.17	2.27

6.9 Cremation and cemeteries

This category oversees cemeteries and crematories, performing the calculation on corpses buried/cremated. In North Macedonia, this mercury source category is represented by the burial of the human corpses at cemeteries, as no crematoria exists.

6.9.1 Cemeteries

Mercury releases estimation

Activity rate

The mercury releases from this source comes from the mercury present in the corpses, mainly as a result of mercury in dental amalgam fillings, which will be released to the soil at the cemetery.

According the State statistical Office, the number of human corpses buried in 2021 was 28,516.

Input factor

Since there was no national data on grams of mercury (in amalgam fillings) per corpse buried, the default input factor suggested in the Toolkit, with a range between 1-4 g Hg per corpse, and the mean value of 2,5 g Hg per corpse was used.

The total mercury input for this sub-category is 28.52-114.06 (71.29 as an intermediate value) kg for 2021.

Output factor

The only output pathway is to land.

The entire mercury input, of 28.52-114.06 (71.29 as an intermediate value) kg is distributed to land.

The mercury input and output calculations for the sub-category “Cemeteries” are presented in Table 87.

Table 87: Mercury input and output calculations for the “Cemeteries” for 2021

Source	Activity rate	Input factor	Mercury input	Pollution abatement	Mercury output (kg/y)
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	(corpses/y)	(g Hg/corpse)	(kg/y)	system	Land
Cemetery	28,516	1-4 (2.5)	28.52-114.06 (71.29)	/	28.52-114.06 (71.29)

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the sub-category “Cemeteries” is presented in Table 88.

Table 88: Certainty assessment for the “Cemeteries” sub-category

Parameter	Level	Description
Activity rate	HIGH	The number of buried human corpses was provided by the State Statistical Office.
Input factor	LOW	The content of the mercury in the corpse was taken from the default Toolkit values which are only indicative ones.
Output distribution factors	HIGH	The entire quantities are distributed in one output pathway, i.e. in the land.

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ANNEX 1: List of samples prepared for analysis

Table 89. List of samples prepared for analysis in accredited laboratory

No.	Sample/Mark	Location/ mine/smelter, g
1	Coal	Suvodol
2	Coal	Gneotino
3	Coal	Oslomej
4	Coal	imported coal
5	Fly ash	REK Bitola
6	Fly ash	REK Oslomej
7	Lead and zinc ore	Sasa
8	Lead and zinc ore	Zletovo
9	Lead and zinc ore	Toranica
10	Copper ore	Buchim
11	Lead and zinc flotation tailings	Sasa
12	Lead and zinc flotation tailings	Zletovo
13	Lead and zinc flotation tailings	Toranica
14	Copper flotation tailings	Buchim
15	Lead concentrate	Sasa
16	Lead concentrate	Zletovo
17	Lead concentrate	Toranica
18	Zinc concentrate	Sasa
19	Zinc concentrate	Zletovo
20	Zinc concentrate	Toranica
21	Copper concentrate	Buchim
22	Lead and zinc smelter slag	Veles
23	Ferrochromium slag	Jugohrom
24	Lead and zinc flotation tailing	Probishtip
25	Arsenic-antimony flotation tailing	Lojane
26	Arsenic concentrate	Lojane
27	Filter dust from a cement factory – 3	Usje, Skopje
28	Filter dust from a cement factory – 4	Usje, Skopje
29	Marl - 1	Usje, Skopje
30	Marl - 2	Usje, Skopje
31	Limestone	Usje, Skopje
32	Cement	Usje, Skopje
33	Sludge from WWTPs	Novo Selo
34	Sludge from WWTPs	Kumanovo

No.	Sample/Mark	Location/ mine/smelter, g
35	Sludge from WWTPs	Kochani
36	Sludge From WWTPS	Radovish
37	Sludge from WWTPs	Strumica
38	Waste water from WWTPs	Novo Selo
39	Waste water from WWTPs	Kumanovo
40	Waste water from WWTPs	Kochani
41	Waste water From WWTPS	Radovish
42	Waste water from WWTPs	Strumica
43	Filter dust from steel production	Makstil

ANNEX 2: Laboratory results

Here below, Table 90, the list of the results is given from the analysis of the samples.

Table 90. Laboratory results from analysis of the samples taken from pre-defined locations

No	Sample	Location/ mine/smelter, g	Sample amount, g	% DW	% Moisture	mg/kg DW	mg/kg FW	(1-%M/100)
1	Coal	Suvodol	40.96	90.1	9.9	0.062	0.055862	0.901
2	Coal	Gneotino	52.44	96.3	3.7	0.04	0.038520	0.963
3	Coal	Oslomej	46.61	86.1	13.9	0.269	0.231609	0.861
4	Coal	imported coal	42.39	93.5	6.5	0.078	0.072930	0.935
5	Fly ash	REK Bitola	51.90	99.7	0.3	0.044	0.043868	0.997
6	Fly ash	REK Oslomej	45.94	98	2	0.033	0.03234	0.98
7	Lead and zinc ore	Sasa	45.57	99.8	0.2	0.017	0.016966	0.998
8	Lead and zinc ore	Zletovo	56.55	99.6	0.4	1.2	1.1952	0.996
9	Lead and zinc ore	Toranica	59.95	99.7	0.3	0.01	0.00997	0.997
10	Copper ore	Buchim	53.28	98.9	1.1	0.033	0.032637	0.989
11	Lead and zinc flotation tailings	Sasa	50.00	99.8	0.2	<0.01		0.998
12	Lead and zinc flotation tailings	Zletovo	51.93	99.3	0.7	0.198	0.196614	0.993
13	Lead and zinc flotation tailings	Toranica	57.06	99.6	0.4	<0.01		0.996
14	Copper flotation tailings	Buchim	53.28	98.9	1.1	0.012	0.011868	0.989
15	Lead concentrate	Sasa	59.64	99.7	0.3	0.037	0.036889	0.997
16	Lead concentrate	Zletovo	56.68	99.7	0.3	6.27	6.25119	0.997
17	Lead concentrate	Toranica	45.79	99.8	0.2	0.013	0.012974	0.998
18	Zinc concentrate	Sasa	50.82	99.8	0.2	0.276	0.275448	0.998

No	Sample	Location/ mine/smelter, g	Sample amount, g	% DW	% Moisture	mg/kg DW	mg/kg FW	(1-%M/100)
19	Zinc concentrate	Zletovo	60.75	99.9	0.1	18.4	18.3816	0.999
20	Zinc concentrate	Toranica	60.14	99.8	0.2	0.01	0.00998	0.998
21	Copper concentrate	Buchim	60.63	99.8	0.2	1.36	1.35728	0.998
22	Lead and zinc smelter slag	Veles	52.36	99.8	0.2	0.117	0.116766	0.998
23	Ferrochromium slag	Jugohrom	52.78	97.5	2.5	0.027	0.026325	0.975
24	Lead and zinc flotation tailing	Probishtip	51.10	98.7	1.3	0.208	0.205296	0.987
25	Arsenic-antimony flotation tailing	Lojane	54.57	97.7	2.3	0.025	0.024425	0.977
26	Arsenic concentrate	Lojane	55.25	98.1	1.9	0.417	0.409077	0.981
27	Filter dust from a cement factory – 3	Usje, Skopje	39.67	99.6	0.4	0.520	0.51792	0.996
28	Filter dust from a cement factory – 4	Usje, Skopje	37.62	99.2	0.8	0.538	0.533696	0.992
29	Marl - 1	Usje, Skopje	50.94	99.2	0.8	0.018	0.017856	0.992
30	Marl - 2	Usje, Skopje	50.95	98.4	1.6	0.034	0.033456	0.984
31	Limestone	Usje, Skopje	56.97	99.8	0.2	0.028	0.027944	0.998
32	Cement	Usje, Skopje	54.56	99.7	0.3	<0.01		0.997
33	Sludge from WWTPs	Novo Selo	39.44	90	10	0.322	0.2898	0.9
34	Sludge from WWTPs	Kumanovo	40.27	89	11	0.605	0.53845	0.89
35	Sludge from WWTPs	Kochani	49.60	93	7	0.409	0.38037	0.93
36	Sludge From WWTPS	Radovish	41.78	90	10	0.356	0.3204	0.9
37	Sludge from WWTPs	Strumica	39.90	85.9	14.1	0.546	0.469014	0.859
38	Waste water from WWTPs	Novo Selo	35 ml		µg/L	<0.0538	<0.0269	mg/m3
39	Waste water from WWTPs	Kumanovo	35 ml		µg/L	<0.0538	<0.0269	mg/m3
40	Waste water from WWTPs	Kochani	35 ml		µg/L	<0.0538	<0.0269	mg/m3

