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MARTA BOŻYM[1], BEATA KLOJZY-KARCZMARCZYK[2]

The content of heavy metals in foundry dusts as one of the criteria for assessing their economic reuse

Introduction

Dust emissions from Polish foundries vary from 0.076 to 6.1 kg of dust per Mg of castings and depend on the type of foundry process (Latała-Holtzer et al. 2002). The highest mass of dust is generated during the smelting of metal in furnaces and the cleaning of castings. In accordance with the waste hierarchy, taking environmental protection requirements into account, this waste should be solidified before landfilling due to the possibility of dispersal from the landfill. In addition, storage costs are high and are steadily increasing. For this reason, foundries are trying to reuse the dust in the production process or direct it to recovery processes carried out by external entities. It should be mentioned here that the foundry, from which dust samples were taken, reuses some types of dust in metallurgy as a raw material or as an inert material for filling mine shafts.

✉ Corresponding Author: Beata Klojzy-Karczmarczyk; e-mail: beatakk@min-pan.krakow.pl

[1] Opole University of Technology, Opole, Poland; ORCID iD: 0000-0003-3756-4929; e-mail: m.bozym@po.edu.pl

[2] Mineral and Energy Economy Research Institute of the Polish Academy of Sciences, Kraków, Poland; ORCID iD: 0000-0002-2003-2291; e-mail: beatakk@min-pan.krakow.pl

The most common method of foundry dust reusing is to reuse it in metallurgical processes, provided that the percentage of iron in dust is high. The advantage of recovery consists in the utilization of problematic waste. This solution applies only to the dust with a high content of iron, mainly dust from a melting plant with electric (arc, induction) furnaces or cupola furnaces. For this purpose, two methods of dust recycling in the furnace are used, i.e. blowing the dust directly into the combustion zone through one or more air nozzles or forming briquettes (Smyksy and Holtzer 2002; Holtzer et al. 2006b). The main advantage of briquetting consists in the ability to mix furnace dust with machined chips or dust from pneumatic cleaners, which significantly reduces the cost of waste management. Such a solution is most often used by foundries using cupola furnaces, slightly less often by electric furnaces. The dust from the latter, so-called electric arc furnace dust (EAFD) is classified as hazardous waste due to a high content of heavy metals (Strobos and Friend 2004; Salihoglu and Pinarli 2008; Mymrin et al. 2016). Therefore, its treatment is a priority for foundries in the field of waste management, as it can pose a threat to the environment (Kicińska 2018). Heavy metals recovery is one of the solutions to manage the foundry dust. Heavy metals such as Zn, Pb and Ni in dust from foundry furnaces come from contaminated automotive scrap, e.g. galvanized car body sheet (Smyksy and Holtzer 2002). The profitability of metal recovery depends on their content in dust and the used technology. In addition, other foundry dust may be used in the construction, ceramic and road industries due to the high percentage of silica. It can be concluded that the direction of dust reusing depends on its composition and physical properties, which depends on the stage and place of casting production.

The current work presents the results of research on heavy metal content in the foundry dust from various stages of casting production. The analyzed waste was taken from a foundry using electric furnaces in the production of steel and iron castings. Samples were taken from five production stages, i.e. from electric furnace dust collectors (EAFD), shock grating unit, transport of moulding sand units, pneumatic blast cabinet units and regeneration of spent foundry sand (SFS) units. Characteristics of the tested dust were presented and the obtained results were compared with the literature data in order to assess their suitability for re-use and the environmental risk due to the presence of mercury was assessed.

1. Material and methods

The dust samples (foundry waste) were collected from one of the Polish foundries, located in southern Poland, which specializes in the production of iron and steel castings. The samples were collected by foundry employees in several periods. Dust samples (18 samples, the exact list of samples in the Table 1) were collected from the dust collectors of: electric arc furnace (P1), shock grating (P2), transport of moulding sands (P3), pneumatic blast cabinet (P4) and regeneration of SFS (P5). The foundry uses bag dust collectors and cassette dust collectors with pulse and jet filters. The weight of each sample was approximately 1 kg. Samples were taken between November 23, 2017 to December 1, 2018.

