

RE-USE OF INORGANIC INDUSTRIAL WASTE

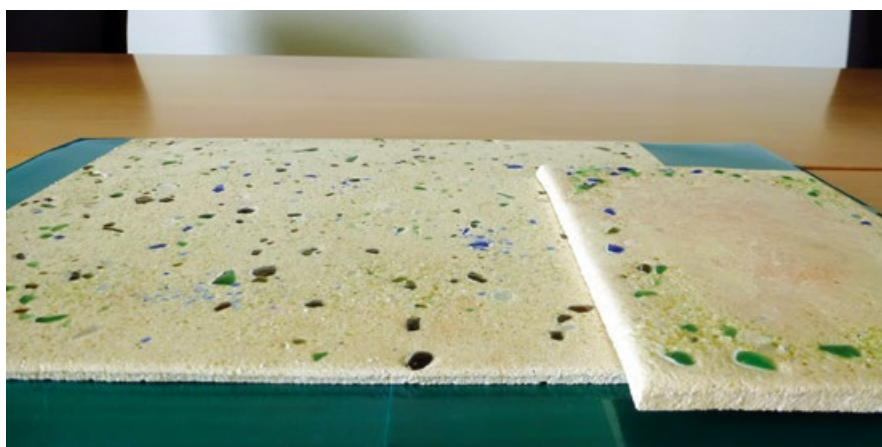
DOWNGRADING THE DANGER CLASS OF WASTE THROUGH INERTIZATION IS COST-EFFECTIVE, THE CONVERSION IN NEW RAW MATERIALS INCREASES REVENUES; THIS IS THE WAY TO ARRIVE TO A SELF-SUSTAINING SYSTEM, IMPLEMENTING THE SHIFT FROM LINEAR TO CIRCULAR GROWTH MODELS.

Sustainable waste management implies not only the quantitative prevention and reduction of hazardous waste but also a greater recourse to energy and material inertisation and re-use. Downgrading the danger class of waste (thus obtaining economic savings) or, better, converting them in proper new raw materials (obtaining more revenues), means moving from a traditional linear growth model based on “take, produce, use and discard” to a circular self-sustaining model where resources remain inside the economic system until their end-of-life in order to be reused several times for production purposes, thus generating new value.

As to material re-use, the European orientations resulting from the VI Environmental Action Programme suggest the match between sustainable use of resources and sustainable management of waste, which is key in those countries, like Italy, with few natural raw materials. Therefore, sustainable waste management needs to be implemented with the best processing and re-use technologies in full consideration of the production proximity principle.

An increase in re-use would not only reduce the demand for raw materials, but would also boost the re-use of valuable materials that are now discarded as waste and would also lead to a decrease in energy consumption and greenhouse gases emissions generated by raw materials extraction and processing. The same frame directive 2008/98/EC, implemented in Italy by Legislative Decree 205/2010, setting specific goals and criteria, also outlined a new cultural attitude affecting directly the national and local public entities as well as business and citizens, the last two being the main waste producers.

This preliminary introduction defines the context for the illustrative and certainly not thorough overview reported below,



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whose main goal is to show how scientific applied research on technologies and materials can lead to sustainable social, economic and environmentally-friendly solutions for inorganic industrial waste management.

Heat processing

Vitrification/devitrification

Vitrification is a process based on high-temperature heating (1,200-1,700°C) of natural raw materials (carbonates, oxides, etc.) that are first liquidized then transformed into glass through water or air cooling. Vitrification turns solid waste into a highly biological and chemical resistant vitreous material. Waste organic compounds are totally destroyed, while inorganic pollutants are partially released through the gas flow as vapours or fine particulate matter (that is why special treatment lines are needed) but are mostly incorporated in the vitreous mass. Other major benefits include volume reduction and waste danger downgrading as well as the opportunity to mix solid waste of different nature and origin. The main disadvantage is that this process is very expensive and energy consuming, but it allows the transformation of

incineration residues, ceramic sludges, light carbon ashes and agri-food waste into highly value-added materials such as ceramic enamels, fibres, fertilizing glasses, vitreous granules that, previously thermally treated, generate semi-crystalline materials (glass-ceramics) with improved properties compared with the original glass, thus justifying the expensive process [1].

Sintering

Sintering is a thermal solidification process through powder compacting, removal of interstitial porosity, coalescence and development of strong bonds between adjoining particles. Usually powders are pressed into specifically sized and shaped masses, according to needs, ready to be finally processed.

The most critical factors in the process are: chemical nature and initial density of the material, particle size, pressure, time and heating cycle, atmosphere inside the furnace (reducing or oxidizing). As to waste processing the major benefits are: volume reduction, production of

1 Glass ceramic plate.

2 Geo-polymer panel.

a highly compacted material, which is extremely weather-resistant, with run-off reduction. Controlled heating leads to the final immobilization and inertisation of dangerous compounds contained in waste, namely it is largely used to incorporate heavy metals in ceramic materials. The new output materials can be used in the building sector as roof tiles, bricks, tiles, etc. Other waste categories that can be used are: packaging glass waste, Weee, ceramic sludges, steel, incineration and agri-food waste, etc. It is also possible to manufacture glass-ceramic products or porcelain tiles that due to the higher glass content have a better stabilisation of the toxic waste components. [1, 2].

Microwave thermal inertisation

Microwaves of consistent and polarized electromagnetic radiations with a frequency between 0.3 and 300 GHz can heat several materials. As many other radiation methods, microwave heating does not require the direct contact between the heating source and the heated material, therefore the furnace structure is quite simple.

There are several benefits with a suitable power level: very quick heating, very short processing times, major energy savings. The material to be heated directly and quickly absorbs energy from the microwave-transported electromagnetic field. It is also possible to apply it to gas or resistance heated furnaces for vitrification or sintering cycles leading to final products having the same features in terms of dangerous waste inertisation. Asbestos containing waste, both in compact and liquid form, absorb very well the microwave-generated energy. The fibre degradation thermal treatment (leading to inert chemical composition and microstructure) takes only a dozen of minutes and this speed, compared to the hours required by conventional treatments, brings about major energy savings. The final product, as the one obtained through conventional processing, is no longer dangerous and can be used for concrete or ceramic material production [1, 3].

Cold processing

Geopolymerization

Geopolymers refer to a technology used to get inorganic products from powders, mainly aluminosilicates ($\text{SiO}_2 + \text{Al}_2\text{O}_3 > 80$ weight %), diluted in a strongly basic solution, so that the use of ambient temperature prevents the emission of



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greenhouse gases. These materials have been largely used over the last ten years to incorporate dangerous substances [4]. Geopolymerization is excellent to reuse and neutralise solid and liquid waste [5]. For instance, non hazardous waste can be used as a precursor of aluminosilicates to get geopolymers, namely steel or incineration waste, light ashes from power stations, etc. Also hazardous waste, like light incineration ashes, residues of ink for ceramic tile digital printing, etc. can be neutralized by this inorganic material like through vitrification. This cool process unfolds as follows: waste, in liquid or powder form, is mixed with a suitable quantity of natural or secondary aluminosilicate powders in an alkaline solution.

In spite of the use of basic solutions the process remains environmentally friendly mainly because it leads to:

- an increase in waste re-use and generation of secondary raw materials;
- the reduction of raw material extraction and CO_2 emissions
- the production of materials that can be discarded in landfills for non-hazardous waste or that can even be recycled.

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