No	Sample	Location/ mine/smelter, g	Sample amount, g	% DW	% Moisture	mg/kg DW	mg/kg FW	(1-%M/100)
41	Waste water From WWTPS	Radovich	35 ml		µg/L	<0.0538	<0.0269	mg/m3
42	Waste water from WWTPs	Strumica	35 ml		µg/L	<0.0538	<0.0269	mg/m3
43	Filter dust from steel production	Makstil	36.31	99.3	0.7	5.84	5.79912	0.993

Certificates of Analysis



CERTIFICATE OF ANALYSIS

Work Order	: PR2391932	Issue Date	: 24-Aug-2023
Customer	: DEKONS-EMA LTD Skopje	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Mrs. Menka Spirovska	Contact	: Client Service
Address	: Stefan Jakimov Dedov 4-1/10 4030007641649 1000 Skopje	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: m.spirovska@ema.com.mk	E-mail	: customer.support@alsglobal.com
Telephone	: ---	Telephone	: +420 226 226 228
Project	: Minamata convention project	Page	: 1 of 3
Order number	: ---	Date Samples Received	: 14-Aug-2023
		Quote number	: PR2023DEKEM-MK0002 (CZ-200-23-0590)
Site	: ---	Date of test	: 16-Aug-2023 - 24-Aug-2023
Sampled by	: customer	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.

The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.

Responsible for accuracy

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories

Lubomír Pokorný

Position

Country Manager



The company is certified according to ČSN EN ISO 14001 (Environmental management systems) and ČSN ISO 45001 (Occupational health and safety management systems)



Analytical Results

Sub-Matrix: SOIL				Client sample ID		1-Coal-Suvodol		2-Coal-Gneotino		3-Coal-Oslomej	
				Laboratory sample ID		PR2391932001		PR2391932002		PR2391932003	
				Client sampling date / time		[14-Aug-2023]		[14-Aug-2023]		[14-Aug-2023]	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU		
Physical Parameters											
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	90.1	± 5.0%	96.3	± 5.0%	86.1	± 5.0%		
Extractable Metals / Major Cations											
Mercury	S-HG-AFSHB	0.010	mg/kg DW	0.062	± 20.0%	0.040	± 20.0%	0.269	± 20.0%		

Sub-Matrix: SOIL			Client sample ID		4-Coal-Imported-coal		5-Fly ash-REKBitola		6-Flyash-REKOslomej	
			Laboratory sample ID		PR2391932004		PR2391932005		PR2391932006	
			Client sampling date / time		[14-Aug-2023]		[14-Aug-2023]		[14-Aug-2023]	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU	
Physical Parameters										
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	93.5	± 5.0%	99.7	± 5.0%	98.0	± 5.0%	
Extractable Metals / Major Cations										
Mercury	S-HG-AFSHB	0.010	mg/kg DW	0.078	± 20.0%	0.044	± 20.0%	0.033	± 20.0%	

Sub-Matrix: SOIL			Client sample ID		7-Pb-Zn ore-Sasa		8-Pb-Zn ore-Zletovo		9-Pb-Zn ore-Toraniva	
			Laboratory sample ID		PR2391932007		PR2391932008		PR2391932009	
			Client sampling date / time		[14-Aug-2023]		[14-Aug-2023]		[14-Aug-2023]	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU	
Physical Parameters										
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	99.8	± 5.0%	99.6	± 5.0%	99.7	± 5.0%	
Extractable Metals / Major Cations										
Mercury	S-HG-AFSHB	0.010	mg/kg DW	0.017	± 20.0%	1.20	± 20.0%	0.010	± 20.0%	

Sub-Matrix: SOIL			Client sample ID		10-Copper ore-Buchim		11-Pb-Zn fotation-tailings-Sa sa		----	
			Laboratory sample ID		PR2391932010		PR2391932011		---	
			Client sampling date / time		[14-Aug-2023]		[14-Aug-2023]		----	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU	
Physical Parameters										
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	98.9	± 5.0%	99.8	± 5.0%	----	---	
Extractable Metals / Major Cations										
Mercury	S-HG-AFSHB	0.010	mg/kg DW	0.033	± 20.0%	<0.010	---	----	---	

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor $k = 2$, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	Method Descriptions
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
S-DRY-GRCI	CZ_SOP_D06_01_045 (CSN ISO 11485, CSN EN 12880, CSN EN 14346:2007), CZ_SOP_D06_07_048 (CSN ISO 11485, CSN EN 12880, CSN EN 14346:2007, CSN 46 5735) Determination of dry matter by gravimetry and determination of moisture by calculation from measured values.
S-HG-AFSHB	CZ_SOP_D06_02_096 (CSN EN ISO 17852, ISO 16772:2004) - Determination of Mercury by Fluorescence Spectrometry. Sample was homogenized and mineralized by aqua regia prior to analysis.
Preparation Methods	Method Descriptions

Issue Date : 24-Aug-2023
 Page : 3 of 3
 Work Order : PR2391932
 Customer : DEKONS-EMA LTD Skopje



Preparation Methods	Method Descriptions
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
*S-PPHOM2	Drying and sieving of sample on the grain size < 2 mm

The symbol "*" for the method indicates a test outside the scope of accreditation of the laboratory or subcontractor. If the UNICO-SUB code is stated in the method table, this only informs that the tests have been performed by a subcontractor and the results are given in an annex to the test report, including information on test accreditation. If the lab used for matrix outside the scope of accreditation or non-standard sample matrix procedure specified in the accredited method and issues non-accredited results, this fact is stated on the title page of this protocol in the section "Notes". If the test report shows the results of subcontracting, the place of performance of the test is outside the laboratories of ALS Czech Republic, s.r.o.

The method for calculating of the summation parameters is available on request in the customer service.



CERTIFICATE OF ANALYSIS

Work Order	: PR2391933	Issue Date	: 24-Aug-2023
Customer	: DEKONS-EMA LTD Skopje	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Mrs. Menka Spirovska	Contact	: Client Service
Address	: Stefan Jakimov Dedov 4-1/10 4030007641649 1000 Skopje	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: m.spirovska@ema.com.mk	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Project	: Minamata convention project	Page	: 1 of 3
Order number	: ----	Date Samples	: 14-Aug-2023
		Received	
		Quote number	: PR2023DEKEM-MK0002 (CZ-200-23-0590)
Site	: ----	Date of test	: 16-Aug-2023 - 24-Aug-2023
Sampled by	: customer	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

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The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.