The pH was measured in an water extract (1/2.5, S/L) after 2h (Ostrowska et al. 1991). The CHNS were determined using Elementar Vario Macro Cube elemental analyzer. The loss of ignition (LOI) at 550°C was analyzed. Hg total content was determined using CVAAS method using an AMA 254 analyzer (Altec Ltd.).

The mineralization of dust samples was carried out using a mixture of HNO_3 (65%, Merck), H_2SO_4 (96%, Merck) and HF (70%, Avantor) in a microwave oven in Teflon vessels (Start D, Milestone). The heavy metals (Cd, Pb, Cu, Zn, Cr, Ni, Mn, and Fe) content in solutions of digested dust (mineralized material) were analyzed using a Thermo atomic absorption spectrophotometer (Solaar 6) with FAAS technique. Each sample was analyzed in triplicate.

For quality control a certified reference material 'Fine dust (PM10–LIKE)' (IRMM) ERM®–CZ120) was analyzed in the same way as the samples. Recoveries obtained for metals ranged between 90% and 115%. During each analysis the certified material (ICP multi-element standard solution XI, Merck) was tested to evaluate the correctness of the calibration curve.

2. Results and discussion

Table 1 presents the basic properties of the tested dust, i.e. the pH of the water extract as well as the elemental composition of solid samples and LOI. Figure 1 presents the mercury and other metals contents in the tested dust as a cumulative diagram. The mercury content in the foundry dust is usually very low, hence these values were not compared with other

Table 1. The characteristic of foundry dust by collecting place, mean ± SD

Tabela 1. Charakterystyka pyłów odlewniczych z uwzględnieniem miejsc pobierania, średnia ± SD

Samples	Type of dust samples	pH (H_2O)	Elementar analysis (%)				LOI (% wt.)
			C	H	N	S	
P1	Electric arc furnane dust (EAFD) (2 samples)	7.6 ±1.5	7.8 ±1.0	0.13 ±0.04	0.04 ±0.00	1.05 ±0.21	10.0 ±0.7
P2	Shock grating dust (2 samples)	5.1 ±0.1	5.3 ±0.0	0.11 ±0.00	0.03 ±0.02	0.40 ±0.00	7.1 ±0.6
P3	Dust from transport of molding sands (2 samples)	6.0 ±0.2	6.1 ±3.3	0.12 ±0.04	0.07 ±0.02	0.40 ±0.14	7.9 ±5.2
P4	Pneumatic blast cabinet dust (10 samples)	8.2 ±0.5	2.1 ±0.3	0.11 ±0.03	0.04 ±0.02	0.37 ±0.13	2.5 ±0.4
P5	Regeneration of spent foundry sands dust (2 samples)	5.4 ±0.5	11.4 ±4.1	0.12 ±0.03	0.08 ±0.01	0.65 ±0.07	13.8 ±3.2

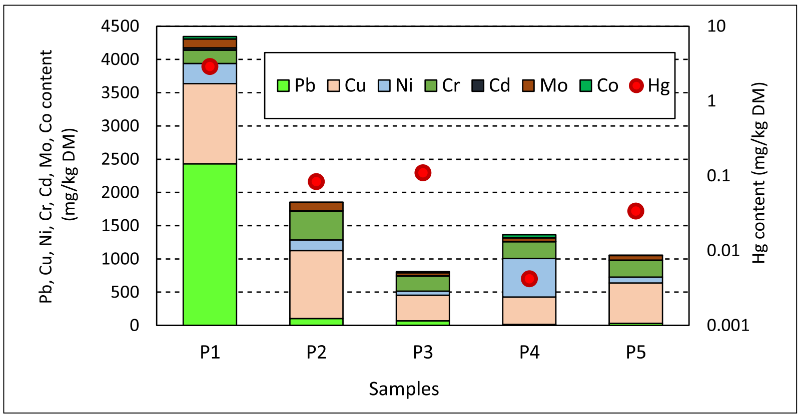

Fig. 1. Heavy metals content in the tested dusts (the mean of obtained results)

Rys. 1. Zawartość metali ciężkich w badanych pyłach (średnia uzyskanych wyników)

analyzed metals. The degree of mercury pollution of foundry dusts allows for the assessment of their impact on the environment. The Hg content also affects the direction of use of these dusts for energy purposes, because the exceeding of Hg limit values in fuel results in an increased emission of this metal, which is limited by Polish law (Journal of Laws 2018 item. 680). The content of heavy metals in dust determines the directions of waste management. Foundry dust is usually characterized by a high content of Fe, Mn and Zn. For this reason, Figure 2 shows the cumulative contents of these metals in the tested samples.

