MATER_SoS Project: technological transfer of the results in the frame of sustainability

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A shortcutting view...

From a linear to a circular economy

Linear economy:
- Raw materials
- Production
- Use
- Non-recyclable waste

Reuse economy:
- Raw materials
- Recycling
- Production
- Use
- Non-recyclable waste

Circular economy:
- Raw materials
- Recycling
- Production
- Use

Any technological constraint?
Any quantitative assessment of materials flow?
Objective

Circular Economy in ceramic tiles: from a case-study in Emilia-Romagna (MATER_SOS) towards a global view on waste recycling

Summary

• «Circularity» in the ceramic sector
• Constraints to waste recycling (technological, commercial, logistic)
• Raw materials flows vs. waste sourcing
• The role of the ceramic industry: today vs. tomorrow
• Conclusions
Circularity in the ceramic tile industry

~100% CDWs construction and demolition wastes

wastes from other industrial sources

residues recycled in the process

non-recyclable residues

20-50 years
A cannibalistic industry

amount of waste recycled in ceramic tile batches
(data from the Italian ceramic district)

<table>
<thead>
<tr>
<th>Waste type</th>
<th>Monoporosa Stoneware</th>
<th>Porcelain stoneware</th>
<th>Large slabs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tile-making process</td>
<td>13% on average</td>
<td>13% on average</td>
<td>20% on average</td>
</tr>
<tr>
<td>unfired tiles, sludges, wastewater, ...</td>
<td>up to 40% in a single batch</td>
<td>up to 20% in a single batch</td>
<td>up to 10% in a single batch</td>
</tr>
<tr>
<td>Pre-consumer</td>
<td>13% on average</td>
<td>13% on average</td>
<td>20% on average</td>
</tr>
<tr>
<td>fired tiles, sanitaryware scraps, ...</td>
<td>up to 40% in a single batch</td>
<td>up to 20% in a single batch</td>
<td>up to 10% in a single batch</td>
</tr>
<tr>
<td>Post-consumer</td>
<td>13% on average</td>
<td>13% on average</td>
<td>20% on average</td>
</tr>
<tr>
<td>waste and waste-of-waste glasses, ...</td>
<td>up to 10% in a single batch</td>
<td>up to 5% in a single batch</td>
<td>not used</td>
</tr>
</tbody>
</table>

Different waste recycling strategies in tile-making industry groups:

- all manufacturing lines recycle the residues
- all the residues are recycled in a single line
- all lines recycle some residues and the excess goes to a single line
Commercial constraints: a moving target

Green labeling

Historical evolution of white-firing floor tiles

- Unglazed porcelain stoneware
- Glazed porcelain stoneware
- Single-fired white stoneware
- Fine stoneware

Maximum size achievable by conventional pressing (tiles)

- 25x20 cm
- 50x50 cm
- 60x60 cm
- 80x80 cm
- 120x120 cm
- 90x180 cm
- 120x240 cm

Comparison of maximum area achievable by the different technologies

- G
- S
- C
- Conv

Maximum size achievable by the novel compaction technologies (slabs)

- 540x160 cm
- 480x160 cm
- 360x180 cm
- 320x160 cm
- 240x120 cm
- 160x100 cm

2000 2010 2020 2030
Technological and environmental constraints in the industrial practice

Legal requirements for emissions in the tile-making cycle (e.g., hot)

Technological requirements to fulfil during the various stages of the tile-making cycle

Considerable knowledge gap in the literature!
Raw Materials Flows
(data from the Italian ceramic district)
Survey of wastes actually available for recycling in Emilia-Romagna, Italy
Amount of wastes actually available for recycling
(survey for the Emilia-Romagna region, Italy)

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount (thousand tons per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorting</td>
<td>2570</td>
</tr>
<tr>
<td>745 kt MWI ash</td>
<td></td>
</tr>
<tr>
<td>191 kt Glass</td>
<td></td>
</tr>
<tr>
<td>78 kt Inert</td>
<td></td>
</tr>
<tr>
<td>21 kt WEEE</td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td>3900</td>
</tr>
<tr>
<td>Ceramic</td>
<td>525</td>
</tr>
<tr>
<td>Chemicals</td>
<td>190</td>
</tr>
<tr>
<td>Mining &amp; Quarrying</td>
<td>190</td>
</tr>
<tr>
<td>Metallurgy &amp; Metalmechanics</td>
<td>324</td>
</tr>
<tr>
<td>Machinery &amp; Automotive</td>
<td>29</td>
</tr>
<tr>
<td>Food &amp; Beverage</td>
<td>65</td>
</tr>
<tr>
<td>Wood &amp; Paper</td>
<td>189</td>
</tr>
<tr>
<td>Electricity production</td>
<td>177</td>
</tr>
<tr>
<td>Water treatment</td>
<td>87</td>
</tr>
<tr>
<td>Biomass</td>
<td>37</td>
</tr>
</tbody>
</table>

**Note:** The values are approximate and represent the amount of wastes available for recycling in the Emilia-Romagna region, Italy.
Selected wastes for recycling

- RIFIUTI URBANI
  - RAEE
  - Vetro lampade
  - Vetro schermo
  - Scarti pneumatici

- INDUSTRIA ALIMENTARE
  - Scarto di gusci d’uovo
  - Scarto di conchiglie

- RIFIUTI URBANI
  - Aghi di pino

- IMPIANTI POTABILIZZ.
  - ACQUA
  - Fanghi da filtrazione acque

- INDUSTRIA SIDERURGICA
  - Scorie nere e bianche

- INDUSTRIA CERAMICA
  - Scarto rettifica
  - Calce esausta
  - Fanghi filtropressati
  - Fanghi smalteria
  - Vetroceramici