Responsible for accuracy

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories

Lubomír Pokorný

Position

Country Manager



The company is certified according to ČSN EN ISO 14001 (Environmental management systems) and ČSN ISO 45001 (Occupational health and safety management systems)

Issue Date : 24-Aug-2023
Page : 2 of 3
Work Order : PR2391933
Customer : DEKONS-EMA LTD Skopje



Analytical Results

Sub-Matrix: SOIL			Client sample ID		12-Pb-Zn flotation tailings-Zletovo		13-Pb-Zn flotation tailings-Toranica		14-Coper flotation tailings-Buchim	
					Laboratory sample ID		PR2391933001		PR2391933002	
			Client sampling date / time		[14-Aug-2023]		[14-Aug-2023]		[14-Aug-2023]	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU	
Physical Parameters										
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	99.3	± 5.0%	99.6	± 5.0%	98.9	± 5.0%	
Extractable Metals / Major Cations										
Mercury	S-HG-AFSHB	0.010	mg/kg DW	0.198	± 20.0%	<0.010	----	0.012	± 20.0%	

Sub-Matrix: SOIL			Client sample ID		15-Lead concentrate-Sasa		16-Lead concentrate-Zletov o		17-Lead concentrate-Torani ca	
			Laboratory sample ID		PR2391933004		PR2391933005		PR2391933006	
			Client sampling date / time		[14-Aug-2023]		[14-Aug-2023]		[14-Aug-2023]	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU	
Physical Parameters										
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	99.7	± 5.0%	99.8	± 5.0%	99.8	± 5.0%	
Extractable Metals / Major Cations										
Mercury	S-HG-AFSHB	0.010	mg/kg DW	0.037	± 20.0%	6.27	± 20.0%	0.013	± 20.0%	

Sub-Matrix: SOIL				Client sample ID		18-Zinc concentrate-Sasa		19-Zinc concentrate-Zletov o		20-Zinc concentrate-Toranica	
				Laboratory sample ID		PR2391933007		PR2391933008		PR2391933009	
				Client sampling date / time		[14-Aug-2023]		[14-Aug-2023]		[14-Aug-2023]	
Parameter		Method		LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters											
Dry matter @ 105°C		S-DRY-GRCI		0.10	%	99.8	± 5.0%	99.9	± 5.0%	99.8	± 5.0%
Extractable Metals / Major Cations											
Mercury		S-HG-AFSHB		0.010	mg/kg DW	0.276	± 20.0%	18.4	± 20.0%	0.010	± 20.0%

Sub-Matrix: SOIL				Client sample ID		21-Coper concentrate-Buchi m		22-Pb-Zn smelter slag-Veles		----	
				Laboratory sample ID		PR2391933010		PR2391933011		----	
				Client sampling date / time		[14-Aug-2023]		[14-Aug-2023]		----	
Parameter		Method		LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters											
Dry matter @ 105°C		S-DRY-GRCI		0.10	%	99.8	± 5.0%	99.8	± 5.0%	----	----
Extractable Metals / Major Cations											
Mercury		S-HG-AFSHB		0.010	mg/kg DW	1.36	± 20.0%	0.117	± 20.0%	----	----

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor k = 2, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	Method Descriptions
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
S-DRY-GRCI	CZ_SOP_D06_01_045 (CSN ISO 11465, CSN EN 12880, CSN EN 14346:2007), CZ_SOP_D06_07_046 (CSN ISO 11465, CSN EN 12880, CSN EN 14346:2007, CSN 46 5735) Determination of dry matter by gravimetry and determination of moisture by calculation from measured values.

Issue Date : 24-Aug-2023
Page : 3 of 3
Work Order : PR2391933
Customer : DEKONS-EMA LTD Skopje



Analytical Methods	Method Descriptions
S-HG-AFSHB	CZ_SOP_D06_02_096 (CSN EN ISO 17852, ISO 16772:2004) - Determination of Mercury by Fluorescence Spectrometry. Sample was homogenized and mineralized by aqua regia prior to analysis.
Preparation Methods	Method Descriptions
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
* S-PPHOM2	Drying and sieving of sample on the grain size < 2 mm

The symbol "*" for the method indicates a test outside the scope of accreditation of the laboratory or subcontractor. If the UNICO-SUB code is stated in the method table, this only informs that the tests have been performed by a subcontractor and the results are given in an annex to the test report, including information on test accreditation. If the lab used for matrix outside the scope of accreditation or non-standard sample matrix procedure specified in the accredited method and issues non-accredited results, this fact is stated on the title page of this protocol in the section "Notes". If the test report shows the results of subcontracting, the place of performance of the test is outside the laboratories of ALS Czech Republic, s.r.o.

The method for calculating of the summation parameters is available on request in the customer service.



CERTIFICATE OF ANALYSIS

Work Order	: PR2391934	Issue Date	: 24-Aug-2023
Customer	: DEKONS-EMA LTD Skopje	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Mrs. Menka Spirovska	Contact	: Client Service
Address	: Stefan Jakimov Dedov 4-1/10 4030007641649 1000 Skopje	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: m.spirovska@ema.com.mk	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Project	: Minamata convention project	Page	: 1 of 3
Order number	: ----	Date Samples	: 14-Aug-2023
		Received	
		Quote number	: PR2023DEKEM-MK0002 (CZ-200-23-0590)
Site	: ----	Date of test	: 16-Aug-2023 - 24-Aug-2023
Sampled by	: customer	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.

The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.

Sample(s) PR2391934/001, method S-HG-AFSHB - results are the average of triplicate determination - non-homogeneous sample(s).

Responsible for accuracy

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories

Lubomír Pokorný

Position

Country Manager



The company is certified according to ČSN EN ISO 14001 (Environmental management systems) and ČSN ISO 45001 (Occupational health and safety management systems)



Analytical Results

Sub-Matrix: SOIL			Client sample ID	23-Ferrochromium slag-Jugohrom	24-Pb-Zn flotation tallings-Probishtip	25-As-Sb flotation tallings-Lojane			
			Laboratory sample ID	PR2391934001	PR2391934002	PR2391934003			
			Client sampling date / time	[14-Aug-2023]	[14-Aug-2023]	[14-Aug-2023]			
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	97.5	± 5.0%	98.9	± 5.0%	97.7	± 5.0%
Extractable Metals / Major Cations									
Mercury	S-HG-AFSHB	0.010	mg/kg DW	0.027	± 20.0%	0.208	± 20.0%	0.025	± 20.0%

Sub-Matrix: SOIL			Client sample ID	26-Arsenic concentrate-Lojane	27-Filter dust-3 from Cement factory-Usje	28-Filter-dust-4 from Cementsfactory-Usje			
			Laboratory sample ID	PR2391934004	PR2391934005	PR2391934006			
			Client sampling date / time	[14-Aug-2023]	[14-Aug-2023]	[14-Aug-2023]			
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	98.1	± 5.0%	99.6	± 5.0%	99.2	± 5.0%
Extractable Metals / Major Cations									
Mercury	S-HG-AFSHB	0.010	mg/kg DW	0.417	± 20.0%	0.520	± 20.0%	0.538	± 20.0%

Sub-Matrix: SOIL			Client sample ID	29-Marl-1 from Cement factory-Usje	30-Marl-2 from cement factory-Usje	31-Limestone from Cement factory-Usje			
			Laboratory sample ID	PR2391934007	PR2391934008	PR2391934009			
			Client sampling date / time	[14-Aug-2023]	[14-Aug-2023]	[14-Aug-2023]			
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	99.2	± 5.0%	98.4	± 5.0%	99.8	± 5.0%
Extractable Metals / Major Cations									
Mercury	S-HG-AFSHB	0.010	mg/kg DW	0.018	± 20.0%	0.034	± 20.0%	0.028	± 20.0%

Sub-Matrix: SOIL			Client sample ID	32-Cement from Cement factory-Usje	33-Filter dust-Makstil	----			
			Laboratory sample ID	PR2391934010	PR2391934011	----			
			Client sampling date / time	[14-Aug-2023]	[14-Aug-2023]	----			
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	99.7	± 5.0%	99.3	± 5.0%	----	---
Extractable Metals / Major Cations									
Mercury	S-HG-AFSHB	0.010	mg/kg DW	<0.010	----	5.84	± 20.0%	----	---

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor $k = 2$, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	Method Descriptions
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	

Issue Date : 24-Aug-2023
Page : 3 of 3
Work Order : PR2391934
Customer : DEKONS-EMA LTD Skopje



<i>Analytical Methods</i>	<i>Method Descriptions</i>
S-DRY-GRCI	CZ_SOP_D06_01_045 (CSN ISO 11465, CSN EN 12880, CSN EN 14346:2007), CZ_SOP_D06_07_046 (CSN ISO 11465, CSN EN 12880, CSN EN 14346:2007, CSN 46 5735) Determination of dry matter by gravimetry and determination of moisture by calculation from measured values.
S-HG-AFSHB	CZ_SOP_D06_02_096 (CSN EN ISO 17852, ISO 16772:2004) - Determination of Mercury by Fluorescence Spectrometry. Sample was homogenized and mineralized by aqua regia prior to analysis.
<i>Preparation Methods</i>	<i>Method Descriptions</i>
<i>Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00</i>	
*S-PPHOM2	Drying and sieving of sample on the grain size < 2 mm

The symbol "*" for the method indicates a test outside the scope of accreditation of the laboratory or subcontractor. If the UNICO-SUB code is stated in the method table, this only informs that the tests have been performed by a subcontractor and the results are given in an annex to the test report, including information on test accreditation. If the lab used for matrix outside the scope of accreditation or non-standard sample matrix procedure specified in the accredited method and issues non-accredited results, this fact is stated on the title page of this protocol in the section "Notes". If the test report shows the results of subcontracting, the place of performance of the test is outside the laboratories of ALS Czech Republic, s.r.o.

