54/2015
Trinkel, V.; Kieberger, N.; Rechberger, H.; Fellner, J. (2015) “Material flow accounting at plant level case study: heavy metal flows in blast furnace process” In Proceedings: International Workshop “Mining the Technosphere - Drivers and Barriers, Challenges and Opportunities”, Lederer, J.; Laner, D.; Rechberger, H.; Fellner, J. (Ed.), 1-2 Oct. 2015, TU Wien, p. 125-130. ISBN 978-3-85234-132-3

International Workshop
**MINING THE TECHNOSPHERE "Drivers and Barriers, Challenges and Opportunities"**

Editors: J. Lederer, D. Laner, H. Rechberger, J. Fellner

Vienna, 2015

ISBN 978-3-85234-132-3

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http://iwr.tuwien.ac.at/mining-the-technosphere

# MATERIAL FLOW ACCOUNTING AT PLANT LEVEL CASE STUDY: HEAVY METAL FLOWS IN BLAST FURNACE PROCESS

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## Introduction

In a blast furnace process a huge turnover of materials takes place. The bulk of this material turnover is made up by Iron (Fe) and Carbon (C). However, the different input materials utilized carry to a minor extent also other substances, such as heavy metals (e.g. Zinc (Zn), Lead (Pb), Chromium (Cr), Nickel (Ni), Cadmium (Cd), Mercury (Hg)) into the blast furnace, which are subsequently transferred to different output flows. These so called micro-elements are either of interest for the quality of the product and by-product, due to their contents of Cr, Ni, for the process stability (e.g. Zn, Pb) or due to environmental reasons (e.g. Hg, Cd).

Material flow analysis (MFA) represents an appropriate tool to trace the flows of substances through industrial processes and to derive characteristic patterns for their behavior and distribution to certain output flows. The latter also named as transfer coefficients (TC) can (after their determination and validation) be used to substantially reduce sampling and measurements efforts usually necessary to adequately monitor substance flows through industrial processes. This has been successfully demonstrated by Morf and Brunner (1998), who applied the MFA for analyzing the feed composition of waste incineration plants by simply analyzing the residues arising from the process.

However, with respect to the application of MFA to the blast furnace process some challenges are to be tackled. These challenges include sampling and measurement methods as well as the variable behavior of some elements in the process (Trinkel et al., 2015a).

In the following the application of MFA for tracing Pb through a blast furnace and its satellite processes (top gas cleaning) is discussed. The heavy metal Pb has been chosen since it is relevant with respect to environmental and process control aspects.

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## Materials and Methods

The investigated blast furnace process (including satellite processes necessary for top gas cleaning) with all its input and output flows is illustrated in Figure 1.

