Targeted treatment of selected waste streams to produce added value materials

S. Schreurs[1], R. Carleer[2], J. Yperman[2], Y. Pontikes[3], M. Hult[4], K. Vanreppelen[1,2], J. Maggen[2], S. Vanderheyden[2], T. Croymans[1], N. Vandevenne[1], W. Schroeyers[1]

[1]Research Group of Nuclear Technology, CMK, Hasselt University, Diepenbeek, Belgium

[2]Research Group of Analytical and Applied Chemistry, CMK, Hasselt University, Diepenbeek, Belgium

[3]Research Group of MTM, KULeuven University, Heverlee, Belgium

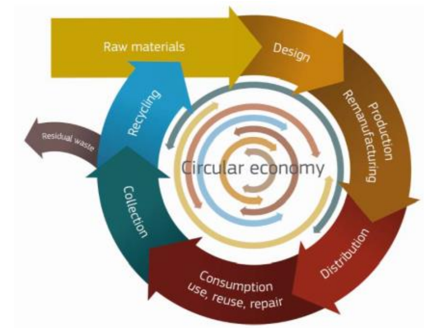
[4]European Commission, Joint Research Centre, Institute for Reference Materials and Measurements, Geel, Belgium

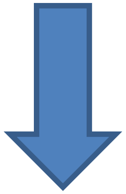
universiteit hasselt

KNOWLEDGE IN ACTION

Circular economy – zero waste policy

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





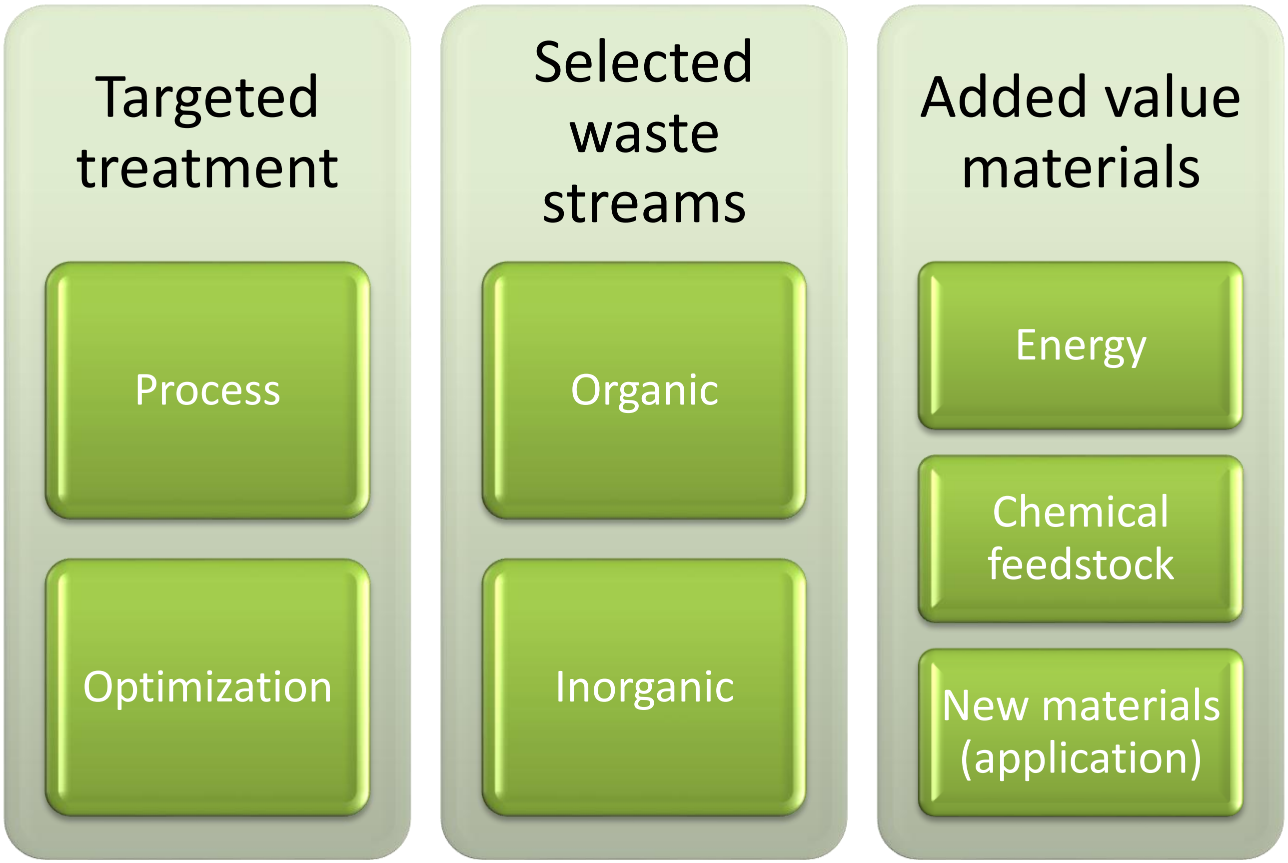
Production of renewable, abundant and cleaner alternatives for current natural resources

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 of selected waste streams to produce added value materials