The pH value of aqueous solutions from the foundry dust is affected by their composition and may vary within wide limits (Andres et al. 1995; Salihoglu et al. 2007). On the basis of current research it was found that solutions from shock grating dust (P2), dust from the transport of moulding sands (P3) and regeneration of spent foundry sands dust (P5) were characterized by an acidic reaction. The aqueous extracts from EAFD (P1) were neutral, while those from pneumatic blast cabinet (P4) were alkaline. The reaction has no major effect on the reuse of dust, it can only indicate the presence of acidic (anions) or alkaline (cations) substances of various origins.

Based on the analysis of elemental composition, it can be stated that the highest percentage of carbon was found in the dust from SFS regeneration (P5). This dust mainly consists of moulding sands from organic binders. A high percentage of organic matter in this dust resulted in a high LOI value. According to Holtzer et al. (Holtzer et al. 2006a) and Dańko et al. (Dańko et al. 2016) the dust from SFS regeneration containing a significant proportion of organic matter from binders can be used for energy purposes. The authors proposed its use in cement plants as a fuel and at the same time as a raw material, due to a high content of silica from foundry sands. The remaining tested dust contained a significantly lower percentage of carbon. As stated by Gengel et al. (Gengel et al. 2010) in studies of various types

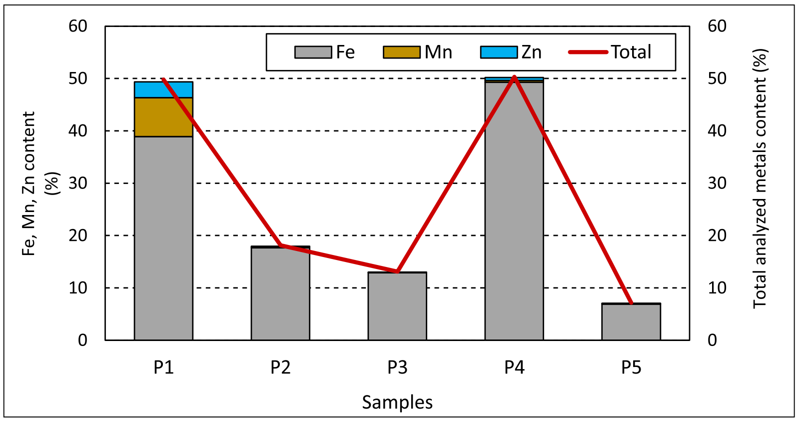

Fig. 2. Fe, Mn, Zn content in tested dusts (the mean of obtained results)

Rys. 2. Zawartość Fe, Mn, Zn w badanych pyłach (średnia uzyskanych wyników)

of foundry dust, the carbon content may vary within very wide ranges of 0.84–17.5%. The sulphur content is evaluated in waste used for energy and as a raw material in construction. Sulphur is an undesirable element due to the possibility of SO_2 emissions during combustion, and because of the reduction of binding properties in building materials. In the tested dust, the highest sulphur content at 1.05% (Table 1) was determined in EAFD dust (P1). The source of sulphur in this dusts may be the smelting of contaminated scrap metal. For comparison, Chirila and Luca (Chirila and Luca 2011) determined the sulphur content of EAFD at 0.54–1.5%.

As mentioned before, the LOI value indicates the possibility of using the tested dust for energy purposes. EAFD (P1) was characterized by a high LOI, only slightly lower than the dust from regeneration (P5). For this reason, EAFD can also be used for energy purposes, provided that the pollution limits are not exceeded. For comparison, Laforest and Duchesne (Laforest and Duchesne 2006) determined a significantly lower value of LOI in EAFD at 3.67%.

