END-OF-WASTE MATERIAL AND BY-PRODUCTS SUITABLE FOR CERAMIC TILE INDUSTRY

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1. SUMMARY

The European regulations encourage industries towards a green and circular economy in which "reuse" and "preparation for reuse" are keywords to reach an Innovating-to-Zero, ideal future at zero emission, zero waste and zero non-recyclable products.

Directive 2008/98/EC sets the basic concepts and definitions related to waste management, such as the definition of waste, recycling and recovery. Waste and resources are positively defined as End-of-Waste material.

The manufacturing of ceramic tiles is a traditional way for waste recovery, going back to at least the 1970's, with an increasing industrial interest and growing number of scientific papers.

Since 2000, more than one hundred scientific studies have been conducted about waste recycling in porcelain stoneware mixes. The search word "porcelain stoneware" generated about 300 results on the website Scopus, more than 100 of which revolved around "waste". Figure 1 shows the geographical distribution of these studies.

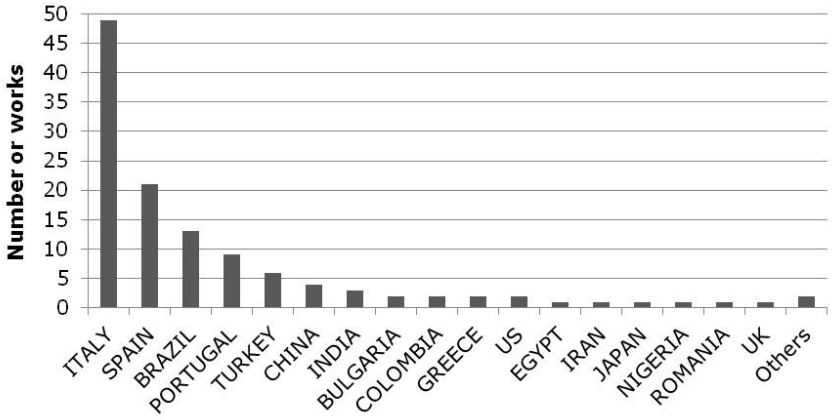

Figure 1. *Geographical provenance of scientific papers on waste recycling in porcelain stoneware mixes (from 2000 till 2017).*

Despite all the studies and manufacturing experiments, conclusions about the recycling of a given waste are often controversial. Improved reliability, industrial transferability and connection to tile-manufacturers are needed.

All in all, to our knowledge there is still not a complete study that considers multiple typologies of waste and their economic sustainability, together with the evaluation of their effects during the ceramic process.

Thus, the purpose of this study is to carry out the first detailed assessment of all the available waste in the Emilia Romagna Region (Italy), their availability and the required process to render them usable as secondary raw materials by ceramic industries.

Recycled waste in the ceramic industry can be classified into two main typologies: *waste coming from ceramic processes* and *other waste suitable for ceramics*.

Italian ceramic industry is rather virtuous, being able to recycle almost all the residues from the ceramic process. It allows a significant saving of natural resources, considering that $1m^2$ of porcelain stoneware tiles has a mass of about 22kg and the Italian production is more than 400 Million of m^2/y.

The Waste Reuse Factor (% WRF) is an indicator of the performance of a factory for the global waste management. For the Italian factories, this index is always higher than BAT (Best Available Technique) and Ecolabel limits (50% and 85%, respectively) and, frequently, it is also higher than 100% indicating that factories recycle also waste coming from other industries [Italian Integrated Report 2010-2015, Confindustria Ceramica, 2017].

The waste coming from ceramic processes is mainly the following: unfired scrap tiles, fired scrap tiles, mud coming from washing lines, lapping and polishing mud, dried grinding residues, exhausted lime.

Almost all of this waste (pre-consumer waste) is reused in the same process, in a closed loop cycle. Only exhausted lime is still landfill confined as dangerous waste, mainly due to the preferred approach of the industrial practice to avoid any risks in its reuse in a traditional tile mix (i.e. rheological risks and risks related to workers' health and safety).

The use of non-ceramic waste (urban waste or waste coming from other industrial productions) in traditional ceramic tiles has been under investigation since late 90s.Many literature studies revolve around recycling this waste in traditional ceramic materials, in particular porcelain stoneware tiles (recycled waste % below 10-15%).

Over the last few years, a new concept of "traditional" ceramic has been developed by replacing a bigger amount of natural raw materials with different types of waste in a more balanced way in order to obtain a sort of "waste synergy" during firing. The aim of this concept was to demonstrate a reduction of the environmental impact and a significant reuse of End-of-Waste materials. The most studied waste is packaging soda lime scrap glass coming from urban collection. It is mainly addressed to the glass industry, in line with the principle of the Circular Economy. However, about 30% of this waste is not suitable to be recycled in a closed loop cycle due to the high level of purity requested in the glass production. Therefore, this fraction is available for other uses, such as ceramic use.

Another waste to consider is the waste of cathode ray tubes scrap glass, lamp scrap glass, fly and bottom ashes coming from biomass thermoelectric plants.

Fig. 2 reports the role of the recycled waste (from 20 to 60%) in a porcelain stoneware mixtures regarding the optimised firing temperatures (able to reach a water absorption of ≤0.5%).

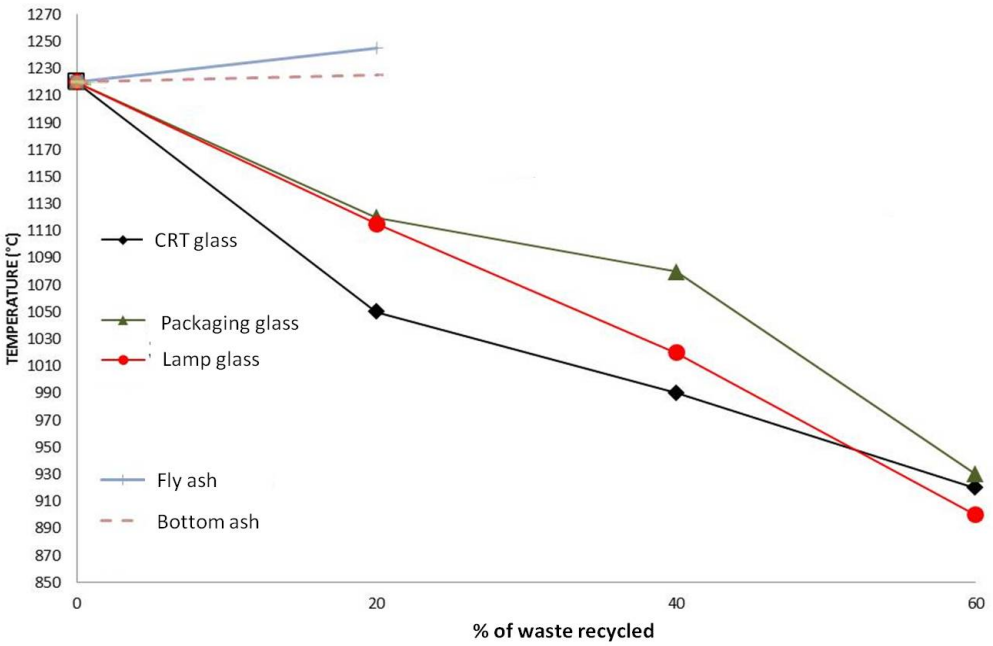

Figure 2. *Percentages of waste recycled in a ceramic mix with regard to firing temperatures.*

2. ACKNOWLEDGEMENT

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