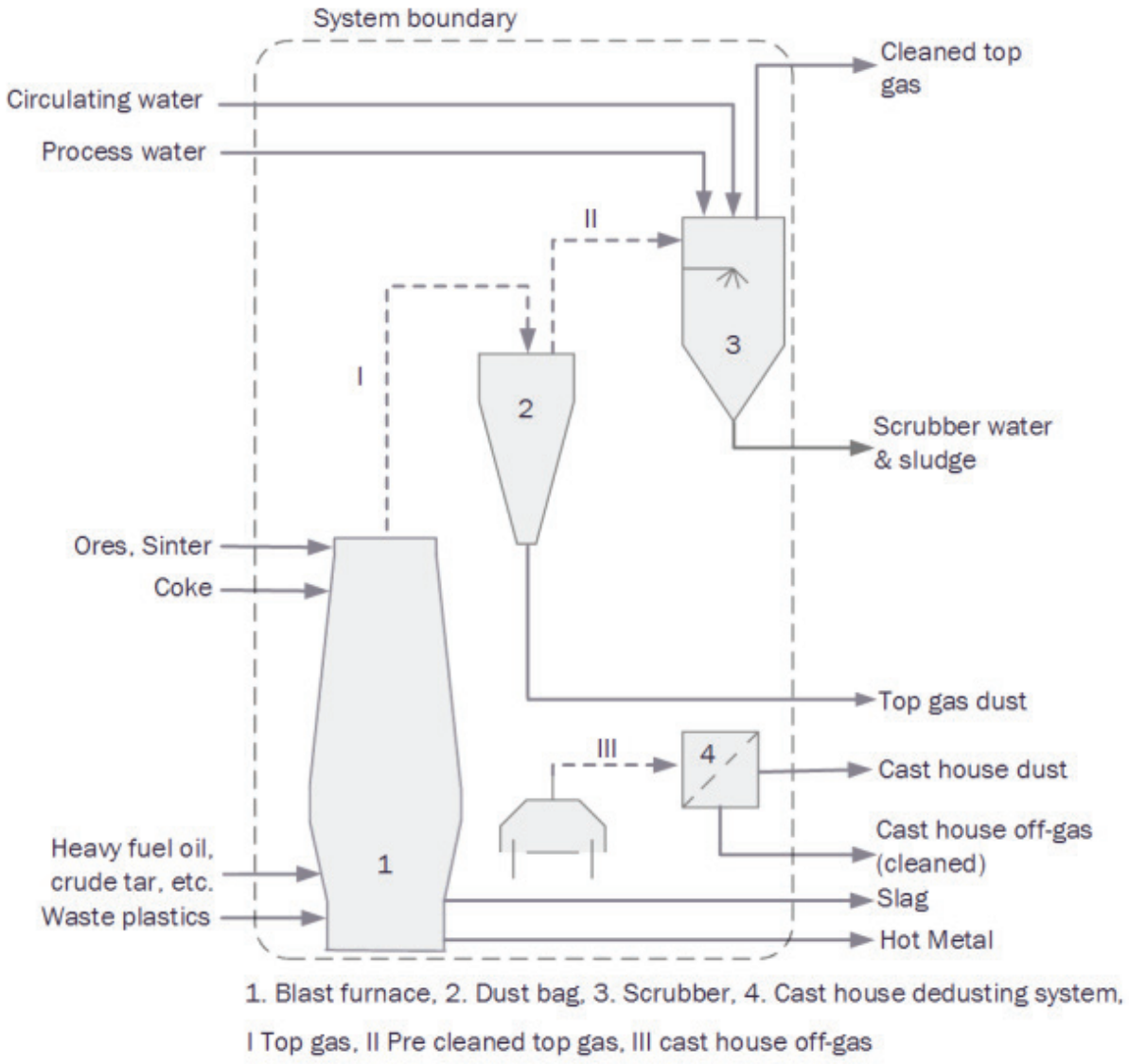


**Figure 1: Blast furnace model (based on Trinkel et al. (2015b))**

For the investigated plant annual mean values including mass/volume flow measurements for all inputs and outputs and concentration measurements for the respective heavy metal were available. These data were used to trace Pb flows by applying MFA.

In addition to routinely measured data by the plant operator, comparative measurements for the Pb content of the hot metal (HM) using X-ray fluorescence spectroscopy (XRF) and optical emission spectrometer (OES) were available.

## Results

MFA was conducted for different heavy metals (Zn, Pb, Ni, Cr, Hg, Cd) for the years 2009 to 2012. In the following, the results for the Pb MFA are exemplary discussed. Based on the MFA conducted for the years 2009 to 2012 it became obvious that the differences in balances (total input versus total output of Pb) as well as the output of Pb via the HM have risen every year (see Figure 2). Whereas, in 2009 the difference in balance for Pb amounted to about 20 %, it doubled to almost 40 % in 2012 (output > input). During the same time the output of Pb via the HM indicated a similar development: in 2009 about 25 % of the total Pb output were discharged via the HM, this share increased to more than 35 % in 2012.