The method for calculating of the summation parameters is available on request in the customer service.



CERTIFICATE OF ANALYSIS

Work Order	: PR2391936	Issue Date	: 24-Aug-2023
Customer	: DEKONS-EMA LTD Skopje	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Mrs. Menka Spirovska	Contact	: Client Service
Address	: Stefan Jakimov Dedov 4-1/10 4030007641649 1000 Skopje	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: m.spirovska@ema.com.mk	E-mail	: customer.support@alsglobal.com
Telephone	: ---	Telephone	: +420 226 226 228
Project	: Minamata convention project	Page	: 1 of 3
Order number	: ---	Date Samples	: 14-Aug-2023
		Received	
		Quote number	: PR2023DEKEM-MK0002 (CZ-200-23-0590)
Site	: ---	Date of test	: 16-Aug-2023 - 24-Aug-2023
Sampled by	: customer	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.

The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.

Samples PR2391936/006-010, method W-HG-AFSDG - LOR for particular samples raised due to dilution prior to analysis.

Responsible for accuracy

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories

Lubomir Pokorny

Position

Country Manager



The company is certified according to ČSN EN ISO 14001 (Environmental management systems) and ČSN ISO 45001 (Occupational health and safety management systems)



Analytical Results

Sub-Matrix: SOIL				Client sample ID				34-Sludge from WWTP-Novoselo	35-Sludge from WWTP-Kumanovo	36-Sludge from WWTP-Kochani
				Laboratory sample ID				PR2391936001	PR2391936002	PR2391936003
				Client sampling date / time				[14-Aug-2023]	[14-Aug-2023]	[14-Aug-2023]
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU	
Physical Parameters										
Dry matter @ 106°C	S-DRY-GRCI	0.10	%	90.0	± 5.0%	89.0	± 5.0%	93.0	± 5.0%	
Extractable Metals / Major Cations										
Mercury	S-HG-AFSHB	0.010	mg/kg DW	0.322	± 20.0%	0.806	± 20.0%	0.409	± 20.0%	

Sub-Matrix: SOIL				Client sample ID				37-Sludge from WWTP-Radovish	38-Sludge from WWTP-Strumica	---
				Laboratory sample ID				PR2391936004	PR2391936005	---
				Client sampling date / time				[14-Aug-2023]	[14-Aug-2023]	---
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU	
Physical Parameters										
Dry matter @ 106°C	S-DRY-GRCI	0.10	%	90.0	± 5.0%	86.9	± 5.0%	---	---	
Extractable Metals / Major Cations										
Mercury	S-HG-AFSHB	0.010	mg/kg DW	0.368	± 20.0%	0.648	± 20.0%	---	---	

Sub-Matrix: WATER				Client sample ID				39-Wastewater from WWTP-Novoselo	40-Wastewater from WWTP-Kumanovo	41-Wastewater from WWTP-Kochani
				Laboratory sample ID				PR2391936006	PR2391936007	PR2391936008
				Client sampling date / time				[14-Aug-2023]	[14-Aug-2023]	[14-Aug-2023]
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU	
Total Metals / Major Cations										
Mercury	W-HG-AFSDG	0.0200	µg/L	<0.0538	---	<0.0538	---	<0.0538	---	

Sub-Matrix: WATER				Client sample ID				42-Wastewater from WWTP-Radovish	43-Wastewater from WWTP-Strumica	---
				Laboratory sample ID				PR2391936009	PR2391936010	---
				Client sampling date / time				[14-Aug-2023]	[14-Aug-2023]	---
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU	
Total Metals / Major Cations										
Mercury	W-HG-AFSDG	0.0200	µg/L	<0.0538	---	<0.0538	---	---	---	

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor $k = 2$, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	Method Descriptions
Location of test performance: Na Harte 33d/0 Prague 9 - Vysocany Czech Republic 190 00	
S-DRY-GRCI	CZ_SOP_D06_01_045 (CSN ISO 11465, CSN EN 12880, CSN EN 14346:2007), CZ_SOP_D06_07_046 (CSN ISO 11465, CSN EN 12880, CSN EN 14346:2007, CSN 46 5735) Determination of dry matter by gravimetry and determination of moisture by calculation from measured values.
S-HG-AFSHB	CZ_SOP_D06_02_096 (CSN EN ISO 17852, ISO 16772:2004) - Determination of Mercury by Fluorescence Spectrometry. Sample was homogenized and mineralized by aqua regia prior to analysis.
W-HG-AFSDG	CZ_SOP_D06_02_096 (US EPA Method 245.7, CSN EN ISO 17852) - Determination of Mercury by Fluorescence Spectrometry. Sample was homogenized and mineralized by nitric acid in autoclave under high pressure and temperature prior to analysis.
Preparation Methods	Method Descriptions
Location of test performance: Na Harte 33d/0 Prague 9 - Vysocany Czech Republic 190 00	

Issue Date : 24-Aug-2023
Page : 3 of 3
Work Order : PR2391936
Customer : DEKONS-EMA LTD Skopje



Preparation Methods	Method Descriptions
* S-PPHOM2	Drying and sieving of sample on the grain size < 2 mm

The symbol "*" for the method indicates a test outside the scope of accreditation of the laboratory or subcontractor. If the UNICO-SUB code is stated in the method table, this only informs that the tests have been performed by a subcontractor and the results are given in an annex to the test report, including information on test accreditation. If the lab used for matrix outside the scope of accreditation or non-standard sample matrix procedure specified in the accredited method and issues non-accredited results, this fact is stated on the title page of this protocol in the section "Notes". If the test report shows the results of subcontracting, the place of performance of the test is outside the laboratories of ALS Czech Republic, s.r.o.

The method for calculating of the summation parameters is available on request in the customer service.

ANNEX 3: Alternative scenario for the calculation of the mercury releases from the sub-category “Coal combustion in power plant”

The conservative, Scenario 2 uses the default input and output distribution factors provided in the Toolkit. For the input factor, the interval of 0.05-0.5 g Hg/t of lignite was taken into consideration (0.15 g Hg/t as the default factor given in the Toolkit).

The total mercury input for this scenario is estimated within the interval of 230.09-2,300.92 kg or a mean of 690.28 kg for 2021.

The Toolkit provides the distribution of the mercury releases as 98% to the air and 2% to the sector specific treatment/disposal output.

The mercury releases are distributed within the ranges of 225.49-2,254.91 (676.47) kg to the air and 4.60-46.02 (13.81) kg to the sector specific disposal/treatment.

The mercury input and output calculations for the Scenario 2 are presented in **Error!**
Reference source not found..

