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Foundry waste as a raw material for agrotechnical applications

Introduction

It is estimated that over 100 million tonnes of foundry waste containing mainly spent foundry sands (SFS) are produced in the world every year (Díaz Pace et al. 2017; Modern Casting 2017). The mass of that waste depends on the number of castings produced. The largest global producers of castings are China, India, and the USA (Modern Casting 2017). China annually produces over thirty million tonnes of foundry waste (Zhang et al. 2014). According to the EPA, the US produces about ten million tonnes of SFS per year (EPA Report 2014). Other casting producers, such as Japan, South Korea, Mexico and Brazil, also produce significant amounts of SFS. For example, Brazil produces three million tonnes of SFS per year (Alves et al. 2014). The main European producers of castings are Germany, Russia, Italy, Turkey, France and Spain. Polish production of castings is estimated at 5% of the European production (Modern Casting 2017). In Europe, eighteen million tonnes of SFS (Layman's report 2018) are produced every year. For example, Spain produces one million tonnes of SFS each year, while Finland only 100,000 tonnes (Carlsson and Nayström

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2016; Layman's report 2018). Annually in Poland, about 600,000 tonnes of foundry waste is produced, including about 500,000 tonnes from iron foundries (Polish Monitor 2016). In Poland, foundry waste from iron foundries is included in the group of waste from thermal processes with the code 10 09 (Waste catalog 2020). Foundry waste, especially SFS, may be reused in foundries. In the USA, 74% of SFS is recycled by foundries (EPA Report 2014), while in Scandinavia as much as 80–98% is reused (Carlsson and Nayström 2016). According to the principles of sustainable development, SFS should be primarily recycled at the source (foundry). The remainder of the waste should be used outside of the foundry. Due to its composition and physical properties, the popular direction of SFS management is the production of cement, building materials and asphalt (Sorvari and Wahlstrom 2014). The chemical composition of the SFS depends on the type of sand and binders, the casting composition and the combustible material. SFS mainly consists of quartz sand covered with a thin layer of burnt carbon, binder residues (bentonite, organic carbon, resins/chemicals) and dust (Siddique et al. 2010) (Table 1). SFS are characterized by their high mechanical strength; therefore, they may be used to strengthen embankments, banks or soils. The physical properties of SFS-based foundry wastes are shown in Table 2.

SFS can also be used in agriculture and horticulture as a soil substitute. However, it may provide environmental contamination and result in the accumulation of toxic substances in the food chain. For this reason, only SFS with mineral binders, the so-called '*green sands*'

Table 1. Composition example of foundry waste based on SFS (%)

Tabela 1. Przykład składu odpadów odlewniczych bazujących na SFS (%)

Constituent (%)	Siddique et al. (2010)	Own research*
SiO_2	87.91	47.13–84.90
Al_2O_3	4.70	2.35–29.77
Fe_2O_3	0.94	2.01–12.82
CaO	0.14	0.25–17.60
MgO	0.30	0.40–5.26
SO_3	0.09	0.01–0.67
Na_2O	0.19	0.10–1.11
K_2O	0.25	0.48–1.32
TiO_2	0.15	0.19–1.53
Mn_2O_3	0.02	no data
SrO	0.03	no data
P_2O_5	–	0.01–0.05

* Unpublished data, analytical methods: X-ray fluorometry (XRF).

Table 2. Physical properties of SFS-based foundry waste according to various authors

Tabela 2. Właściwości fizyczne odpadów odlewniczych na bazie SFS według różnych autorów.

Physical properties	Deng and Tikalsky (2008)	Naik et al. (2001)	Javed and Lovell (1994)	Own research*
Moisture content (%)	0–4.85	0.25	0.1–10.1	3.2
Material finer than (75 µm) sieve (%)	0–9.21	1.08	–	0.2
SSD absorption (%)	0.38–4.15	5.0	–	4.8
Bulk relative density (kg/m^3)	1,052–1,554	1,784	2,589	–
Specific gravity	2.38–2.72	2.44	2.39–2.55	–
Coefficient of permeability (cm/s)	–	–	10^{-3} to 10^{-6}	1.2×10^{-3}

* Unpublished data, analytical methods according to Polish Standards: PN-B-04481, PN-EN 933-1, PN-EN 933-1,10; PN-EN 12697-6; PKN CEN ISO/TS 17892-11.