Although heavy metal contamination of foundry waste has been thoroughly investigated, Hg content has not received much attention. Foundry waste is usually characterized by a low mercury content, which is why the content of this metal is usually omitted in the assessment of toxicity. However, due to a high toxicity of mercury, even a minimal content can have a negative impact on the environment and biota. The presence of mercury in alternative fuels based on waste is limited in Poland due to emission requirements (Journal of Laws 2018, item 680). In the tested dust, the mercury content was very low (0.004–0.110 mg/kg DM), except for EAFD (2.88 mg/kg DM). For comparison, the Hg content in soils around the foundry and landfilled foundry waste (not dust) is 0.017–0.092 mg/kg DM and 0.023–0.065 mg/kg DM, respectively (unpublished results). This means that the mercury content in the tested EAFD was much higher than in other foundry waste and soils. EAFD may pose a threat to the environment in terms of mercury content if reused. For comparison, the mercury content in mining waste, i.e. coal sludge, was 0.097–0.205 mg/kg DM (Klojzy-Karczmarczyk and Mazurek 2019; Klojzy-Karczmarczyk et al. 2019), and in hard coal it was 0.003 to 0.303 mg/kg DM, with an mean value of 0.074 mg/kg DM (Klojzy-Karczmarczyk and Mazurek 2013).

3. Characteristics and management of EAFD

Electric Arc Furnace Dust (EAFD), which is generated during the metal smelting process, is one of the most hazardous industrial waste because it contains a high percentage of heavy metals (Mymrin et al. 2016). It is estimated that the amount of EAFD produced is 15–20 kg/Mg of produced steel, which leads to the production of 4,000–8,000 Mg/year of this dust in the world (Chigwedu et al. 1995; Salihoglu et al. 2007; Woollett and Minet 2007; Li et al. 2010; Chirila and Luca 2011). For comparison, the amount of dust generated from metal smelting in cupolas is estimated at 4–15 kg/Mg of cast iron (Smyksy and Holtzer 2002; Holtzer et al. 2006b). In Europe, 0.5 to 1.0 million Mg of EAFD is produced annually (Chirila and Luca 2011) The most EAFD is produced by countries that are among the leading casting producers, including Italy (170,000 Mg/year), Germany (160,000 Mg/year), France (140,000 Mg/year) and Spain (115,000 Mg/year) (Chirila and Luca 2011). In Poland, about 4,000 Mg of dust is generated annually from cupolas (Latała-Holtzer et al. 2002). For comparison, the US produces 700–800 thousand Mg/year, like all European countries taken together.

Both EAFD and cupola furnace dust is reused during the smelting process due to a high iron content (10–60% wt.) (Chirila and Luca 2011). Miyoshi et al. (Miyoshi et al. 2008), proposed the granulation of EAFD with coal dust and the use of briquette combustion and the sintering of iron ore. The advantage of this solution is to reduce the amount of problematic waste and use it as a raw material, due to a high content of iron and carbon from coke. In the furnace, the dust is bound by slag and does not pose a threat to the environment. A good solution for dispensing dust into the furnace is briquetting (Smyksy and Holtzer 2002; Holtzer et al. 2006b; Kicińska et al. 2018). The obtaining of granules or briquettes of appropriate strength requires high material fragmentation, constant humidity, the use of binding material and a proper selection of the briquetting device. An additional condition is the proper storage of briquettes before re-use. Smyksy and Holtzer (Smyksy and Holtzer 2002) suggest that the balance of individual components in the briquettes should be carefully equalized. Another method of dispensing dust into the furnace is to blow it into the combustion zone through one or more air nozzles.

The chemical composition of EAFD depends on the quality of processed steel scrap, technological and operational conditions, and the degree of dust during metal smel-ting. The content of heavy metals in this dust varies within very wide limits, e.g. Zn 2–46%, Pb 0.40––15.14%, Cr 0.2–11%, Cd 0.01–0.3%, Mn 1–5% (Chirila and Luca 2011). Table 2 presents the content of heavy metals in the tested EAFD compared to the results obtained by other authors.