Table 91: Mercury releases for the “Coal combustion in power plants” by different scenarios

Source	Activity rate	Input factor	Mercury input	Pollution abatement system	Mercury output (kg/y)		Stack height	
	(t/y)	(g Hg/t)	(kg/y)		Air	Sector Specific	(m)	
REK Bitola		4,248,420			ESP	208.17-2081.73 (624.52)	4.25-42.48 (12.75)	250
Suvodol	3,404,469	0.05-0.5 (0.15)	170.22-1,702.23 (510.67)					
Gneotino	843,951	0.05-0.5 (0.15)	42.2-421.98 (126.59)					
REK Oslomej		353,428			ESP	17.32-173.18 (51.95)	0.35-3.53 (1.06)	185
domestic lignite	66,425	0.05-0.5 (0.15)	3.32-33.21(9.96)					

	imported lignite	287,003	0.05-0.5 (0.15)	14.35-143.50(43.05)		
TOTAL		4,601,848		230.09-2300.92 (690.28)	0	225.49-2254.91 (676.47) 4.6-46.01 (13.81)

The certainty assessment of the calculations related to the Scenario 2 is presented in **Error!**
Reference source not found..

Table 92: Certainty assessment for the coal combustion in power plants (Scenario 2)

Parameter	Level	Description
Activity rate	HIGH	The quantities of the combusted coal were provided by the thermo power plants, and the results were cross-checked with the official state statistics data.
Input factor	LOW	The content of the mercury in the coal was taken from the default Toolkit values which are only indicative ones.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

Comparison of the two scenarios is given in the table below.

Table 93. Mercury releases for the “Coal combustion in power plants” by different scenarios

Source		Activity rate (t/y)	Input factor (g Hg/t)	Mercury input (kg/y)	Pollution abatement system	Mercury output (kg/y) Air Sector Specific		Total (kg Hg/y)
Scenario 1	REK Bitola	4,248,420		244.84				
	Suvodol	3,404,469	0.062	211.08	ESP	186,34	58.5	
	Gneotino	843,951	0.04	33.76				
	REK Oslomej	353,428		40.26				285
	domestic lignite	66,425	0.269	17.87	ESP	37.5	2.5	
	imported lignite	287,003	0.078	22.39				
Scenario 2	REK Bitola	4,248,420						
	Suvodol	3,404,469	0.05-0.5 (0.15)	170.22-1,702.23 (510.67)	ESP	208.17-2081.73 (624.52)	4.25-42.48 (12.75)	230.09-2300.92 (690.92)
	Gneotino	843,951	0.05-0.5	42.2-421.98 (126.59)				

(0.15)

REK							
Oslomej		353,428					
	domestic	66,425	0.05-	3.32-	ESP	17.32-	0.35-
	lignite		0.5	33.21(9.96)		173.18	3.53
			(0.15)			(51.95)	(1.06)
	imported	287,003	0.05-	14.35-			
	lignite		0.5	143.50(43.05)			
			(0.15)				

ANNEX 4a: Calculation of the mercury input from the ore, concentrates and floatation tailings (in zinc extraction) based on laboratory analysis of samples

In order to get a more detailed preview on the situation with mercury content in North Macedonia, among others, analysis of the ore, concentrates and floatation tailings in the mines Sasa, Toranica and Zletovo was performed, results are shown in Table 94.

Table 94. Quantities of ore, concentrates and floatation tailings, including their mercury concentration for the mines Sasa, Toranica and Zletovo

Mine (Zn & Pb)	Ore		Concentrate				Floatation tailings	
			Zinc (Zn)		Lead (Pb)			
	quantity (t)	mercury content (gHg/t)	quantity (t)	mercury content (gHg/t)	quantity (t)	mercury content (gHg/t)	quantity (t)	mercury content (gHg/t)
Sasa	818,609	0.017	44,383	0.276	37,893	0.037	736,333	<0.01
Toranica	285,499	0.01	8,641	0.01	9,877	0.013	284,926	<0.01
Zletovo	152,620	1.2	2,696	18.4	9,341	6.27	139,163	0.198
Total:	1,256,728		55,720		57,111		1,160,422	

Calculation of the mercury input from the ore, concentrates and floatation tailings is presented below.

Sasa

- Ore

$$MI_{OS} = Q_{OS} \times C_{OS} = 818,609 \times 0.017 = 13.916 \text{ kg Hg/y}$$

- Concentrate

Zinc concentrate

$$MI_{ZCS} = Q_{ZCS} \times C_{ZCS} = 44,383 \times 0.276 = 12.25 \text{ kg Hg/y}$$

Lead concentrate

$$MI_{LCS} = Q_{LCS} \times C_{LCS} = 37,893 \times 0.037 = 1.402 \text{ kg Hg/y}$$

It is important to be noted, again, that since all of the concentrate is exported, this quantity of 13.65 kg Hg/y is exported.

- Floatation tailings

$$MI_{FTS} = Q_{FTCS} \times C_{FTCS} = 736,333 \times 0.005 = 3.681 \text{ kg Hg/y}$$

Where,

MI_{OS} - Mercury input from the ore in the mine Sasa (kg Hg/y)

Q_{OS} – Quantity of ore in the mine Sasa (t)

C_{OS} – Mercury concentration in the ore in the mine Sasa (g Hg/t)

MI_{ZCS} – Mercury input from the zinc concentrate in the mine Sasa (kg Hg/y)

Q_{ZCS} - Quantity of zinc concentrate in the mine Sasa (t)

C_{ZCS} - Mercury concentration in the zinc concentrate in the mine Sasa (g Hg/t)

MI_{LCS} – Mercury input from the lead concentrate the mine Sasa (kg Hg/y)

Q_{LCS} - Quantity of lead concentrate in the mine Sasa (t)

C_{LCS} - Mercury concentration in the lead concentrate in the mine Sasa (g Hg/t)

MI_{FTS} – Mercury input from the floatation tailings in the mine Sasa

Q_{FTCS} - Quantity of floatation tailings in the mine Sasa (t)

C_{FTCS} - Mercury concentration in the floatation tailings in the mine Sasa (g Hg/t)

If we sum the mercury input from the concentrates and the floatation tailing the amount is 17,333 kg Hg/y, which is higher than the mercury input in the ore. However, it has to be taken into account that for the floatation tailing, the mercury concentration was below detection limit (of 0.01), and half of the detection value is assumed, which can be the reason for the discrepancy.

Toranica

- Ore

$$Q_{OT} \times C_{OT} = 285,499 \times 0.01 = 2.85 \text{ kg Hg/y}$$

- Concentrate

Zinc concentrate

$$MI_{ZCT} = Q_{ZCT} \times C_{ZCT} = 8,641 \times 0.01 = 0.09 \text{ kg Hg/y}$$

Lead concentrate

$$MI_{LCT} = Q_{LCT} \times C_{LCT} = 9,877 \times 0.013 = 0.13 \text{ kg Hg/y}$$

As above mentioned, since all of the concentrate is exported, this quantity of 0,103 kg Hg/y is exported.

- Floatation tailings

$$MI_{FTT} = Q_{FTCT} \times C_{FTCT} = 284,926 \times 0.005 = 1.43 \text{ kg Hg/y}$$

Where,

MI_{OT} - Mercury input from the ore in the mine Toranica (kg Hg/y)

Q_{OT} – Quantity of ore in the mine Toranica (t)

C_{OT} – Mercury concentration in the ore in the mine Toranica (g Hg/t)

MI_{ZCT} – Mercury input from the zinc concentrate in the mine Toranica (kg Hg/y)

Q_{ZCT} - Quantity of zinc concentrate in the mine Toranica (t)

C_{ZCT} - Mercury concentration in the zinc concentrate in the mine Toranica (g Hg/t)

MI_{LCT} – Mercury input from the lead concentrate the mine Toranica (kg Hg/y)

Q_{LCT} - Quantity of lead concentrate in the mine Toranica (t)

C_{LCT} - Mercury concentration in the lead concentrate in the mine Toranica (g Hg/t)

MI_{FTT} – Mercury input from the floatation tailings in the mine Toranica (kg Hg/y)

Q_{FTCT} - Quantity of floatation tailings in the mine Toranica (t)

C_{FTCT} - Mercury concentration in the floatation tailings in the mine Toranica (g Hg/t)

Comparing the sum of the mercury input in the concentrate and floatation tailings with the mercury input from the ore, the mercury input from the ore is double the amount from the concentrate and the floatation tailings. As above, the reason behind this discrepancy can be explained with the input factor taken for calculation of the mercury input from the floatation tailings. Namely, the mercury concentration was below detection limit (of 0.01), and half of the detection value is assumed, which can be the reason for the discrepancy.