Targeted treatment

- **Process**
  - **Pyrolysis and activation**
- Optimization

Selected waste streams

- **Organic**
- Inorganic

Added value materials

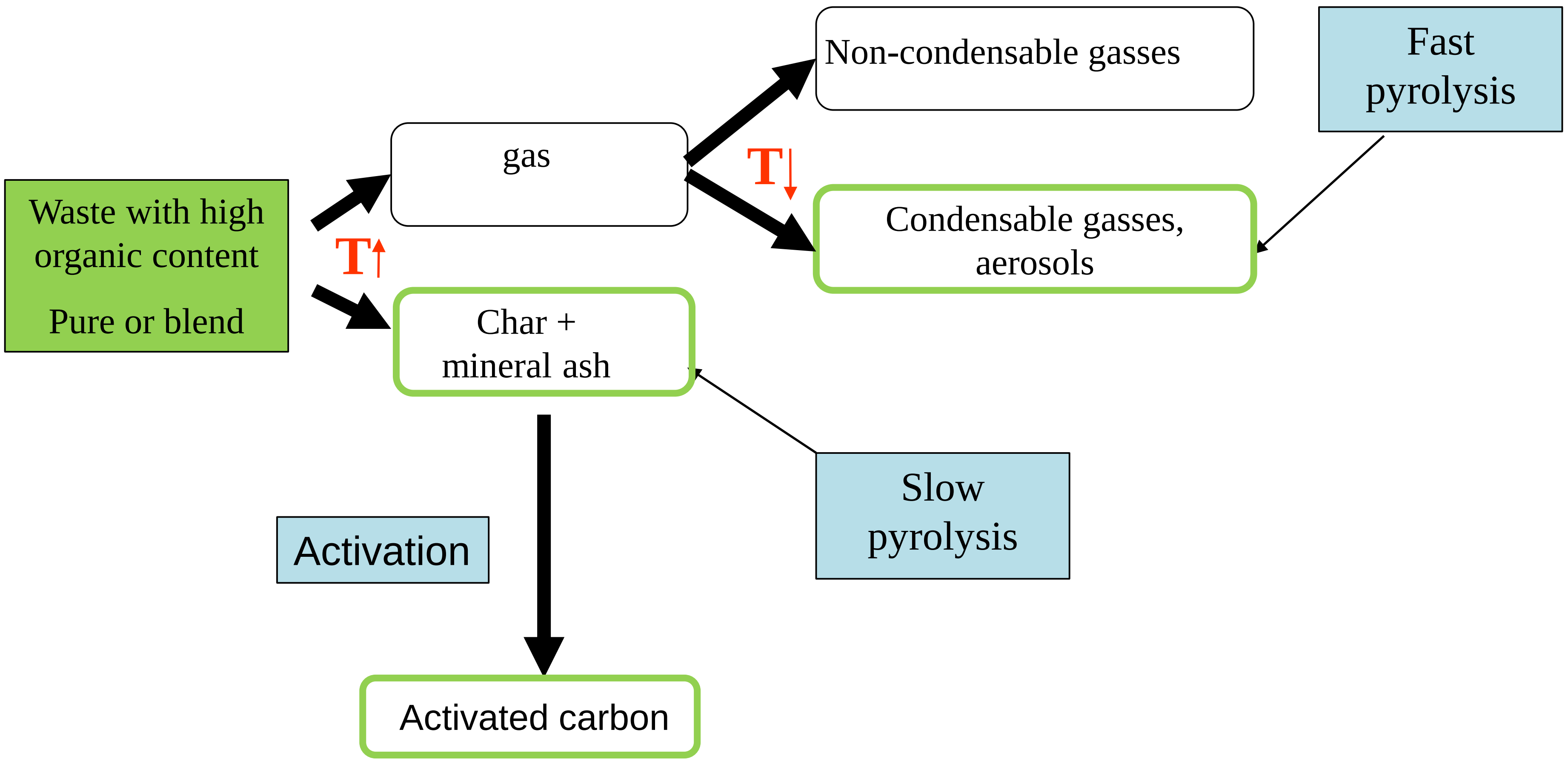
- Energy
- Chemical feedstock
- New materials (application)

Multidisciplinary Research

- Reactor Design
- Process Control
- Chemical Characterization of input and output materials
- Application
- Techno Economic Analysis

