LIFE12 ENVIT 000295 FIBERS Fibers innovative burning and reuse by Self-propagating High temperature Synthesis (SHS)

Laura Gaggero¹, Valentina Caratto¹, Claudio Belfortini², Luigi Musi², Maurizio Ferretti²,

¹) Department of Earth, Environment and Life Sciences, University of Genoa, Corso Europa 26, 16132 Genova, Italy
²) Department of Chemistry and Industrial Chemistry, University of Genoa, Via Dodecaneso 31, 16146 Genova, Italy,
A multidimensional problem

• Health and occupational exposure

• Social outreach (local authorities, experts in management, monitoring networks, quality in monitoring…)

• Normative harmonisation (international ban, decommissioning, end of life for waste, second life for inertised products…)

• Environmental (geohazard from ophiolites, waste landfill)

• Technological (substitute materials, effective inverting)
Following the WHO prescriptions:

- All nations should have a “national asbestos profile” as for occupational and health responsibilities, as recommended by International Labour Organization (ILO)
- Up to now 55 countries worldwide adhered to total or partial ban of asbestos

**European normative**

EC directive n. 77 26 July 1999
Starting from 1 Jan 2005 ban of asbestos from EU territory

EC directive n. 148 30 November 2009
Workers protection against asbestos exposure
European normative

European Parliament resolution of 14 March 2013
Asbestos related occupational health threats and prospects for abolishing all existing asbestos

The EU proposes to adopt a shared strategy for the total elimination of asbestos still present in buildings, machinery, pipelines, trains and ships of the continent.

The 2028 will be deadline for its completion

32. Measures must also be taken to promote and support research into, and technologies using, eco-compatible alternatives, and to secure procedures, such as the inertisation of waste-containing asbestos, to deactivate active asbestos fibres and convert them into materials that do not pose public health risks.
LANDFILL OPTION In ITALY

- **73** landfills
- **23** still operating landfills host Demolition Waste containing asbestos
- **5** landfills receive other ACW (total 2000 tons)
- On the whole: 111,202 m³ residue volume

- dati Inail 2013
Italy has been a major asbestos producer since the 70ies and consumer until the 80ies. Between world war II and 1992 4 million tons of raw asbestos were extracted from the Balangero mine. The imported amount attained 2 millions tons.

In 2011 the German Saar region of communicated to the Lombardy region that wouldn’t accept asbestos to be landfilled due to the risk of receiving polluted material.
In the perspective of reducing the environmental issue and to explore recycling of the breakdown products, we experimented the use of highly exothermic and fast thermite reactions exploiting the **Self–propagating High temperature combustion Synthesis (SHS)** taking to the **chemical** and **physical** breakdown of fibers.
What is a thermite reaction?

An highly exothermic reaction, involving reduction of a metallic oxide by aluminium or another reducing element:

$$ AO + M \rightarrow MO + A + \Delta H^\circ $$

once ignited by means of external heat sources for a few seconds, the reaction proceeds as a combustion wave through the reactant volume without any additional energy input.

The maximum attainable temperature in a reaction of this kind is defined as adiabatic temperature $T_{ad}$ estimated from

$$ \Delta H_{298}^0 = \int_{298}^{T_{ad}} C_{ps}(AB) \, dT $$

Because of heat dissipation, adiabatic conditions are seldom reached, as well as the theoretic $T_{ad}$.

As a consequence, the $T_{max}$ attained at the reaction front is the exothermic threshold during the synthesis.
### Experimented (*alumino*) Mg-thermic reactions

\[
\begin{align*}
\text{Fe}_2\text{O}_3 + 3\text{Mg} & \rightarrow 3\text{MgO} + 2\text{Fe} & (\Delta H_r = -979.22 \text{ kJ/mol}) \\
\text{Fe}_3\text{O}_4 + 4\text{Mg} & \rightarrow 4\text{MgO} + 3\text{Fe} & (\Delta H_r = -1291.10 \text{ kJ/mol})
\end{align*}
\]

**Chrysotile** was mixed with Hem + Mg and Mgt + Mg in stoichiometric amounts, according to the following:

1. \[
\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4 + \text{Fe}_2\text{O}_3 + 3 \text{Mg} \rightarrow 2 \text{Mg}_2\text{SiO}_4 + 2\text{MgO} + 2\text{Fe} + 2\text{H}_2 \\
(\Delta H_r = -846.43 \text{ kJ/mol})
\]