Zletovo

- Ore

$$MI_{OZ} = Q_{OZ} \times C_{OZ} = 152,620 \times 1.2 = 183.144 \text{ kg Hg/y}$$

- Concentrate

Zinc concentrate

$$MI_{ZCZ} = Q_{ZCZ} \times C_{ZCZ} = 2,696 \times 18.4 = 49.61 \text{ kg Hg/y}$$

Lead concentrate

$$MI_{LCZ} = Q_{LCZ} \times C_{LCZ} = 9,341 \times 6.27 = 58.57 \text{ kg Hg/y}$$

Similarly, since all of the concentrate is exported, therefore 108.18 kg Hg/y is exported.

- Floatation tailings

$$MI_{FTZ} = Q_{FTCZ} \times C_{FTCZ} = 139,163 \times 0.198 = 27.55 \text{ g Hg/y}$$

Where,

MI_{OZ} - Mercury input from the ore in the mine Zletovo (kg Hg/y)

Q_{OZ} – Quantity of ore in the mine Zletovo (t)

C_{OZ} – Mercury concentration in the ore in the mine Zletovo (g Hg/t)

MI_{ZCZ} – Mercury input from the zinc concentrate in the mine Zletovo (kg Hg/y)

Q_{ZCZ} - Quantity of zinc concentrate in the mine Zletovo (t)

C_{ZCZ} - Mercury concentration in the zinc concentrate in the mine Zletovo (g Hg/t)

MI_{LCZ} – Mercury input from the lead concentrate the mine Zletovo (kg Hg/y)

Q_{LCZ} - Quantity of lead concentrate in the mine Zletovo (t)

C_{LCZ} - Mercury concentration in the lead concentrate in the mine Zletovo (g Hg/t)

MI_{FTZ} – Mercury input from the floatation tailings in the mine Zletovo (kg Hg/y)

Q_{FTCZ} - Quantity of floatation tailings in the mine Zletovo (t)

C_{FTCZ} - Mercury concentration in the floatation tailings in the mine Zletovo (g Hg/t)

As for this mine, the sum from the mercury input from the concentrates and the floatation tailings, is more than 50 kg lower than the mercury input in the ore. This is most likely a result of discrepancy in the reported data. To clarify, the mine Zletovo reported 152,620 tons of ore, 12,037 tons of concentrate and 139,163 tons of floatation tailings. Therefore, controlling for the quantities reported and comparing the amount of ore reported with the amount of concentrates and floatation tailings, there is a significant difference of 1,420 tons missing.

ANNEX 4b: Alternative scenario for the calculation of the mercury releases from the sub-category “Zinc/lead extraction and processing”

Input factor

This scenario, uses input factors of 0.69-9 (4.85 as mean value), based on limited measurements, where the lower-end value of the interval was taken for the mercury content of the reject material from the Canadian mine, while the upper-end value from the Russian mine.

The total mercury input for this sub-category, conservative scenario, is estimated within range 809.04 – 10,522.69 (5,686.83 as an intermediate value) kg for 2021.

Output distribution

The output distribution factors were estimated based on a consultant’s assumption.

The mercury releases are distributed within the ranges of 40.45-522.19 (281.4 as an intermediate value) kg to the air, 20.01-261.09 (140.7 as an intermediate value) kg to the water and 740.63-9,660.51 (5,260.22 as an intermediate value) kg to the land.

The mercury input and output calculations for the conservative approach are presented in Table 95.

Table 95: Mercury input and output calculations for the alternative approach for the “zinc/lead extraction and initial processing” sub-category

Source	Activity rate	Input factor*	Mercury input (kg/y)	Mercury output (kg/y)		
	(t/y)	(g Hg/t)		Air	Water	Land
SASA	736,333	0.69-9 (4.85)	508.07- 6626.99(3571.22)	25.40-331.35 (178.56)	12.70- 165.67 (89.28)	469.96- 6,129.97 (3,303.65)

Toranica	284,926	0.69-9 (4.85)	196.6 -2564.33 (1381.89)	9.83-128.22 (69.09)	4.91- 64.11 (34.55)	181.85- 2372.01 (1,278.25)
Zletovo	139,163	0.69-9 (4.85)	96.02- 1252.47(674.94)	4.8-62.62 (33.75)	2.4- 31.31 (16.87)	88.82- 1,158.53 (624.32)
Total:	1,187,422		800.69-10,443.8 (5,628,05)	40,03-522.19 (281.4)	20.01- 261,09 (140.7)	740.63- 9,660.51 (5,206.22)

Evaluation of the estimation certainty

The certainty assessment of the calculations related to the conservative approach is presented in Table 96.

Table 96: Certainty assessment for the zinc/lead extraction and processing (conservative approach)

Parameter	Level	Description
Activity rate	HIGH	The quantities of the generated reject material were provided by the mining company.
Input factor	LOW	The content of the mercury in the reject material was determined based on the limited measurements provided in the Toolkit.
Output distribution factors	MEDIUM	The output distribution factors were derived based on consultant's assumptions.

A comparison between the specific mercury releases calculation approach (resulting in 32.65 kg Hg/y) and the one that uses only the default factors presented in the Toolkit in a range between 801,04-10,443.8 (5,628,05 as an intermediate value) kg Hg/y shows that the mercury input is much lower when using specific, derived factors (see Table 97).

Table 97: Mercury releases for the “Zinc/lead extraction and processing” by different scenarios

	Source	Activity rate (t/y)	Input factor * (g Hg/t)	Mercury input (kg/y)	Mercury output (kg/y)			TOTAL
					Air	Water	Land	
Scenario 1	SASA	736,33 3	0.005	3.68	0.18	0.09	3.41	
	Toronica	284,92 6	0.005	1.42	0.07	0.04	1.32	32.65
	Zletovo	139,16 3	0.198	27.55	1.38	0.69	25.49	
Scenario 2	SASA	736,33 3	0.69-9 (4.85)	508.07- 6626.99(3571.2 2)	25.40-331.35 (178.56)	12.70- 165.67 (89.28)	469.96- 6,129.97 (3,303.65)	
	Toronica	284,92 6	0.69-9 (4.85)	196.6 -2564.33 (1381.89)	9.83-128.22 (69.09)	4.91- 64.11 (34.55)	181.85- 2372.01 (1,278.25)	800.69- 10,443.8 (5,628,05)
	Zletovo	139,16 3	0.69-9 (4.85)	96.02- 1252.47(674.94)	4.8-62.62 (33.75)	2.4- 31.31 (16.87)	88.82- 1,158.53 (624.32)	

* The numerical value for SASA and Toronica was defined as a half of the limit detection value of <0.010 g Hg/t

ANNEX 5a: Calculation of the mercury input from the ore, concentrates and flotation tailings (in copper extraction) based on laboratory analysis of samples

The following calculations, depict quantities of mercury present in the ore, concentrates and flotation tailings in the copper extraction process in R. North Macedonia, more specifically in the mine Bucim.

- Ore

$$MI_{OB} = Q_{OS} \times C_{OB} = 3,297,500 \times 0.033 = 108 \text{ kg Hg/y}$$

- Concentrate

Copper concentrate

$$MI_{CCB} = Q_{CCB} \times C_{CCB} = 28,866 \times 1.36 = 39.26 \text{ kg Hg/y}$$

Since all of the concentrate is exported, this quantity of 39.26 kg Hg/y is exported.

