LIFE FOUNDRYTILE. VALORISATION OF IRON FOUNDRY SANDS AND DUST IN THE CERAMIC TILE PRODUCTION PROCESS

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Introduction

The foundry industry generates more than 4 million tonnes/year of foundry sands and dusts at European level for the five main foundry producers (Germany, France, Turkey, Italy and Spain). There are different valorisation alternatives that have been validated (cement manufacturing, road construction, landfill covers, filling material for construction as well as for the manufacture of asphalt) and may be applicable to some foundry by-products[1], specially to sands. However, dusts have limited applications, especially in the case of chemical moulding dusts. This leads to a global percentage of by-products currently landfilled higher than 50%.

On the other hand, the ceramic tile production sector consumes high quantities of raw materials, especially sand and clays, which could be partially replaced by foundry by-products due to their similar chemical composition. According to the economic activity of both sectors at European level, with a degree of substitution of 5%, ceramic tile production could reach a 75% of foundry by-products valorisation.

Objective and strategy

The LIFE+ FOUNDRYTILE project[2] aims at demonstrating the technical, economic and environmental feasibility of the valorisation of iron foundry sands and dusts in the ceramic tile production process. This will lead to an improvement of the management of the foundry by-products and to a reduction of the environmental impact caused by extractive activities in quarries (Directive 2006/21/EC and related) and by the preparation of sands. Consequently, the solution proposed in this project, clearly promotes the concept of circular economy, key to sustainable development, since it reinforces the industrial symbiosis between companies from the foundry and the ceramic sector, as it is shown on the flow chart of Figure 1.

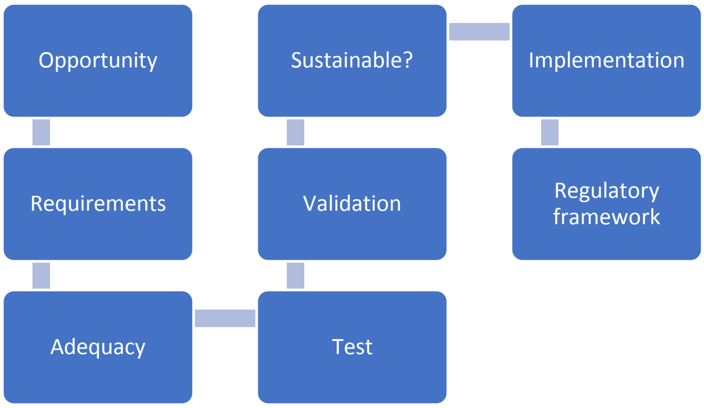

Figure 1: Flow chart for the approach of Industrial Symbiosis strategies.

Opportunity, methodology and requirements

Opportunity

The opportunity, as already stated, is based on the similarity of the chemical and mineralogical composition of both foundry by-products[3] and ceramic raw materials[4], as well as on the ratio by-products generation / ceramic tile production.

Methodology

In order to obtain a representative sample at national level, 23 samples of foundry sands and dusts provided by 11 Spanish foundry companies have been characterised in the project. For each by-product chemical composition and organic carbon were determined.

Chemical composition was determined by wavelength-dispersive X-ray fluorescence spectrometry, using reference standards that assure measurement traceability.

The organic carbon determination was carried out with a LECO model RC-412 carbon analyser. The test was performed by taking an appropriate portion of sample, weighed with an accuracy of 0.1 mg. This portion of sample was subjected to thermal treatment from a temperature of 25 ºC to 490 ºC in a kiln with O_2 atmosphere, and the CO_2 release was measured with an infrared (IR) detector.

Requirements

Table 1 shows the results obtained in the characterisation. The samples have been divided into four groups. A first division was made considering the two typologies of moulding processes used in the foundries: Green moulding (G) and Chemical Moulding (C). The second division was made in order to differentiate between sands (S) and dusts (D), thus resulting in the following groups: sands and dusts from green

moulding processes, GS and GD respectively; and sands and dusts from chemical moulding processes, CS and CD respectively.

