Drying characteristics, Thermal properties and Inorganic Nutrient analysis in Faecal Sludge

B. MAKUNUNIKA, S. SEPTIEN, A. SINGH, K. VELKUSHANOVA, C.A. BUCKLEY

Pollution Research Group, University of KwaZulu-Natal, Howard College, Durban 4041, South Africa

Planning

1 – Introduction

2 – Material and Methods

3 – Results and Discussion

4 – Conclusions

Reinvent the Toilet Challenge

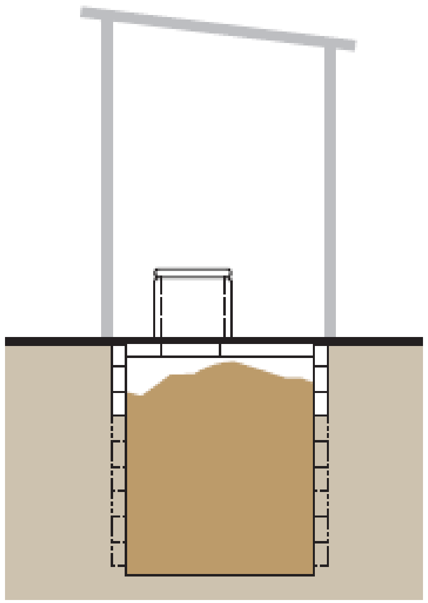
Challenge from the Bill and Melinda Gates Foundation

“ To bring sustainable sanitation to the 2.5 billion people worldwide who don’t have access to safe, affordable sanitation”

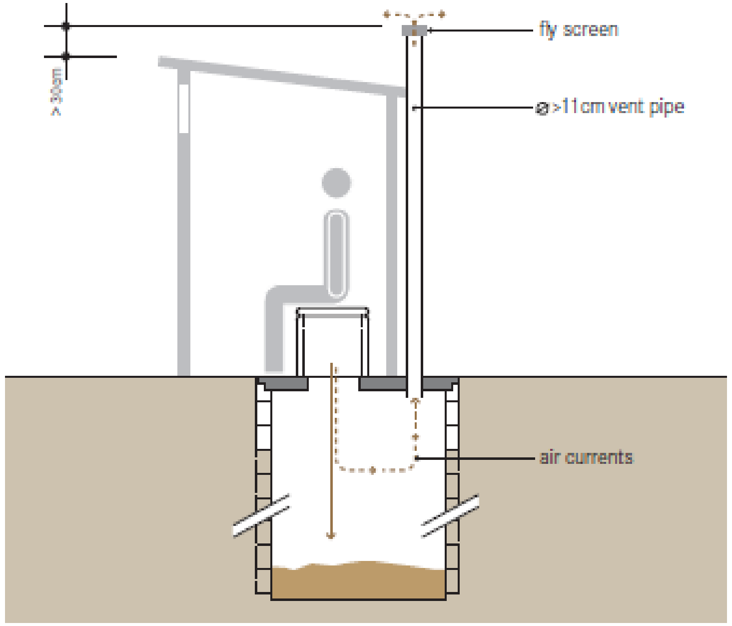
- Pathogen removal and recovery of valuable resources from waste
- No connection to the water, sewage and electricity grid
- Cost < 0.05 US$ / user / day

Pit latrines

Most widespread toilet system in developing countries



Single Pit latrine



Ventilated Improved Pit (VIP) latrine

~ 30,000 VIP Latrines

ETHEKWINI MUNICIPALITY

Source: Tilley et al. (2008), Compendium of Sanitation Systems and Technologies, Dubendorf: Swiss Federal Institute of Aquatic Science and Technology (Eawag)

Faecal sludge disposal

At the end of the cycle use of pit latrines, the disposal of faecal sludge can be problematic, particularly in dense populated areas.

Faecal sludge drying

Volume and mass reduction

Transport cost decrease

Pasteurization

Low moisture content + Organic content

Biofuel

Agriculture use

Objectives of the present work

- ❑ Kinetic study of faecal sludge convective drying for unit design
- ❑ Evaluation of the agriculture potential of dried faecal sludge
- ❑ Evaluation of dried faecal sludge as a biofuel

