Zuckerberg Institute for Water Research at
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Hydrothermal Carbonization of Human Excreta: Characterization and Potential Uses

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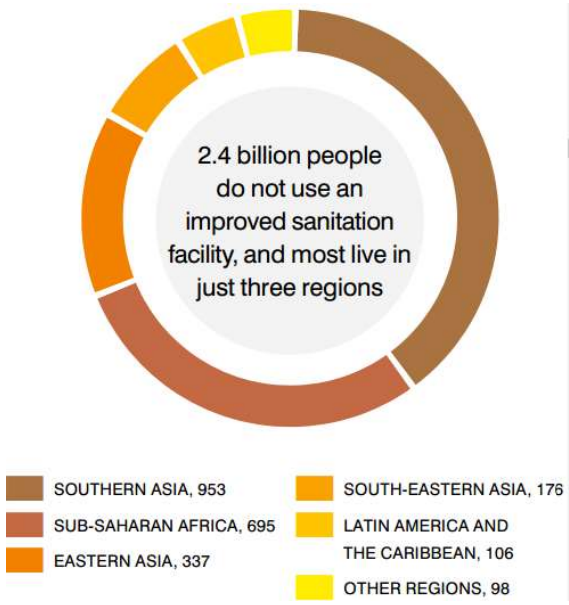
How good is our

after using Hydrothermal Carbonization?

Sanitation problems around the world

Background | Methods | Results

Population without improved sanitation in 2015 , by region



data.unicef.org

Background | Methods | Results

Current decentralized sanitation practices are problematic

- Human pathogen contamination (water and soil) - outbreaks of diseases
- Environmental - greenhouse emissions, nutrient contamination
- Water based sanitation is not feasible (flushing toilet)
- Often not economical
- Waste of resource (C, N, P, K)

Need for an alternative solution

What is Carbonization?

Carbonization is a chemical process in which there is a breakdown of complex carbonaceous substances under heat

as a result there is an increase in the relative carbon content.

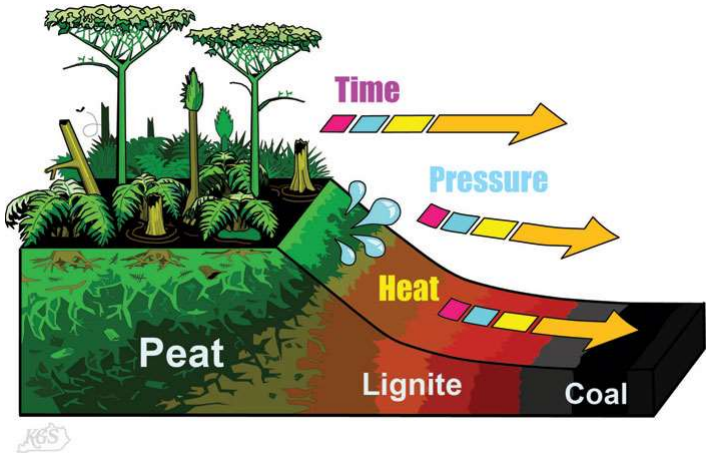
Background Methods Results

Hydrothermal Carbonization (HTC)

- Thermo-chemical conversion of **wet** biomass
- Temperature range of 180-250°C and self-generated **pressure**
- Reaction time from minutes to several hours
- Main Chemical reaction : dehydration & decarboxylation

