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SCENARIOS OF MERCURY EMISSION TO AIR, WATER AND SOIL IN POLAND TO YEAR 2020

SCENARIUSZE EMISJI RTĘCI DO POWIETRZA, WÓD I GLEBY W POLSCE DO ROKU 2020

Abstract: Among European countries Poland has fourth place in mercury emission to atmosphere in 2005, mainly due to hard and brown coal combustion in energy sector. NILU Polska estimated Polish national mercury emission to air and loads discharged to water and soil for the base year 2008, then it prepared mercury emission scenarios to 2020. Inventory of emission to the atmosphere covered industrial processes, mercury use in products and dental practice. Loads of mercury discharged to water and soil were estimated for large and medium industrial facilities, municipal waste water treatment plants and also for potential mercury release from municipal landfills and dental amalgam in buried bodies. In comparative Status Quo scenario it was assumed that current practices and methods of mercury emission control will be maintained, but the growth of production and consumption will lead to the increase of mercury emission. In EXEC (*EXtended Emission Control*) scenario mercury emission to air will fall from 17.7 Mg in base year to 6.3 Mg in 2020 and total emission to air, water and soil from 25.7 to 8.9 Mg. In MFTR (*Maximum Feasible Technical Reduction*) scenario emission to air will achieve level 2.8 Mg Hg in 2020 and total emission to the environment – 3.6 Mg Hg annually.

Keywords: emission scenarios, mercury, air, water, soil

Problem of mercury emission to environment

Mercury is one of toxic heavy metals introduced to environment as a result of human activity. However considering its high volatility mercury is not only regional pollution as SO_2, NO_x, Cd or Pb. Mercury can appear in many chemical forms, that is crucial for

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further changes of mercury and its compounds. *Gaseous elemental mercury* (GEM or Hg^0) is one of mercury forms. Mercury can appear also in oxidized forms: *reactive gaseous mercury* (RGM or Hg^{2+}) and mercury adsorbed on dust – *total particulate mercury* (TPM). The sum of all gasous mercury compounds and elemental mercury is defined as *total gaseous mercury* (TGM).

Atmospheric lifetime for gasous elemental mercury to 18 months [1] places mercury in group of global pollutants. Main problem of mercury pollution is bioaccumulation and negative influence of methyl mercury compounds (methylmercury and dimethylmercury) on human populations eating many fishes and marine mammals. The most known case of methylmercury poisoning is ecological disaster which happened in Minamata Bay in Japan in the fifties. There were damages of nervous system of people eating fish and crab meat. Death of almost 1800 and diseases of further thousands people were officially recognised.

Human fetus is most vulnerable for methylmercury exposure. Mercury filtrates from mother's blood to fetus blood and causes neurological damages manifested in later period as lower intelligence quotient or even autism. Therefore, resolution of global mercury convention on mercury trade limitation and emission reduction is planned until 2013.

Mercury emission inventory for base year

Among European countries Poland had fourth place (second place among EU member states after Germany) in mercury emission to atmosphere in 2005 [2]. Hard and brown coal combustion in Polish energy sector is main source of this emission. Annually combusted 80 million Mg of hard coal (40 million Mg for electricity generation) and 60 million Mg of lignite contain above 20 Mg of mercury. Review of data on mercury content in Polish coals [3] shows that scopes of content are different. Values of 100 mg/Mg for hard coal and 250 mg/Mg for lignite are generally published as averages. The majority of research studies show higher mercury content in lignite than in hard coal. Amount of mercury emitted to air depends on the use of primary measures – coal washing – as well as on dedusting and desulfurization method efficiencies – mercury emission reduction in Poland achieves 70 %.

NILU Polska estimated Polish national mercury emission to air and loads discharged to water and soil for the base year 2008 [4]. Inventory of emission to the atmosphere covered industrial processes, mercury use in products and dental practice. Emission from industrial processes and fuel combustion in residential sector (15.75 Mg) was estimated as annual average, based on official emission inventories of IOS-KOBiZE for years 2005–2007.

Mercury emission to air from mercury use in products was estimated based on model for distribution and emissions [5], in reference to following groups of products: batteries, measuring and control equipment, light sources and other electrical and electronic equipment. About 9 Mg of mercury was launched to Polish market in mercury-containing products in 2008. The ban on placing mercury on market in fever thermometers and measuring devices intended for sale to the general was introduced in 2009. It will effect on reduction of mercury amount in products.