Reactor design and process control

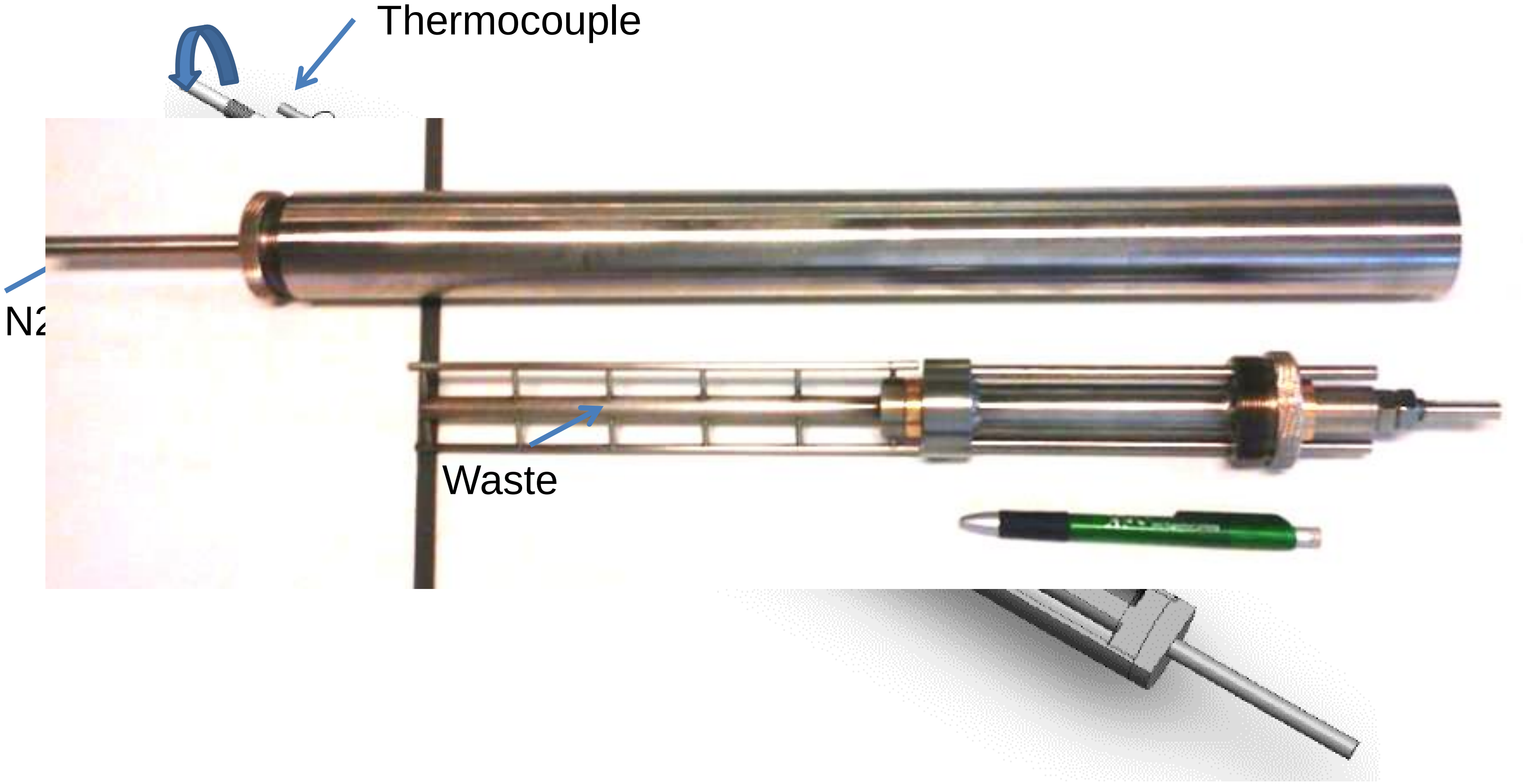
Pyrolysis : thermochemical conversion method in an oxygen deficient atmosphere



(Flash) pyrolysis reactor

(Activation- &) pyrolysis reactor

Designed by Kenny Vanreppelen



universiteit hasselt KNOWLEDGE IN ACTION

Characterization input waste stream

- Energy
  - Bom calorimetry
  - Theoretical calculation (eq of Channiwala f.i.)

- Thermal behavior
  - Thermogravimetric analysis (TGA)
  - Pyrolyse-GC/MS

- Composition
  - FTIR
  - Element Analysis (CHNS-O)
  - Component Analysis (cellulose, hemi-cellulose, lignine, fats,…)
  - Water
  - Contamination (heavy metals)
  - ….

Characterization of Oil, Char and AC

- Composition
  - GC-MS and LC-MS
  - FTIR
  - Element analysis (CHNS-O)
  - Point of zero charge
  - Boehm titration
  - Contamination (e.g. heavy metals)
- Surface
  - SEM (porous network)
  - XPS (CNO functionalities at surface)
- Porosity
  - N_2 adsorption

Applications

- Adsorption (AC)
  - Adsorption isotherms studies
  - Adsorption kinetic studies
    - Organic polluents: phenol, ibuprofen, …
    - Inorganic polluents: chroom-VI, radiocaesium
    - Influence of pH, temperature, ionic strength

- Biological parameters (Char)
  - Growth of plants
  - Soil characteristics (nutrients, water,…)

Current PhD research

- Techno Economic Analysis : Production of special AC from N-rich input waste materials using pyrolysis and activation
- Adsorption of Cs-134 on different types of AC
- From Pig manure to biochar…

Towards a circular economy – Development, characterisation, techno-economic analysis and applications of activated carbons from industrial rest streams

K. Vanreppelen, S. Schreurs, W. Schroeyers, J. Yperman, R. Carleer

Kenny.vanreppelen@uhasselt.be

universiteit hasselt
KNOWLEDGE IN ACTION

From N-rich waste to AC

Activated carbons → large number of applications

- →water treatment
- →chemical and pharmaceutical processing
- →air and gas purification
- →…