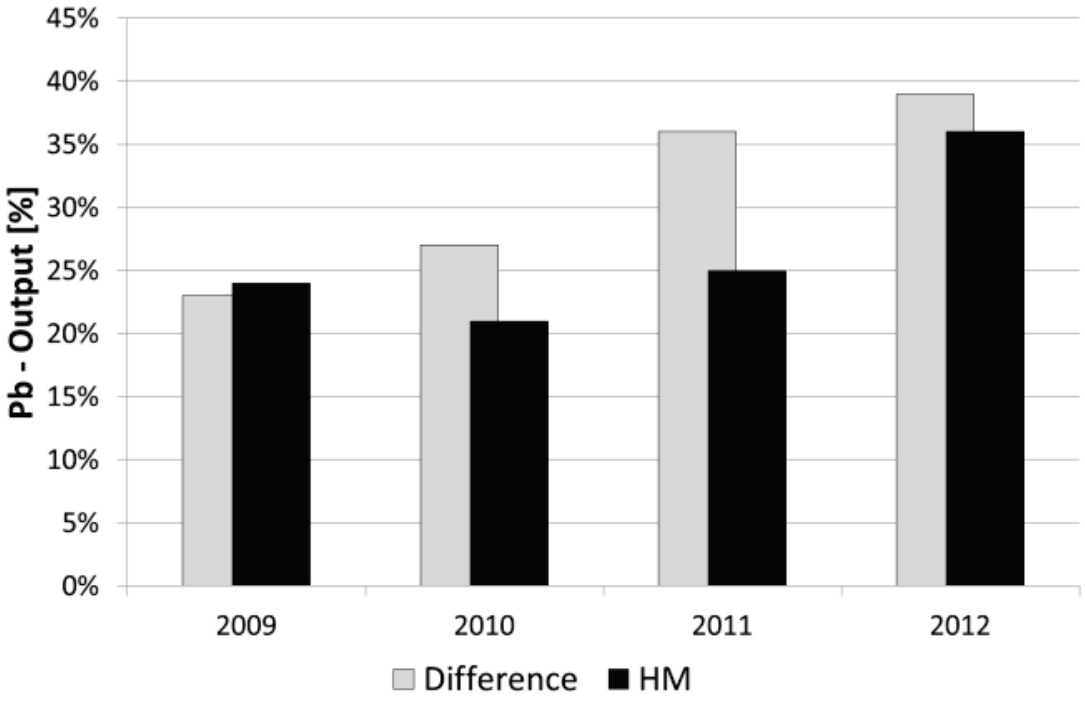


**Figure 3: Differences in Pb balances and Pb output via HM for the years 2009 – 2012**

The Pb discharge via the HM observed for the years 2009 to 2012 is in contradiction to the investigations conducted at the same plant by Morf (2007) in earlier times. His results indicate that only 10 % of the total lead input leaves the blast furnace process via the HM.

In order to clarify these differences, the output flow HM was investigated in more detail. Since the HM represents the sellable product of the process, its mass is well determined. Thus, the concentration measurement of Pb can be considered as the only potential source for errors, which could explain the observed differences.

The Pb content of the HM is measured by XRF. In a first step HM samples (which are characterized by a flat cylindrical shape) have been analyzed for their Pb content at both sample surfaces (the upper and lower base area of the cylindrical sample) using XRF. Thereby, it turned out that Pb is not equally distributed within the HM sample, since the analysis results for both

sides showed large differences (see Figure). The Pb concentration on one surface of the sample can even be twice as high as the concentration on the opposite sample side (e.g., Sample 1, Sample 2 and Sample 5 in Figure).

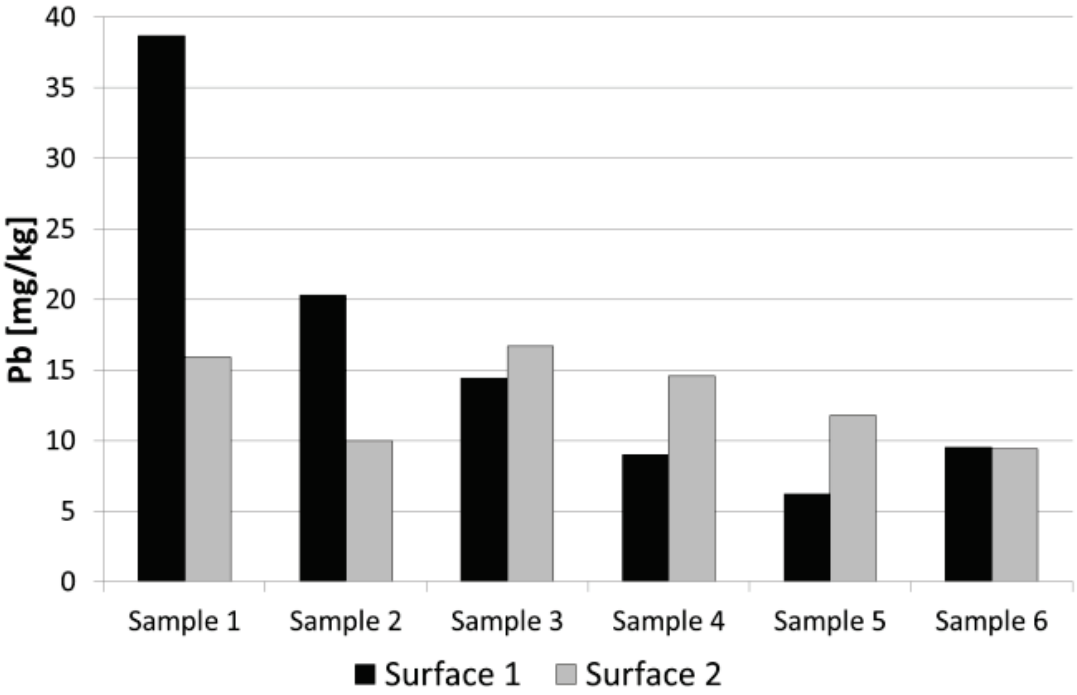


**Figure 3: Pb concentration in HM samples measured at the upper and lower surface of the cylindrical HM samples**

In a second step the reliability/accuracy of the measurement method itself was questioned. Pb occurs only in trace amounts in the HM and thus, the applicability of XRF is limited. Comparative measurements using OES demonstrate that the Pb concentrations determined by XRF most likely overestimate the Pb content of the HM (see Figure).

