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DEPLETION OF ABIOTIC RESOURCES IN THE STEEL PRODUCTION IN POLAND

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Steelmaking processes consume a lot of energy and materials, therefore researchers are constantly looking for new ways of reducing the consumption of resources in the production processes. The main purpose of the article is to present abiotic resource depletion the in steel production in the case of integrated steelmaking route in Poland and its role in life cycle assessment. There are different methods of life cycle assessment for abiotic resources, the use of which affects the quality of the obtained information. The article presents some results of life cycle assessment of abiotic depletion.

Key words: steel production, minerals, metals, fossil fuel, life cycle assessment

INTRODUCTION

Reduction of natural resource depletion is one of the key elements of the balanced development strategy in the European Union (EU) for numerous branches of industry, including the steel industry. In the EU, a more efficient use of resources is at the core of the policy aimed at promoting sustainable growth [1]. Natural resources management and environmental implications of critical raw materials assessment are priorities of the environmental policy in the EU industries [2]. For several years innovative methods have been used in the steel sector for greenhouse gas emission reduction [3], new models of the decision-making process for steel [4,5] and methods of natural resources depletion assessment. Life Cycle Assessment (LCA) is a technique which allows to assess abiotic resource depletion [6]. According to the life cycle assessment approach, natural resources cover biotic and abiotic resources. Abiotic resources are inorganic or non-living materials at the moment of extraction. Abiotic resources include minerals, metals and fossil fuels. Biotic resources are living at least until the moment of extraction from the natural environment [7]. Abiotic resources are the basis for economic growth and play a crucial role for technological developments in the steel industry and other sectors. Abiotic resources include minerals and fossil fuels [8]. Abiotic resource depletion is an impact category in the life cycle assessment [9]. Evaluation of potential environmental impacts for steel production in Poland based on the life cycle assessment (LCA) was shown in [10]. Water depletion because of steel production in Poland was presented in [11].

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METHODS

Life cycle assessment for abiotic resource depletion in the integrated steel production in Poland was conducted according to the requirements of the ISO 14040 [12]. The objective of the study was to carry out assessment of resource depletion in the integrated steel plants in Poland. The system boundary for environmental assessment included the following processes: iron ore sinter plant, blast furnace, lime production plant, basic oxygen furnace, continuous casting plant and hot rolling plant. Input and output data was obtained from existing steel plants in Poland. The functional unit (FU) of this analysis was one ton of steel produced in the integrated steel plant in Poland. Results were obtained according to the mass allocation in steel production. The results was obtained for main product (cast steel) and include LCA for co-products (blast furnace slag and basic oxygen furnace slag). More on the topic of LCA methodology and inventory data for steel production was presented in [10].

Assessment of abiotic resource depletion was carried out using the LCA software package SimaPro v.8.0.4 (Pre Consultants B.V) and the Ecoinvent database within the program. The study performed an environmental analysis according to two impact assessment methods: Instititute of Environmental Sciences (CML) and ReCiPe Midpoint which acronym represents the initials of the institutes that were the major collaborators in design the LCA method: Rijksinstituut voor Volksgezondheid en Milieu - National Institute for Public Health and the Environment (RIVM) and Radboud University, Instititute of Environmental Sciences (CML) and PRé Consultants (PRé).

According to CML, depletion of abiotic resources is divided into two impact categories: abiotic depletion for minerals and abiotic depletion for fossil fuels. The characterisation factor is the abiotic depletion potential (ADP). This factor is derived for each extraction of minerals and fossil fuels and is a relative measure with depletion of mineral antimony as a reference [13,14]. ADP is determined for each extraction of minerals. ADP is expressed in kg antimony equivalents/kg extraction based on concentration reserves and the rate of deaccumulation [15]. CML method allows for an assessment of depletion of the following minerals resources: aluminium, antimony, arsenic, barium, beryllium, bismuth, boron, bromine, cadmium, chlorine, chromium, cobalt, copper, gallium, germanium, gold, indium, iodine, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, niobium, palladium, phosphorus, platinum, potassium, rhenium, selenium, silicon, silver, sodium, strontium, sulphur, tantalum, tellurium, thallium, tin, titanium, tungsten, uranium, vanadium, yttrium and zinc.