Average growth 5.2%/year

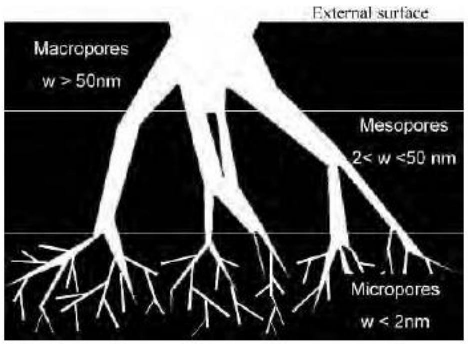
1.2 Mt/Year by 2012

Standard AC 1,6 – 3,0 kEUR/t

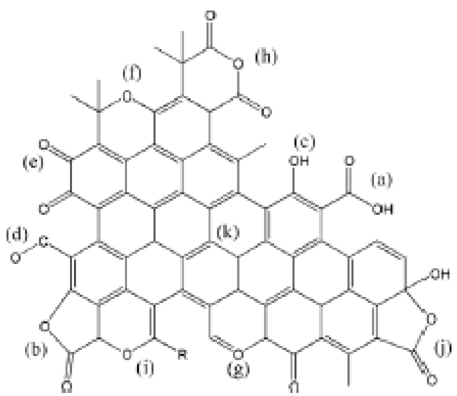
Specialty AC 3,3 – 10,0 kEUR/t

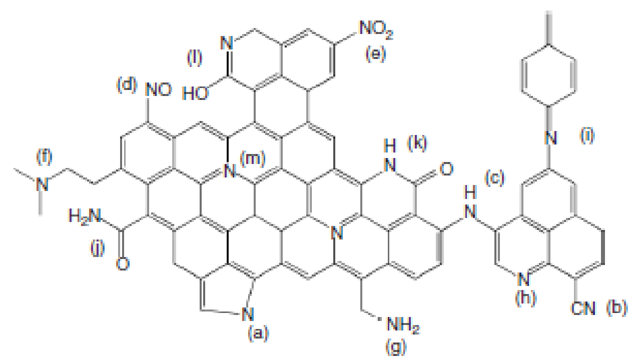
From N-rich waste to AC

Activated carbons → Normally low N (~0.5%)



→ N **key parameter** for adsorptive properties, catalytical activity and catalyst supports





N introduction → (post-)treatment with reagents

→ **Raw material : e.g. PB/MF**

Techno-Economic model

Proces Design → **Economic Model**
- Total capital investment
- Total Expenditure
- Total Revenue

→ **Net Present Value**
- Minimal selling price

$$NPV = \sum_{n=1}^{T} \frac{CF_n}{(1+i)^n} - I_0$$

With:

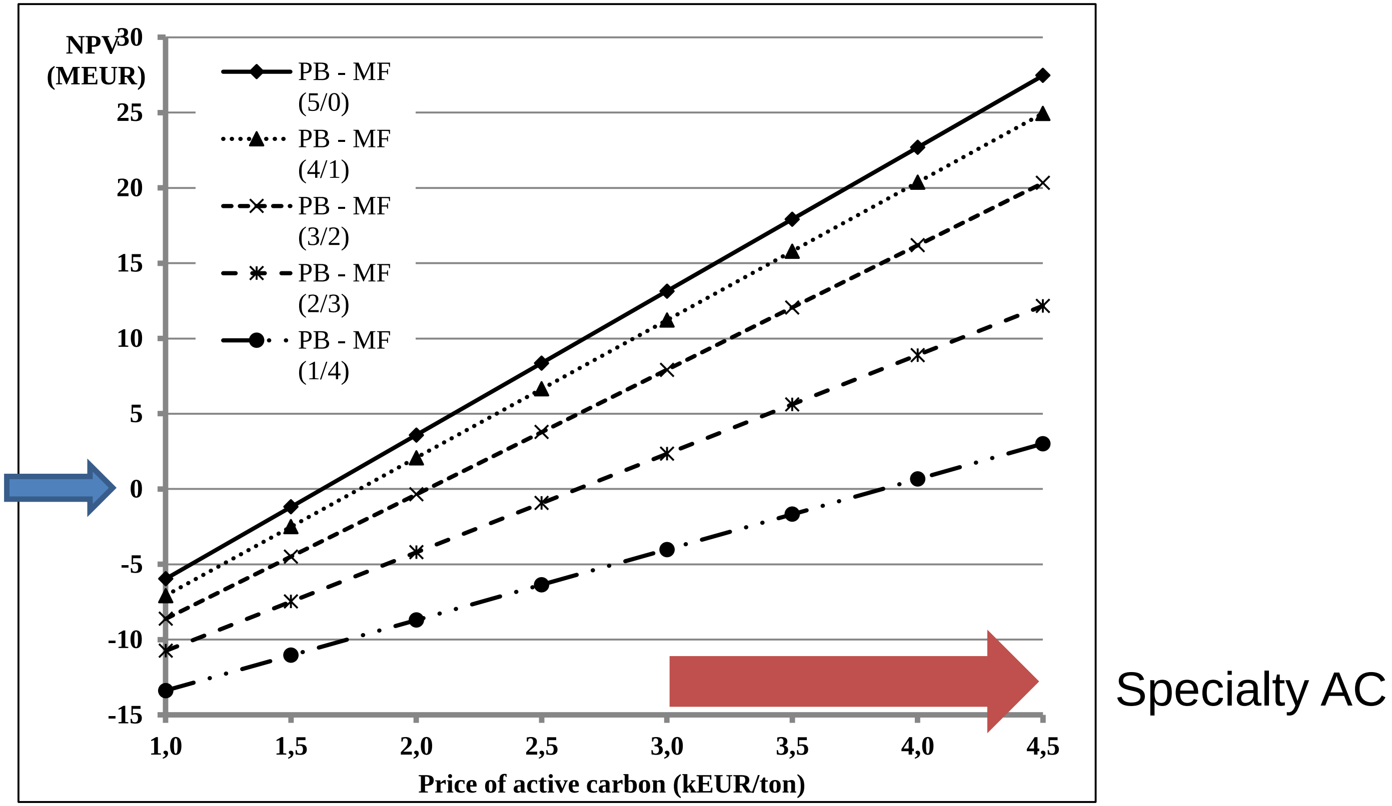
- CF_n = cash flows generated in year n
- I_0 = initial total capital investment (s
- T = the life span of the investment;
- i = discount rate.