with a low content of heavy metals, may be used for this purpose. Another advantage of using '*green sands*' is to increase the content of clay fractions in the artificial soil substrates. Agricultural use of SFS is recommended only for iron, steel and aluminum foundries (EPA Report 2014). SFS from non-ferrous metal foundries may be contaminated with heavy metals such as Cu, Zn, Cr, and/or Ni, which pose a risk to the environment (Ji et al. 2001; Dungan et al. 2009; Sorvari and Wahlstrom 2014; Díaz-Pace et al. 2017). It should also be noted that SFS are not suitable to be used as an artificial soil but only as a component of such soil due to its low nutrient content (Bożym 2018). In the USA, Argentina, South Africa and Brazil, SFS are used in horticulture and agriculture. In Europe, this direction of use is not popular. In the USA, over 220,000 tonnes of SFS is reused for the production of topsoil or in horticulture, and 140,000 tonnes is reused in road construction (excluding the use in the production of asphalt) (EPA Report 2014). A report published by the Environmental Protection Agency (EPA) in 2014 presents the environmental benefits of reusing SFS. The calculation takes into account the amount of energy and water consumption and the amount of CO_2 emission which may be avoided by using SFS (Table 3). The analysis included the volume of

Table 3. Main environmental benefits of using SFS outside of a foundry (EPA Report 2014)

Tabela 3. Główne korzyści środowiskowe wynikające ze stosowania SFS poza odlewnią

Avoided impact	Road base use extrapolated to 144,288 tons of SFS	Manufactured soil use extrapolated to 220,949 tons of SFS
Energy consumption (megajoules)	17,800,000	27,900,000
Water consumption (1,000 gallons)	3,000	4,800
CO_2 emissions (tonnes)	1,500	2,500

SFS per 1000 cubic yards, and then extrapolated to the total amount of SFS used in road and agriculture in the USA. The EPA analysis also included an assessment of the health and environmental risk during SFS use. Based on these calculations, the environmental and economic benefits were taken into account. The EPA and the United States Department of Agriculture (USDA) supported the use of silica-based SFS, in particular from iron, steel and aluminum foundries, for the production of artificial soils, soilless potting media and as a foundation for roads. The EPA and USDA concluded that these beneficial applications provide significant opportunities for the development of sustainable materials management (SMM) (http://www.epa.gov/smm). In a previous report in 2002, the EPA also presented directions for the use of SFS, including examples of applications in horticulture and agriculture (EPA Report 2002). For example, in Ohio, one company uses SFS to produce artificial potting mixes for the cultivation of trees and ornamental plants. According to state law, the percentage of SFS in substrates cannot exceed 50% and it cannot be used for food production. On the other hand, Indiana State has a more liberal law of SFS use, and it may be applied directly on land designed for horticultural or agricultural purposes. As a result of the initiative of the USDA for SFS reuse, a geographic inventory of US foundries has been established with extensive information on the type of waste and the locations of foundries (Lindsay and Logan 2009).

The condition for the use of SFS for agricultural purposes is a low content of pollutants. The environmental risk of SFS is the potential leaching of heavy metals. Although heavy metals in SFS are usually bound with a silica matrix, they may be mobilized during liquid metal casting processes by melting the crystal structure. It has also been noticed that the metal leaching from SFS increases during the regeneration process (Alves et al. 2014). Kim and Owens (Kim and Owens 2010) found differences in the chemical processes of landfilled foundry waste compared to those used in agriculture. According to the authors, the mobility of heavy metals depends on the physicochemical and biological factors occurring in the soil. Another negative effect of using SFS as a soil substitute is possible environmental contamination with organic compounds such as formaldehyde, phenol, etc. Therefore, it is recommended to use only '*green sands*' with mineral binders in agriculture (EPA Report 2014). The problem of the content and the leachability of pollutants is discussed in the next section.

Many scientists from the USA, Argentina and Brazil are conducting research on the use of SFS as a soil substitute (Dungan et al. 2006, 2007, 2009; Dungan and Dees 2009; Dayton et al. 2010; Oliveira et al. 2011; Carnina et al. 2012; Miguel et al. 2012, 2014; Alves et al. 2014). Projects to assess the suitability of SFS for agrotechnical applications in some European countries have also been conducted. For example, in Finland and Spain, composting SFS with organic binders has been carried out (LIFE–Foundry sand project LIFE13 ENV/FI/285) (http://life-foundrysand.com). The use of SFS for the production of construction materials and in horticulture, including the production of artificial soil substrates, is permitted.