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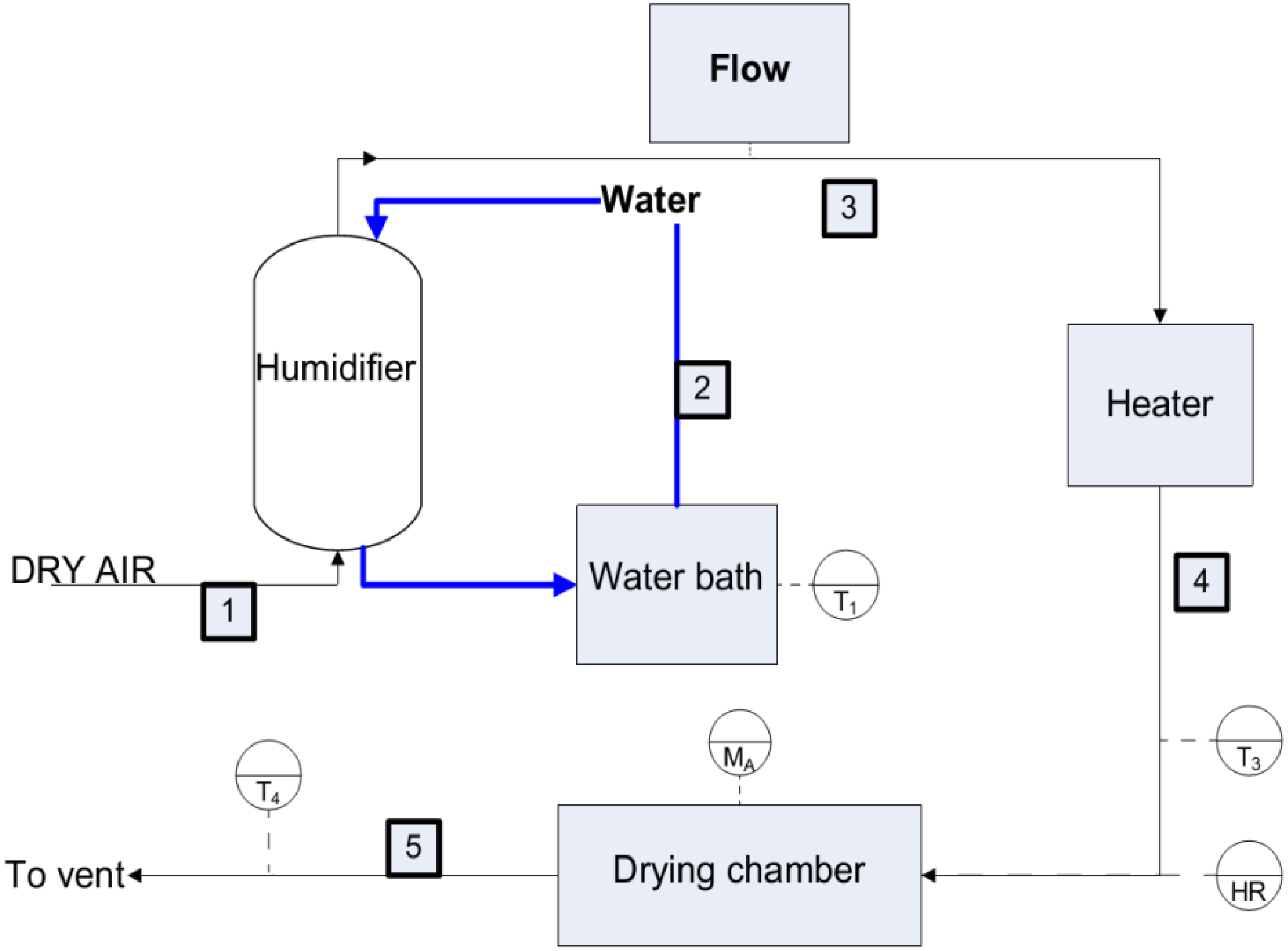
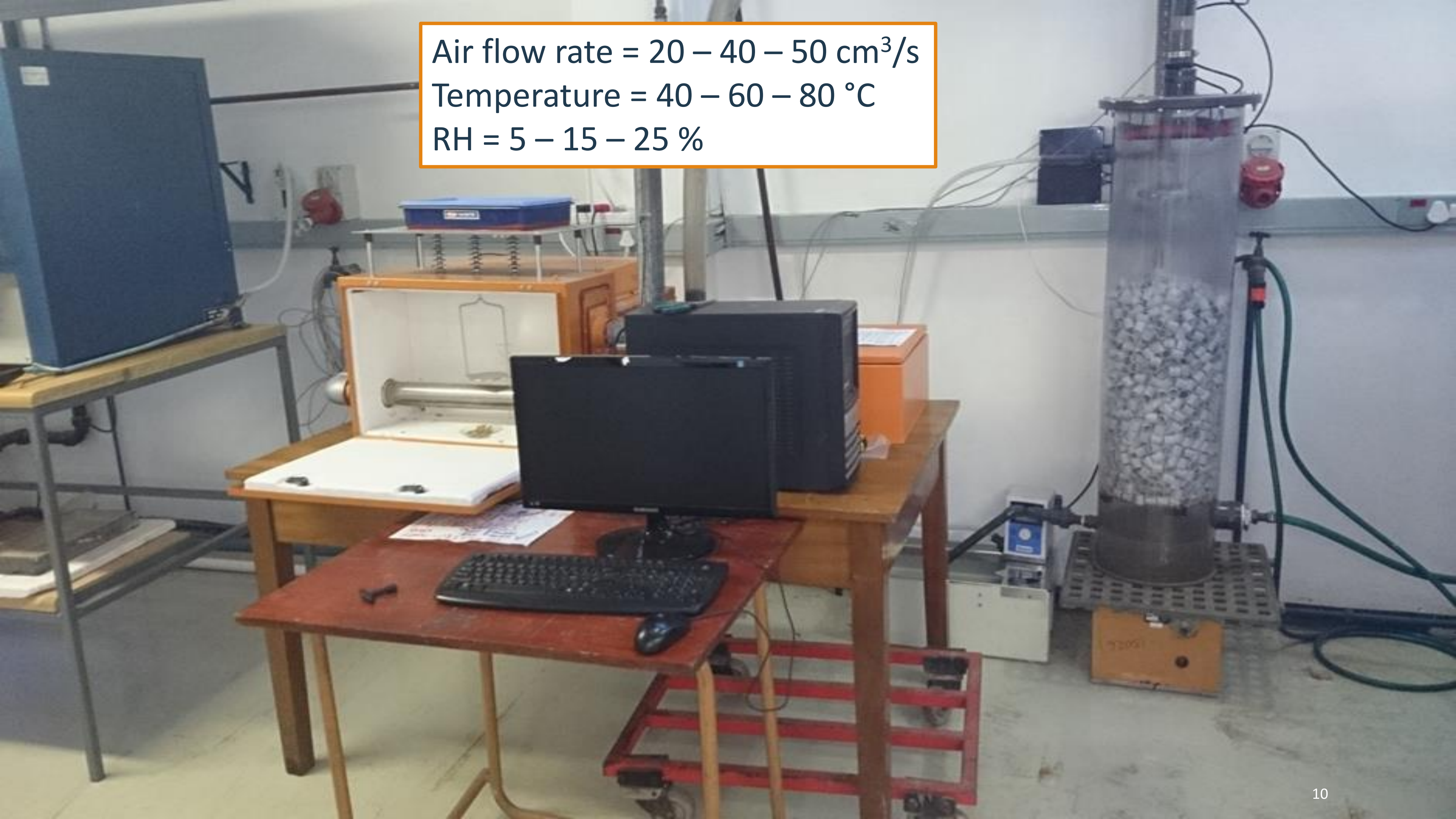
Convective drying rig



Air flow rate = 20 – 40 – 50 cm^3/s
Temperature = 40 – 60 – 80 °C
RH = 5 – 15 – 25 %



Faecal sludge

Faecal sludge sampled during the emptying of VIP latrines in peri-urban settlements within the eThekwini municipality

Preparation of the sample

Feacal sludge spread on the crucible as a flat thin layer (7 mm thickness)