- Flotation tailings

$$MI_{FTB} = Q_{FTCB} \times C_{FTCB} = 3,268,685 \times 0.012 = 39.22 \text{ kg Hg/y}$$

Where,

MI_{OB} - Mercury input from the ore in the mine Bucim (kg Hg/y)

Q_{OB} – Quantity of ore in the mine Bucim (t)

C_{OB} – Mercury concentration in the ore in the mine Bucim (g Hg/t)

MI_{CCB} – Mercury input from the copper concentrate the mine Bucim (kg Hg/y)

Q_{CCB} - Quantity of copper concentrate in the mine Bucim (t)

C_{CCB} - Mercury concentration in the copper concentrate in the mine Bucim (g Hg/t)

MI_{FTB} – Mercury input from the flotation tailings in the mine Bucim (kg Hg/y)

Q_{FTCB} - Quantity of flotation tailings in the mine Bucim (t)

C_{FTCB} - Mercury concentration in the flotation tailings in the mine Bucim (g Hg/t)

There is a significant discrepancy between the mercury input in the ore and the mercury input from the concentrate and flotation tailing. According to experts opinion, one possible explanation could be that the samples do not date from the same period of time, since the quality and composition of ore is changing over time.

ANNEX 5b: Alternative scenario for the calculation of the mercury releases from the sub-category “Copper extraction and processing”

Input factor

The semiconservative approach uses the default input factors provided in the Toolkit based on limited data base. Thus, as an input factor mercury concentration in the reject material from the production of copper concentrates from two mines, from Canada (average 0.69 g Hg/t reject material) and from Russian Federation (1-9 g Hg/t reject material) was utilized.

The total mercury input for this scenario is estimated within the interval of 225.54-29,418.17 (15,853.12 as an intermediate value) kg for 2021.

Output distribution

The output distribution factors were, again, estimated based on consultant’s assumption (5.% to air, 2.5% to water and 92.5% to land).

The mercury releases are distributed within the ranges of 11.28-1,470.91 (792.66 as an intermediate value) kg to the air, 5.64-735.45 (393.33 as an intermediate value) kg to the water and 208.62-27,211.80 (14,664.14 as an intermediate value) kg to the land.

The mercury input and output calculations for the semi-conservative approach are presented in Table 98.

Table 98: Mercury input and output calculations for the conservative approach for “Copper extraction and initial processing” sub-category.

Source	Activity rate (t/y)	Input factor* (g Hg/t)	Mercury input (kg/y)	Mercury output (kg/y)		
				Air	Water	Land
Bucim	3,268,685	0.069- 9 (4.85)	225.54- 29,418.17 (15,853.12)	11.28-1,470.91 (792.66)	5.64- 735.45 (393.33)	208.62- 27,211.80 (14,664.14)

Evaluation of the estimation certainty

The certainty assessment of the calculations related to conservative approach is presented in Table 99.

Table 99: Certainty assessment for the conservative approach for the “Copper extraction and initial processing” sub-category

Parameter	Level	Description
Activity rate	HIGH	The quantities of the generated reject material were provided by the mining company.
Input factor	LOW	The content of the mercury in the reject material was derived based on the limited measurements data provided in the Toolkit.
Output distribution factors	MEDIUM	The output distribution factors were derived based on consultant’s assumptions.

A comparison between the specific mercury releases calculation approach (resulted in 36.28 kg Hg/y) and the ones that uses conservative approach (only the default factors presented in the Toolkit) in a range between 225.54-29,418.17 (15,853.12) kg Hg/y shows that the mercury input is much lower when using specific, derived factors (see Table 100).

Table 100: Mercury releases for the “Copper extraction and processing” by different scenarios

	Source	Activity rate (t/y)	Input factor* (g Hg/t)	Mercury input (kg/y)	Mercury output (kg/y)		
					Air	Water	Land
Scenario 1	Bucim	3,268,685.00	0.01	39.22	1.96	0.98	36.28
Scenario 2	Bucim	3,268,685	0.069-9 (4.85)	225.54-29,418.17 (15,853.12)	11.28-1,470.91 (792.66)	5.64-735.45 (393.33)	208.62-27,211.80 (14,664.14)

Annex 6: Alternative scenario for the calculation of the mercury releases from the sub-category “Primary ferrous metal production”

Input factor

The semiconservative approach uses the default input factor(s) provided in the Toolkit based on limited data base. Thus, in this case, 0.05 g Hg/t is assumed by the Toolkit.

The total mercury input for this scenario is estimated to 67.65 kg for 2021.

Output distribution

As explained in 6.2.3, the distribution factors are taken as follows: 90.5% to air and 9.5% to sector specific treatment/disposal.

The mercury releases are distributed within the ranges of 61.22 kg to the air and 6.43 kg to sector specific treatment/disposal.

The mercury input and output calculations for the semi-conservative approach are presented in **Error! Reference source not found.101**.

Table 101: Mercury input and output calculations for the conservative approach for “Copper extraction and initial processing” sub-category.

Source	Activity rate (t/y)	Input factor* (g Hg/t)	Mercury input (kg/y)	Mercury output (kg/y)	
				Air	Sector specific treatment/disposal
Euronickel	1,352,988	0.05	67.65	61.22	6.43

Evaluation of the estimation certainty

The certainty assessment of the calculations related to conservative approach is presented in 102.

Table 102: Certainty assessment for the conservative approach for the “Primary ferrous metal production” sub-category

Parameter	Level	Description
Activity rate	HIGH	The quantities of the produced ferronickel were provided by the plant.
Input factor	LOW	The quantities of the mercury released for the production of ferronickel were taken from the default Toolkit values which are only indicative ones.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

Since the input factors are almost equal, there is a slight difference in the mercury input. Namely, calculation based on actual measurements leads to lower mercury input (62.24 kg/y), than using proposed/default input factors, yielding 67.65 kg/y, shown in Table 103.

Table 103: Mercury releases for the “Primary metal production” by different scenarios

	Source	Activity rate	Input factor*	Mercury input	Mercury output (kg/y)	
		(t/y)	(g Hg/t)	(kg/y)	Air	Sector specific treatment/disposal
Scenario 1	Euronickel	1,352,988	0.046	62.24	56.32	5.91
Scenario 2	Euronickel	1,352,988	0.050	67.65	61.22	6.43

ANNEX 7: Alternative scenario for the calculation of the mercury releases from the sub-category “Cement production”

The semiconservative approach uses the default input factor provided in the Toolkit in the interval of 0.004-0.5 g Hg/t cement produced (0.11 g Hg/t as the average figure).

The total mercury input for this sub-category, conservative scenario, is estimated within range 4.06-507.62 (111.68 as an intermediate value) kg for 2021 .

The Toolkit provides the distribution of the mercury releases using (FF+SNCR / FF+WS / ESP+FGD / optimized FF) as air emissions reduction measures of 40% to the air and 20% to the “product “output and 40% to sector specific treatment/disposal.

The mercury releases are distributed within the ranges of 1.63-203.06 (44.68 as an intermediate value) kg to the air, 0.82-101.53 (22.34 as an intermediate value) kg to the product and 1.63-203.06 (44.68 as an intermediate value) kg to the sector specific treatment/disposal.

The mercury input and output calculations for the conservative approach are presented in **Error! Reference source not found.104.**

Table 104. Mercury input and output calculations for the conservative approach for “Cement production” sub-category.

Source	Activity rate (t/y)	Input factor (g Hg/t)	Mercury input (kg/y)	Pollution abatement system	Mercury output (kg/y)		
					Air	Product	Sector specific treatment/disposal
TITAN-USJE	1,015,244	0.004-0.5 (0.11)	4.06-507.62 (111.68)	ESP/FF	1.63-203.06 (44.68)	0.82-101.53 (22.34)	1.63-203.06 (44.68)

Evaluation of the estimation certainty

The certainty assessment of the calculations related to conservative approach is presented in **Error! Reference source not found.105.**

Table 105: Certainty assessment for the conservative scenario for the “Cement production” sub-category

Parameter	Level	Description
Activity rate	HIGH	The quantities of the raw materials used and the produced cement were provided by the cement production company.
Input factor	LOW	The quantities of the mercury released for the production of cement were taken from the default Toolkit values which are only indicative ones.
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

A comparison between the specific mercury releases calculation approach (resulted in 37.77 kg Hg/y), the and the conservative approach (only the default factors presented in the Toolkit) in a range between 4.08-507.64 (111.7 as mean value) shows that the mercury input is higher when derived from default input factors, shown in Table 106.