Based on a rather pessimistic scenario:

- Low average operating time (7 000 h)
- First plant cost (pyrolysis/activation reactor)
- No subsidies
- Zero gate fee of MF

Based on : Vanreppelen, K., Kuppens, T., Thewys, T., Carleer, R., Yperman, J., and Schreurs, S., *Activated carbon from co-pyrolysis of particle board and melamine (urea) formaldehyde resin: A techno-economic evaluation* Chem Eng J, Vol. 172, No. 2-3: p. 835-846, 2011

- 1 th^{-1} production facility



- Impact of N-content (quality), gate fee (MF), production scale
- PhD defence : spring 2016

Adsorption of Cs-134 on different types of activated carbon

Sara R. H. Vanderheyden, R. Van Ammel, K. Sobiech-Matura, K. Vanreppelen, S. Schreurs, W. Schroeyers, J. Yperman, R. Carleer

sara.vanderheyden@uhasselt.be

European Commission

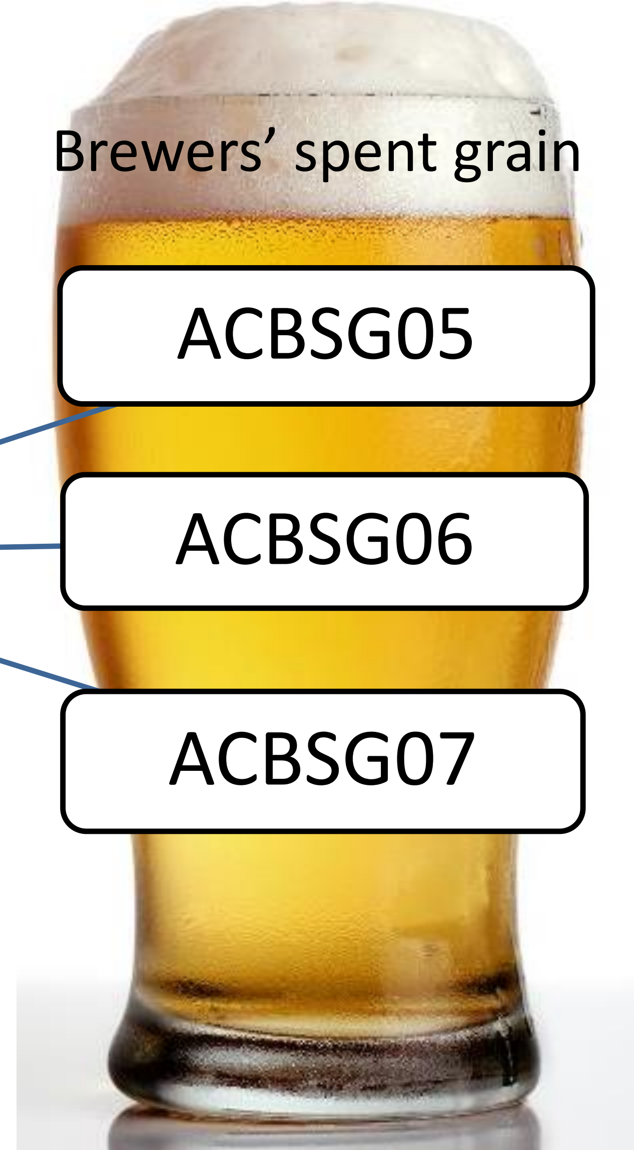
universiteit hasselt
KNOWLEDGE IN ACTION