Mercury emission to air in period of first 10 years of use of products launched to market in base year was estimated as 0.46 Mg, see Table 1.

Table 1

Emission to air, recycling, safe storage and other places of mercury accumulation from mercury-containing products launched to Polish market in 2008 [6]

	In first year [Mg]	Within 10 years [Mg]
Emission to air	0.32	0.46
Recycling and safe storage of mercury	2.17	2.89
Landfilling of municipal wastes + mercury accumulated in products	6.90	6.04
Total	9.40	9.40

In this period 2.9 Mg of mercury contained in products will be collected selectively and then recycled or stored safely. Majority of mercury will get to municipal waste landfills, with problem of mercury release to water and soil, or will be still accumulated in products.

Emission to air from dental practice was also estimated. It is sum of emission from processes of old amalgam combustion in mass of infectious wastes from dental practice and emission from bodies cremation.

Essential problem is the use of amalgam fillings in dentist surgeries and clinics which entered into contracts with *National Health Fund* (NFZ) for cost-free services for public. Dental amalgam is now purchased in capsule form. Preparation of single filling needs making of excessive amount of prepared mixture in relation to real necessity. This excess is easily recollected as hazardous wastes. Old amalgam wastes are greater problem. Only the biggest parts of extracted old amalgam are collected to jars with water, reducing mercury evaporation, and separately delivered. Rest of extracted old amalgam deposited on single use filters on spittoons, get to mass of infectious wastes and is incinerated or get into sewage system.

For mercury emission to air from bodies cremation this value estimated for Poland is less significant than in west and north European countries. It results from cultural patterns and historical experience of Poland. Only 5 % of corpses were cremated in Poland in 2006, that causes share of mercury released in these processes is relatively low.

Annual consumption of 10 Mg of mercury for dental fillings in Poland results emission 1.45 Mg to air from combustion of displaced old amalgam in stream of infectious medical wastes. Mercury emission from dental fillings in creamation processes is 0.04 Mg.

National mercury emission to air from described sources was estimated for base year 2008 on level 17.7 Mg annually – see Fig. 1.

Main problem is emission from public power and heating plants. Second place have other industrial sectors, third – dental practice, and following places – commercial heating plants and households. The smallest participation in emission structure concerns mercury use in products.

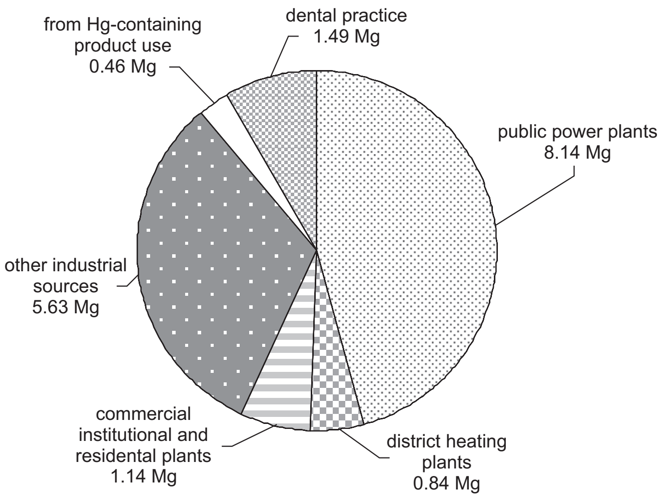

Fig. 1. Mercury emission to air in base year

Loads of mercury discharged to water and soil were estimated for large and medium industrial facilities together with its landfills (1.90 Mg), municipal waste water treatment plants in agglomerations above 100 thousand residents (1.07 Mg) and additionally for potential mercury release from municipal landfills (4.84 Mg) and dental amalgam in buried bodies (0.16 Mg). Total emission to air, water and soil in Poland was estimated as 25.7 Mg/year. This stream not covers re-emission of mercury before accumulated in environment.

Status Quo scenario

NILU Polska prepared also scenarios of mercury emission to atmosphere and loads discharged to water and soil to year 2020. In first scenario – Status Quo [4] – it was assumed that current practices and methods of mercury emission control from the end of 2008 will be maintained. This scenario is only comparative one. It is expected that in reality national and international pressure will cause actions leading to reduction of mercury emission.

