Targeted treatment of selected waste streams to produce added value materials

CERG - JRC - MTM - NUTEC - TANC - Environm Biology

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Circular economy – zero waste policy

- Depletion of non-renewable resources
- Growing environmental concerns
- Increasing energy demands

Production of renewable, abundant and cleaner alternatives for current natural resources

Success => holistic approach
Research: scientific and technical expertise scale, market, legal and social aspects
Targeted treatment of selected waste streams to produce added value materials

Targeted treatment
- Process
- Optimization

Selected waste streams
- Organic
- Inorganic

Added value materials
- Energy
- Chemical feedstock
- New materials (application)
Targeted treatment of selected waste streams to produce added value materials

Targeted treatment
- Process
  - Pyrolysis and activation
- Optimization

Selected waste streams
- Organic
- Inorganic

Added value materials
- Energy
- Chemical feedstock
- New materials (application)
Multidisciplinary Research

➢ Reactor Design
➢ Process Control
➢ Chemical Characterization of input and output materials
➢ Application
➢ Techno Economic Analysis
Pyrolysis: Principle

• Thermal energy breaks down chemical bonds
• No oxygen -> no burning

Char

Bio oil
Condensable

Bio gas
Not condensable

Chemical structures:

1. [Chemical structure]
2. [Chemical structure]
3. [Chemical structure]
Reactor design and process control
Pyrolysis: thermochemical conversion method in an oxygen deficient atmosphere

- Waste with high organic content
- Pure or blend

- Fast pyrolysis
- Slow pyrolysis

- Gas
  - T↑
  - Char + mineral ash
  - Non-condensable gasses
  - Condensable gasses, aerosols

- Activation
  - Activated carbon
(Flash) pyrolysis reactor

input
(Activation- &) pyrolysis reactor

Thermocouple

N2

Waste

Designed by Kenny Vanreppelen
Waste -> value : waste candidates

• Organic waste streams
  – Industrial waste (car tyres, municipal waste,...)
  – Agricultural waste (spent grain, manure, olive stones,...)

• Preferably low ash content

• Also possible contaminated waste
  – Phytoremediation for heavy metals
  – What about radioactive contamination?
Waste -> value: Bio-oil and bio gas

• Mixtures
• Energy recovery: afterburn
• Bio oil
  – Possible additive to diesel
    • Very acidic
    • Viscosity
    • ‘Aging’
    • Lower heating value
  – Extraction of specific organic molecules
Waste -> value: Biochar

• Use in agriculture as fertilizer
  – Nutrient
  – Water adsorption
  – Soil improvement
  – “Carbon sink”

• Use as stable precursor
  – For further biogas/oil production
Waste -> value: activated carbon

- Biochar + steam (850 °C)
  - Burn out
  - Micro/mesoporous structure
  - Activated carbon (AC)
- Adsorption of metals/organics
  - Surface area
  - Surface groups
Research topics

Brewery waste...

Industrial waste...

Pig manure...
From manure to...

- Biochar for soil amendments
  - Concentration of N and P ➔ Alternative for artificial fertilisers
  - Plant tests are positive
  - But... Environmental norms for Zn and Cu often surpassed

- Biochar as P source?
  - P recuperation from biochar
    - PASH-process

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From industrial wastes to...

- Green roof substrate
  - Baekeland project with Act&Sorb
- Industrial waste streams to biochar
  - Microwave or conventional pyrolysis
- Characterisation of produced biochars
  - WHC
  - NCHS-O analysis
  - Leaching of nutrients and heavy metals
  - ...

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From industrial wastes to...

• a part of commercially available green roof substrate
  – (To replace e.g. Expanded clay or lava stone)

• What do we expect?
  – Diversification of plants on green roofs
  – Less maintenance
  – Less nutrient leaching
  – Less plant deaths
  – Environmentally and energetically beneficial production

(Vijayaraghavan, 2016)  
Source: http://ecoworks.be/
AC from Brewer’s Spent Grain

Coal / Biomass

Surface area

AC

Steam activation

Heat Pressure Radiation

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Why Brewer’s spent grain?