Almost all the samples are characterized by high contents of silica and variable contents of alumina and iron. In general terms, loss on ignition is low, although some of the dust samples provide very high values. The carbon and the organic compounds present in the by-products have been identified as the most critical aspects for their valorisation as raw materials for the production of ceramic tiles, since they generate the defect called "black core" in the ceramic pieces (Figure 2). Iron, which could have been a problem for white ceramic bodies, is in low proportion in almost all the by-products. Heavy metals are also in very low proportion.

Table 1: Chemical composition (main compounds) and content of organic carbon of the foundry by-products.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Corg	LOI
GS	89-95	2.5-3.0	0.7-0.8	0.3-0.5	0.4-0.6	0.4-0.5	0.1-0.3	0.8-3	1.7-5.1
GD	66-72	6.5-8.5	2.0-2.1	1.4-1.7	1.1-2.0	0.9-1.5	0.3-1.2	10-14	14-18
CS	33-95	0.4-13	0.4-4.5	0.0-2.5	<0.1-18	0.2-1.0	0.1-1.0	0.1-2.5	0.4-4.1
CD	25-94	0.9-21	0.4-5.5	0.1-3.5	<0.1-22	0.1-9.0	0.3-2.3	0.1-40	0.4-54

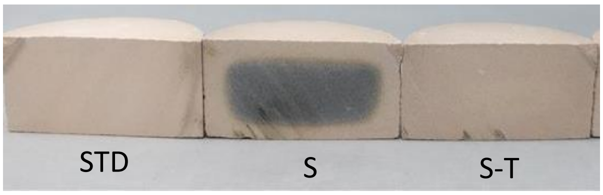

Figure 2: "Black core" formation of a ceramic composition (STD) and samples obtained by adding 5% of treated (S-T) and untreated (S) by-products.

Adequacy

The adequacy of the valorisation strategy has been improved by evaluating different pre-treatments. Thermal treatments (with 600ºC as peak temperature) have been proved as the most successful to increase the percentage of valorisation, since they almost eliminate carbon and organic compounds (Figure 2). This can imply an increase in the percentage that could be valorised from 2 to 5%.

Test and validation

A mixture composed of all the types of foundry by-products (each type in a percentage related to the volumes that nowadays are being landfilled) has been used in the main four types of ceramic tiles produced in Europe: red firing bodies (wall tiles and floor tiles) and white firing bodies (wall tiles and porcelain tiles). In this way, the

by-products that nowadays imply large volumes in landfills, will be valorised in larger extent with respect to others that have more possibilities of valorisation. The mixture has been used in a percentage of 2.2% replacing clays and sands except in the case of porcelain tiles, in which the percentage has been 1% as this type of product has an increased tendency to form "black core". These percentages have been determined with the criteria of not increasing substantially the content of organic carbon in the composition. These compositions have been prepared and initially characterized on a laboratory scale, subsequently on a pilot scale and finally, industrial trials have been performed, producing 800 m^2 of porcelain tiles and wall tiles in a ceramic tile manufacturing company located in the province of Castellón, the core of the Spanish ceramic cluster.