Based on assumptions of project for Energy Policy of Poland from 2007, it was estimated that emission from industrial processes will increase (16.2 Mg) as result of increased coal consumption in power plants by 6 % and lack of significant changes in the other industrial sectors. Emission to air from mercury use in products (0.47 Mg) will be similar to emission in base year, because mercury consumption and waste management will not change. Predicted increase of mercury launched to market in batteries is exception. It is expected that average EU consumption factor (11 batteries per person) will be achieved in 2020.

Emission to air from dental practice (1.52 Mg) will change slightly in comparison with the base year considering the further use of amalgam in dentist surgeries and increase of cremated bodies to level 10 %. Total mercury emission to air for Status Quo scenario in 2020 will be 18.2 Mg annually.

For mercury discharges to water it was assumed that emission from industrial and municipal wastewater treatment plants (2.97 Mg) will not change in comparison with the base year. Potential releases of mercury from municipal landfills and dental fillings for Status Quo scenario will increase to 5.48 Mg annually. Finally total national anthropogenic emission to air, water and soil will increase from 25.7 Mg in base year 2008 to 26.6 Mg in 2020.

EXEC scenario

EXEC (*EXtended Emission Control*) scenario is the prognosis of economic growth continuation, assuming implementation of EU directives and international conventions [6]. Taken into account requirements of the IPPC directive 96/61/EC and BAT reference documents (BREFs), implementation of *best available techniques* for mercury emission reduction from industrial processes is expected. Changes to the IPPC directive are introduced by the new *Industrial Emission Directive* (IED) 2010/75/EU. This directive is a link between Large Combustion Plants directive (2001/80/EC) and directive on the incineration of waste (2000/76/EC). IED directive requirements will be in force since 1 January 2016. Demands of Poland extending transitory periods for large combustion plants to 30 June 2020 were taken into consideration. It concerns sources below 500 MW, for which the first permit was given before 27 November 2002 and which will prepare transitional national plans including limits of annual emissions. Exemptions from the obey of emission limit values – on condition that appropriate conditions are fulfilled – will be in force also for older power plants, combined heat and power plants as well as for heating plants below 200 MW until the end of 2023 at the longest.

EXEC scenario is based on projection of fuel consumption included in the final version of the "Energy Policy of Poland until 2030" [7]. In this projection until 2020, 28 % decrease of brown and hard coal consumption for power generation as well as 10 % decrease of coal consumption in district heating plants, residential sector and commercial plants is expected. BAT techniques will be implemented in energy sector, iron and steel production, non-ferrous metal production, cement production and chlorine production using mercury cell plants [8].

For fuel combustion processes implementation of primary methods for emission reduction as coal washing or fuel switching is expected. Coal-fired power plants will be equipped with secondary methods for emission reduction as *fabric filters* (FF) or *electrostatic precipitators* (ESP) operated in combination with *flue gas desulfurization* (FGD) techniques. Some power plants will be equipped with simultaneous control of SO_x, NO_x and mercury emission (catalytic methods), non-catalytic methods and techniques using sorbents.

In iron and steel production implementation of fine wet scrubbing systems and fabric filters together with carbon sorbents and then the use of catalytic oxidation is expected in sinter plants. Blast furnaces will be equipped with scrubbers and wet ESPs. Basic oxygen furnaces will be equipped with dedusting methods: dry ESPs and scrubbers as well as FFs or ESPs. For electric arc furnaces implementation of systems for dust collection and dedusting in FFs is predicted.

In projection for non-ferrous metal production it is expected implementation of best available techniques allowing to remove of mercury from process gases and to reduce of mercury amount which occurs during sulfuric acid production. Additionally high--effective FFs will be used. In copper production the use of modern FFs with burst-bag detectors and automatic filter cleaning system is recommended, whereas in lead and zinc production the use of combination of dry ESPs, wet scrubbers, mercury removal system and wet ESPs before sulfuric acid plants is recommended.

In cement production it is assumed that plants will be equipped with ESPs and FFs with burst-bag detectors and dust abatement techniques (minimization or prevention of fugitive dust emission). It is predicted that FGD techniques (wet scrubbers) will be used in many plants and some of plants will be also equipped with systems designed for heavy metals removal like activated carbon injection and dedusting.