80 % of moisture content on wet basis

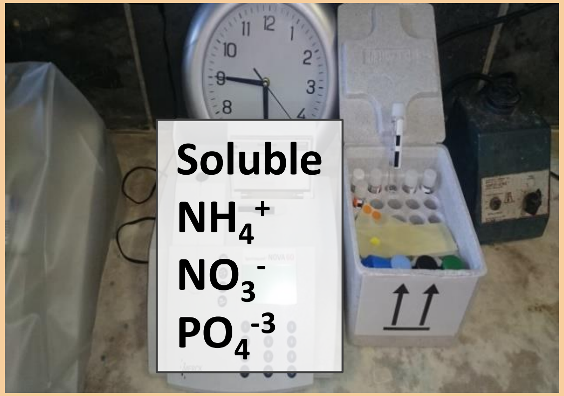
Hand held extruder

Pellets

Diameter
8 mm
10 mm
14 mm

Characterization of the dried pellets

Chemical analysis

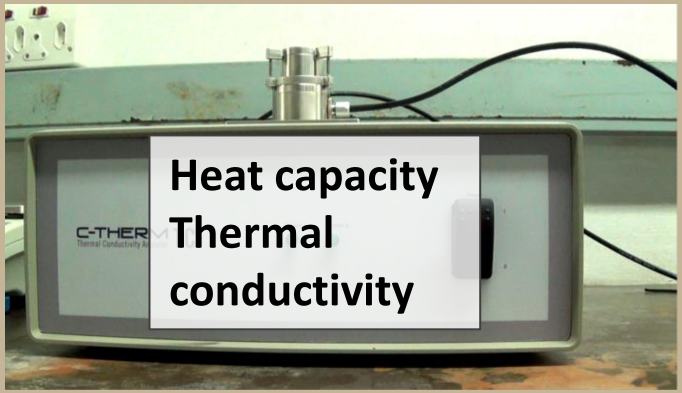


Spectrophotometer

Spectroscopy

Thermal analysis

Calorimeter bomb



Tci analyser

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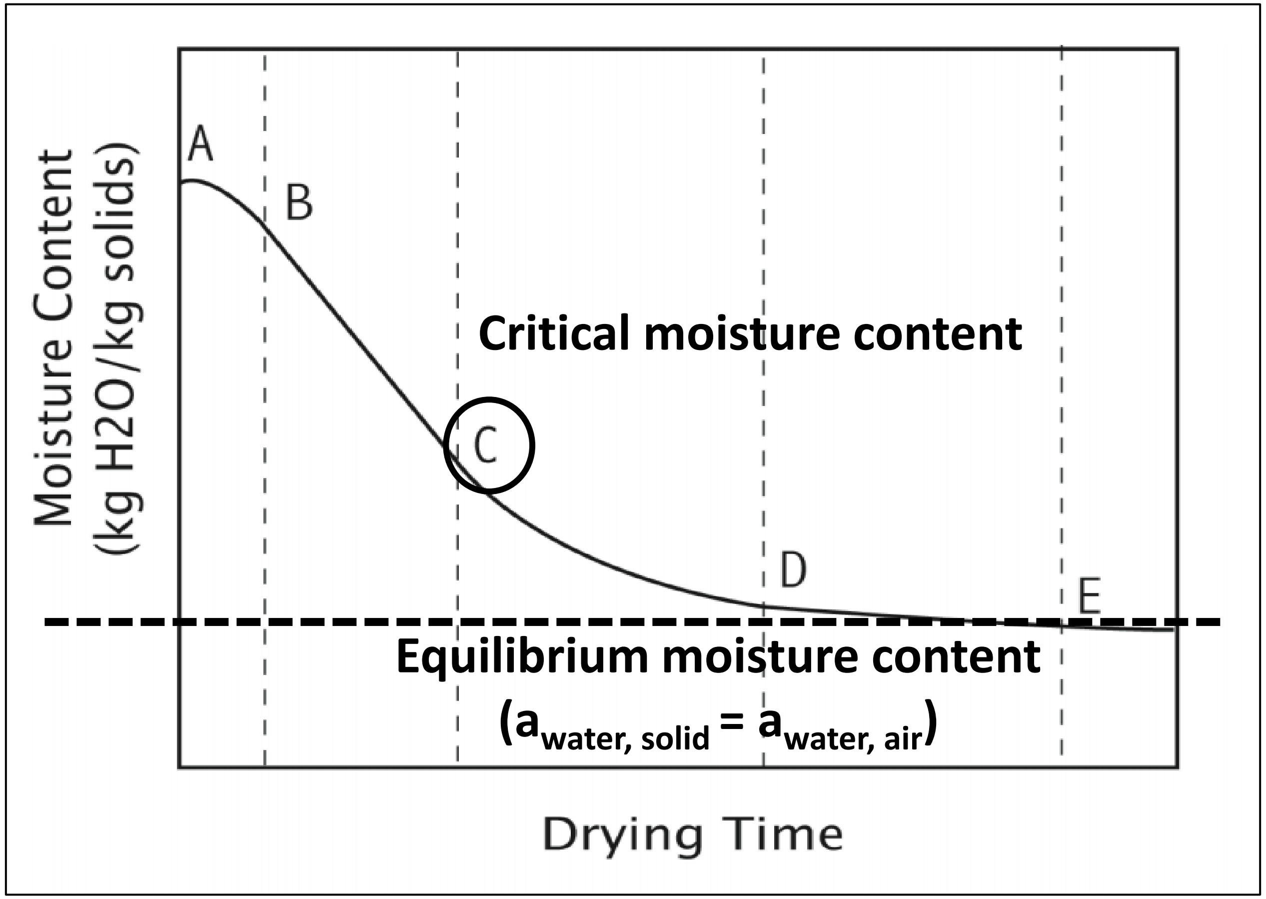
Theory of drying



Source: J.F. Richardson, J.H. Harker, J.R. Backhurst (2002). Coulson and Richardson's chemical engineering: Particle technology and separation processes.