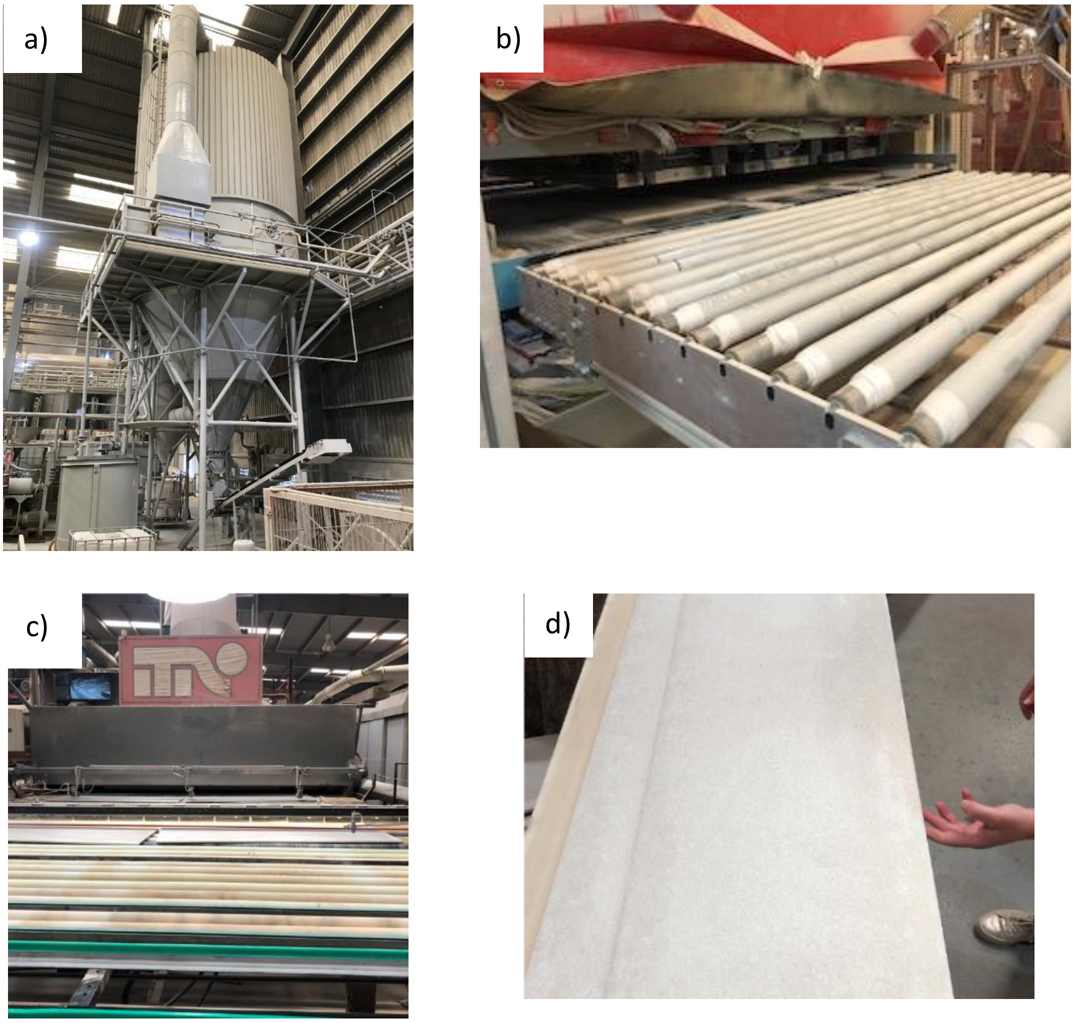

Figure 3: Industrial trials, a) spray-drying, b) pressing, c) firing and d) wall tiles produced.

Very similar behaviour in the manufacturing process has been observed between standard compositions and compositions with foundry by-products. The only difference has been the longer firing cycles that the tiles with foundry by-products

have required in comparison to standard tiles (15% longer) in order to avoid the presence of “black core”. Also, the prototypes obtained at pilot and industrial scale from both standard compositions and compositions with foundry by-products have similar properties (water absorption, flexural strength, thermal shock resistance, …) when characterized according to the European Standards for Ceramic Tiles.

From these results, a matrix with the different types of foundry by-products and their application in the different types of ceramic tiles has been developed. The matrix obtained indicates the feasibility of use of almost all the types of foundry by-products in ceramic tiles in percentages from 1 to 5% depending on their content of organic carbon, with a limit for this parameter of 2-3% for their use. In the case of white firing wall tiles and porcelain tiles an additional limit for Fe_2O_3 has also been established: 1.5% for wall tiles and 1% for porcelain tiles. With thermally treated by-products the percentages can increase up to 6%.

Sustainability and regulatory framework

The sustainability of the use of by-products in ceramic tiles has been checked by different ways. Firstly, the absence of impact on gaseous emissions of the typical compounds of ceramic bodies (CO_2, NOx, SO_2 and HF) and particulate emissions associated with the industrial firing of ceramic tiles has been verified.