Background Methods Results

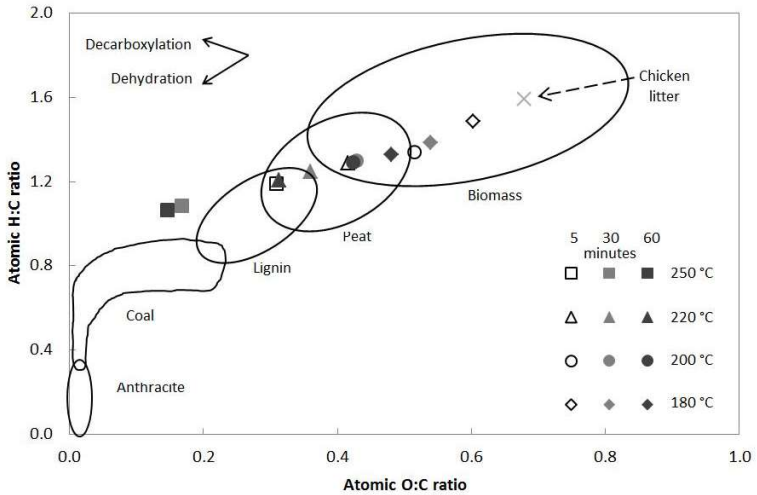
Mimicking coal formation



www.pmfias.com

Background Methods Results

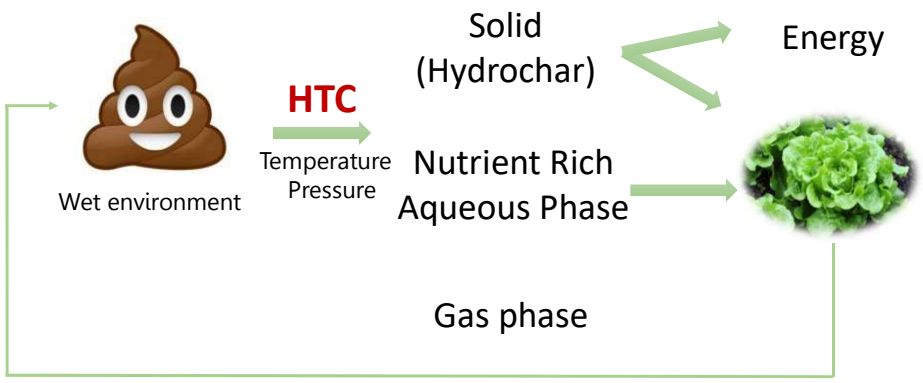
Chicken manure to Coal like material



Mau et al., 2016

Background Methods Results

HTC
Human Waste to Resource



Background Methods Results

HTC of Human Excreta - Potential Advantages

- Relative short process time VS compost, anaerobic digestion
- Sterile products VS compost, anaerobic digestion
- Significant degradation of micro-pollutants (endocrine disrupting, pharmaceuticals)
- Energy efficient

Objectives-
Potential New Sanitation Treatment

Explore the properties and major chemical processes occurring during HTC of raw human excreta under typical solid content (e.g. 25% solids), Specifically:

- Aqueous and solid phases characterization
- Mass balances of C and N
- Potential use of aqueous phase as fertilizer
- Energy balance