Projection for chlorine production assumes the end of the mercury cell plants use as the mercury cells and asbestos diaphragm processes are not considered to be BAT and are significant source of mercury emission. Phase-out of mercury cells should eliminate problem of mercury emission in this sector. As a result of changes in production structure of particular sectors and implementation of proper methods for mercury emission reduction, predicted mercury emission from industrial processes will decrease to 6.1 Mg.

For mercury use in products 40 % reduction of mercury consuption for their production is expected. The ban on placing mercury on market in fever thermometers and measuring devices (eg manometers, barometers) intended for sale for public since 2009 results from directive 2007/51/EC. Other regulations define minimum collection rates for batteries and accumulators (45 % since 2016) and for electrical and electronic equipment (40 % for light sources and 24 % for other equipment). At the same time the increase of mercury-free button cell batteries production and fluorescent lamps share with low mercury content are expected.

Mercury emission to air in period of first 10 years of product use will decrease to 0.10 Mg, see Table 2. In this period 3.3 Mg of mercury contained in products will be recycled or stored safely. Smaller stream of mercury will get to municipal landfills or be still accumulated in products.

Table 2

Emission to air, recycling, safe storage and other places of mercury accumulation from mercury-containing products launched to Polish market in 2020 for EXEC scenario [6]

	In first year [Mg]	Within 10 years [Mg]
Emission to air	0.07	0.10
Recycling and safe storage of mercury	2.49	3.29
Landfilling of municipal wastes + mercury accumulated in products	2.84	2.01
Total	5.40	5.40

In case of dental practice mercury emission will decrease significantly (to 0.03 Mg), as result of the lower dental amalgam use and proper management of infectious wastes, incinerated in modern waste incineration plants.

It is assumed that suction systems and amalgam separators will be used in most dental surgeries, what allows to capture and treat it as a hazardous waste. Ceramic--polymer composites are alternative materials for dental fillings used for years, but their exclusive using in Poland would be more expensive for National Health Fund (NFZ). Another issue is a case of mercury emission from dental fillings resulting from bodies cremation hovewer it is less important in Poland in comparison with Western Europe.

At the same time it is expected that ten modern waste incineration plants will be operate in 2020: in Warsaw (with the annual capacity of 320 thousand Mg of wastes), in Silesian conurbation, Lodz, Gdansk-Gdynia conurbation and Krakow (each 250 thousand Mg), in Poznan (200 thousand Mg), in Szczecin and Bydgoszcz-Torun conurbation (each 180 thousand Mg), in Koszalin (120 thousand Mg) and Bialystok (100 thousand Mg).

Total mercury emission to air from industrial processes, mercury use in products and dental practice will achieve level 6.3 Mg – see Fig. 2. In emission structure, there will be a significant drop of the share of public power and heating plants, which will draw level with other industrial sectors.

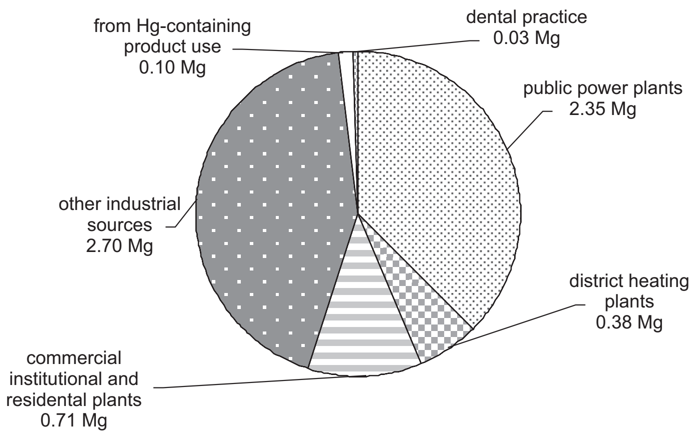

Fig. 2. Mercury emission to air in 2020 for EXEC scenario

For mercury loads discharged to water implementation of best available techniques is assumed, allowing decrease of emission from industrial processes to 0.87 Mg and decrease of emission from municipal waste water treatment plants to 0.49 Mg. Load of mercury gradually released from municipal landfills (1.22 Mg) will decrease significantly. It will be result of the smaller use of mercury in products and higher amount of modern waste incineration plants. Annual economic activities and consumer behavior will result the total anthropogenic mercury emission to the environment on level 8.9 Mg, what makes three-times drop of emission in comparison with the base year.