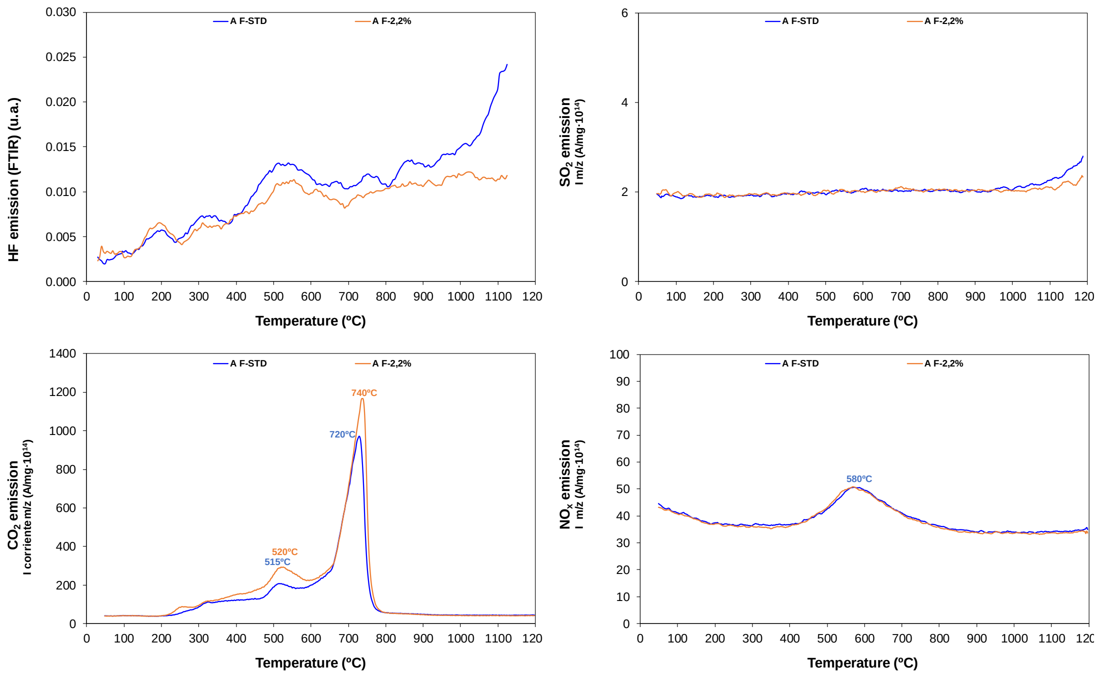

Figure 4: Gaseous emissions of the wall tile compositions (STD and with 2.2% of foundry by-products).

Also, Life Cycle Analysis (LCA) has demonstrated that the valorisation provides environmental advantages over conventional production for a maximum transport distance of by-products between 875 and 1,025 km (depending on the type of tile), taking into account CO_2 emissions. Moreover, the carbon footprint establishes a saving up to 8,500 tons/year of CO_2 at national level. The Life Cost Cycle Analysis (LCCA) shows a cost reduction in both sectors involved, mainly due to the reduction of raw materials consumption in the ceramic sector and to the reduction of waste management costs in foundry industry. And finally, it has been checked that the use and production of tiles with foundry by-products does not result in an unacceptable additional risk to human health (with silica as main indicator in the method of Chemical Risk Analysis for Human Health). Regarding the regulatory framework, this valorisation strategy will be included in the BREF documents both from the ceramic sector and from the foundry sector.

Acknowledgements

LIFE FOUNDRYTILE (LIFE14 ENV/ES/000252) is a project co-financed by the European Union within the LIFE Environment and Resource Efficiency Programme and supported by IVACE (GVA Valencian Government). Likewise, the authors would like to thank the 17 companies that have provided data and samples, as well as project partners: Asociación de Fundidores del País Vasco y Navarra (AFV), Asociación Española de Fabricantes de Azulejos y Pavimentos Cerámicos (ASCER) and Grupo Euroatomizado.

References

1. Z. Pytel, "Evaluation of potential applications of recycled moulding and core sands to production of ceramic building materials", *Ceramics International*, **40**(3), 4351–4358 (2014).
2. https://foundrytile.eu/
3. R. L. P. Carnin, M. V. Folgueras, R. R. Luvizão, S. L. Correia, C. J. Da Cunha, R. S. Dungan, "Use of an integrated approach to characterize the physicochemical properties of foundry green sands" *Thermochimica Acta*, **543**, 150–155 (2012).
4. E. Sánchez, J. García, V. Sanz, E. Ochandio, "Raw material selection criteria for the manufacturing of ceramic paving and tiling", in Qualicer: I World Congress on ceramic tile quality. General lectures and open-papers. 101-118 (1990).