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Mineral processing techniques dedicated to the recycling of river sediments to produced raw materials for construction sector
River Sediments

- Regular dredging to maintain shipping and hydraulic flow

<table>
<thead>
<tr>
<th></th>
<th>Annual dredging (m³/year)</th>
<th>Inland waterways (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flanders</td>
<td>1,850,000</td>
<td>990</td>
</tr>
<tr>
<td>Wallonia</td>
<td>120,000 to 250,000</td>
<td>450</td>
</tr>
<tr>
<td>France</td>
<td>2,800,000</td>
<td>8,501</td>
</tr>
</tbody>
</table>

- Generally considered as waste: therefore landfilled
- However, potential source of mineral materials:
  - Granulates
  - Sand
  - Silt
  - Clay
- Mainly for building sector
- Can be obtained by mineral processing techniques:
  - Simple
  - Cheap
  - Without chemicals
CHALLENGES IN THE USE OF SEDIMENTS

• Social: Citizen acceptance of construction materials made from secondary and polluted materials

• Legislation:
  • Lower and lower organic and inorganic pollutants maximum levels, without taking account (or lesser) to leaching behavior
  • Stringent legislations in valorization: doesn’t allow all valorizations

• Economics: treatment costs in addition of dredging, transportation,... costs
  • Calcination: generally expensive (> 90€/ton DM)
  • Stabilization/solidification: use of reactants, generally expensive (50-75€/ton DM)
  • Size classification: lot of steps (± 30€/ton DM)
  • Flotation: use of expensive reactants (10-40€/ton DM)

In comparison with cheap materials (clay [40-50€/ton], sand [± 40€/ton], ...)

• But also technical/scientific challenges
## Technical Challenges in the Use of Sediments

<table>
<thead>
<tr>
<th>River sediments</th>
<th>Building materials</th>
<th>Dehydration</th>
<th>Size classification</th>
<th>Organic matter (organics and inorganics)</th>
<th>Pollutants phases</th>
<th>Crystalline phases</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>Concrete</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>Increase of water demand</td>
</tr>
<tr>
<td></td>
<td>Road Building</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cement</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Asphalt</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granulates</td>
<td>Concrete</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Road Building</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>Concrete</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Road Building</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Silt</td>
<td>Embankment</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Fines (Clay / fine silt) | Brick | X           | X                   | X                                        |                   |                   | • Brick aspect (color, efflorescence)  
• Porosity and water adsorption (thawing freeze) |
|                 | Expanded clay      | X           | X                   |                                           |                   |                   | • SiO₂ and Al₂O₃ contents modify viscosity  
• Lack of iron oxide |
DIRECT INTEGRATION OF RIVER SEDIMENTS IN CONCRETE

- Combination of sieving, drying and disagglomeration to create a bicycle path in concrete with sediment

Sieving → Refusal → Exogenous: stones, bottles, glass, wood

Passing → Drying → Disagglomeration
DIRECT INTEGRATION OF RIVER SEDIMENTS IN CONCRETE

Substitution of 50% of the sand by sediments
Laboratory works under progress at IMT Lille Douai

<table>
<thead>
<tr>
<th>Fractions</th>
<th>Mass (kg)</th>
<th>DM:</th>
<th>±70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td>1109</td>
<td>±70</td>
<td>70%</td>
</tr>
<tr>
<td>(-5 mm)</td>
<td>849</td>
<td>±85</td>
<td>85%</td>
</tr>
<tr>
<td>(+5 mm)</td>
<td>101,6</td>
<td>±&lt;5</td>
<td>9,2%</td>
</tr>
<tr>
<td>Water loss</td>
<td>158,4</td>
<td></td>
<td>14,3%</td>
</tr>
</tbody>
</table>

Disagglomerated material
DM: ±85%
< 5 mm
MINERAL PROCESSING TREATMENT

- Aim: separate sediment components:
  - +2 mm: all exogenous (stones, wood, bottle, glass,...)
  - -2 mm; +250 µm: coarse sand
  - -250; +63 µm: fine sand
  - -63; +15 µm: silt
  - -15 µm: clay and fine silt
REMOVAL OF EXOGENOUS AND COARSE SAND

