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The material flows of lead in the Czech Republic

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ABSTRACT

The material flows of lead in the Czech Republic have been surveyed through their identification and quantification (in 2011). The results obtained from there were used for the appraisal of the process of creating closed-loop material flows of lead in the Czech Republic. The study was based on the conceptual and strategic documents of both national and European provenance. The results achieved have shown that the economic system of the Czech Republic is influenced by lack of primary lead resources, and as such, it is dependent on the import of Pb-containing waste materials and commodities, as well as reusable waste and secondary raw materials. The process of creating closed-loop material flows of lead in the Czech Republic achieves adequate levels; considering the idea of so called "recycling society," economic activities, such as collection, accumulation, disposal and treatment of waste, should be made more efficient on an ongoing basis as a part of sustainable consumption and production systems.

1. Introduction

Lead represents a significant source of contamination for the environment. Lead can be most frequently found in polymetallic ores, which are composed mainly of lead and zinc and/or copper sulphides. They used to be accompanied by exploitable amounts of argent, aurum and a variety of trace elements such as indium, cadmium or bismuth. Main minerals of the above mentioned ores are represented by galena and sphalerite, usually together with pyrite or chalcopyrite (CGS, 2010). Most lead concentrations that are found in the environment result from human activities, and to a lesser extent, they come from natural resources (NIPH, 1997). Lead concentrations in areas not affected by human activities may not exceed 1 ng m^{-3} (Bencko et al., 1995).

Incineration processes are the main anthropogenic sources of lead in the environment. From the contaminated atmosphere lead then passes on to other environmental media (Černá et al., 2009). Gravitational deposition is another important mechanism that burdens the ecosystem with heavy metals, including lead. Lead gets into the atmosphere naturally mainly through dust, smoke, forest fires and sea water aerosols. Lead emissions caused by humans are approx. 17.5 times higher than the natural emissions (Cibulka, 1991).

Apart from sedimentation, lead gets into the soil from the air or from leaks from poorly secured waste landfills, as well as from the direct application of sewage sludge and industrial composts (IPR 2008; Černá et al., 2009). The concentration of lead in the soil is directly reflected in its concentration in groundwater (Bencko et al., 1995). Other sources of lead in the water environment may be found in wastewater produced during ore processing, colored metallurgy, battery production or the glass industry (Černá et al., 2009).

Environmental and health risks are mainly caused by contaminated soil, atmosphere and food (Wang et al., 2009). The lead-bearing products that are most commonly used are automotive batteries, lead paints, sealing materials, glass for TV screens, weights, lead pipes for drinking water and lead shots or lead stabilizers in vinyl materials (Tukker et al., 2006).

Tetraethyl lead is another compound that is worth mentioning as it was used in early model cars as flame retardant to help reduce engine knocking and boost octane ratings of fuel. This admixture is being replaced by organometallic compounds of manganese (IPR, 2008).

This element enters the human body predominantly through respiration or the digestive system. Inside the body it accumulates in the blood, soft tissues, teeth and bones (Mayer and Wilson, 1998). Adverse effects on the human body include, in particular, the negative effects on the central and peripheral nervous system and reproductive organs, kidney dysfunction or negative effects on the cardiovascular system and metabolism of vitamin D. Also, prenatal and neonatal exposure to lead manifests itself mainly in the decrease of neurobehavioral and visual-motoric functions (Lehr et al., 2005). Lead and its compounds may also have carcinogenic effects since research has confirmed a significant relationship

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between the level of lead in blood >20 μg/dl and the increased risk of death due to tumorous illnesses (Silbergeld and Voet, 2003). Evidence exists that even low levels of lead in the human body (below 25 μg/dl) may cause brain damage, so there is almost no acceptable level for it (Salvato et al., 2003).

Considering its high risk potential, Pb is subjected to stringent surveillance legislation and control mechanisms. Continuous improvement in the treatment of lead commodities is, among others, one of possible ways to an economic growth. According to the Organization for Economic Cooperation and Development (OECD, 2008), effective treatment methods help reduce negative impacts on the environment.

Due to the above reasons, the research focuses on the assessment of the overall level of lead handling in the Czech Republic and the closing of the Pb lead material cycle. The results can then be used as a basis for the up-date of "The Secondary Raw Materials Policy of the Czech Republic" (MIT, 2014).

2. Materials and methods

An analysis of the material flows of lead in the Czech Republic was performed on macro-economic scale for 2011. The analysis included identification and quantification of Pb resources in the Czech Republic.

