The 73rd World Foundry Congress
„Creative Foundry"
23 - 27 September 2018, Krakow, Poland

FROM WASTE FOUNDRY SAND TO A NEW BIODEGRADED RAW MATERIAL AN ECOLOGICAL SOLUTION FOR FOUNDRIES

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Key words: Creative-foundry, Ecology, Foundry-sand, Bio-compost, Circular-economy-foundry

1. Introduction

Today, the majority of spent moulding sand from foundries (around 18M tons per year in Europe) is disposed of in landfill sites. This method of disposal represents a waste of material and carries environmental and industrial costs. Additionally, the formaldehyde present in used foundry sand has recently been classified as carcinogenic. With this backdrop, the European Life project "Foundry Sand" described herein, set out to investigate the viability of transforming waste sand into inert compost via biodegradation. This material would potentially have a commercial use as fertilizer or as added-value filler for geothermal energy applications, for example.

The principle objective was to investigate the potential of a natural process (biodegradation) as a method to neutralize contaminants resulting from an industrial process. Other aims included reducing the volume of waste sent to landfill sites by foundries, and, if found to be viable, encouraging the uptake of the method through appropriate dissemination channels Europe wide; around 3,000 foundries and around 1,000 potential customers for the sand.

2. Materials and Methods

Using the principle of biodegradation as the transformation process, all types of waste foundry sand (containing added binding agents) were mixed with organic material in open air "composting" heaps, weighing from 12 to 30 tons. Over a period of three years in two climatically different European test sites (located inland in Finland, and on the coast of northern Spain), the evolution of the heaps was periodically monitored and analyzed for the following: temperature, humidity, gas emissions, DOCs, TOCs, BTEXs, phenols, conductivity and chemical and metallic components.

Temperature, an indicator of the different stages of biodegradation, was monitored via Wi-Fi connected thermocouples inserted in the heaps. Humidity was monitored using similarly placed digital hygrometers.

Gas emissions were captured by overhead intake and analyzed using portable equipment. Liquid seepage and solid matter were collected periodically for laboratory analysis.

In order to take into account, the effects of seasonal climate conditions, the heaps were assembled at different times throughout the year. The total weight of sand processed was 600 tons, and the heaps occupied a combined total area of 2,000m^2. In order to accelerate biodegradation, the heaps were aerated every fifteen days using forklift trucks or mechanical grabs. To maintain humidity levels when RH < 60% in year one (2015) threatened to compromise biodegradation, irrigation water was applied to the heaps in Spain.

As a complementary test in Finland, odor emissions in some of the heaps were measured using specific bio-filtration equipment. The composition of each heap reflected the variety of sand and moulding processes used in the wide range of foundries in operation, e.g. silica sand used in green sand moulding was combined with a standard mix of organic material (forest waste and horse manure). Similarly, olivine sand used in the silicate moulding process was combined with the organic mix to constitute a different trial heap. See full Table 1. The forest waste combined with the sand constituted the bulk of the final material, while the horse manure primarily acted as an accelerant of biodegradation. Prior to the trials, horse manure was found to be more effective than that of other ruminants due to its higher concentration of elements such as ammonia and phenol. The optimum proportion of forest waste to manure had been researched over a period of one year at Helsinki University.

Laboratory tests were made using silicate sand (formaldehyde binder). In field tests, after three months on average, the material was considered ready for shredding to create a compost-like texture. This was then analyzed as compost, fertilizer and filler, in order to evaluate compliance with the corresponding national and European regulations on these materials.

Table 1.

MOULDING PROCESS	SAND TYPE	BINDER TYPE
Green sand	Silica	Bentonite
Silicate	Silica	Silicate and ester
Silicate	Olivine	Silicate and ester
Furanic	Silica	Furanic resins
Furanic	Chromite	Furanic resins
Phenol	Silica	Alkaline phenolic
Alfa-set	Silica	Phenolic no bake
Pep-set	Silica	Phenolic urethane

During the project over 6,000 chemical and biological analyses and tests were carried out in Finland and over 2,900 analyses in Spain from surplus foundry sand samples, composting materials and waste, including water runoff.

3. Results

Initial concentrations of hazardous components in the sand, such as fluoride, phenols, PAH and BTEX, diminished sufficiently during the process to fall within the required limit values: 10 mg/kg for fluoride, PAH 55mg/kg, BTEX 6mg/kg.

In the majority of cases, analysis of the biodegraded material gave results that met the norms and pertinent regulations for compost, fertilizer and filler at national and European levels. Following the biodegradation process, BTEX and PAH found in all foundry sand types were reduced to levels considered safe and non-carcinogenic.

Other hazardous substances (chloride, fluoride and phenol etc.) were also found to diminish sufficiently to meet limit values (Fig. 1).

Hazardous parameters	Green sand (stage 3)	Phenolic sand (stage 3)	Silicate sand (Stage 3)	Limit value for inert waste
Chlorides (mg/kg)	89,5	79	766,75	800
Fluorides (mg/kg)	2,3	<5	5,3	10
Suphates (mg/kg)	<50	<50	153,25	1000
Phenol (mg/kg)	<0.5	0.5	<0.5	1
DOC mg/kg)	846	736	2987,5	500
BTEX (mg/kg)	0	<0.040	0,031	6
PCB (mg/kg)	<0.1	<0.1	<0.1	1
Mineral oil (mg/kg)	<20	<20	<20	500
PAH (mg/kg)	0,302	<0.160	0,16	55
pH (UpH)	8,75	8.7	7,35	>6

Fig. 1. Relation sands and hazardous components

In the case of Furanic sand used in valve casting (duplex steel) which represents around 3.5% of total foundry sand, DOC and TOC levels were reduced, but remained above thresholds. As well silicate sand. See Fig. 2.

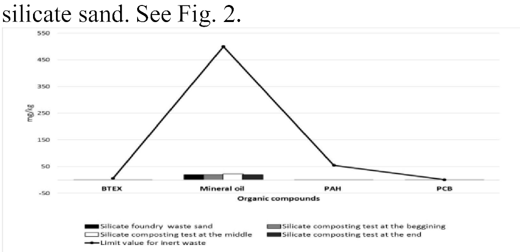

Fig. 2. Relations of reducing hazardous components by biodegradation compos

The irregular results in phenol content were originally thought to be due to binder type (organic or non-organic). However, tests show that the principle source of phenol was pasture grass, traces of which are found in horse manure, and, to a lesser extent, the type of binder used to harden the mold sand, and elements of the feeder system such as sleeves.

Microbiological and phytotoxicity tests were carried out and gave results which were not considered toxic. In addition, the germination index was 82%, above the threshold for toxicity set at 75%. The results achieved (Fig.3) are in line with the principles of a circular economy in which material and energy usage are optimized in a regenerative loop.

Fig. 3. Circular economy applied to foundry sand

4. Conclusions and future actions

The experiments carried out between 2015 and 2017 demonstrate that the proposed method is an innovative, viable and ecological way to recycle 96.5% of waste foundry sand destined for landfill. The final product complied with the pertinent limit values for compost, fertilizer and construction filler in Europe. Foundries adopting this solution would make an industrial cost saving in landfill disposal costs (transport, space occupied and admin) and could even obtain a return on the sand. Further investigations for geo-thermal applications include pilot trials (scheduled for the near future) into conductivity and resistivity.

Acknowledgments

The authors are grateful for the support received from the EU LIFE programme (LIFE13 ENV/FI/285).

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