

REDUCING THE CONTENT OF HARMFUL SUBSTANCES IN INPUT RAW MATERIALS IN THE BLAST-FURNACE PROCESS

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Abstract

The blast furnace process can be negatively affected by a number of harmful elements. These may interfere with the course of the technological process, but can also increase production costs. Harmful elements are contained in the blast furnace's charge and they disrupt chemical, physical, and also the thermal processes in the production of iron. Changes in the above processes may produce a range of effects from changes in the flow of gases to problems with a decrease of the charge or excessive heating or cooling of the hearth. In the ideal process, we can remove harmful elements into the slag. But it remains crucial to monitor and reduce the contents of negative elements already in input raw materials. Thus, their continuous circulation in the blast furnace is limited. Alkali carbonates represent a large group of harmful substances. They can re-enter the process and negatively affect the technological as well as economic and operational indicators of the blast furnace process. Alkalis may enter the process, for example, in the form of silicates or carbonates. This article aims to analyse the content of Na₂O compounds entering the blast furnace process and the possibility of reducing their negative consequences. The contents of the compounds and their effects were monitored for a long term scale in the context of the research.

Keywords: Blast furnace, iron making process, production costs, alkali, input raw materials, harmful substances

1. INTRODUCTION

The main components of the blast furnace charge are the metal-bearing component in the form of agglomerates, briquettes, pellets or lumps, fuel and bases [1]. Fuel is most often a blast furnace coke, made of hard coal, characterized by sufficient strength and porosity, with the lowest possible sulphur content and an appropriate size. Due to the acidity of the ores used in our country, most slag-forming additives are alkaline, most often calcium carbonate CaCO₃. With the input materials, harmful substances, both for the environment and for the technology itself, enter the blast furnace process or they are produced during the process [2].

1.1. Harmful elements in the blast-furnace process

Major harmful substances produced not only during the blast furnace process, but also while sintering ore, are, among others, mainly SO₂ and NO_x. The rate of their formation is affected, in addition to burning coke, mainly by the moisture content of the materials, limestone granulation, the MgO content and the return of fine particles [3]. Together with CO, CO₂, volatile organic compound and particulate matter, they represent the group of the most significant harmful substances arising during the production of iron [2]. SO₂ and NO_x are the major factors in the formation of acid rain and respiratory diseases [4]. These harmful substances are addressed in a number of recent studies and several ways of reducing their emissions have been introduced. Methods of reducing SO₂ and NO_x emissions are based, for example, on the use of plasma, activated carbon, chemical absorption or selective catalyst reduction [5], [6]. There are also toxicity concerns with a number of metals (e.g. cadmium, lead, and mercury) and even metals that are biologically essential may also become toxic at high levels (e.g. zinc and copper), which is considered in more detail, for example, in Norgate et al. [6]. There has been also a significant effort made to deal with sulphur content in iron ore [8].

Given the scale of the issue of harmful substances in blast furnace processes, this article is focused on alkaline substances, especially Na₂O and its content in input materials and output products. Alkaline substances cause higher reactivity of coke, premature mellowing of metalliferous batch, and disintegration of sinter; they also take a share in the creation of deposits in fire resistant blast-furnace lining and they accelerate its wear. Heavy metals have similar effects. These problems lead to the higher consumption of coke and irregular blast-furnace runs [9]. Circulation and accumulation of dangerous elements, especially K, Na, Pb and Zn, is also discussed in Jiao's study [10], pointing out, in addition to increased coke consumption, also the reduction of gas utilization.

Besides the negative effects of the mentioned substances, especially with regard to the Na₂O and K₂O content in the batch, it is discussed that their influence on studies indicate that the increased Na₂O or K₂O content in the batch reduces melting temperature and viscosity, enhancing the dephosphorization ability under the same temperature and main slag composition. The slag melts more quickly, which improves the dynamic conditions for dephosphorization [11].

Alkaline carbonates enter the blast furnace process mainly from agglomerates and pellets. This is mainly due to the use of cheap ores that contain a lot of harmful substances. Other sources of alkali can also be coarse ore or limestone and dolomite. The presence of alkali in the blast-furnace process is, among other things, referred to as one of the key causes of lining strength reduction, or even its cracking [12]. One of the major concerns of the blast furnace operators is alkali balancing, especially Na₂O and K₂O content, as accumulation of alkali in the blast furnaces leads to adverse conditions that affect production. During the process of iron making, they accumulate in the blast furnace in the form of carbonates, intercalation compounds of carbon and as complex silicates. These compounds decompose in the lower part of the blast furnace to give a metallic alkali, which consumes high heat and releases the same in colder areas during condensation. The overall effect is the cooling of the hearth and the heating of the top zone. Alkalis in the stack lead to the formation of accretions and descend intermittently, which can result in serious instability.

When evaluating the amount of alkali in the blast-furnace process, the sum of Na₂O + K₂O compound contents is generally used. The allowable limit is always given by the specificity of each particular blast furnace. Basic reduction reactions of carbonates are carried out at temperatures above 1250 °C. The reaction can be written in the form of equations 1 and 2.