To be able to identify the material flows of lead in the Czech Republic, a simplified diagram was created, and afterwards, each of the flows indicated therein has been quantified. The data on natural deposits of lead are published by the Czech Geological Service (CGS, 2012b). The only direct material inputs are based on the import of refined and crude lead, Pb-bearing products and waste. There is no extraction of natural Pb resources being run now in the Czech Republic. Quantification of these items is based on the data published in the External Trade Database of the Czech Statistical Office (CSO, 2012a), which uses the Harmonized System Nomenclature (CSO, 2014b) as drawn up by the World Customs Organization (HS) together with the Combined Nomenclature of the European Union's classification (CN) (European Union, 2013).

The Czech economic system relating to the material flows of lead includes metallurgical production, as well as production of goods and consumption including stock items. Because of the lack of available national-scale data, we have used internal data provided by the companies. One of the key processing capacities is represented by Company Kovohutě Příbram nástupnická, a.s. situated in the Central Bohemian region. The company's core business includes recovery of Pb from waste and the follow-up production of lead and its alloys, as well as processing of waste bearing precious metals, or electric and electronic scrap materials for the Central European region (Kunický, 2006). The quantification was made for both Pb components of a blast-furnace charge, including numerical representation of the lead content, and the resultant production of refined lead and other by-products or items returnable into the recycling process.

Calculation of the amount of recycled lead in the blast furnace is based on the method as defined in Annex II to the Commission Regulation (EU) No. 493/2012, laying down, pursuant to Directive 2006/66/EC of the European Parliament and of the Council, detailed rules regarding the calculation of recycling efficiencies of the recycling processes of waste batteries and accumulators. According to Article 3, section 2 of the above-mentioned Regulation, the said method can be applied to the calculation of the percentage of recycled lead content for any recycling process. The amount of recycled lead (R_{Pb}) obtained from the recycling process for the purposes of Art. 12, section 14 of the Directive 2006/66/EC is given as a weight percentage value and determined on the basis of Pb weight in the output fractions generated by recycling ($m_{Pb\ output}$) and by the weight of Pb in the input fraction entering the recycling process ($m_{Pb\ input}$). Lead contained in slag and matte, and in further output fraction at the end of the recycling process, is not included in the calculation.

$$R_{Pb}[wt\%] = \frac{\sum m_{Pb\ output}}{m_{Pb\ input}} \times 100$$

The international company Johnson Controls, Inc., from the region of Liberec is focused, besides other industrial branches, in the production of lead automotive batteries. There was no specific data on the production and consumption available; nevertheless, information about the production capacity is included in the Decision on the Integrated Permit Amendment (RALR, 2012). As far as Pb consumption in the Czech Republic and goods in stock relating thereto are concerned, the study limited itself to the identification only because of impossibility of gaining or replacing the data.

Secondary raw materials, waste from production intended for re-use and waste intended for other ways of recovery were also subjected to the analysis of the material flows of lead in the Czech Republic. Secondary raw materials are evaluated due to their relationship to the Raw Material Policy of the Czech Republic, which aims to create favorable conditions for the extraction of raw materials from products and materials that have completed their life cycle for their further processing and use. However, issues concerning of non-ferrous metals, resp. lead, have not yet been included.

Information for the quantification was obtained from the document Generation, Recovery and Disposal of Waste (CSO, 2012b). To get a clear classification, relevant catalog codes as per Annex 1 to the Decree No. 381/2001 Coll. were added thereto.

Quantification of the outputs is demonstrated by the data on the export of crude and refined lead, as well as Pb products and waste, which were searched out in the above mentioned External Trade Database of the Czech Statistical Office by using the HS/CN classification (CSO, 2012a). The Statistical yearbook on environment of the Czech Republic helped quantify Pb outputs into the environment, namely leaks into water, soil and atmosphere and Pb transfer through wastewater and waste (MOE, 2013). Based on the obtained summary data on the inputs and outputs and the difference between them, a balance of material flows of lead in the Czech Republic could be established and respective change in Pb accumulation in the economic system could be determined.

3. Results

3.1. Identification of the material flows

Identification of the material flows of lead in the Czech territory is documented by a simplified diagram in Fig. 1.

3.2. Material inputs

There is currently no extraction of polymetallic deposits of lead running in the Czech Republic. The extraction was terminated in 1994. The end product of the extraction process was a Pb–Zn concentrate that was used for export purposes since there were no inland capacities for its processing available (CGS, 2010).

There are eight exclusive registered deposits located mostly in the Moravian-Silesian region and six exhausted deposits and other sources in South Bohemia (CGS, 2012a). Reserves that are present in Czech lead deposits are estimated to reach 152,000 tons (CGS, 2012b).

The major material inputs, including crude and refined Pb as well as Pb products and waste are imported from abroad (Table 1). The imported lead quantities totalled to 625,916 tons in 2011. The key items include, among others, unwrought refined lead