Table 2. Heavy metal content in EAFD according to various authors compared to own results

Tabela 2. Zawartość metali ciężkich w pyłach EAFD według różnych autorów i wyników własnych

Metal	Andres et al. (1995)	Hamilton and Sammes (1999)	Fernandez et al. (2003)	Sofilic et al. (2004)	Laforest and Duchesne (2006)	Woollett and Minet (2007)	Salihoglu and Pinarli (2008)	Li et al. (2010)	Chirila and Luca (2011)	Bożym and Zalejska (2014)	Own results (P1 sample)
Fe (%)	28.9	39.9	8.22	41.1–48.58	13.45	No data	11.58	38.7	41.06–48.58	No data	35.9–41.9
Mn (%)	4	2.4	No data	No data	No data	No data	No data	No data	5.2–5.93	No data	4.7–10.2
Zn (%)	24.37	37.6	39.9	3.75–8.1	5.2	22–40	19.05	10.06	3.75–8.3	2.96–3.55	2.5–3.6
Ni (%)	0.06	No data	0.1	0.02–0.04	4.1	0.03	0.02	0.07	No data	0.03–0.04	0.03–0.04
Pb (%)	5.7	1.7	5.34	0.94–2.07	1.4	3.0	2.48	0.94	0.92–2.3	0.76	0.24–0.25
Cu (%)	0.5	0.1	3.1	0.22–0.30	No data	0.25	0.15	0.08	0.21–0.33	0.10–0.12	0.11–0.13
Cr (%)	0.3	No data	1.8	0.19–0.33	10.9	0.12	0.22	0.09	0.19–0.35	0.38–0.40	0.02–0.03
Cd (%)	0.07	No data	0.3	0.01–0.03	No data	0.08	0.04	No data	0.01–0.028	0.010–0.013	0.003–0.004
Hg (mg/kg DM)	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	1.53–4.24

P1 – the values for EAFD samples.

Most of the studies on EAFD management focus on methods for the recovery of heavy metals from this dust and its subsequent use in metallurgical processes (Li et al. 2010). Metal recovery from EAFD is carried out using hydro- or pyro-metallurgical processes. Most metal recovery processes are based on pyrometallurgy in rotary kilns, plasma furnaces or flame reactors. The disadvantage of these processes consists in high energy consumption, dedusting and waste gas purification. Hydrometallurgical processes are less expensive, have high efficiency and do not generate gases and dust polluting the environment. This method involves leaching heavy metals using acid (Strobos and Friend 2004) or alkaline (Li et al. 2010) extractants. Hydrometallurgical processes are mainly used to recover zinc, aluminum or lead. The profitability of metals recovery depends on their percentage in dust. The residue after metal recovery may be used in the metallurgy as a raw material, due to a high iron content or landfilled after solidification. The landfilling of hazardous waste is still the most commonly used solution to the emerging EAFD problem. Before landfilling, EAFD should be solidified or stabilized in Portland cement or calcium and magnesium oxides which are used to reduce heavy metal leaching (Andres et al. 1995; Hamilton and Sammes 1999; Fernandez et al. 2003; Sofilic et al. 2004; Laforest and Duchesne 2006; Salihoglu et al. 2007). However, landfilling is expensive and prevents the recovery of valuable metals.

Another direction of EAFD utilization from induction furnaces is its use as a raw material for the production of composite ceramics, due to appropriate granulation (<20 μm), high content of iron oxides (30–50%), silica and silicates (approx. 25%) and carbon (3–10%) (Holtzer et al. 2006b). Mymrin et al. (Mymrin et al. 2016) proposed the use of EAFD as a component in composite ceramics, while using other waste materials, such as spent foundry sand (FS), rejected galvanic glass (GG) and salt from acid battery neutralization (SAN). The percentage of EAFD in these composites is 15–30 wt. The authors found an increase in the mechanical strength of such composites compared to conventional materials. This is due to a high percentage of heavy metals in EAFD with a low melting point (Pb, Zn, Sn etc.) and acting as flux in the sintering process. An additional advantage of the sintering process is the binding of heavy metals into crystal structures, which reduces their leaching from such materials. Gengel et al. (Gengel et al. 2010) evaluated mixtures of foundry dust with sand and their reuse. The authors found appropriate mechanical properties of such mixtures, except cupola dusts.