The resulting potassium and sodium are then in the gaseous state. Since there is a strong flow of gases towards the higher blast furnace spaces, these elements are transported in this form to cooler parts. Here it is possible to re-create carbonates by reacting potassium (sodium) with carbon dioxide. Again, the original carbonates of K₂CO₃ and Na₂CO₃ are formed. These are concentrated in the cooler portions of the batch and gradually shifted to the lower parts of the blast furnace. In this way, the alkali is continuously circulated in the blast furnace.

1.2. Problem formulation

As mentioned above, in the case of harmful substances, apart from the environmental impact, these are also the technologies and managed processes which can be disturbed or damaged by their increased content, and their lifetime shortened. Since the blast furnace is a device that has been in continuous operation for many years, it is desirable that all of its components, including the lining, withstand the planned service life without damage and without having a negative effect on the quality of the output products, namely mainly pig iron. The issue of harmful substances in the blast-furnace process is topical for several reasons. The harmfulness of the present or emerging substances can be assessed, for example, by their influence on the environment and human health, on the technological processes, on the technologies and, last but not least, on the blast furnace's economy or on their influence on secondary metallurgy.

2. EXPERIMENTAL WORK

The presented research was conducted in a selected metallurgical plant, where data for analysis was collected over a one year period. During the research, samples were taken from raw materials, as well as from output products. Samples were subjected to wet chemical laboratory analysis, resp. to spectral analysis for gases. In addition to the above, the chemical analysis of the blast furnace's lining was part of the research, but this is not discussed in the article. Due to the focus of the article, the results of the analyses focused on the Na₂O content in the samples are presented below. The results and discussion chapter presents the measurement results and a comparison of individual input, resp. output raw materials in terms of Na₂O content.

3. RESULTS AND DISCUSSION

As part of the research, the content of a number of heavy metals and harmful substances was monitored over a one year period. Close attention was paid to the Na₂O content. **Table 1** shows the measured values in all relevant input raw materials. The Na₂O content is given in **Table 1** as the specific concentration in each feedstock (%). At the same time, the quantity per kilogram of the raw material was enumerated. Based on this calculation, the total amount of compound was subsequently determined for each feedstock.

Table 1 Measured amount of Na₂O in feedstock

	Weight	Quantity	Na ₂ O	
	[t]	[kg·kg ⁻¹]	[%]	[kg·kg ⁻¹]
Sinter I. (Russia)	952 000	0.782	0.08	6.26·10 ⁻⁴
Sinter II. (Belarus)	368 450	0.303	0.07	2.11·10 ⁻⁴
Sinter III. (Brazil)	103 741	0.086	0.06	5.11·10 ⁻⁵
Coke	531 400	0.436	0.07	3.54·10 ⁻⁴
Slag	47 987	0.039	0.09	3.06·10 ⁻⁵
Over limit sinter	33 951	0.027	0.11	8.72·10 ⁻⁵
Granules	176 968	0.141	0.06	3.48·10 ⁻⁴
Lump ore I. (Russia)	84 741	0.071	0.05	4.23·10 ⁻⁵
Lump ore II. (Belarus)	17 174	0.023	0.03	2.72·10 ⁻⁶
Mn - Ca concentrate	8 690	0.008	0.38	3.15·10 ⁻⁵
Limestone	29 147	0.023	0	0
Cast iron shavings / scrap	71 357	0.058	0.01	5.86·10 ⁻⁵
Magnesite break	99 137	0.081	0.20	1.62·10 ⁻⁵
Dross oiled	81 200	0.066	0.05	2.72·10 ⁻⁵
Coal (Czech Republic)	142	0.001	0.71	8.28·10 ⁻⁷
Blast furnace dust	17 320	0.013	0.16	2.27·10 ⁻⁵

The results are graphically depicted in **Figure 1**. The largest amount of Na₂O enters the blast furnace process in the form of agglomerate made of ore coming from Russia (38.2 %). Another significant source of harmful substances is coke (18.6 %) and agglomerate made of Belarusian ore (12.6 %). Content in other feedstock may be considered less significant.