Abiotic depletion of fossil fuels is related to the Lower Heating Value (LHV) expressed in MJ per kg or m^3 of fossil fuel. The reason for using LHV is that fossil fuels are considered to be fully substitutable [16-18] CML method allows for an assessment of depletion of the following fossil fuels: hard coal, lignite, natural gas and crude oil.

Another analysis was conducted with use of the ReCiPe method in order to present the results of the assessment of metal depletion.

The objective of the ReCiPe Midpoint method is evaluation of eighteen environmental indicators, including metal depletion [19]. ReCiPe method allows for an assessment of depletion of following metals: aluminium, chromium, cobalt, copper, gold, iridium, iron, lead, manganese, molybdenum, nickel, osmium, palladium, platinum, rhodium, ruthenium, silver, tin, uranium and zinc. According to ReCiPe Midpoint, extracted metals are converted, with iron as a reference substance kg Fe eq [20].

RESULTS AND DISCUSSION

The studies of abiotic resource depletion were conducted to explore the environmental aspects of steel production in Poland in terms of depletion of fossil fuels, minerals and metals. The results of the fossil resources and minerals depletion were presented in Table 1. The results of the metal depletion were shown in Table 2. Depletion of particular fossil fuels and minerals was shown on Figure 1 and 2. Particular metal depletion in integrated steel plant was presented on Figure 3.

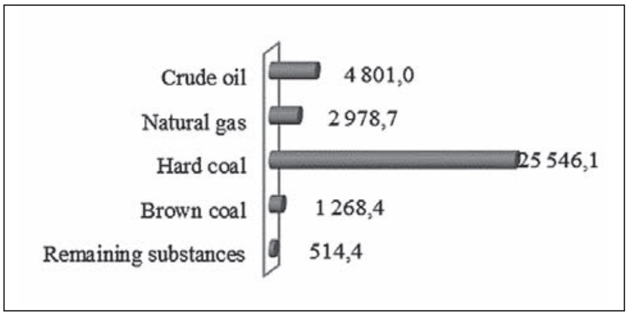

Figure 1 Fossil fuel depletion in integrated steel plant

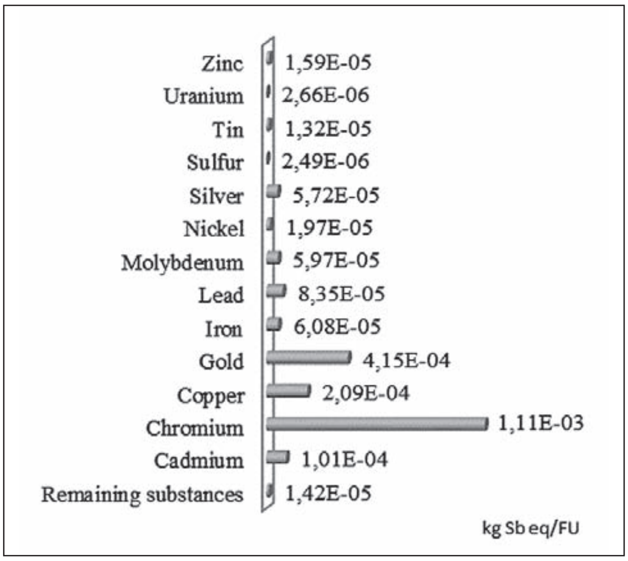

Figure 2 Minerals depletion in integrated steel plant

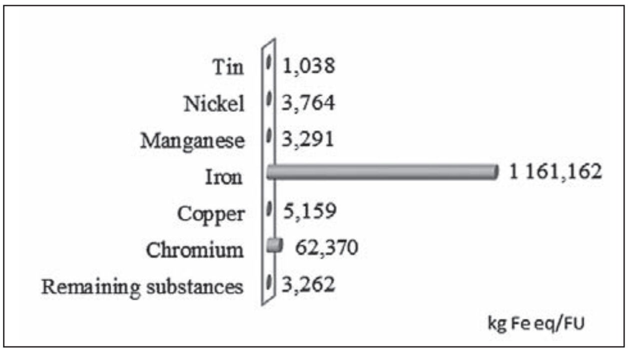

Figure 3 Metal depletion in integrated steel plant

Table 1 **Abiotic depletion (AD) for steel production in integrated steel plant based on CML**