Foundries are often involved in research on the possible future uses of SFS. Collective projects are conducted in Scandinavia with the participation of the foundry industry.

Carlsson and Nayström (2016) described two projects performed in Sweden. The first, ENVIROMAN, assessed the sealing properties of SFS containing bentonite. The aim of another project, called KASKAD, was to evaluate the suitability of SFS with organic binders for composting. Additionally, the aim of the research was to determine the degree of reduction of organic pollutants during the process. It was found that in the final product, SFS is a structural component and can only be used for the production of soil substrates if the content of heavy metals is low (Carlsson and Nayström 2016).

1. Toxicity assessment of foundry waste

The first step in assessing the toxicity of foundry waste is the analysis of the composition and content of pollutants and their leachability. In some cases, the content of heavy metals may be high in SFS as a result of the contact of the foundry sands with the liquid metal

Table 4. Content of heavy metals and metalloids (mg/kg DM) in waste from iron and steel foundries

Tabela 4. Zawartość metali ciężkich i metaloidów [mg/kg sm] w odpadach odlewniczych z odlewni żelaza i stali

Metal/loid	Alves et al. (2014)	EPA Report 2014	Dayton et al. (2010)	Miguel et al. (2012)	Bożym (2020); Bożym and Klojzy-Karczmarczyk (2021)
Type of foundry	iron	iron, steel, aluminum	iron, steel, aluminum,	iron, steel, aluminum, bronze	iron
Cd	<1.3	0.05	<0.04–0.36	<0.2–0.97	<0.2
Pb	<2–6.7	3.74	<1–22.9	<4.2–647	33±13
Cu	<2–32.4	6.22	<0.5–137	<0.5–303	78±56
Zn	5.8–64.3	5.00	<10–245	6.1–171	98±24
Ni	<2–9.2	3.46	1.11–117	41–260	63±27
Cr	<2–40.9	–	<0.5–115	297–931	118±48
Fe	475–27,081	4,260	1,280–64,400	4,769–18,217	14.1±1.0*
Mn	22–401	54.4	5.56–707	34.2–202	3.38±0.57*
As	<2	1.05	0.126–7.79	–	0.24±0.07
Se	<1.5	0.20	<0.4–0.438	–	0.10±0.00
Sb	<1.3–5.5	0.17	–	<3.2–439	1.16±0.32
Hg	<0.2	–	–	–	0.023–0.031
Co	≈2	0.88	<0.5–6.62	<0.7–77.7	17±7
Mo	<2.7	0.50	<1–22.9	0.99–20.8	27±10

* – (%).

(Alves et al. 2014). However, Dungan and Dees (Dungan and Dees 2009) found that the content of heavy metals in the tested SFS from iron and steel foundries was lower than in the local soils. Some heavy metals, such as mercury, are not analyzed in SFS due to its low content (Bożym and Klojzy-Karczmarczyk 2020, 2021); much higher contents of mercury could be found in other mineral wastes (Klojzy-Karczmarczyk et al. 2021).

An important indicator of SFS toxicity is the leaching of heavy metals. The leachability of metals from SFS is influenced by the cast metal composition (iron, steel, copper, zinc, aluminum foundries), type of binder, pH and the number of regenerations (Ji et al. 2001). Another factor that increases the leaching of metals from industrial landfill waste (Kicińska 2021), including SFS, is the weather conditions (Carnina et al. 2012). Therefore, various tests simulating natural conditions are used to assess the leachability of metals from foundry waste (Bożym 2017). Usually, the leachability of heavy metals from SFS with water is low, which may indicate no groundwater pollution during its landfilling or agricultural use (Siddique et al. 2010; Bożym 2017, 2019, 2020). Alves et al. (Alves et al. 2014) found that SFS have no negative impact on groundwater. The authors tested '*green sands*' and SFS with organic binders from ten iron foundries in Brazil. They found that the heavy metals in SFS were strongly bound to the matrix and its leaching depended on the particle size and

Table 5. Leachability of heavy metals and metalloids from SFS (mg/kg DM)

Tabela 5. Wymywalność metali ciężkich i metaloidów z SFS (mg/kg sm)

Metal/loid	Deng (2009)*	Naik et al. (2001)*	Bożym (2017)	Bożym (2020)	Limit for landfill inert waste **
Cd	0.006	0.004	<0.05	<0.05	0.04
Pb	0.16	0.3	<0.5	<0.5	0.5
Cu	1.74	–	<0.5	0.6	2.0
Zn	3.54	0.6	<0.5	0.5	4.0
Ni	0.12	–	<0.5	0.2	0.4
Cr	0.014	0.22	<0.5	0.3	0.5
Fe	24.9	18.6	–	0.5	not limited
Mn	1.22	0.2	–	0.6	not limited
As	0.06	0.02	–	0.03	0.5
Se	0.04	<0.02	–	<0.01	0.1
Sb	–	–	–	<0.1	0.06

* Compared with the legal requirements for waste landfilling.