Activated carbon (AC) from Brewers Spent Grain

Norit GAC 1240

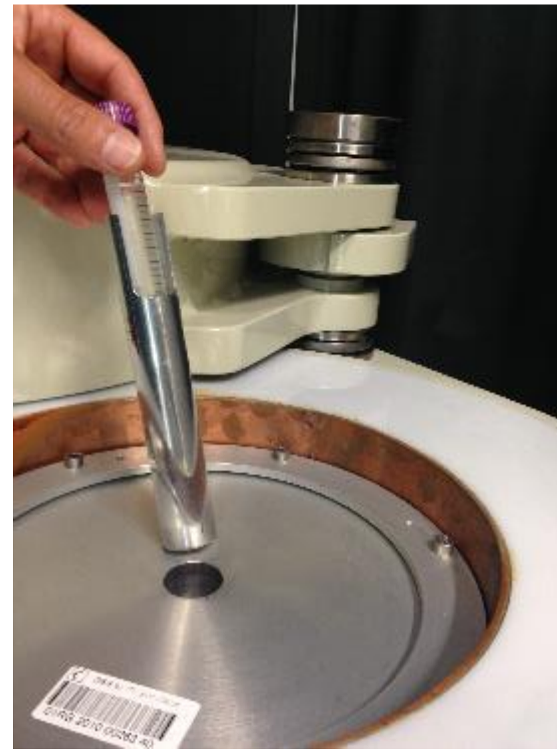
Filtrasorb F400

Commercial

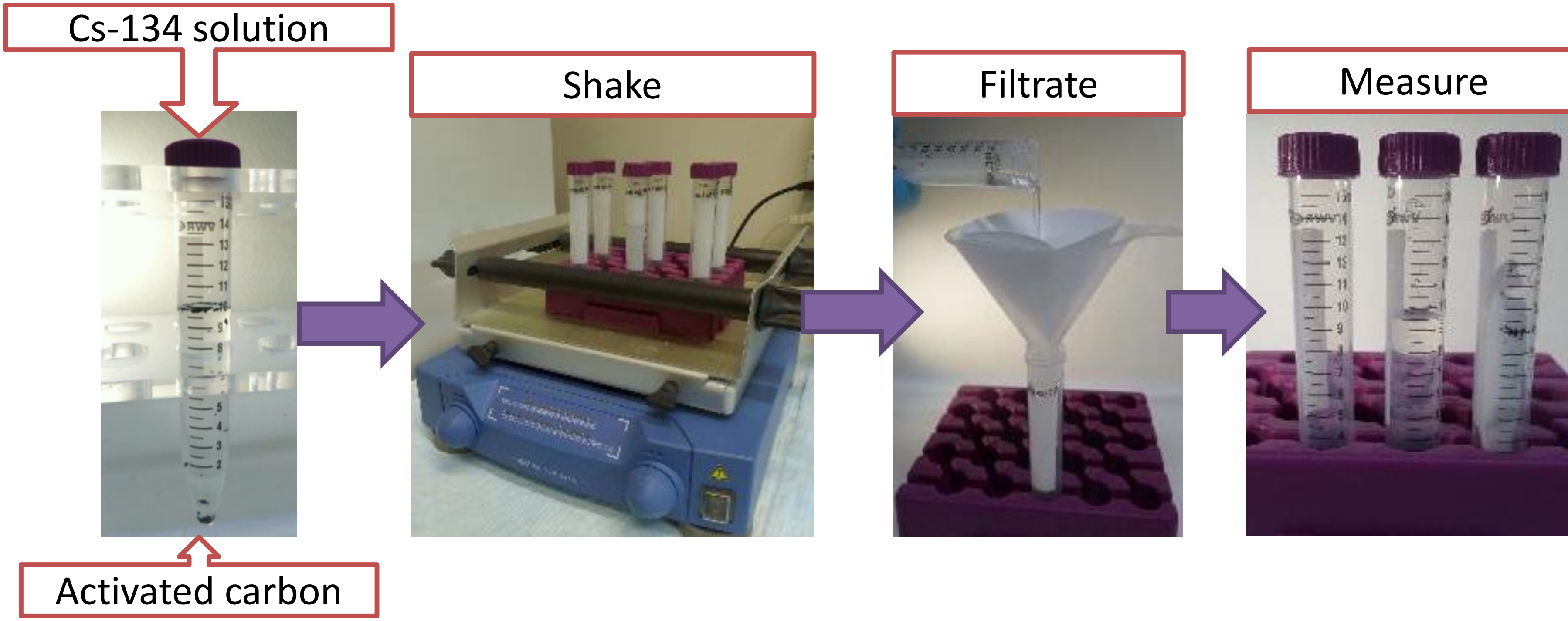


Experimental set-up at IRMM

- Tracer: Cs-134
  - Cs standard (1000 mg/l)
  - Cs-133 + n -> Cs-134 (SCK.CEN)
- Diluted approximately 1:1000
  - ± 60 Bq/g = ± 1.18 mg Cs/l
- pH adjustment using ammonia
- NaI(Tl) well-type detector