BC → Constant rate period

Drying on saturated surface

Controlled by external transfer

CD → First falling period

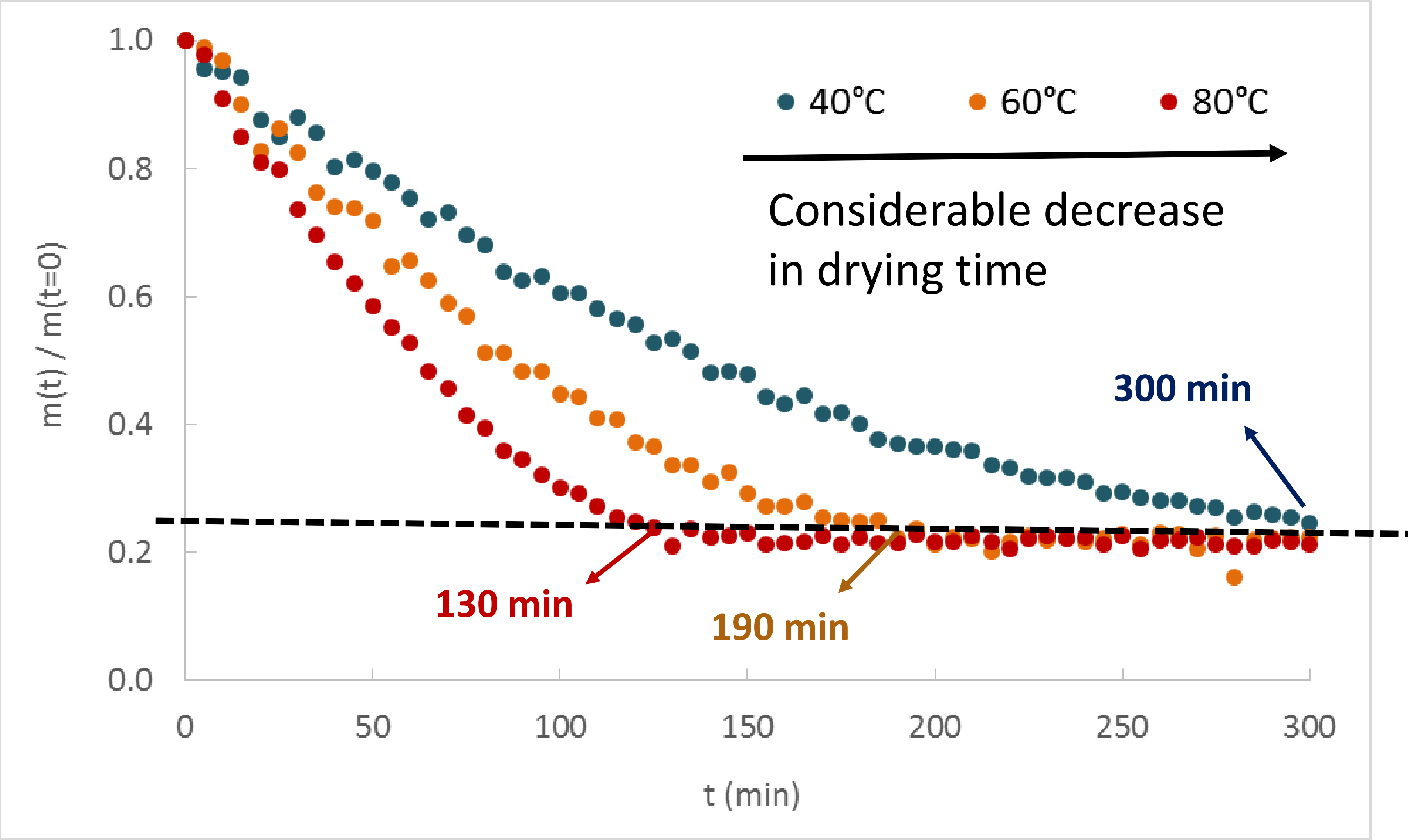
Drying on unsaturated surface

DE → Second falling period

Drying within particle

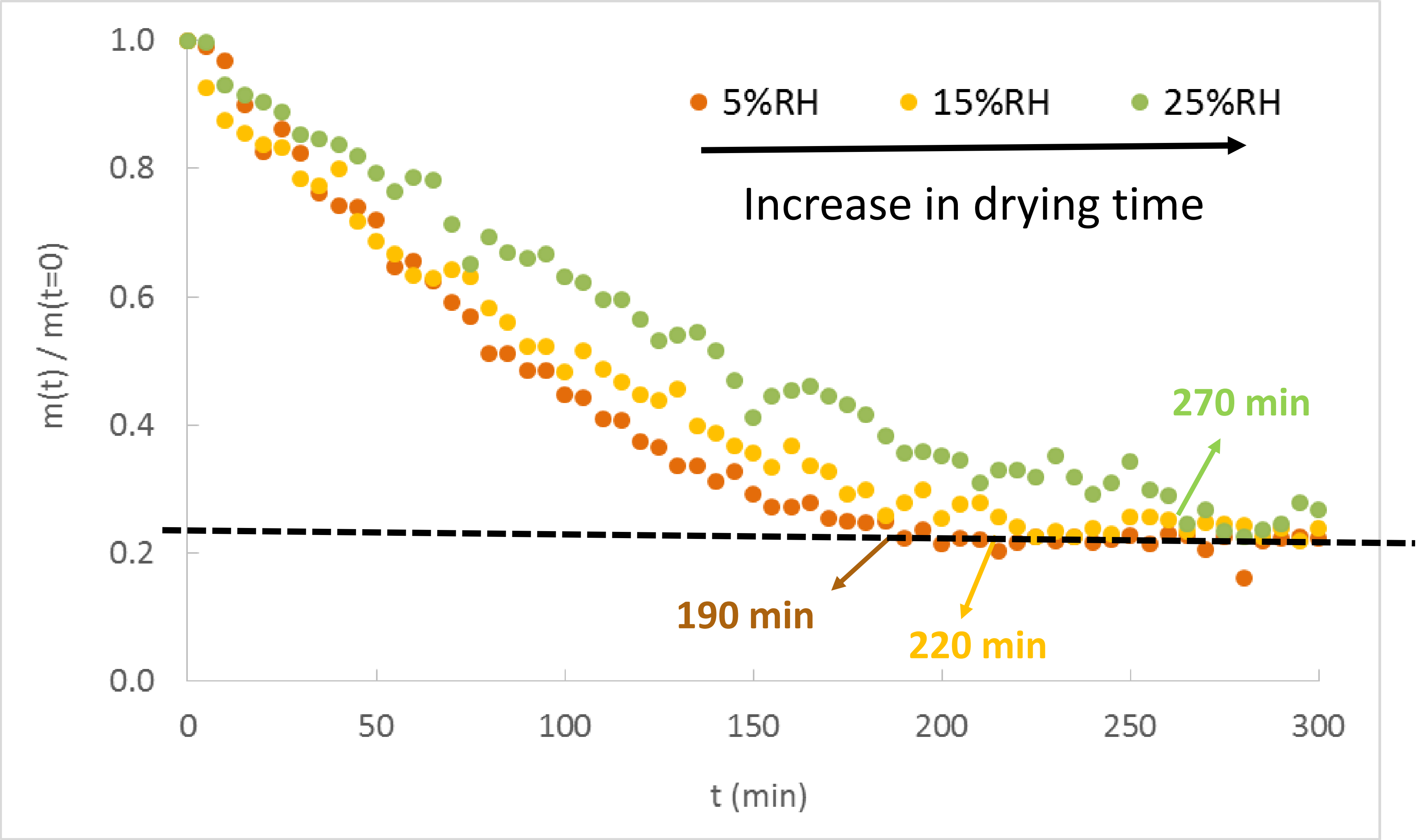