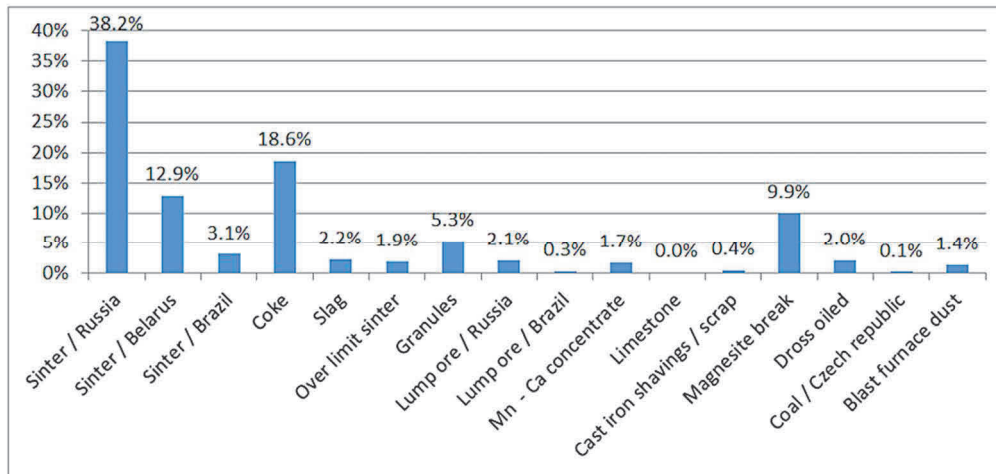


Figure 1 Relative share of Na₂O sources by origin in feedstock

Na₂O concentration was also measured at the output side of the blast furnace process. **Table 2** shows the measured values. The measured specific concentrations were again recalculated to the tonnage of the component. In the case of the output products of the blast furnace process, the largest amount is concentrated in the form of slag at 95.3 %. This can indicate an efficient course of iron production technology in the blast furnace. While respecting technological procedures, most harmful substances should be concentrated in the slag. A detailed view of the total amount of Na₂O in the output products is shown in **Figure 2**.

Table 2 Measured amount of Na₂O in output products

	Weight	Quantity	Na ₂ O	
	[t]	[kg·kg ⁻¹]	[%]	[kg·kg ⁻¹]
Pig iron	1 216 674	1	0	0
Slag	420 327	0.345	0.31	10.70·10 ⁻⁴
BF sludge fine	12 003	0.009	0.12	1.18·10 ⁻⁵
BF sludge rough	11 174	0.009	0.13	1.19·10 ⁻⁵
Discharge / separate	9 920	0.008	0.15	1.22·10 ⁻⁵
Discharge / other	17 197	0.014	0.12	1.69·10 ⁻⁵

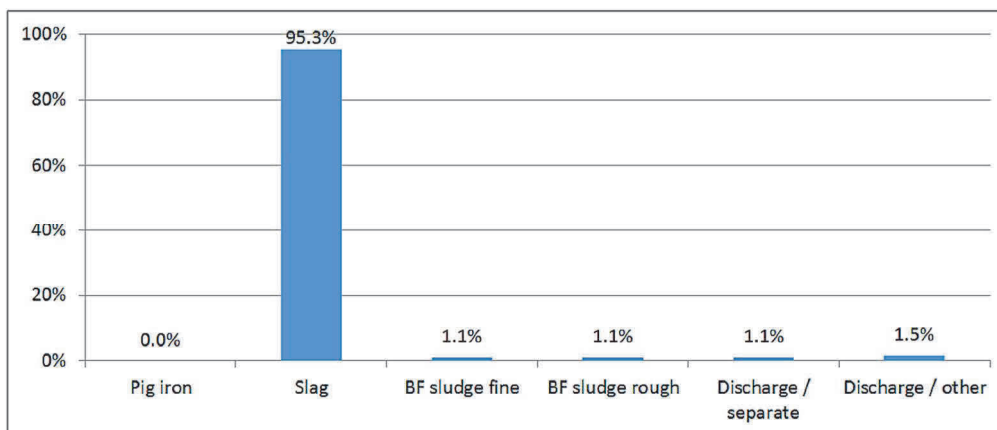


Figure 2 Share of individual products in the total amount of detected Na₂O

4. CONCLUSIONS

Minimizing the effects of harmful substances in the blast-furnace process can be accomplished by various procedures. In the case of heavy metals and alkaline carbonates, it is crucial to reduce the amount entering the blast furnace process. The research has shown that, at the input side of the process, the largest amount of harmful substances is allocated to cheap ore raw materials from which agglomerate is subsequently produced. Harmful substances that enter the blast-furnace process in this form are the most significant in terms of volume. Another source is blast furnace coke. In the case of ores, it is possible to reduce the proportion of harmful substances to some extent during the agglomeration process. This can be done with increased fuel. This procedure can reduce the amount of zinc and alkaline carbonates. At the same time, however, a more limited sulphur removal occurs. Alkaline carbonates may not adversely affect just the iron production technology itself. They may also influence the quality of blast furnace coke. Higher contents can reduce the strength of blast furnace coke, which influences the technological progress of the blast furnace process. A major problem for heavy metals and alkaline carbonates is their continuous cycle in the blast-furnace process. Harmful substances, which pass into the gaseous phase in the oxidation space, settle in the upper parts on cold batch pieces. Then, they re-enter the process. At the same time, they are concentrated in some parts of the blast furnace, mainly in the form of lining. Secondly, this can also affect the cost of producing metal. The cost of iron production is also closely related to the problem of choosing adequate ores. High-quality raw materials with a low content of harmful substances are significantly more expensive, which may also be affected by the cost of transporting them from more remote locations. At the same time, however, these raw materials usually contain a larger amount of metal. Therefore, when choosing raw materials, it is necessary to take into account not only the technological but also the cost and logistical indicators.

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