Based on presented above directions it could be stated that the recovery of Zn from the tested EAFD may not be cost effective, due to a low percentage of this metal (<10%) (Strobos and Friend 2004; Li et al. 2010). The content of other metals in the tested EAFD was low, which did not allow for their recovery. To assess the environmental impact of this dust and its classification as hazardous waste, it is necessary to determine the degree of leaching of these metals. In summary, it can be stated that due to the low content of heavy metals in the tested EAFD, their recovery may not be cost effective, as the percentage of these metals did not exceed 10%. However, a high percentage of Fe and Mn allows for the reuse of this dust as a raw material in metallurgy. Due to the high value of the LOI, the tested EAFD can also be used as a fuel. The restriction of this application may be an increased mercury content, which may affect the emission of this metal from foundry furnaces.

4. Other foundry dust types

Foundry dust, with the exception of EAFD and cupola dust, can be used as a raw material for the production of building materials due to its appropriate grain sizes, binding properties and a high silica content. This dust can be used by foundries as a raw material for the preparation of bentonite-coal mixtures used as an addition to moulding sands (Bednárová and Mikšovský 2005; Holtzer et al. 2007; Gengel et al. 2010). The dust from dedusting of the bentonite mass processing station may be granulated without the addition of a binder, due to the binding properties of the active binder contained in the dust. The granules remain plastic and have appropriate strength properties during seasoning. Foundries may store and reuse granules for their own purposes or sell them to other foundries as a substitute for raw material. The transport of granules does not cause dusting and disintegration (Holtzer et al. 2007). In the Netherlands, dust from the regeneration of moulding sands with bentonite is used to produce ceramic materials to strengthen the landfills (Smoluchowska 2002).

Other foundry dusts are used as substitutes for raw materials in ceramics and in the production of building materials. Gengel et al. (Gengel et al. 2010) evaluated the mechanical properties (compression strength, shearing strength and permeability) of foundry dust and sand mixtures. The authors divided the foundry dust by appropriate composition and physical properties, i.e. flue dust from cupola furnace, dust from moulding and the non-magnetic part of dust from casts blasting. They found that the tested dust improved the mechanical properties of mixtures, except for cupola dust. In other studies, Skvara et al. (Skvara et al. 2002) described the benefits of using metallurgical (blast furnace flue dust) and foundry (steel foundry flue dust) dust for the production of Portland cement. The authors stated that the most important features of dust used in the production of building materials include its proper granulation, composition (silica content) and mechanical properties. This is the dust from SFS regeneration installations or the mechanical machining of castings (shock screens) (Holtzer et al. 2006a; Gengel et al. 2010; Dańko et al. 2016). On the other hand, the dust from pneumatic cleaning contains significant amounts of iron from abrasive steel granules. Therefore, it can be reused as a raw material in metallurgy. The content of heavy metals in the tested dust, except for EAFD, is presented in Table 3. Own results were compared with those obtained by other authors.

In the current study, the highest percentage of iron was found in the dust from pneumatic cleaners. This dust mainly consists of grated steel from steel balls used to clean castings. Hence, this dust can be reused in metallurgy. Some authors found a high percentage of iron also in the dust from foundry furnaces, both from electric furnaces (Table 2) and cupola furnaces (Table 3), which has not been confirmed by own research. In the current research,

Table 3. Heavy metal content in other type of foundry dust according to various authors compared to own results

Tabela 3. Zawartość metali ciężkich w innych rodzajach pyłów odlewniczych wg różnych autorów i wyników własnych

Element	Skvara et al. (2002)	Gengel et al. (2010)	Holtzer et al. (2006)	Bożym and Zalejska (2014)			Own results (the range)			
	steel foundry flue dus	flue-dust from cupola furnace*	dust after regeneration SFS	shock grating dust	pneumatic blast cabinet dust	SFS regeneration dust	P2 sample	P3 sample	P4 sample	P5 sample
Fe (%)	55.7	16.2	No data	No data	No data	No data	16.0–19.4	12.7–13.0	10.4–84.0	4.1–9.8
Mn (%)	No data	2.2	No data	No data	No data	No data	0.07–0.18	0.07–0.08	0.11–0.54	0.05–0.06
Zn (mg/kg DM)	No data	7300	49	934	427	103	444–2756	599–671	850–13740	880–920
Ni (mg/kg DM)	120	No data	3	104	1599	29	44–276	60–67	95–1374	88–92
Pb (mg/kg DM)	17.6	1100	67	95	86	<2.5	35–168	51–89	2–24	22–39
Cu (mg/kg DM)	74.3	No data	23	265	863	148	304–1744	252–515	171–705	532–683
Cr (mg/kg DM)	1000	No data	351	949	3059	548	365–506	197–249	94–750	134–370
Cd (mg/kg DM)	39.3	No data	25	5.9	<0.3	3.6	<0.2	5.9–8.2	0.2–4.5	0.2–2.6
Hg (mg/kg DM)	No data	No data	No data	No data	No data	No data	0.071–0.096	0.097–0.123	<0.001–0.014	0.031–0.037