- INDUSTRIA ELETTRICA
  - Ceneri da biomasse (leggere e pesanti)

- SCARTI DA COSTRUZIONE E DEMOLIZIONE

- FORLI’ CESENA
- FERRARA
- BOLOGNA
- MODENA
- REGGIO EMILIA
Case-study: waste assessment for the ceramic tile industry (Emilia-Romagna)

7-8% urban wastes

33-37% industrial wastes

unsuitable for ceramics

physical status

slip rheology

7-8% urban wastes

33-37% industrial wastes
Potential demand for recycling

### RAW MATERIALS DEMAND x WASTE OFFER

<table>
<thead>
<tr>
<th>Waste type</th>
<th>Porcelain stoneware</th>
<th>DEMAND</th>
<th>OFFER</th>
<th>ROOM FOR (% of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tile-making process</td>
<td>13% on average</td>
<td>~1000</td>
<td>~940</td>
<td>~60</td>
</tr>
<tr>
<td>Tile-making process</td>
<td>unfired tiles, sludges</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-consumer</td>
<td>up to 20% in a single batch</td>
<td>~600</td>
<td>~200</td>
<td>~400</td>
</tr>
<tr>
<td>Pre-consumer</td>
<td>fired tiles, sanitaryware scraps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-consumer</td>
<td>up to 5% in a single batch</td>
<td>~240</td>
<td>~60</td>
<td>~180</td>
</tr>
<tr>
<td>Post-consumer</td>
<td>waste-of-waste glasses, ...</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Testing different wastes

**Tile-making process**
Glaze-making wastes (glaze scraps and washing residues)
Tile-making wastes (unfired tiles and washing residues)

**Pre-consumer**
Tile grinding wastes (cutting and grinding porcelain stoneware)
Sanitaryware wastes (vitreous china scraps and kiln furniture)

**Post-consumer**
Container glass wastes
PC-TV screen glass wastes
Lamp glass wastes
Biomass combustion ashes
Getting different results

Body compressibility

Firing behavior

- Ceneri pesanti
- Ceneri SMB
- Vetro Schermo
- Vetroceramici
- Vetro Bottiglia
- Fango Gigacer
- Vetro Lampada
- Ceneri leggere
- Fango Retifica

GREEN BULK DENSITY (g/cm³)

TEMPERATURE (°C)

% SCARTO

SCARTO (%)
A new role for the ceramic tile industry

<table>
<thead>
<tr>
<th>Waste type in porcelain stoneware</th>
<th>PRESENT</th>
<th>FEASIBLE WASTE RECYCLING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tile-making process</strong></td>
<td>13%</td>
<td>30%</td>
</tr>
<tr>
<td>unfired tiles, sludges</td>
<td>on average</td>
<td>20-40%</td>
</tr>
<tr>
<td><strong>Pre-consumer</strong></td>
<td>up to 20% in a single batch</td>
<td>-</td>
</tr>
<tr>
<td>fired tiles, sanitaryware scraps</td>
<td></td>
<td>10-30%</td>
</tr>
<tr>
<td><strong>Post-consumer</strong></td>
<td>up to 5% in a single batch</td>
<td>55%</td>
</tr>
<tr>
<td>waste-of-waste glasses, ...</td>
<td></td>
<td>20-40%</td>
</tr>
</tbody>
</table>
Greening the industrial process

- 100% Natural raw materials
- Wet milling
- 85% waste, 15% clay
  - -20% Energy consumption
- Spray drying
- Pressing & glazing
  - Pressing & glazing
  - Firing ~1200°C
  - Firing ~1000°C
  - -10% Methane consumption
  - -10% CO₂ emission

Traditional porcelain stoneware

85% GREEN ceramic stoneware
Product certifications

**UNI Keymark**

**CERTIQUAILITY**

EN 14411: “Ceramic tiles: Definitions, classification, characteristics, evaluation of conformity and marking”
Class Bla (water absorption $E \leq 0.5\%$)

**LEED**
WINCER tiles obtained the certification **LEED Certiquality** for the amount of recycled materials: 85% (30% pre-consumer and 55% post-consumer wastes).
Product sustainability

- Environmental sustainability

<table>
<thead>
<tr>
<th>Environmental indicator (EN 15804)</th>
<th>Tile 85% recycled</th>
<th>Traditional tile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Warming Potential, GWP [kg CO₂-eq.]</td>
<td>1.09%</td>
<td>24-25%</td>
</tr>
</tbody>
</table>

- Social sustainability

Lower Respirable fraction of Crystalline Silica (RSC):

<table>
<thead>
<tr>
<th>WINCER spray dried powder</th>
<th>RCS Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional spray dried powder</td>
<td>5.2%</td>
</tr>
<tr>
<td>Traditional spray dried powder</td>
<td>5.2%</td>
</tr>
</tbody>
</table>

- Economic sustainability

Reduction of production costs for mix preparation: -33%
Conclusions

Circular Economy is a systemic approach it does not impose to close the loop in every value chain!

The ceramic tile industry cannot be circular because many «R» actions do not apply to ceramic tiles and end-of-life products flow into demolition wastes.

The ceramic tile production can re-use all wastes a fully cannibalistic approach proved to be viable (Italy) a greater effort is needed to recycle more end-of-life wastes.

The ceramic tile industry can be part of a green system from a closed loop to a circular array of linear chains the ceramic process is crucial to utilize problematic residues, particularly some waste-of-wastes.