Development of methodologies to reduce the toxicity of Respirable Crystalline Silica

SILIFE Project

Dr. Eliseo Monfort
Background

1997. IARC (International Agency for Research on Cancer):
RCS was classified as carcinogenic to humans (Category I)

2002. SCOEL Scientific Committee on Occupational Exposure Limits
Occupational Exposure Limits should lie below 0.05 mg/m³

2006. ACGIH (American Conference of Governmental Industrial Hygienist) proposal
Non-binding OEL limit for RCS of 0.025 mg/m³

2012. IARC (International Agency for Research on Cancer):
There is sufficient evidence of RCS classification as carcinogenic to humans (Category I).

2017. EU. RCS was included in the Directive on exposure to carcinogens at work:
OEL in EU should lie below 0.1 mg/m³
Results of European projects related to RCS developed by ITC
Background. Study in the European ceramic sectors

2005 - 2008

SILICERAM
Health and productivity

Countries:
- United Kingdom
- Italy
- France
- Spain
- Germany
- Rumania

Partners:
- 8 Business Associations
- 22 Companies (SME)
- 8 Research Centres
Objective:

Study of the exposure to RCS and its toxicity in the ceramic sector

Industrial sectors participants (traditional ceramics):

- Ceramic tiles
- Bricks and roof tiles
- Tableware (pressing and casting)
- Refractories
Background. Study in the European ceramic sectors

RCS content of samples obtained with a high volume sampler

<table>
<thead>
<tr>
<th>Industrial sector</th>
<th>Process stage</th>
<th>RCS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiles</td>
<td>Pressing</td>
<td>8,1</td>
</tr>
<tr>
<td>Bricks</td>
<td>Pressing</td>
<td>7,8</td>
</tr>
<tr>
<td>Tableware</td>
<td>Spray drying</td>
<td>5,8</td>
</tr>
<tr>
<td>Tableware</td>
<td>Casting</td>
<td>3,1</td>
</tr>
<tr>
<td>Refractory</td>
<td>Pressing</td>
<td>3,7</td>
</tr>
</tbody>
</table>

Average levels of exposure to RCS registered by personal samplers at different stages of industrial processes

<table>
<thead>
<tr>
<th>Process stage</th>
<th>Number of samples</th>
<th>Average concentration (mg/m³)</th>
<th>Upper quartile (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw materials preparation</td>
<td>53</td>
<td>0.060</td>
<td>0.110</td>
</tr>
<tr>
<td>Wet moulding</td>
<td>43</td>
<td>0.037</td>
<td>0.058</td>
</tr>
<tr>
<td>Dry moulding</td>
<td>16</td>
<td>0.119</td>
<td>0.145</td>
</tr>
<tr>
<td>Glazing</td>
<td>70</td>
<td>0.026</td>
<td>0.052</td>
</tr>
<tr>
<td>Firing</td>
<td>30</td>
<td>0.008</td>
<td>0.036</td>
</tr>
<tr>
<td>Classification, packaging</td>
<td>31</td>
<td>0.011</td>
<td>0.027</td>
</tr>
<tr>
<td>Maintenance</td>
<td>11</td>
<td>0.004</td>
<td>0.073</td>
</tr>
</tbody>
</table>

Background - SILICERAM project (2005-2008)

“Studies aimed at assisting legislation and encouraging continual improvement strategies in the field of respirable crystalline silica”
VI Frame Program “Horizontal Research Activities Involving SMEs”

Objective:

Study of the exposure to RCS and its toxicity in the ceramic sectors.

Results:

Samples of respirable dust from workplaces developed less biological activity than quartz DQ12 (reference)

Clay minerals can have an inhibitor effect on quartz toxicity

Studies are required to determine the changes on quartz surface caused by other substances, which reduce its toxicity
Inhibition of RCS toxicity

- Certain substances can inhibit RCS toxicity:

  Polyvinylpyridine-N-oxide (PVPNO) (Schlipköter & Brockhaus, 1961)
  Aluminium lactate (AL) (Bègin et al., 1986) (SILICERAM)
  Phospholipids (Wallace et al., 1986)
  Organosilanes (Castranova et al., 1996)

Forming a molecular layer on the RCS surface to saturate SiOH groups by “coating” them.

RCS technical approach

Render Respirable Crystalline Silica safer by inhibiting the toxicity in origin:

- **Wet processes:**
  - SILICOAT project (2011-2014)
  - Project focused on ceramic industry

- **Dry processes:**
  - SILIFE project (2016-2019)
  - Project dealing with different quartz users sectors
2011 - 2014

Business associations:

Companies (SME):

Research centres:
Objective:

Developing and implementing technologies of RCS coating at ceramic wet processes to make handling of RCS-containing materials intrinsically safe from the toxicological point of view.
Results

In vitro:

<table>
<thead>
<tr>
<th></th>
<th>Cytotoxicity (%)</th>
<th>Genotoxicity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PTMO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIVO160</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nanoalumina 1.5%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Solution for ceramic processes. Wet method

Industrial trials in PORVASAL (tableware)
Solution for ceramic processes. Wet method

Industrial trials in Walküre
Industrial trials in ATOMIZADORA (ceramic tiles)
Industrial trials in FLAMINIA (sanitaryware)
Research centre:

Supplier companies:

Technological platform:

End-user companies:
Production of coated quartz by dry process

-40
-30
-20
-10
0
10
20
ζ potential (mV)

SILANE B (% w/w)

Dry method

Wet method
Production of coated quartz by dry process

Cytotoxicity

EL01 Coatings, LDH Assay, Primary Rat Alveolar Macrophages
75 µg/cm², 4 h of Incubation, n = 3

% Cytotoxicity

Organosilane coating [%]

I01 Coatings, LDH Assay, Primary Rat Alveolar Macrophages
75 µg/cm², 4 h of Incubation, n = 3

% Cytotoxicity

Organosilane coating [%]
Production of coated quartz by dry process

Design of a treatment pilot plant

Production of treated quartz

Toxicological study

2016-2019

Industrial trials by end users

Elastomers  Adhesives  Frits  Foundry  Colorants
Conclusions

• An industrial-scale technology has been developed to reduce the RCS toxicity in wet processes (SILICOAT).

• An industrial-scale technology is being developed to reduce the RCS toxicity in dry processes (SILIFE).

• The developed coating technologies (wet and dry) can directly be integrated in the production processes.

• The developed processes can be applied to a large amount of companies which use quartz or quartz-containing materials as raw material.
THANKS FOR YOUR ATTENTION
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