The results obtained by Naik et al. (2001) and Deng (2009) in mg/dm^3 are converted to mg/kg DM; the analysis was performed using the ASTM method (18 h, L/S, 20/1).

** According to Journal of Law (2015).

intensity of rainfall. Many authors have stated that the use of stronger eluents (inorganic and organic acids) increases the leaching of heavy metals from foundry waste (Siddique et al. 2010; Bożym 2017, 2019). An example of the heavy metal contents of SFS-based foundry waste is shown in Table 4, and their leachability is presented in Table 5.

To summarize, it may be concluded that the content of heavy metals in SFS depends on:

- the type of casting metal, e.g. a higher Cu content in the SFS from brass and bronze foundries was found (Ji et al. 2001; Dungan 2008; Alves et al. 2012; Miguel et al. 2012; Sorvari and Wahlstrom 2014; Díaz Pace et al. 2017);
- the type of binder, e.g. a lower metal content was found in bentonite-based ‘*green sands*’ than in SFS containing other binders (Alves et al. 2014; EPA Report 2014);
- the type of organic binder, e.g. increased Co and Pb contents were found in SFS with urethane-alkyd binders, which was related to their presence in hardeners (Miguel et al. 2012; Díaz Pace et al. 2017);
- the type of foundry sand – this only applies to the total content of metals bound to the matrix, i.e. the crystal structure of the sand. These metals do not pose a risk to the environment (Kim and Owens 2010; Alves et al. 2012; Miguel et al. 2012). The exception is crushed chromite sands with a high content of Cr and olivine sands with a high content of some heavy metals (Dungan 2008);
- the sources of moulding sands, e.g. a higher content of heavy metals was found in regenerated SFS (Alves et al. 2012);
- the SFS contamination by foundry dust (Salihoglu and Pinarli 2008; Bożym 2020).

Other inorganic pollutants such as chlorides, fluorides, sulphates, etc., and organic toxins may be also leached from foundry waste (Bożym 2020). Figure 1 shows the content of

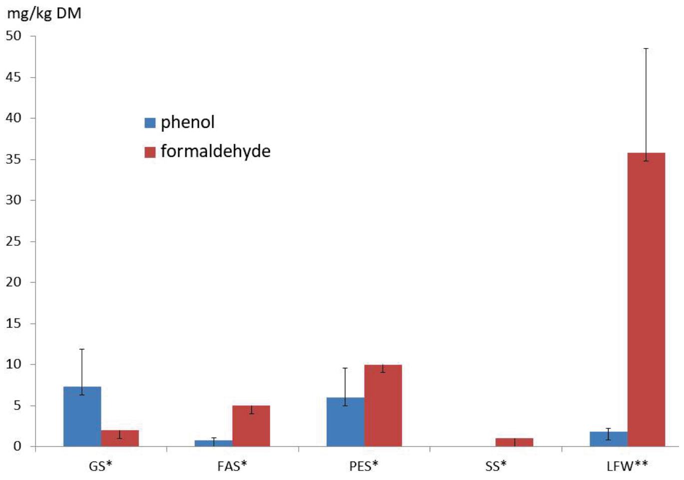

Fig. 1. Water leachability of phenol and formaldehyde from various foundry wastes (Ji et al. 2001; Bożym 2020)
GS – green sands, FAS – furan/acid sands, PES – phenolic/ester sands, SS – silicate sands, LFW – landfill foundry sands

Rys. 1. Wymywalność przy wykorzystaniu wody, fenolu i formaldehydu z różnych odpadów odlewniczych phenol and formaldehyde in the leachate from foundry wastes containing different organic binders than pure silicate sands (SS). Polish legislation regulates the phenol content in the leachate from inert landfill waste; the limit is 1 mg/kg DM (basic test, 1/10, S/L) (Journal of Laws 2015). In Poland, the content of formaldehyde in leachate from landfillwaste is not limited. Formaldehyde is more toxic and harder to oxidize in the environment than phenol. Its content in leachate from foundry waste should therefore also be controlled.