From these two findings it can be concluded that the Pb concentration is most likely overestimated and an improvement of the sampling and measurement technique would enhance the reliability of MFA for tracing Pb through the blast furnace process.

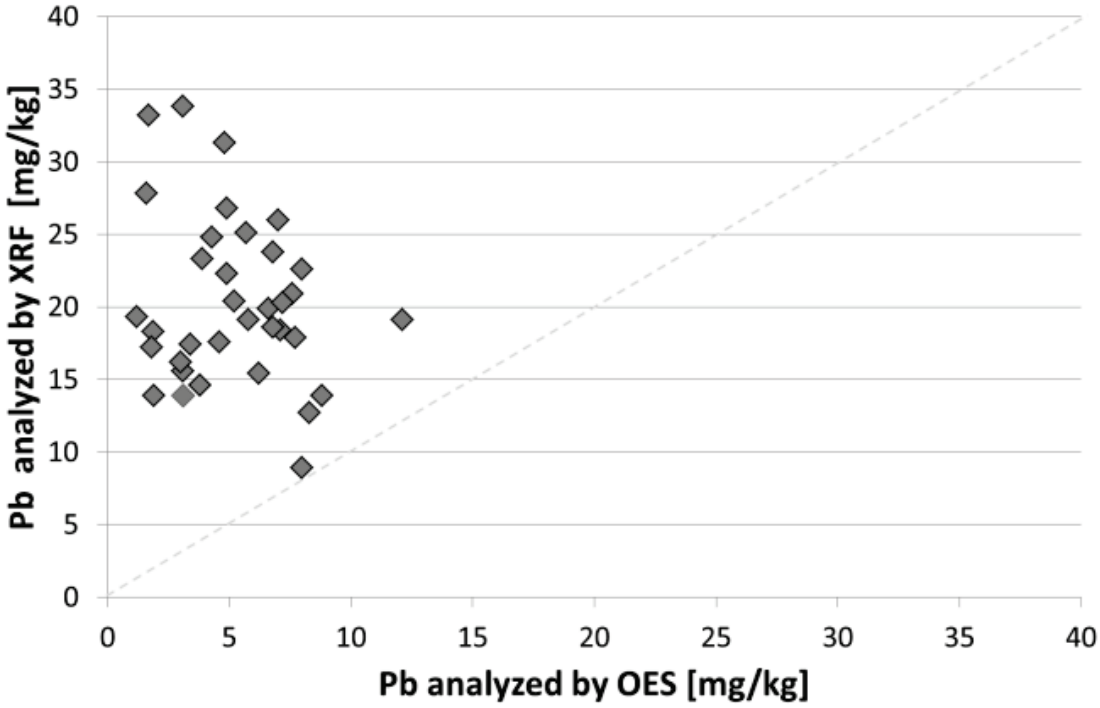


**Figure 4: Comparative measurements of Pb in HM samples using XRF and OES**

## Conclusion and Outlook

MFA was conducted for different heavy metals for a blast furnace process. However, the application of MFA in this context faces different challenges, especially because heavy metals might be present at very small contents in different input and output materials. Moreover, input and output materials are sometimes extremely heterogeneous with respect to their composition, which makes representative sampling and subsequent analysis difficult.

Exemplary for all investigations the MFA results for Pb have been presented and discussed. Thereby, it was shown that the major challenge for this element with respect to enterprise level material flow accounting represents the analytical determination of the Pb content in the HM. Different analysis methods resulted in different Pb contents. Moreover, it was shown that Pb is also unequally distributed in the HM sample, questioning current practice of sampling and analysis.

In a future step, it should be investigated how to obtain a more homogenous HM sample for Pb and how to improve the analysis of the Pb content. Afterwards, it should be evaluated if these enhancements improves MFA results for Pb and allows determining constant TC for the process.

**Acknowledgements**

The present work is part of a large-scale research initiative on anthropogenic resources (Christian Doppler Laboratory for Anthropogenic Resources). The financial support of this research initiative by the Federal Ministry of Science, Research and Economy and the National Foundation for Research, Technology and Development is gratefully acknowledged. Industry partners co-financing the research center on anthropogenic resources are Altstoff Recycling Austria AG (ARA), Borealis group, voestalpine AG, Wien Energie GmbH, Wiener Kommunal-Umweltschutzprojektgesellschaft GmbH, and Wiener Linien GmbH & Co KG.

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