MFTR scenario

MFTR scenario is projection of *Maximum Feasible Technical Reduction* of mercury emission, in which additional mercury emission reduction measures will be applied in comparison with previous EXEC scenario [6]. Measures for mercury emission prevention (limitation of the use of mercury in products and its recycling as well as technological changes in industry).

In this scenario it is expected that power and heat production will still remain the main sources of mercury emission from industrial processes in Poland (2.81 Mg). Projection used in this scenario is based on 450 ppm scenario from IEA report [9], in which 24 % decrease of hard and brown coal consumption for power generation together with 50 % decrease of energy demand for purposes other than power generation are expected.

Until 2020 energy sector and other industrial sectors will be equipped in currently implemented emerging techniques, including techniques for heavy metals removal (activated carbon, sulfur impregnated sorbents and selenium impregnated filters). The share of coal combustion in pulverized boilers will decrease for fluidized bed combustion and clean coal technologies. In case of low-stack emission broaden switch from coal to gas and oil as well as the use of renewable energy sources and termomodernization of buildings are predicted.

In iron and steel production new iron-making techniques will be partially implemented – mainly direct reduction of iron ore. Scrap with controlled mercury content will be used as feedstock to basic oxygen furnaces. In non-ferrous metal production the use of chemical conversion methods of mercury and its compounds for mercury removal from process gases and produced sulfuric acid are proposed. The use of non-chemical methods allowing decrease of mercury amount in sulfuric acid is also recommended. The use of methods with selenium filter and selenium scrubber is considered as future solution.

In cement production it is assumed that all plants will be equipped with primary methods for emission reduction, abatement techniques for minimization of fugitive dust emission, dedusting techniques with the use of activated carbon and desulfurization technologies. In projection for chlorine production it is expected that all mercury using cell plants will be converted to membrane cells technology or to other mercury-free technologies.

Remaining sources of emission will have insignificant share in mercury emission structure. Slight use of mercury for production, only discharge lamps, will cause further drop of emission from mercury use in products (0.02 Mg), see Table 3. At the same time 0.8 Mg of mercury in products will be recycled or stored safely. Only 0.6 Mg of Hg will be landfilled or still accumulated in used products.

The ban on using amalgam in dental fillings will eliminate the problem of mercury emission from incineration of old amalgam with infectious wastes. Total mercury emission to air from industrial processes, mercury use in products and dental practice will equal 2.83 Mg – see Fig. 3. In comparison with EXEC scenario, further decrease of mercury emission to air is expected but emission structure will remain unchanged.

Table 3

Emission to air, recycling, safe storage and other places of mercury accumulation from mercury-containing products launched to Polish market in 2020 for MFTR scenario [6]

	In first year [Mg]	Within 10 years [Mg]
Emission to air	0.02	0.02
Recycling and safe storage of mercury	0.62	0.83
Landfilling of municipal wastes + mercury accumulated in products	0.77	0.55
Total	1.40	1.40

Loads of mercury discharged to water and soil will further decrease (to 0.45 Mg). Slight range of mercury use in products will cause that the potential gradual mercury release from municipal landfills (0.30 Mg) will significantly decrease. Annual economic activities and consumer behavior will result the total anthropogenic mercury emission to the environment on level 3.6 Mg, what makes seven-times drop of emission in comparison with the base year.

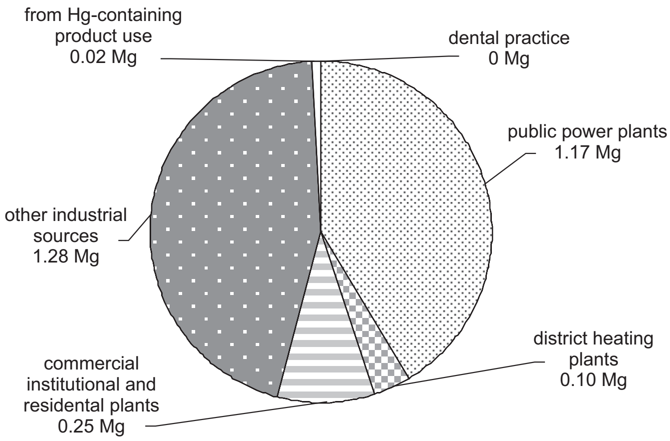

Fig. 3. Mercury emission to air in 2020 for MFTR scenario

Conclusions

It was estimated that mercury emission to air in base year 2008 was 17.7 Mg and total emission to air, water and soil was 25.7 Mg annually. In Status Quo scenario, growth of production and consumption will lead to the increase of mercury emission, see Fig. 4.