Input

1,2 t/h DM
40-80% DM

Exogenous:
+2 mm

1,2 t/h DM
30-40% DM

Coarse sand:
-2 mm; +250 µm

1,2 m³/h
10-20% DM

-250 µm
REMOVAL OF FINE SAND

Fine sand: -250; +63µm

1,2 m³/h
DM: 10-40%

0,8 m³/h
DM: 10-40%

Valse
SEPARATION OF SILT AND CLAY

Silt: -63;+15µm

Clay: -15µm

0,8 m³/h; DM: 5-30%

32 m³; 0,5 m³/h

Clay

DM: 15-40%

30 plates 800 x 800 mm; 15 bar

0,5 m³/h; 1 ton DM/batch

2 x 5 m³
MINERAL PROCESSING TREATMENT

Tank n°1

Curved screen

-250µm

Exogenous

Vibrating screen

Trommel

Feed hopper

Input

Coarse sand

Tank n°2

Hydrocyclone 63 µm

Screw classifier

Tank n°3

Flocculation

Filter press

Dec. n°3

Clay

Exogenous

Silt

Dec. n°2

Dec. n°1

Coarse sand

Hydrocyclone 15µm

-63µm

-15µm

-63;+15µm

Fine sand

Dec. n°3

Dec. n°1

Fine sand

Flotation

Spirals

-15µm

-63;+15µm
MINERAL PROCESSING PILOT PLANT FOR SEDIMENTS
### RESULTS

#### Material balance

<table>
<thead>
<tr>
<th>Products</th>
<th>Particle size distribution</th>
<th>$M_{\text{wet}}$ (kg)</th>
<th>Dry matter (%)</th>
<th>$M_{\text{dry}}$ (kg)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>raw</td>
<td>22.635</td>
<td>42,0</td>
<td>9.507</td>
<td>-</td>
</tr>
<tr>
<td>Exogenous</td>
<td>+3 mm</td>
<td>2.666 780</td>
<td>72,4</td>
<td>1.930 565</td>
<td>20,2 5,9</td>
</tr>
<tr>
<td>Coarse sand</td>
<td>-3 mm +250 µm</td>
<td>1.073</td>
<td>50,0</td>
<td>537 327</td>
<td>5,6 3,4</td>
</tr>
<tr>
<td>Fine sand</td>
<td>-250 µm +63 µm</td>
<td>2.993</td>
<td>75,0</td>
<td>2.245 327</td>
<td>23,5 27,8</td>
</tr>
<tr>
<td>Silt</td>
<td>-63 µm +15 µm</td>
<td>703</td>
<td>46,5</td>
<td>327</td>
<td>3,4</td>
</tr>
<tr>
<td>Clay / fine silt</td>
<td>-15 µm</td>
<td>4.570</td>
<td>57,9</td>
<td>2.648 327</td>
<td>27,8 13,4</td>
</tr>
<tr>
<td>Loss</td>
<td>-</td>
<td>3.625</td>
<td>35,4</td>
<td>1.282 327</td>
<td>13,4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>9.533</strong></td>
<td><strong>100,0</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Pollutants distribution

<table>
<thead>
<tr>
<th>Heavy metals (mg/kg dry)</th>
<th>AGW 1995</th>
<th>Input</th>
<th>Coarse sand</th>
<th>Fine sand</th>
<th>Silt</th>
<th>Clay / fine silt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hg</td>
<td>1,5</td>
<td>1,0</td>
<td>0,6</td>
<td>0,3</td>
<td>0,8</td>
<td>0,3</td>
</tr>
<tr>
<td>As</td>
<td>50</td>
<td>42,3</td>
<td>37,3</td>
<td>13,9</td>
<td>20,0</td>
<td>58,9</td>
</tr>
<tr>
<td>Cd</td>
<td>6</td>
<td>18,1</td>
<td>21,0</td>
<td>1,8</td>
<td>7,5</td>
<td>66,7</td>
</tr>
<tr>
<td>Co</td>
<td>25</td>
<td>12,7</td>
<td>10,5</td>
<td>16,2</td>
<td>11,7</td>
<td>13,5</td>
</tr>
<tr>
<td>Cr</td>
<td>200</td>
<td>203,7</td>
<td>123,3</td>
<td>81,8</td>
<td>86,8</td>
<td>378,2</td>
</tr>
<tr>
<td>Cr$_{\text{tot}}$</td>
<td>-</td>
<td>224,0</td>
<td>146,7</td>
<td>130,5</td>
<td>110,8</td>
<td>419,5</td>
</tr>
<tr>
<td>Cu</td>
<td>150</td>
<td>58,3</td>
<td>48,8</td>
<td>67,0</td>
<td>42,0</td>
<td>83,3</td>
</tr>
<tr>
<td>Ni</td>
<td>75</td>
<td>43,9</td>
<td>35,0</td>
<td>67,3</td>
<td>35,5</td>
<td>44,4</td>
</tr>
<tr>
<td>Pb</td>
<td>250</td>
<td>4.897,6</td>
<td>3.938,1</td>
<td>416,6</td>
<td>1.909,0</td>
<td>10.967,9</td>
</tr>
<tr>
<td>Zn</td>
<td>1200</td>
<td>17.923,3</td>
<td>13.254,3</td>
<td>1.752,8</td>
<td>6.585,9</td>
<td>36.273,1</td>
</tr>
</tbody>
</table>

Pollutants levels according to AGW 30/11/1995
ECONOMIC ASPECTS

Economic study of 100,000 tons/year (dry matter) plant building in Wallonia (2010) and based over the pilot plant (with the scheme given previously)

- Investment: 7,346,464€
- Operational costs: 2,878,440€ namely ± 29€/tons (without outlet costs)
- Net present value: 2,748,433€ after 10 years (taking account outlet costs)
  If: 18% valorized as sand, 40% used as non-polluted sediment and 42% landfilled
  Depreciation: 10%/y during 10 years
- Cost-effectiveness at 83,405 tons
- High sensibility:
  - Public contract remains at 82€/tons
  - Sand fraction still commercialized
  - Silts and gravels without contamination
  - Conversion yield reached and maintained
  - Valorization market maintained
  - Outlet costs remain stable
After characterization, river sediments can be used in building materials:

- Direct integration in concrete: sieving, drying and deagglomeration necessary

- Extraction of valuable materials
  - Pilot plant for sediment treatment available for testing purpose in CTP (Tournai, Belgium)
  - Based on particle size fractionation
  - Allows to concentrate pollutants in smallest fractions
  - Economically viable if the plant works efficiently and low uncertainty in raw sediment supplying and outgoing products markets

- Recommendations to authorities and market participants:
  - Coherent legislations between regions concerning highest limits and definition of hazardous components, allowed valorization ways
  - Working on citizen acceptance to demonstrate the non-hazardousness of reusing sediment
  - Create a sustainable sector for using valuable materials, namely a link between dredgers and raw materials consumer (e.g. brick producer, concrete producer,...)
• Partners:

• Agreement number: 3.5.161
• Project duration: 4 years
• Funding: 4.157.724,61 €
  including ERDF (2.078.862,28 €)
Thank you for your attention

Centre Terre et Pierre asbl
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