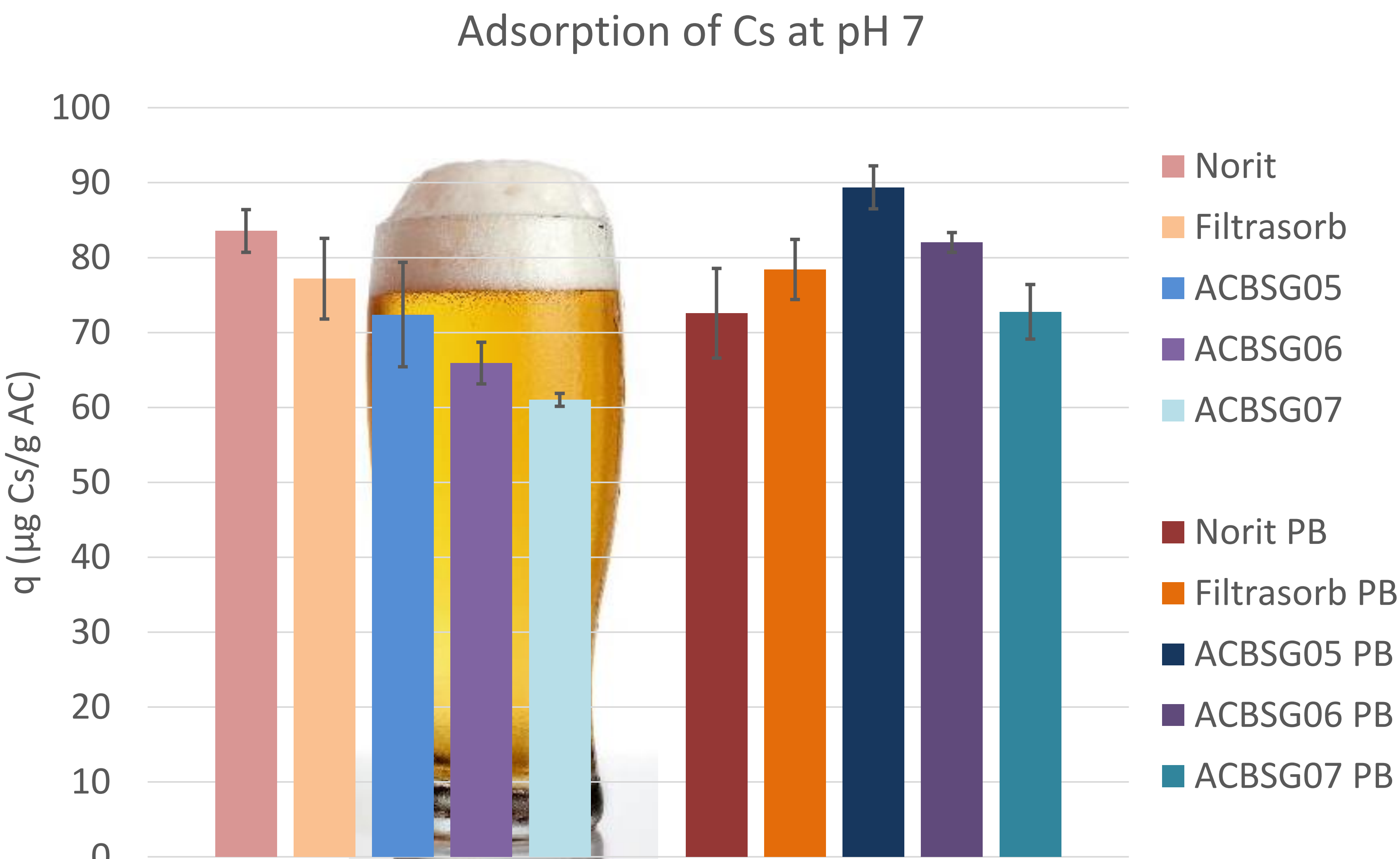


Batch adsorption experiment



- Influence of:
  - pH
  - Type of AC
  - Pretreatment : Prussian Blue adsorption

Batch adsorption experiment



Future Research

- Optimize pretreatments => quality
- Granular AC
- Regeneration of AC
- Simulate actual conditions

From pig manure to biochar…

J. Maggen, S. Schreurs, W. Schroeyers, J. Yperman, R. Carleer

Jens.maggen@uhasselt.be

universiteit hasselt
KNOWLEDGE IN ACTION

From pig manure to biochar

- Slow pyrolysis of pig manure => char with high ash content
  - less suitable for AC production
- Biochar : (slow release) fertilizers
  - high concentrations of N, K and P
  - Too high concentrations of Zn and Cu
- Biochar : Soil amendment improving soil quality and crop productivity.
  - Correct blending of biochar in soils has a positive effect on the growth of plants
  - mobility of heavy metal ions is influenced (less leachable)

Biochar in soil

0wt%

2wt%

5wt%

10wt%

Future research

- Extraction of P from biochar
- Valorisation of bio-oil : Fuel
- Production of AC (after pretreatment of biochar)

- Fruit harvest and nature management

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)

Multidisciplinary Research

Large collaboration between European experts in PhD research

- Process Control
  - UHasselt/KULeuven (MTM)
- Characterization of input and output materials
  - UHasselt/KULeuven/IRMM
- Application
  - UHasselt/IRMM/COST NORM4building network

Main objective ‘NORM4BUILDING’

Stimulate the
reuse of NORM residues in new tailor-made sustainable building materials
(focus on concrete, cement and ceramics)

while
considering exposure to external gamma radiation and the resulting indoor air quality.

Current status COST Network; 110 experts 28 countries
Uhasselt chair and grant holder.
Project leader Prof dr. W. Schroeyers

NORM processing industries

Ore: '**N**aturally **O**ccurring **R**adioactive **M**aterials'