To assess the toxicity of waste, biotests using selected organisms, for example, soil micro-organisms or plants, may be carried out. In the next section, some examples of biotoxicity studies and evaluations of the use of foundry waste in agriculture and horticulture are presented.

2. Assessment of biotoxicity and the use of foundry waste in agriculture

SFS biotoxicity studies can be conducted using soil microorganisms. Dungan et al. (Dungan et al. 2006) analyzed microbial activity on soil on the basis of the dehydrogenase activity (DHA) index over a period of twelve weeks with the addition of 10, 30 and 50% SFS (i.e. '*green sands*'), SFS with phenol–formaldehyde, phenol–urethane and furfuryl alcohol binders from iron, aluminum and copper foundries. The authors found that the DHA was highest in the substrate with 10% SFS, and lowest with 50% SFS. The authors explained this phenomenon as being due to the dilution of the soil mass by SFS, and thus causing a reduction of the DHA. However, unclear results were obtained for the mixture with pure quartz sand. The authors found the highest decrease in DHA for SFS from copper smelters. Due to the high content of heavy metals in these SFS, it is impossible to use them for agricultural purposes. The authors found a higher DHA for the soil containing SFS with organic binders than with bentonite. They suggested that the microorganisms in the soil may have been using the organic binders as a carbon source. The authors concluded that the presence of toxic substances in these binders, such as phenol, formaldehyde and furfuryl alcohol, may prevent the use of these sands in agriculture. Similar studies were conducted by Zhang et al. (Zhang et al. 2014) on the DHA in synthetic soils with 10, 30 and 50% SFS from steel, iron and aluminum foundries. The authors also concluded that the ecotoxicity of SFS was closely related to the content of metals and organic pollutants. They found an increased variety of bacterial species in substrates without plants (ryegrass) due to the influence of the rhizosphere of higher plants and a reduction in the amount of nutrients available to the bacteria. However, they found no significant differences in the diversity of microorganisms in the substrates of the soil with silica sand and SFS. Bastian and Alleman (Bastian and Alleman 1998) tested the toxicity of thirteen types of SFS to *Vibrio fischeri* using the Microtox™ biotest. The authors found that most of the substrates did not reduce the amount and growth of bacteria. In another study, Dungan and Dees (Dungan and Dees 2007) used earthworms to assess the toxicity of artificial soil containing 50% SFS. The substrates were not toxic to earthworms, with the exception of SFS from copper smelters due to their high contamination with Cu, Pb and Zn.

Phytotoxicity tests are the most popular of all biotests. Benzel (Benzel 1998) analyzed the growth of a few species of plants on mixtures of SFS with paper sludge or garden waste compost. The author concluded that SFS had no toxic effect on plants. Dungan and Dees (Dungan and Dees 2007) evaluated the bioavailability of heavy metals to plants (spinach, radish, and perennial ryegrass) in a pot experiment with 50% SFS from aluminum, iron and steel foundries. Despite some differences in the degree of the accumulation of metals, which was associated with the plant species, no excessive accumulation of metals was found in the plants, except for Ni, Pb, and Mo in spinach and ryegrass. By contrast, Dunkelberger and Regan (Dunkelberger and Regan 1997) investigated the effect of SFS-based soil substrates on the growth of three plant species (geranium transplants, juniper, and forsythia). The composition of the substrate was 60% soil, 30% SFS and 10% compost. The biomass of the plants from the tested mixture was higher than the soil without additives.

McCoy (McCoy 1998) conducted laboratory and greenhouse experiments to determine the optimal composition of SFS-based substrates for growing grasses. The author used two types of SFS mixed with peat and sand. He found that soil mixtures applied to grasslands may improve the soil's properties by reducing the bulk density and increasing cation exchange, water availability and the porosity and permeability of the substrates. The authors obtained the optimal composition of the mixtures by adding peat as an organic substance source and the appropriate permeability by adding SFS. The optimal results that he obtained were for substrates with a low percentage of soil or no soil at all.