Table 106: Mercury releases for the “Cement production” by different scenarios

		Activity rate	Input factor	Mercury input	Pollution abatement system	Mercury output (kg/y)		
Source		(t/y)	(g Hg/t)	(kg/y)		Air	Product	Sector specific treatment/disposal
Scenario 1	TITAN - USJE	1,015,244	0.0372	37.77	ESP/FF	32.69	5.08	0.00
Scenario 2	TITAN - USJE	1,015,244	0.004-0.5 (0.11)	4.08-507.64 (111.7)	ESP/FF	1.63-203.06 (44.68)	0.82-101.53 (22.34)	1.63-203.06 (44.68)

ANNEX 8: Alternative scenario for the calculation of the mercury releases from the sub-category “Laboratory chemicals and equipment”

The conservative scenario uses the default input factors presented in the Toolkit.

Input factor

This approach is based on using the input factor of 0.01 g Hg per inhabitant per year and the number of inhabitants as an activity rate.

The total mercury input for this sub-category, conservative scenario, is estimated to be 18.37 kg for 2021.

Output distribution

The Toolkit proposes distribution of 33% to water, 33% to general waste and 34 to sector specific treatment.

The mercury releases are distributed 6.06 kg to water, 6.06 kg to general waste and 6.24 kg to sector specific.

Evaluation of the estimation certainty

The certainty assessment of the calculations related to conservative approach is presented in **Error! Reference source not found.107**.

Table 107. Certainty assessment for the conservative scenario for the “Laboratory chemicals and equipment” sub-category

Parameter	Level	Description
Activity rate	LOW	The data on population was obtained from the State Statistical Office and the usage of the number of inhabitants as activity rate is very general, conservative approach.
Input factor	LOW	The input factor is based on the on limited study presented in the Toolkit
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

When comparing the two approaches, as presented in Table 108, for the estimations of the mercury releases, the mercury input calculated using the real data on import of the mercury compounds is three times lower than the conservative approach.

Table 108: Mercury releases for the “Laboratory chemicals and equipment” by different scenarios

	Source	Activity rate (inhabitants)	Input factor (g Hg/ inhabitant)	Mercury input (kg/y)	Mercury output (kg/y)		
					Water	General waste	Sector specific
<i>Scenario 1</i>	Laboratory chemicals containing mercury			6.77	2.23	2.23	2.30
<i>Scenario 2</i>	Laboratory chemicals containing mercury	1,836,713	0.01	18.37	6.06	6.06	6.24

ANNEX 9: Alternative scenario for the calculation of the mercury releases from the sub-category “Production of recycled ferrous metals”

The conservative scenario uses the default input factors presented in the Toolkit.

Input factor

The Toolkit gives a range of 0.2-2 g Hg/t, but specifies that there is a great variability in the mercury content depending on the region and origin of the materials being recycled (UNEP, 2023) Calculations using 0.2-2 (1,1 as mean value) g Hg/t.

The total mercury input for this sub-category, conservative scenario, is estimated to be within the range of 69.68-696.83 (383.26 as mean value) kg for 2021.

Output distribution

The Toolkit proposes distribution of 33% to air, 33% to general waste and 34% to land.

The mercury releases are distributed 23-229.96 (126.48 as mean value) kg to air, 23.69-236.92 (130.31 as mean value) kg to land and 23-229.96 (126.48 as mean value) to general waste.

The mercury input and output distribution is shown in Table 109.

Table 109: Mercury input and output calculations for the conservative approach for the “Production of recycled ferrous metals” sub-category

Source	Activity rate (t/y)	Input factor (g Hg/t)	Mercury input (kg/y)	Pollution abatement system	Mercury output (kg/y)		
					Air	Land	General waste
MAKSTIL	348,417.25	0.2-2 (1.1)	69.68- 696.83 (383.26)	Filter bags	23.00-229.96 (126.48)	23.69- 236.92 (130.31)	23.00-229.96 (126.48)

Comparison showing that the conservative scenario estimates much larger quantity of mercury input, than actual measurements, as shown in table below.

Source	Activity rate (t/y)	Input factor (g Hg/t)	Mercury input (kg/y)	Pollution abatement system	Mercury output (kg/y)		
					Air	Land	General waste
Scenario 1 MAKSTIL	348417.25	0.07	24.47	Filter bags	2.37	11.05	11.05
Scenario 2 MAKSTIL	348417.25	0.2-2 (1.1)	69.68- 696.83 (383.26)	Filter bags	23-229.96 (126.48)	23.69- 236.92 (130.31)	23-229.96 (126.48)

Evaluation of the estimation certainty

The certainty assessment of the calculations related to conservative approach is presented in **Error!**
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Table 110: Certainty assessment for the conservative approach for the “Production of recycled ferrous metals” sub-category

Parameter	Level	Description
Activity rate	HIGH	The data was obtained by the company; therefore it is relevant source.
Input factor	LOW	The input factor is based on the on limited study presented in the Toolkit
Output distribution factors	LOW	The output distribution factors are based on the Toolkit default output distribution factors which are only indicative ones.

ANNEX 10: Alternative scenario for the calculation of the mercury releases from the sub-category “Incineration of medical waste”

The conservative approach for this sub-category uses the default input factor provided in the Toolkit in the interval of 8-40 g Hg/t incinerated medical waste (24 g Hg/t as the mean value).

The total mercury input for this sub-category is estimated within the interval 9.23-46.15 (2.76 kg mean value) for 2021.

In a situation when there are no air pollution control devices implemented, the Toolkit recommends the entire mercury releases to be emitted in the air.

The entire mercury input within the range of 9.23-46.15 (27.69 as mean value) is released to air.

The mercury input and output calculations for the conservative approach are presented in **Error! Reference source not found.11**.

Table 111: Mercury input and output calculations for the alternative approach for the “Incineration of medical waste” sub-category

Source	Activity rate (t/y)	Input factor (g Hg/t)	Mercury input (kg/y)	Pollution abatement system	Mercury output (kg/y) Air
DRISLA	1,153.77	8-40 (24)	9.23-46.15 (27.69)	/	9.23-46.15 (27.69)

The certainty assessment of the calculations related to the sub-category “Incineration of medical waste” is presented in **Error! Reference source not found.12**.

Table 112: Certainty assessment for the conservative scenario of the “Incineration of medical waste” sub-category

Parameter	Level	Description
Activity rate	HIGH	The quantities of the incinerated medical waste were provided by the incinerators.
Input factor	LOW	The quantities of the mercury released for the incineration of the medical waste were taken from the default Toolkit values which are only indicative ones.
Output distribution factors	MEDIUM	The entire quantities are distributed in one output pathway, i.e. in the air, but as mentioned in the Toolkit, small quantities of mercury may be contained in the fugitive PM emissions from ash handling operations.

In comparison, the semi-conservative approach of using measurements for the emissions in air, taken in 2011, shows much lower mercury input than the conservative approach with default factors given in the Toolkit, as shown in Table 113.

Table 113: Mercury releases for the “Incineration of medical waste” by different scenarios

	Source	Activity rate (t/y)	Input factor (g Hg/t)	Mercury input (kg/y)	Pollution abatement system	Mercury output (kg/y) Air
<i>Scenario 1</i>	DRISLA	1,153.77	7.51	8.66	/	8.66
<i>Scenario 2</i>	DRISLA	1,153.77	8-40 (24)	9.23-46.15 (27.69)	/	9.23-46.15 (27.69)