• Nitrogen content -> specific adsorption abilities
• Specific adaptations for specific adsorptions
• Economically viable

• Adsorption of Phenol – chromium VI – Cesium – heavy metals

Using Ce-134 @ JRC-GEEL
Targeted treatment of selected waste streams to produce added value materials

- Targeted treatment
  - Process
  - Alkali activation
  - Optimization

- Selected waste streams
  - Organic
  - Inorganic (NORM)

- Added value materials
  - Energy
  - Chemical feedstock
  - New materials (application)
NORM in AAMs

Fly ash  Red mud  Blast furnace slag  Phosphogypsum
Production process: Alkali activated materials (AAM)

Solid aluminosilicate source + Alkali silicate/hydroxide activating solution

NORM precursor  
Dissolution  
Oligomerization  
Polymerization  
Activator

Synthesis parameters

Aluminosilicate polymer

Adapted from Deventer (2007)

AAM

Adapted from Rowles (2008)
Ongoing PhD research

NORMs

Alkali activation

Use in publicly accessible environment

• γ dose evaluation

• Radon exhalation

• Leaching of radionuclides

Use in nuclear safety applications

• Leaching of radionuclides

• Durability prediction in γ radiation field

Tom Croymans

Katrijn Gijbels

Niels Vandevenne

Bram Mast
1. Reuse of NORM in AAMs

- Blast furnace slag
- Phosphogypsum

Production @MTM KULeuven
1. Reuse of NORM in AAMs

<table>
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<tr>
<th>Type of Radiation</th>
<th>Nuclide</th>
<th>Half-life</th>
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<tr>
<td>$\alpha$</td>
<td>Uranium-238</td>
<td>$4.5 \times 10^{9}$ years</td>
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<tr>
<td>$\beta$</td>
<td>Thorium-234</td>
<td>24.5 days</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Protactinium-234</td>
<td>1.14 minutes</td>
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<tr>
<td>$\alpha$</td>
<td>Uranium-234</td>
<td>$4.23 \times 10^{5}$ years</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Thorium-230</td>
<td>$8.3 \times 10^{4}$ years</td>
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<tr>
<td>$\alpha$</td>
<td>Radium-226</td>
<td>1590 years</td>
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<tr>
<td>$\alpha$</td>
<td>Radon-222</td>
<td>3.825 days</td>
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<tr>
<td>$\alpha$</td>
<td>Polonium-218</td>
<td>3.05 minutes</td>
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<tr>
<td>$\beta$</td>
<td>Lead-214</td>
<td>26.8 minutes</td>
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<tr>
<td>$\beta$</td>
<td>Bismuth-214</td>
<td>19.7 minutes</td>
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<tr>
<td>$\beta$</td>
<td>Polonium-214</td>
<td>$1.5 \times 10^{-4}$ seconds</td>
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<tr>
<td>$\beta$</td>
<td>Lead-210</td>
<td>22 years</td>
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<td>$\beta$</td>
<td>Bismuth-210</td>
<td>5 days</td>
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<td>$\beta$</td>
<td>Polonium-210</td>
<td>140 days</td>
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<tr>
<td>$\alpha$</td>
<td>Lead-206</td>
<td>stable</td>
</tr>
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Tank & Column Leaching tests

Radon exhalation tests
2. Leaching of Cs & Sr

                   | EN/TS 15863:2015 (*Dynamic monolithic leaching test with periodic leachate renewal*) |
|--------------------|----------------------------------------------------------------------------------------------------------------|
| Sample             | 25 x 25 x 20 mm³  
                   | Fixed in centre of leaching agent by PP-support |
| Leaching agent     | 400 ml MQ |
| Container          | PP 500-ml-bottle (minimize air content in container) |
| Leaching           | 90 °C; 28 d  
                   | Aliquots at 1 h, 24 h, 7 d, 28 d  
                   | ICP-OES & ICP-MS |
3. Effects of ionizing radiation on AAMs

A combined approach:
1) Experimentally
2) Computationally

Water
Radiolysis $\rightarrow$ H$_2$, H$_2$O$_2$, ... $\rightarrow$ reaction of H$_2$O$_2$ with paste
Hydration of cement
Heating $\rightarrow$ drying $\rightarrow$ shrinkage

Solids
Decomposition of siliceous aggregates
Dislocation of atoms $\rightarrow$ amorphization $\rightarrow$ expansion

RESULT:
Increase of total pore volume
Cracking
Loss of strength

GOAL: PREDICT THE LONG TERM EFFECT
3. Effects of ionizing radiation on AAMs

A combined approach:
1) Experimentally

- $^{60}$Co
- Low dose rate (7 Gy/h)
- Up to 50 kGy

- $^{137}$Cs
- High dose rate (2 kGy/h)
- Up to 5 MGy

2) Computationally

- Generation of microstructure
  RVE: representative volume element
- Mesh + Periodic Boundary Conditions
- Determination of displacements/strain related to irradiation effects
- Stress/strain distribution
- Homogenization
- Effective Young’s Modulus
4. Study of NORs in fayalite slag, improvement of dose model

Picture of measurement set up in EGSnrc
Activity concentration index – Safe to use? 1 month production screening
5. Experiments @ NuTec

- Radon Exhalation
- Column Leaching test
- Tank Leaching test
- Irradiation experiments
- Gamma-spectrometry
- Material pretreatment (grinding – sieving – drying)
- ...


Research is open for new ideas and new partnerships!

Thank you for your attention!

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