Royle et al. (Royle et al. 2000) examined the biological remediation of landfill using grass grown on a mixture of gypsum, clay, SFS, green waste compost, sewage sludge, peat and compost. The authors stated that the addition of gypsum from the production of phosphoric acid caused an increased content of phosphorus, sulphates and fluorides in the mixtures. In addition, the authors found that the addition of inorganic materials in the form of gypsum and SFS may have a negative impact on plants and increased environmental risk. Logan and Linsey (Logan and Linsey 2001) investigated the risk of contaminants from SFS entering the food chain. The research was carried out on plots with different proportions of SFS, soil, green waste compost and manure. Vegetables and ornamental plants were sown on the plots. After two years of research, it was found that the germination of plants was higher on the substrate with SFS than on the loamy soil due to the its lighter structure. The authors found that the salt concentration in the substrate solution was similar in all samples, and the initial alkaline reaction of the SFS did not negatively affect the plants. The pH decreased to neutral after two years of the experiment.

Dayton et al. (Dayton et al. 2010) investigated the growth of lettuce on a substrate containing 50% SFS and clay soil. The authors tested thirty-nine types of SFS from eleven iron, steel and aluminum foundries in the US. They concluded that most of the tested SFS may be used as soil substrates due to the structure and metal content that is similar to soils. Additionally, they found a low percentage of leached forms of metals in SFS and no negative effect on plant germination. Similar results were obtained in my own research on landfilled foundry wastes containing >50% SFS. The stimulating effect of leachate from landfilled foundry waste on germination and biomass of *Lepidium sativum* was confirmed (Bożym 2020). However, in the same tests, foundry dusts were phytotoxic. This effect was related to the high leachability of heavy metals and the wide pH range of the dust samples (from 5.1 to 8.2).

3. Other agricultural applications SFS

An additional use of SFS is the production of Technosols, due to their similar physical properties and mineral composition to natural soils. Technosola can contain a mixture of SFS, sewage sludge, agri-food industry waste, fly ash, gypsum, dolomite, clay, and metallurgical slags (Camps Arbestain et al. 2008; Yao et al. 2009). SFS is used as a structural material in Technosols. The use of Technosols to reduce phosphorus availability, eliminate pathogens, reduce the availability of heavy metals and fertilise natural soils have been described in the literature (Camps Arbestain et al. 2008).

Technosols belong to the group of new artificial soils and their properties and pedogenesis are dominated by their technical origin and include artificial soil made from human activities waste. Technosols are included in the new Reference Soil Group, classified by the World Reference Base for Soil Resources (Camps Arbestain et al. 2008). One of the conditions of the production of Technosols is knowledge about their origin and the composition of the raw materials. The percentage of each component is selected according to the required composition of the final product. A Technosol produced from waste should perform the main functions of soil, as defined in EC-COM 231/2006 (EU 2006). The assessed parameters of Technosols are particle size, porosity, water retention capacity, appropriate mineralogical and biogeochemical conditions (reactive surface, acid-base and redox properties), content of nutrients and organic carbon in a stable form, appropriate biological environment (soil microorganisms) and low content of contaminants.

Chemical and biological tests are usually used to assess the toxicity of a Technosol. However, Camps Arbestain et al. (2008) concluded that these tests are not sufficient to assess the environmental risk of Technosols. The authors suggest that research should focus on understanding the geochemistry of each of the environmental elements and changes over time in order to predict the environmental impact of Technosols. By contrast, Yao et al. (Yao et al. 2009) suggest that in addition to testing the contaminants content and toxicity of Technosols, their buffer capacity should be tested. The authors noted that consolidating the components of Technosols is time consuming. Usually, Technosols are not stabilized after mixing the ingredients, which may have an impact on the environment due to the instability of the organic matter and organic carbon (Camps Arbestain et al. 2009).

Conclusions

The advantages of using SFS in agricultural engineering include grain composition and physical properties similar to soil, including high permeability and low leaching of heavy metals. The disadvantages are the presence of organic pollutants such as formaldehyde that can be leached into the environment, the low proportion of organic matter and macronutrients that requires supplementing and the content of toxic heavy metals in the SFS from non-ferrous metal foundries. Therefore, it is recommended to use only SFS from iron foundries containing mineral binders in agrotechnics.