Controlled by internal transfer

Effect of temperature



Flow rate = 40 cm³/s
RH = 5 %
Flat thin layer

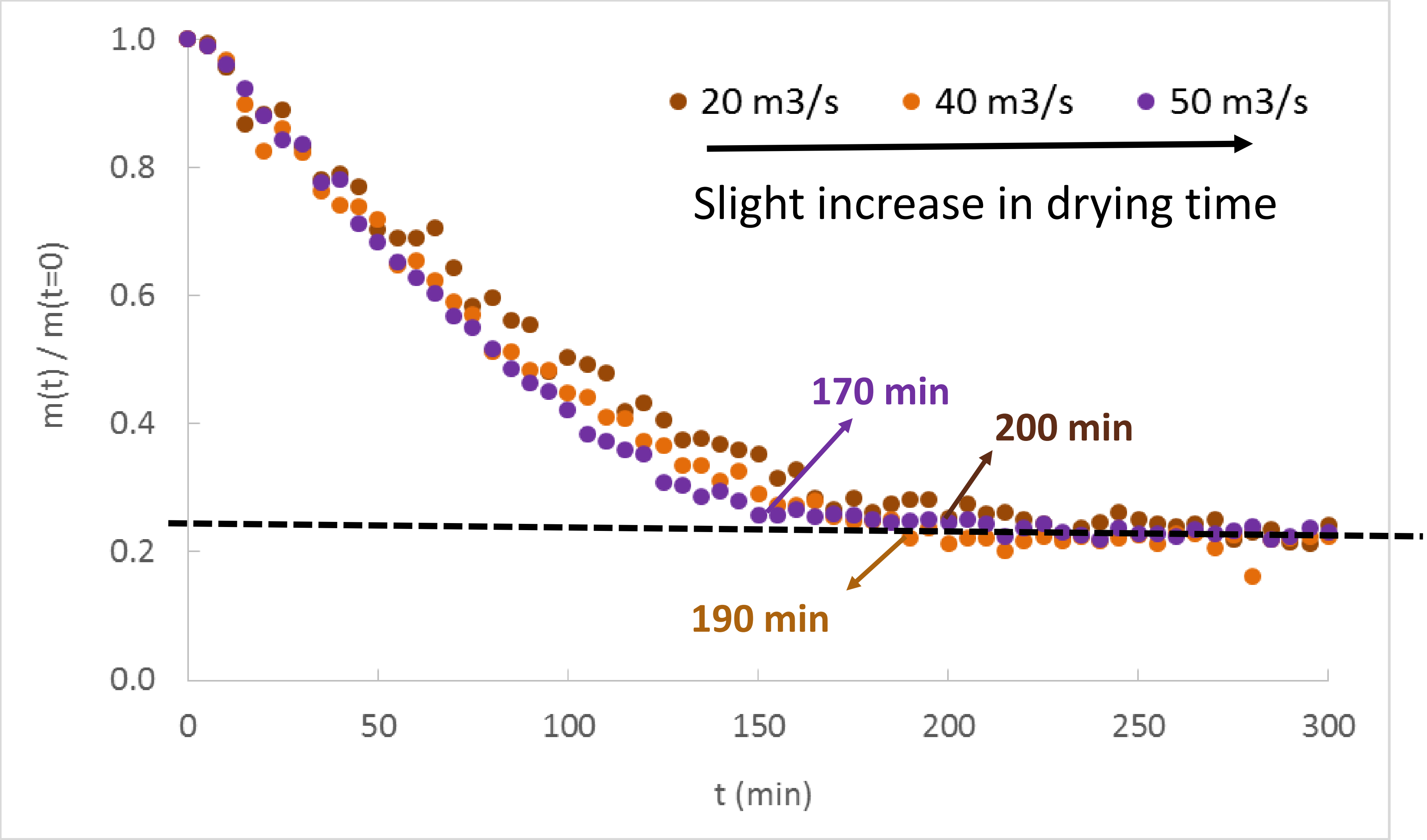
Effect of air humidity



Flow rate = 40 cm³/s
T = 60 °C
Flat thin layer

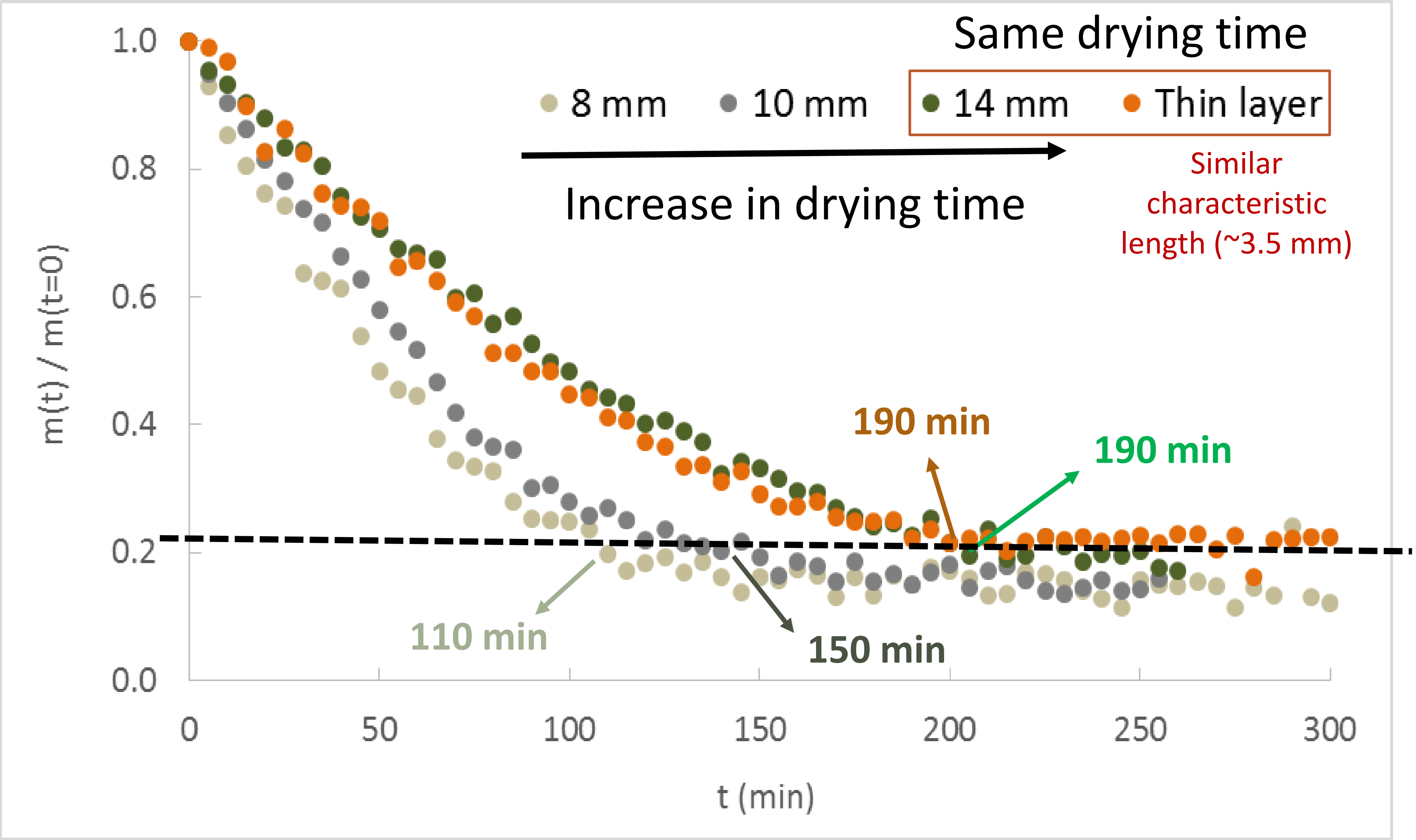
Equilibrium moisture content close to 0%