Processing

Residues with enhanced concentrations of NORM

Fly ash

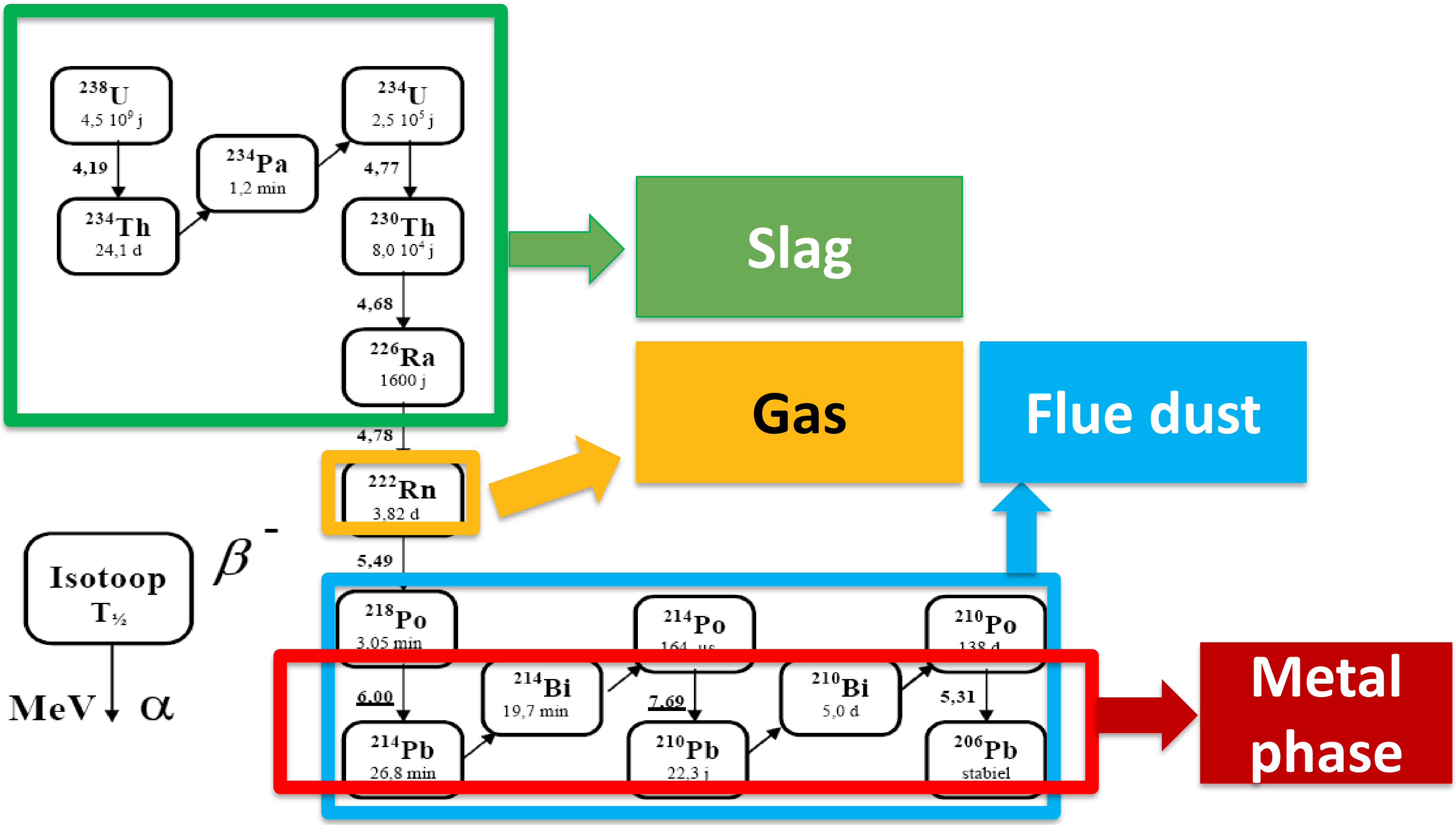
Red mud

Non-ferrous slag

Produced in millions of tons per year
Some are stored in large landfills waiting for feasible reuse options

universiteit hasselt
KNOWLEDGE IN ACTION

Distribution of natural radionuclides in non ferro metal industrial process



Production process : Alkali activated materials (AAM)

Solid aluminosilicate source + Alkali silicate/hydroxide activating solution

NORM precursor

Dissolution

Oligomerization

Polymerization

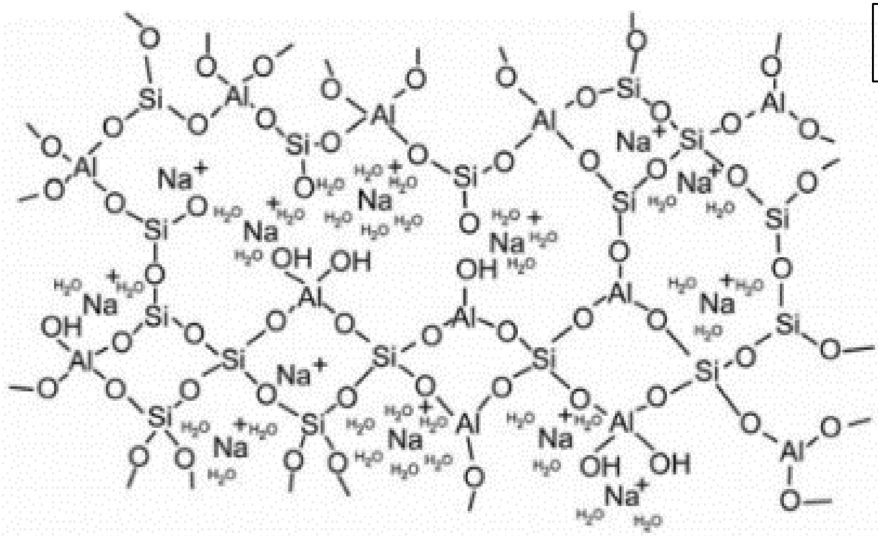
Activator

Synthesis parameters

Aluminosilicate polymer

Adapted from Deventer (2007)

AAM



Adapted from Rowles (2008)

Characterization of NORM precursor and the final AAM

- Chemical Composition
  - XRF
- Radiological
  - HPGe spectrometry
- Physical characterization
  - XRD
  - Grain size distribution
  - Density
- Application
  - Compressive strength test
  - Leaching
  - Radiological characterization
    - HPGe spectrometry
    - ACI (BSS for building materials)
    - Radon

Current PhD research

- **Using NORM precursors to develop high added value materials**
  - **new construction materials for niche markets**
  - **new conditioning matrices for RA and other types of waste**

Similar materials, different uses

Construction	Waste immobilisation
▪ High strength ▪ Fast strength development ▪ Control of flow properties with organic admixtures ▪ Durability for 50-200 years service life ▪ Passivation of mild steel ▪ Low cost	▪ Durability for 100,000 – 1,000,000 years service life ▪ Binding of radionuclides ▪ Low heat evolution ▪ Dimensional stability ▪ Controlled corrosion of reactive metals ▪ Stability under irradiation

Research is open for new ideas and new partnerships!

Thank you for your attention!