Collection campaign

Autoclave

Dried 105ºC

Ground

Characterization

Background | Methods | Results

\+
Water
ratio1:4

HTC

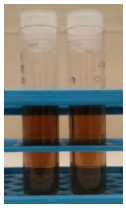
Temp:
180, 210, 240ºC

Time:
30, 60, 120 minutes

Hydrochar

C, H, N, O, S (%)
Yield
Energy content
FTIR

Aqueous Phase



pH, EC
TOC, TN
SAR

Characterization- Pilot scale reactor

Background | Methods | Results

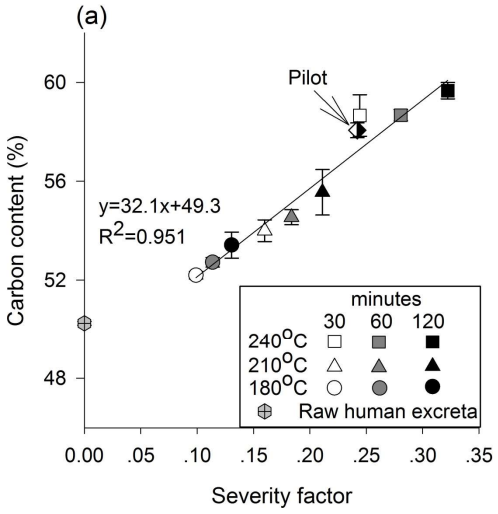
A- 30 liter reactor

B- external electric heating

2 operations-210°C, 240min

Background | Methods | Results-Solid

High correlation - severity factor VS carbon content



$$Severity = 50 * t^{0.2} * e^{\frac{-3500}{T}}$$

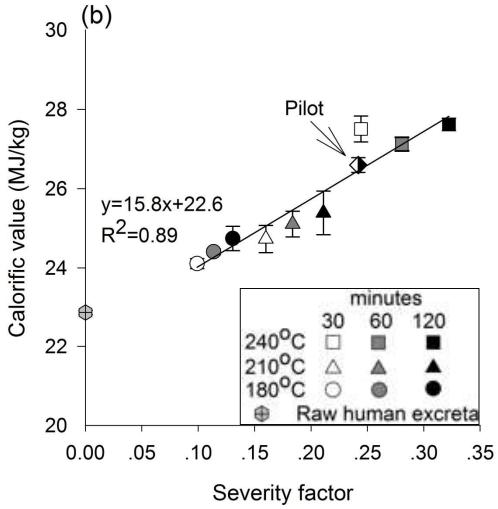
t-time, T-temp

Background | Methods | Results-Solid

High correlation - severity factor VS calorific value

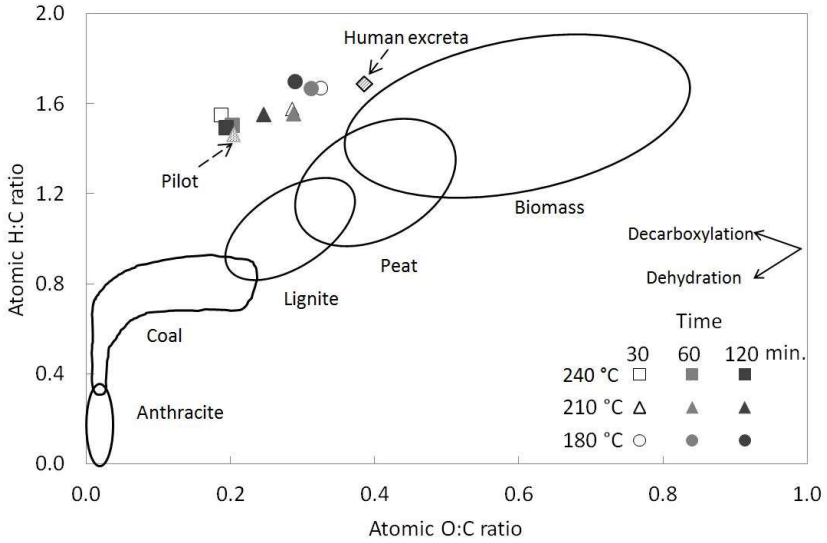
$$Severity = 50 * t^{0.2} * e^{\frac{-3500}{T}}$$

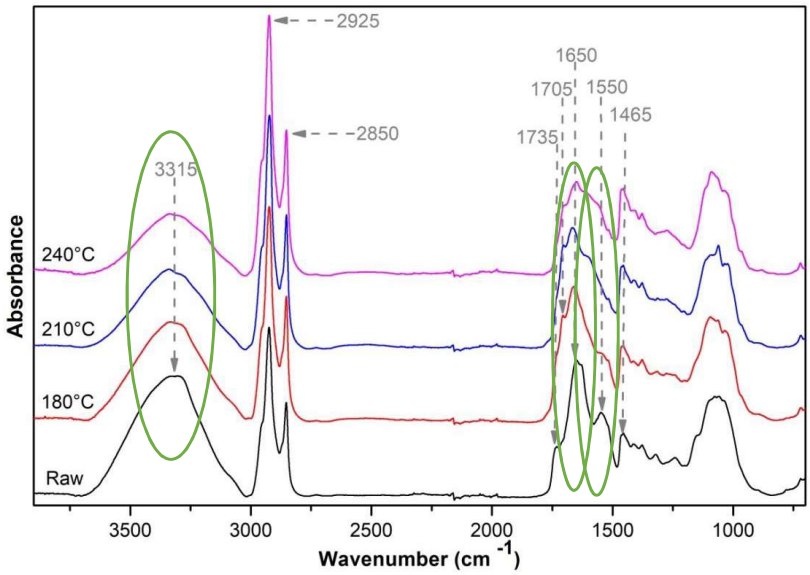
t-time, T-temp



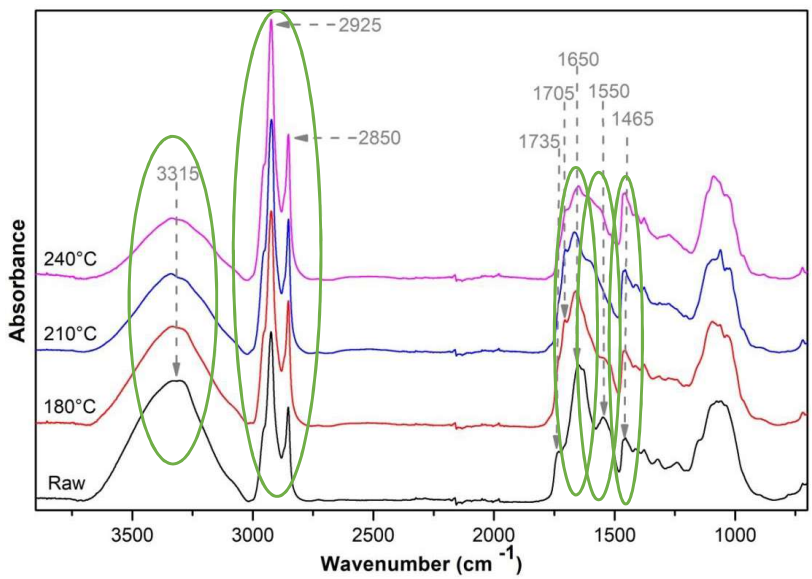
Background | Methods | Results-Solid

Decarboxylation is more pronounced than dehydration





(3315) –OH stretching; (2925,2850) asymmetric and symmetric –CH stretching; (1735) C=O stretching; (1705) carboxylic acid or ketone functional group (1650) C=O stretching of ketone and amide groups; (1550) –NH vibrations; (1465) O-CH_3.