Effect of air flow rate



RH = 5 %
T = 60 °C
Flat thin layer

Effect of sample



Flow rate = 40 cm³/s
RH = 5 %
T = 60 °C

Critical moisture content

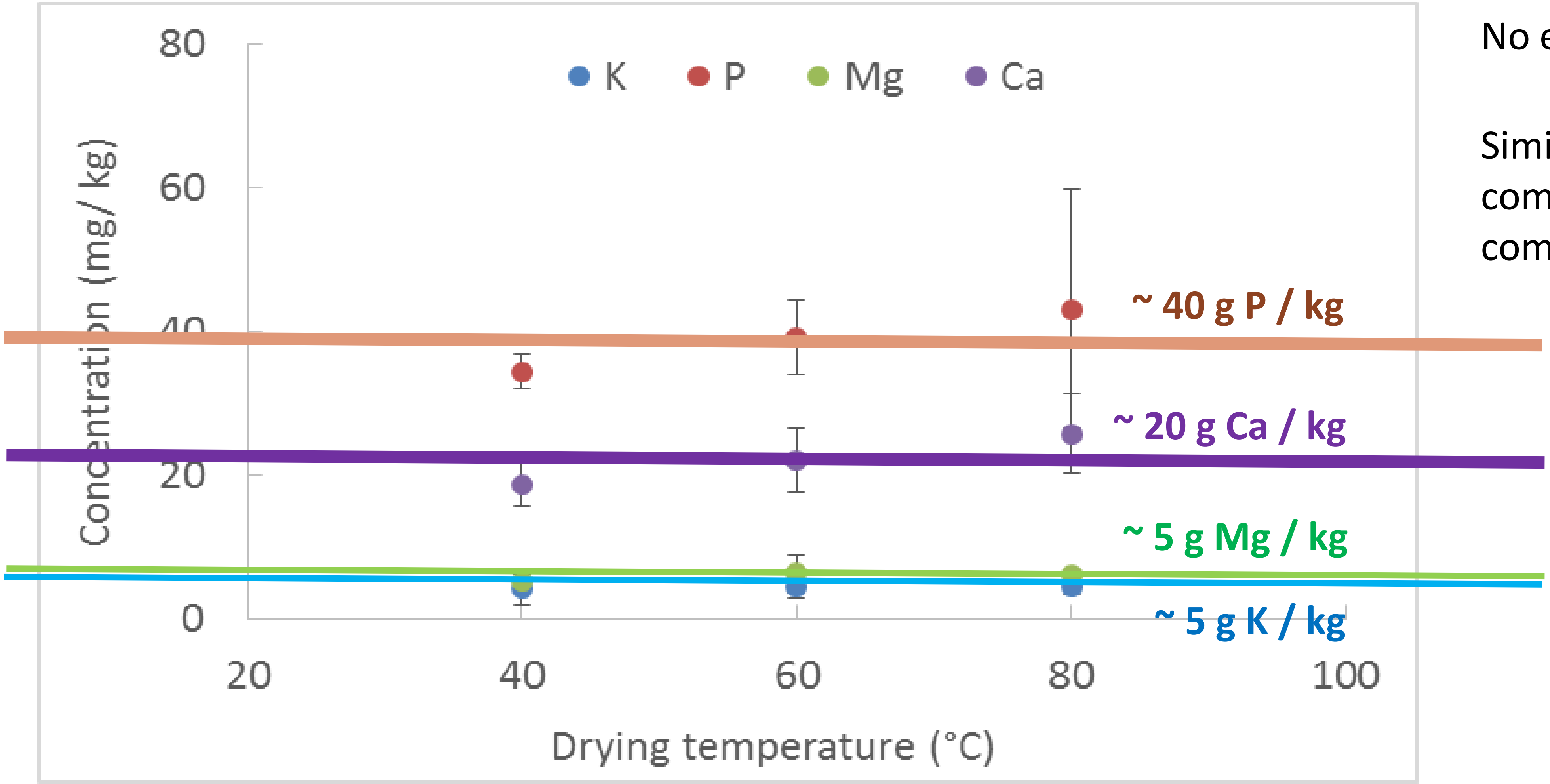
Critical moisture content depends only on sample geometry:

~ 60 % for the flat thin layer
(near middle of the transformation)

~ 30 % for the pellets
(3/4 of the transformation)