2. \[
\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4 + 2\text{Fe}_3\text{O}_4 + 2\text{Mg} \rightarrow 2\text{Mg}_2\text{SiO}_4 + \text{MgO} + 6\text{FeO} + 2\text{H}_2\text{O} \\
(\Delta H_r = -437.21 \text{ kJ/mol})
\]
Operating conditions
- Reaction triggered by Electric impulse
  (W ignition coil)
  - 20 V for 4-5 sec
- Oxygen-free atmosphere
PARAMETERS IN SAMPLE MOULDING

- Mg-thermic reactants: Hem + Mg; Mgt + Mg;
- Chrysotile amount: Ctl 45 %, Ctl50%, Ctl54%, Ctl60%, Ctl65%;
- Pellet size: diameter (10 mm – 13 mm); height (h_{avg} = 7-8 mm; h_{max} = 13 mm);
- Pellet type (homogeneous or layered)
Chrysotile breakdown

- New effective technique addressed to chrysotile breakdown
- New effective application of self-propagating high temperature synthesis (SHS) involving natural materials
- Fast and energy-saving method
- Reaction products are NOT industrial waste
- Reaction products are liable to become a second resource (refractory, abrasive etc)
THE PRODUCTS

- **Voids originated in the volatile release from chrysotile, surrounded by blocky, homogeneous forsterite**
- **Irregular, swirlly, amygdalar texture of bubble distribution, ➔ volatile release occurred in visco-plastic host material**
- **Spongy texture defined by wustite shells enclosed in forsterite**
Life FIBERS - LIFE12 ENV IT 000295
FIBERS INNOVATIVE BURNING AND REUSE BY SHS

www.fibers-life.eu
• Implementation of SHS technology for Asbestos-waste treatment

• Two scaled-up plants: (prototype 1, ≈ 1 Kg capacity, prototype 2 ≈ 100 Kg capacity)

• Reproducibility of SHS reaction on different asbestos waste (Eternit™ tiles, loose fibers, linoleum, fiberglass etc).

• Post-SHS characterization of by products for possible re-use.
Prototype 1 discontinuous

 Prototype 1 continuous

• Different ACWs: fiber cement and friable asbestos
• ACW amount: from 50 to 70 weight %
• Pellet size: diameter 25 mm; height 20 - 80 mm
• Weight of samples: from 20 to 100 g
• The reaction is triggered by an oxyacetylene torch
PROGRESS STATE

Successful steps towards prototype 2

70 gr SiO₂ sand, 30% reagents

Trigger: W coil

Fiberglass, 40% reagents

Trigger: oxyacetylene torch
Scaling up from lab to plant
**Friable asbestos**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Asbestos waste</th>
<th>% of waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIBERS-1</td>
<td>friable asbestos</td>
<td>50</td>
</tr>
<tr>
<td>FIBERS-2</td>
<td>friable asbestos</td>
<td>60</td>
</tr>
<tr>
<td>FIBERS-3</td>
<td>friable asbestos</td>
<td>70</td>
</tr>
<tr>
<td>FIBERS-5</td>
<td>fiber cement</td>
<td>50</td>
</tr>
<tr>
<td>FIBERS-6</td>
<td>fiber cement</td>
<td>60</td>
</tr>
</tbody>
</table>

Results after SHS treatment
Final results

- Both prototypes achieved the goal. We optimized the parameters to achieve **complete conversion** of the asbestos to mineral grains in all the cases.
- The SHS process in comparison with conventional thermal treatments, due to **fast reaction time, low activation energy**, particularly advantages the asbestos inertization and positively reflects into time and costs of the process.
- Finally, the product of this transformation is liable to be re-used, e.g. as abrasive, or refractory material; this represents the end of waste status and a **second life** as secondary raw material.
FALLOUT:
- Treatment of hazardous waste in confined environment
- Development of advanced technologies

JOB CREATION

WASTE MANAGEMENT

ENVIRONMENTAL POLICIES EU
- Considerable decrease of waste to landfill
- Decreased need of landfills
- Better use of the territory

SUSTAINABILITY
Thank you for your attention
POWDER RESIDUAL TOXICITY AFTER SHS TREATMENT

In vitro test with macrophages

- Wet grinding→ l>4μm, d<0,25 μm (Stanton et al., 1981)
- Cells suspension (5 mg) and cells culture(19 mg)
- Incubation: 37 °C per 2 h
- Inflammatory mediator concentration 100 μg/ml (Q. A1)

**TNF EXPRESSION LEVEL**

<table>
<thead>
<tr>
<th></th>
<th>control</th>
<th>A1 0.1 mg/ml</th>
<th>A2 0.15 mg/ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNF expression level</td>
<td>-60%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Before treatment ![Image](image1.png)

After treatment ![Image](image2.png)