* – values calculated from oxide forms.
P2 – shock grating dust.
P3 – dust from transport of molding sands.
P4 – pneumatic blast cabinet dust.
P5 – regeneration of spent foundry sands dust.

it was found that the dust from pneumatic cleaners (P2) was also characterized by an increased content of other metals compared to other dust types. The presence of metals does not limit the use of this dust as a raw material in metallurgy. Due to a low content of heavy metals, the dust from casting cleaning, transport and regeneration should not pose a threat to the environment. Usually heavy metal leaching from this dust is low (Bożym 2020). For comparison, Table 3 additionally presents the results of dust from the same foundry collected in 2012 (Bożym and Zalejska 2014). Significant differences were found in the content of heavy metals in the dust collected in 2017/18 and 2012, as well as samples collected in 2017 and 2018. This indicates that the composition of dust varies depending on the type of materials used to manufacture castings and moulds. To assess the suitability of foundry dust for reuse, the variability of its composition should be taken into account. According to Holtzer et al. (Holtzer et al. 2006a) the dust from mechanical dry regeneration of moulding sands is a serious problem for foundries. The amount of this dust is about 5–10% of the weight of the regenerated material. The chemical composition, i.e. the content of main components and impurities, grain and phase composition and impact on the environment decide on the directions of dust management. The dust characterized by a high content of organic matter (high LOI value) may be used for energy purposes. In addition, the particle size of dust from the regeneration of moulding sands is similar to the raw flour used in the production of Portland cement, and the rheological properties are suitable for storage and dosing (Holtzer et al. 2006a). Due to the high proportion of organic compounds derived from binders (30% LOI), the dust can also be treated as an alternative fuel, which saves fuel consumption by 1.5–2%.

According to Holtzer et al. (Holtzer et al. 2006a) this dust is of a heave nature, which, combined with high LOI, prevents its direct use in road construction. However, it is possible to burn this dust with coal in a 25 kW central heating boiler, which reduces toxic gas emissions. In other studies, Dańko et al. (Dańko et al. 2015) evaluated post-regenerative dust for combustion in gas furnaces or co-firin with carbon carriers (hard coal/lignite). The results confirmed that this dust is suitable for use only in cement plants, due to the optimal composition as a raw material and fuel, due to the appropriate calorific value. The energy use of regenerative dust is conditioned by the development of an optimal thermal system with adjustable dosing of other fuels, depending on the current calorific value of dust (Dańko et al. 2016). In the current research, the regeneration dust (P5) had a higher LOI value (13.8% wt.) compared to other dusts and can be considered for use in cement plants or other energy purposes. In addition, a low mercury content will not generate emissions of this metal during energy processes. However, additional tests should be carried out on the content of silica and other oxides to assess its suitability as a raw material in cement plants. It should be mentioned here that the tested dust did not exceed the heavy metal content limits for alternative fuels by Polish cement plants (Bożym 2013).

Conclusions

Based on the obtained results, the usefulness of dust from pneumatic treatment and EAFD for reuse in metallurgy was confirmed, due to the high iron content. On the other hand, the recovery of zinc or lead from EAFD will not be profitable due to the low percentage of these metals in dust. For other dust types, their use for the production of building materials or ceramics is suggested. However, an additional examination of their oxide composition and mechanical properties is required. Dusts from the regeneration of moulding sands can be considered for use in cement plants, due to the increased content of carbon and LOI and a low mercury content. However, an analysis of the oxide composition is also required along with a comparison with the cement plant requirements regarding the composition of the raw material. The content of heavy metals in all tested dust types, except for EAFD, was low. Therefore, this waste should not pose a threat to the environment.