Longer constant rate period for pellets → positive for process

Chemical analysis



No effect of temperature

Similar nutrient composition than home compost and manure

Chemical analysis

Low concentrations in terms of soluble compounds

SLOW NUTRIENT RELEASE

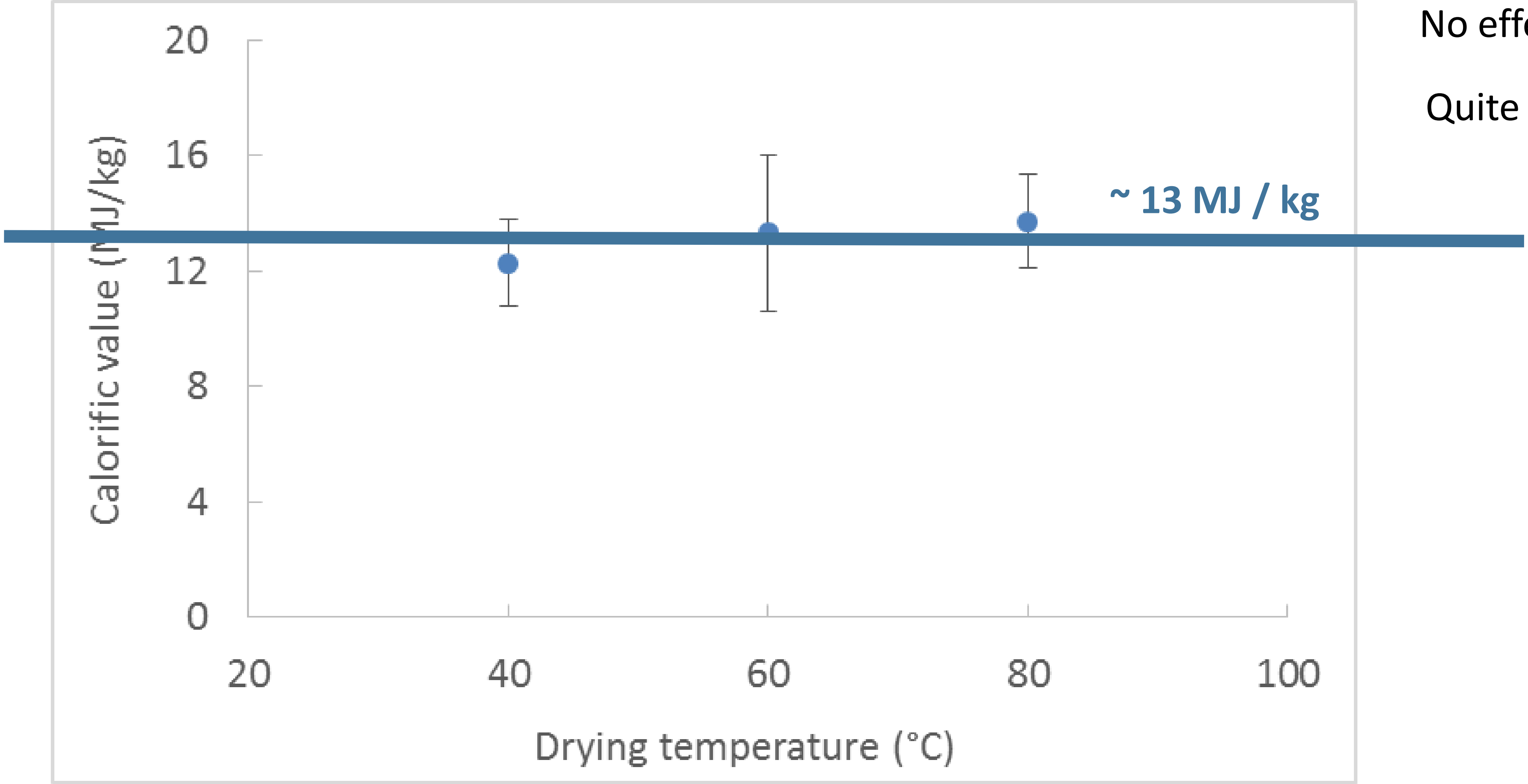
< 10 g NH_4^+ / kg

< 5 g NO_3^- / kg

~ 2 g PO_4^- / kg

5 % of total P

Thermal analysis: calorific value

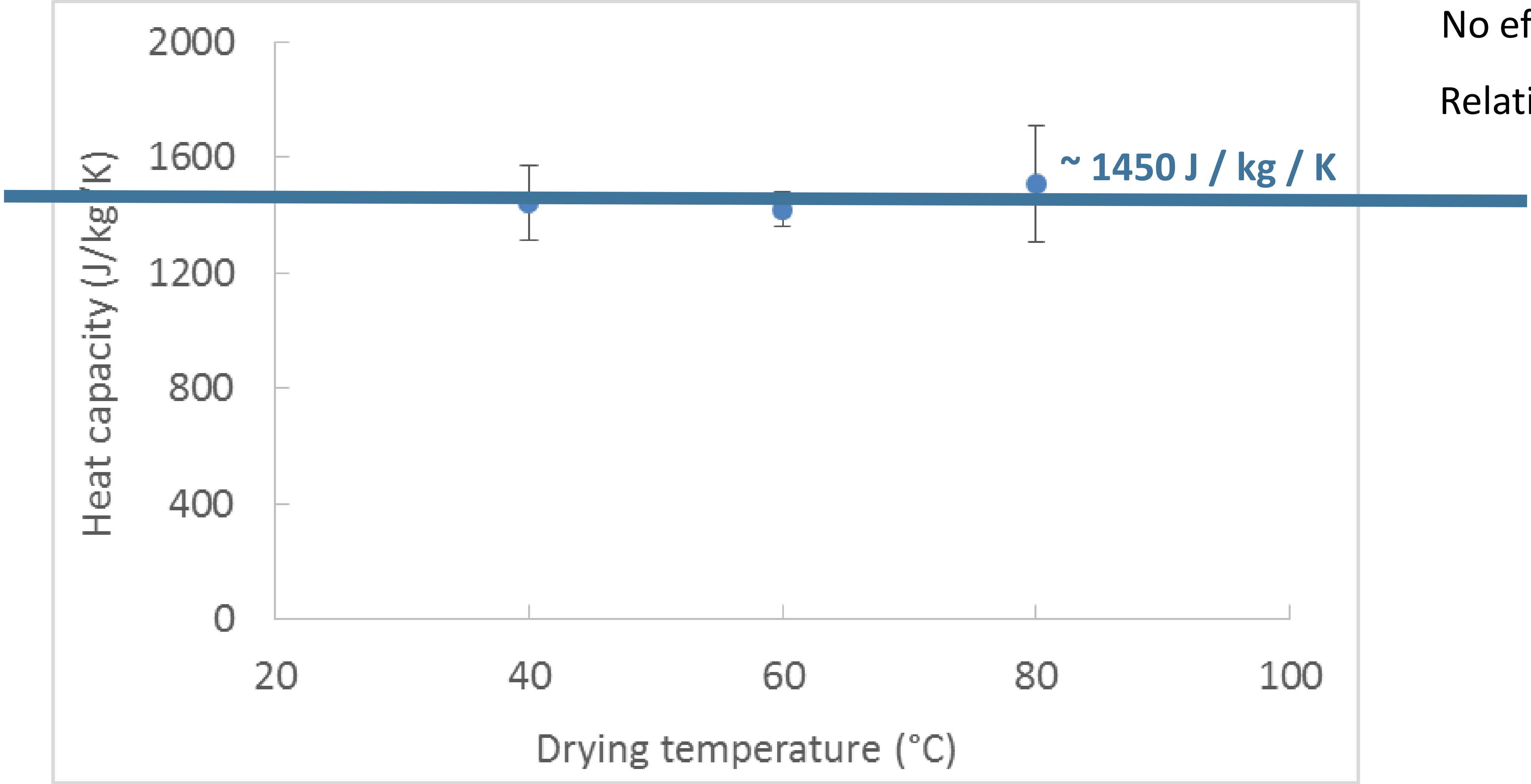


No effect of temperature

Quite high calorific value

~ Wood
~ 1/3 Diesel
~ 1/3 Natural gas
~ 1/2 Coal

Thermal analysis: heat capacity

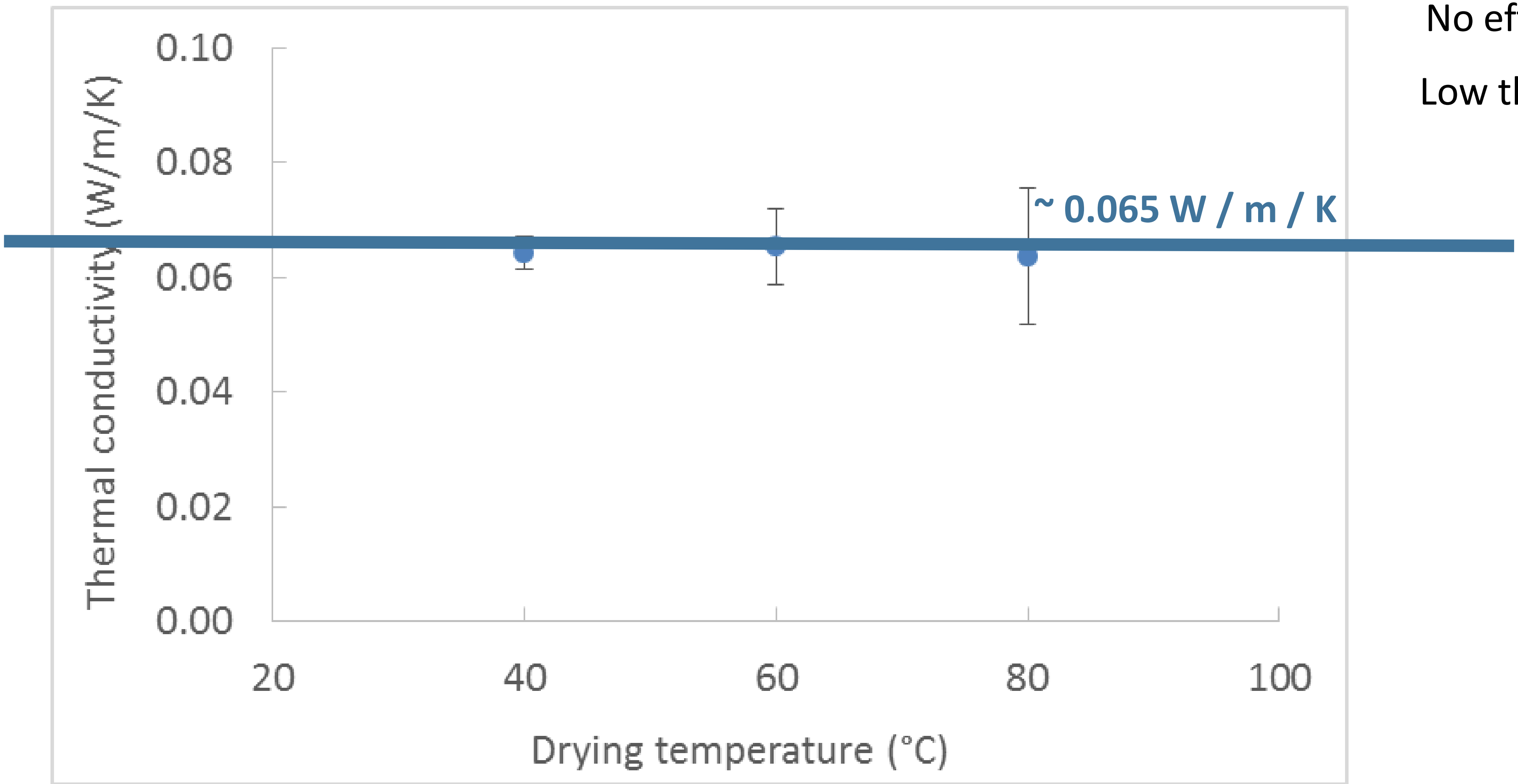


No effect of temperature

Relative low heat capacity

- < Wood
- < Diesel
- < Natural gas
- > Coal

Thermal analysis: thermal conductivity



No effect of temperature

Low thermal conductivity

< Wood
< Diesel
> Natural gas
< Coal

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Conclusions of the kinetic study

- ✓ Trends obtained as expected: increase of drying rate by increasing temperature and gas velocity, and by decreasing air humidity and particle size
- ✓ Most influent parameter : temperature
- ✓ Under the explored conditions, 2 h minimal time for complete drying, 1 h for middle transformation
- ✓ Critical moisture content depending only on sample geometry

Conclusions of dried FS characterization

- ✓ Nutrient composition of dried faecal sludge similar than manure or home compost
- ✓ Potential use of faecal sludge as a slow release fertilizer or soil container in agriculture lands close to the plant processing
- ✓ Good fuel characteristics of dried faecal sludge
    - Calorific value similar to wood
    - Low heat capacity but also low thermal conductivity


BLESSING

Thank you for attention!

Acknowledgment: BMGF

Corresponding author:
septiens@ukzn.ac.za