Resource	Fossil resources depletion / MJ/FU	Minerals depletion / kg Sb eq/FU
Iron ore	446,08	8,20E-05
Lime	36,86	1,85E-05
Dolomite	13,68	1,31E-06
Iron pellet	733,71	8,13E-05
Iron scrap	206,56	5,66E-04
Lubricating oil	3 412,70	2,07E-04
Refractory	1 324,81	1,10E-03
Tap water	371,12	2,70E-05
Electricity	2 368,97	1,87E-05
Anthracite	567,67	1,89E-06
Hard coal coke	1 7867,15	4,22E-05
Coke oven gas	4 300,16	1,21E-05
Natural gas	1 040,70	3,15E-06
Coke breeze	2 418,37	5,71E-06

ADP of fossil fuels for steel amount in total to 35 108,56 MJ/FU and ADP for minerals resources is 0,0022 kg Sb eq/FU. Hard coal coke used in blast furnaces (50,89 %), coke oven gas (12,25 %) and lubricating oil (9,72 %) have the largest abiotic depletion for fossil fuels. Fossil fuel scarcity was related mainly to hard coal (97,23 %). The largest mineral depletion in the steel production occurred in the basic oxygen furnace system produced by refractories (50,71 %) and iron scrap sites (26,16 %). Minerals scarcity in refractories was related mainly to chromite ore concentrate (97,23 %) and in case of iron scrap sites it was related mainly to gold (42,91 %) and copper (12,90 %).

Table 2 **Metal depletion for steel production in integrated steel plant based on ReCiPe Midpoint**

Resource	Metal depletion / kg Fe eq/FU
Iron ore	950,55
Lime	0,72
Dolomite	0,07
Iron pellet	204,42
Iron scrap	8,84
Lubricating oil	3,60
Refractory	61,77
Tap water	1,99
Electricity	1,26
Anthracite	0,26
Hard coal coke	4,56
Coke oven gas	1,16
Natural gas	0,23
Coke breeze	0,62

LCA for metal depletion impact category for steel amounts in total to 1 240,045 kg Fe eq/FU. The largest metal depletion was related to iron ore in sinter processes (76,65 %) and iron pellet in blast furnaces.

On the basis of a comparative analysis of the results from the analysis for abiotic depletion based on CML and ReCiPe significant differences were found. On the basis of the conducted analyses, it was proven that the choice of a method (LCIA methods) is crucial in case of the assessment of abiotic depletion. It was found that both selected methods: CML and ReCiPe yield different results due to different methodology and other reference substances. The analysis of the CML method pointed out that refractories were the main sources of mineral resource depletion, whereas the analysis of the ReCiPe method proved iron ore consumption to be the main source of metal resource depletion in the steel production.

CONCLUSIONS

This paper discussed the depletion of abiotic resources caused by steel technologies. This research was the first to account abiotic resource scarcity for the entire steel production in the integrated steelmaking route in Poland. It was found that the fossil resource depletion was mainly related to hard coal coke, coke oven gas and lubricating oil. The depletion of minerals was mainly related to refractories and iron scrap sites and the metal depletion was mainly related to ores and iron pellets.

The results of this study can be used as a base for a depletion assessment of critical raw materials in the supply chain of steel. The paper can help decision makers in the steel sector understand the problem of natural resource depletion and to improve resource management with the life cycle approach.

Limited use of abiotic resources is one of the priorities of the environmental policy in the steel sector. LCA is a useful technique for assessment of natural resources including critical raw materials.

It was found that LCA can be suited to measure the environmental impacts related to abiotic resources and LCA can be used for the management of critical raw material.

The results presented in this paper are a first stage towards a comprehensive, holistic analysis of natural resource depletion. The following stages will develop further analyses of other resource depletion cases like land, biomass and water in the steel life cycle.

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Note: The responsible for English language is M. Sokołowska, Gliwice, Poland