It seems that most of the methods of foundry dust use presented in the paper can be used to manage the tested dust. At the assessment of the re-use direction, it is necessary to estimate the cost of the solution and the cost-effectiveness of the process. In addition, when assessing the directions of further use, the variability of its composition should also be taken into account.

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THE CONTENT OF HEAVY METALS IN FOUNDRY DUSTS AS ONE OF THE CRITERIA FOR ASSESSING THEIR ECONOMIC REUSE

Keywords

waste, dust, foundry, heavy metals (Cd, Pb, Cu, Zn, Cr, Ni, Mn, Fe, Hg), dust management

Abstract

The heavy metal content is one of the criteria for foundry dust commercial use. To assess the possibility of foundry dust use, it is necessary to analyze its composition, including the content of basic heavy metals, and its mechanical properties. The paper presents the results of research on foundry dust from one of the Polish foundries. The aim of the study was to assess the waste management based on its composition and content of heavy metals. Dust samples were taken from one of the Polish foundries, producing iron and steel castings. Samples were taken from several places in the foundry, i.e. from electric furnace dust collectors, shock grating unit, transport of moulding sands unit, pneumatic blast cabinet units and the regeneration of spent foundry sand units. Samples were taken twice from each place at the turn of 2017–2018. The total content of heavy metals such as Cd, Pb, Cu, Zn, Cr, Ni, Mn, and Fe for recovery and additionally Hg as environmental pollution was analyzed. Based on the results of the research, it was found that the dust from foundry furnaces and pneumatic cleaners can

be used in metallurgy due to a high percentage of iron. It was found that the dust from casting cleaning, transport and regeneration department can be used in the cement or construction industry. In addition, an assessment of the mercury content showed that the re-use of this dust would not cause an environmental hazard. It was found that the profitability of foundry dust use depends on the stability of its composition and requires testing for each batch of dusts.

ZAWARTOŚĆ METALI CIĘŻKICH W PYŁACH ODLEWNICZYCH JAKO JEDNO Z KRYTERIÓW OCENY ICH GOSPODARCZEGO WYKORZYSTANIA

Słowa kuczowe

odpady, odlewnia, pył odlewniczy, metale ciężkie (Cd, Pb, Cu, Zn, Cr, Ni, Mn, Fe, Hg), zagospodarowanie pyłów

Streszczenie

Jednym z kryteriów wykorzystywania komercyjnego pyłów odlewniczych jest zawartość metali ciężkich. Aby ocenić możliwość ich wykorzystania, należy przeanalizować ich skład, w tym zawartość podstawowych metali ciężkich i ich właściwości mechaniczne. W pracy przedstawiono wyniki badań pyłów odlewniczych z jednej z polskich odlewni. Celem badań była ocena zagospodarowania odpadów na podstawie składu i zawartości metali ciężkich. Próbki pyłu zostały pobrane z jednej z polskich odlewni produkującej odlewy z żeliwa i staliwa. Próbki zostały pobrane z kilku miejsc w odlewni, tj. z kolektorów pyłu z pieca elektrycznego, urządzenia z rusztem udarowym, działu transportu piasków formierskich, działu pneumatycznych komór śrutowniczych i urządzenia do regeneracji zużytych piasków odlewniczych. Próbki pobrano dwukrotnie z każdego miejsca na przełomie lat 2017–2018. Analizowano całkowitą zawartość metali ciężkich, takich jak Cd, Pb, Cu, Zn, Cr, Ni, Mn i Fe do odzysku oraz dodatkowo Hg jako zanieczyszczenie środowiska. Na podstawie wyników badań stwierdzono, że pyły z pieców odlewniczych i pneumatycznych środków czyszczących mogą być stosowane w metalurgii ze względu na wysoki procent żelaza. Stwierdzono, że pył z działu czyszczenia, transportu i regeneracji odlewów może być użyty w przemyśle cementowym lub budowlanym. Ponadto ocena zawartości rtęci wykazała, że ponowne użycie tego pyłu nie spowoduje zagrożenia dla środowiska. Stwierdzono, że opłacalność wykorzystania pyłu odlewniczego zależy od stabilności jego składu i wymaga badań dla każdej partii pyłu.