As SFS have physicochemical properties similar to soil, they are an attractive material for use as artificial potting soil, soilless substrate and artificial soil (Technosol). According to the abovementioned EPA Report (EPA Report 2014), the contamination distribution in the silica-based SFS from iron, steel and aluminum foundries is very similar to the background in native soils. The presence of manganese and iron and the neutral pH of the SFS suggest that soil-related applications probably reduce the mobility, bioavailability and toxicity of the metallic components in SFS. Extensive research by many scientists from the USA, Brazil, Argentina and EU countries indicates the possibility of using foundry waste in agriculture, especially SFS from iron, steel and aluminum foundries. The EPA Report (2014) stated that the SFS probably do not have a negative impact on human health and the tested ecological indicators. The EPA analysis considered the concentration of metals and other components in the SFS and used highly conservative screening techniques and risk-control models. Despite EPA recommendations, the use of SFS in Europe for agricultural purposes is marginal and rather experimental. Important issues in assessing the use of foundry waste is the content of contaminants such as heavy metals and their leaching and also biotoxicity. I recommend conducting research on the leaching of formaldehyde from SFS used for agrotechnical purposes. The use of SFS and other foundry wastes for non-industrial purposes should be preceded by extensive research to prove the lack of any negative impact on the environment and human health.

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FOUNDRY WASTE AS A RAW MATERIAL FOR AGROTECHNICAL APPLICATIONS

Keywords

foundry, waste, agriculture, Technosols, heavy metals

Abstract

This paper discusses the agrotechnical use of foundry waste based on spent foundry sands (SFS). The advantage of foundry waste use is its high concentration of quartz sands and its similar physical properties to soils, including good permeability and filtration rate. An important component of foundry waste containing a mineral binders (green sands) is the presence of a clay fraction. In contrast, organic binders in some foundry wastes increase the percentage of organic matter. However, organic binders may contain toxic substances that are hazardous to the biota. Therefore, it is not recommended to use foundry waste with organic binders in agriculture or horticulture. Moreover, heavy metals may be problematic in the agrotechnical use of foundry waste mainly derived from cast metal. The disadvantage of using foundry waste as soil substrates is the low proportion of fertilizing components. Due to the low content of nutrients in foundry waste, it is recommended that it is used as a structural component mixed with other additives, such as sewage sludge or compost. The paper presents the results of research on the content of pollutants and the assessment of the biotoxicity of foundry waste. Based on the analyzed literature reports and own research, it was found that the use of foundry waste for non-industrial purposes, such as the production of artificial horticultural substrates, soilless substrates and artificial soils (Technosols), should be preceded by numerous studies to confirm the absence of negative impacts on the environment and human health.

ODPADY ODLEWNICZE JAKO SUROWIEC DO ZASTOSOWAŃ AGROTECHNICZNYCH

Słowa kluczowe

odlewnie, odpady, rolnictwo, Technosol, metale ciężkie

Streszczenie

W pracy przedstawiono agrotechniczne wykorzystanie odpadów odlewniczych na bazie zużytych piasków formierskich (SFS). Zaletą wykorzystania odpadów odlewniczych jest wysoka zawar-

tość piasków kwarcowych i zbliżone właściwości fizyczne do gleb, w tym dobra przepuszczalność i współczynnik filtracji. Ważnym składnikiem odpadów odlewniczych zawierających spoiwa mineralne (*green sands*) jest obecność frakcji ilastej. Poza tym spoiwa organiczne obecne w niektórych odpadach odlewniczych zwiększają udział materii organicznej. Spoiwa organiczne mogą jednak zawierać substancje toksyczne, które są niebezpieczne dla organzimów żywych. Dlatego nie zaleca się wykorzystywania odpadów odlewniczych zawierających spoiwa organiczne w rolnictwie lub ogrodnictwie. Ponadto metale ciężkie mogą stanowić problem w agrotechnicznym wykorzystaniu odpadów odlewniczych, pochodzących głównie z odlewów. Wadą stosowania odpadów odlewniczych jako podłoża glebowego jest niski udział składników nawozowych. Z tego powodu zaleca się stosowanie ich jako składnik konstrukcyjny, po zmieszaniu z innymi dodatkami takimi jak osady ściekowe czy kompost. W pracy przedstawiono wyniki badań zawartości zanieczyszczeń oraz oceny biotoksyczności odpadów odlewniczych. Na podstawie przeanalizowanych doniesień literaturowych oraz badań własnych stwierdzono, że wykorzystanie odpadów odlewniczych do celów nieprzemysłowych, takich jak produkcja sztucznych podłoży ogrodniczych, podłoży bezglebowych i gleb sztucznych (Technosols), powinno być poprzedzone licznymi badaniami, które potwierdzą brak negatywnego wpływu na środowisko i zdrowie ludzi.