In EXEC scenario mercury emission to air will decrease to 6.3 Mg in year 2020 and total emission to air, water and soil to 8.9 Mg. This scenario is combination of measures oriented to mercury emission reduction (modern techniques of flue gas cleaning in industry, combustion of municipal and infectious wastes, technologies of wastewater

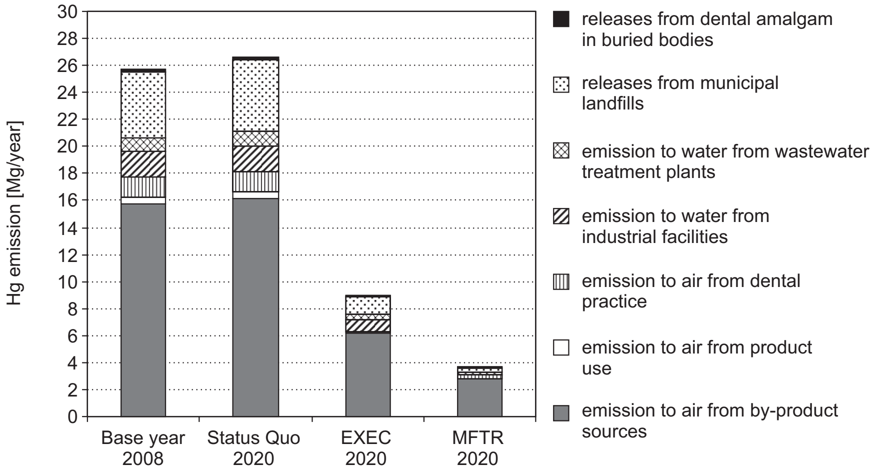

Fig. 4. Mercury emission to air, water and soil for particular scenarios

treatment) and strategies of emission prevention (reduction of coal consumption in energy sector, selective collection of mercury-containing product wastes and decrease of dental amalgam consumption).

In MFTR scenario mercury emission to air will achieve level 2.8 Mg Hg and total emission to environment – 3.6 Mg Hg annually. This scenario is most concentrated on cheaper strategies of emission prevention (ban on using mercury in batteries, electrical and electronic equipment, measuring and control equipment as well as in dental practice). Additional reduction of emission results from the use of emerging techniques.

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SCENARIUSZE EMISJI RTĘCI DO POWIETRZA, WÓD I GLEBY W POLSCE DO ROKU 2020

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Abstrakt: W 2005 r. Polska zajmowała czwarte miejsce wśród państw europejskich w emisji rtęci do powietrza, głównie z powodu spalania węgla kamiennego i brunatnego w energetyce. Zespół NILU Polska oszacował krajową emisję rtęci do powietrza oraz ładunki odprowadzane do wód i gleby dla roku bazowego 2008, a następnie przygotował scenariusze emisji rtęci do 2020 r. Inwentaryzacja emisji do powietrza objęła procesy przemysłowe, użytkowanie produktów zawierających rtęć i praktykę dentystyczną. Ładunki rtęci zrzucane do wód i gleby zostały oszacowane dla dużych i średnich zakładów przemysłowych, oczyszczalni ścieków komunalnych oraz dla potencjalnego uwalniania się rtęci ze składowisk odpadów komunalnych i z wypełnień dentystycznych w grzebanych zwłokach. W porównawczym scenariuszu Status Quo założono, że będą utrzymane bieżące praktyki i metody kontroli emisji rtęci, ale wzrost produkcji i konsumpcji będzie prowadzić do wzrostu emisji rtęci. W scenariuszu EXEC (zwiększonej kontroli emisji) emisja rtęci do powietrza spadnie z 17,7 Mg w roku bazowym do 6,3 Mg w 2020 r., a łączna emisja do powietrza, wód i gleby z 25,7 do 8,9 Mg. W scenariuszu MFTR (maksymalnej możliwej technicznie redukcji) emisja do powietrza osiągnie w 2020 r. poziom 2,8 Mg Hg, a łączna emisja do środowiska – 3,6 Mg Hg rocznie.

Słowa kluczowe: scenariusze emisji, rtęć, powietrze, woda, gleba