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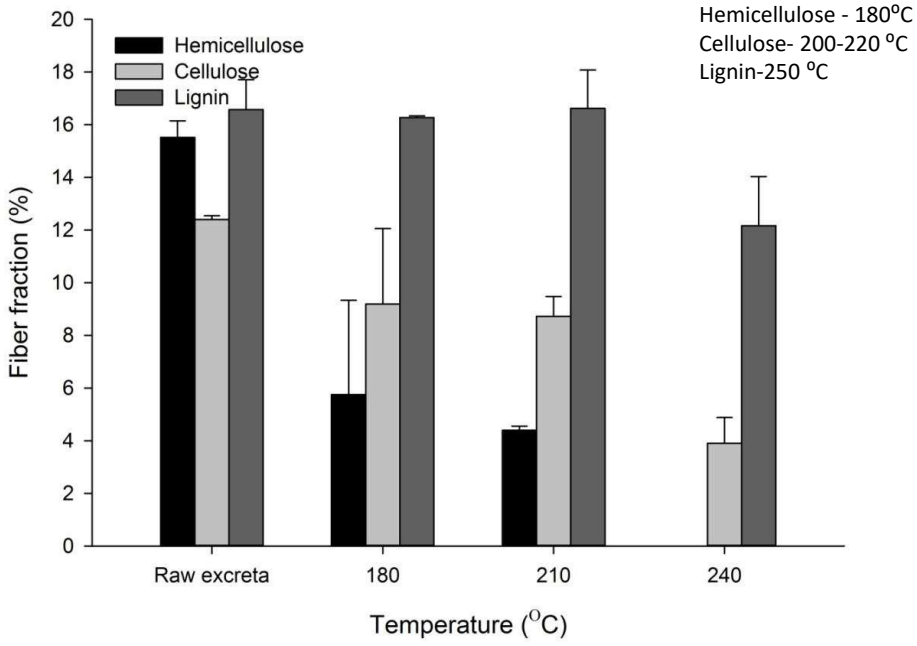

Most of C retained in the solid phase
Transformation of N from solid to aqueous phase

Aqueous phase can be potentially used as a fertilizer

	Raw	180°C	210°C	240°C
pH	6.2 ±0.0	5.4 ±0.1	6.1 ±0.1	7.4 ±0.0
EC (mS/cm)	15.5 ±0.4	23.6 ±0.1	25.5 ±0.4	29.90 ±1.4
TN (mg/L)	4178 ±400	7801 ±648	8718 ±489	7908 ±1501
P (mg/L)	982 ±30	1188 ±45	380 ±11	71 ±8
K (mg/L)	4160 ±79	5707 ±182	6018 ±271	5585 ±94
SAR	15 ±0.0	15 ±0.0	27 ±1	47 ±6

To conclude

HTC could be used as a new sanitation alternative,
at the same time potentially generating:

- Energy
- Liquid fertilizer

It is FECE-ble!

Summary and conclusions

- Pilot and laboratory scale HTC reactors obtained similar results
- Good correlation of severity factor vs. C content and calorific value
- Calorific value resemble sub-bituminous coal
- Decarboxylation is more pronounced than dehydration
- Raw human excreta- not under conventional classification of biomass
- High salinity, SAR, and nutrient values in the aqueous phase – potential use as fertilizer after dilution
- Energy demand 17-27% of energy output

Further research and raised questions:

- What is the role and influence of oil phase on the physicochemical characteristic of hydrochar and aqueous phase?
- What are the combustion properties of the hydrochar? What is the environmental impact of its combustion?
- Better understand the coalification model and its ability to predict yield, calorific value and C content (specifically, the role of time) ?

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- My lab and office colleagues

רשות המים

Rosenzweig–Coopersmith Foundation

Paratherm HEAT TRANSFER FLUIDS

Sanitation categories

"Improved" sanitation:

- Flush toilet [v]
- Piped sewer system [v]
- Septic tank [v]
- Flush/pour flush to pit latrine [v]
- Ventilated improved pit latrine (VIP) [v]
- Pit latrine with slab [v]
- Composting toilet [v]
- Special case [v]

"Unimproved" sanitation:

- Flush/pour flush to elsewhere [v]
- Pit latrine without slab [v]
- Bucket [v]
- Hanging toilet or hanging latrine [v]
- Shared sanitation [v]
- No facilities or bush or field [v]

JMP | WHO / UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation