Hydrothermal Liquefaction of Digested Sewage Sludge to Produce Bio-Oil

Thermochemical conversion of digested sewage sludge in water or ethanol as an in-situ solvent system has been optimized at small and large scale

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AIM AND APPROACH

Sewage Sludge is a promising feedstock in several green chemistry processes due to its abundancy. In this study, sewage sludge has undergone an anaerobic digestion at Bergen Biogas Facility.[1] The digested sewage sludge (DSS) (Figure 1, top) is converted in order to produce bio-oil (Figure 1, bottom), using hydrothermal liquefaction (HTL). Multivariate screening processes are performed to gain knowledge regarding which factors contribute to a higher oil yield and / or better specifications of the oil product itself. This is performed both in a reactor of 25 mL (Figure 2, top) and a larger one of 5.3 L (Figure 2, bottom), as previously reported with other feedstocks.[2]

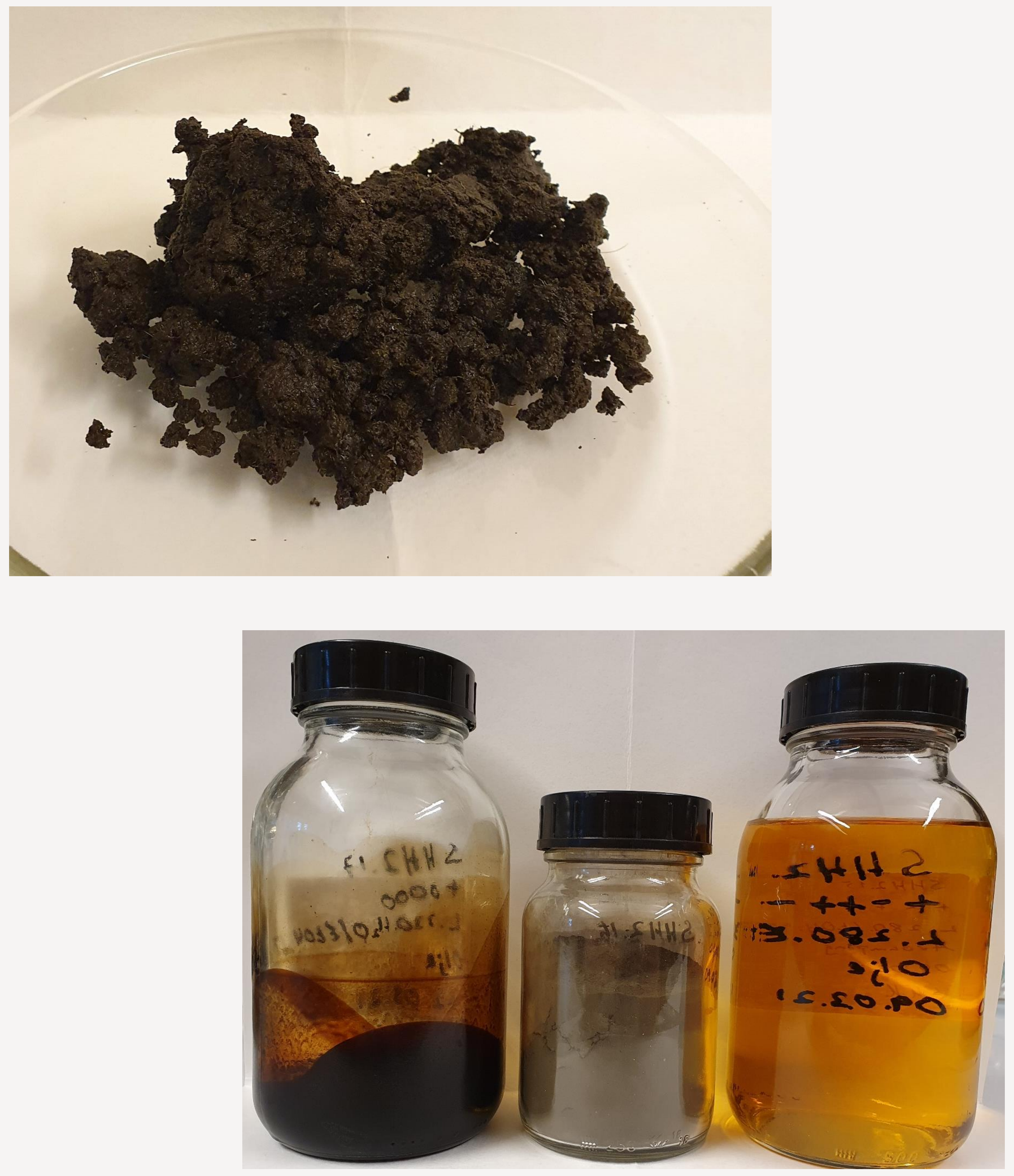

Figure 1: Top: Feedstock; Bottom: From left to right, bio-oil, coke, aqueous phase

EXPERIMENTAL

The process used is HTL in which the feedstock is heated and pressurized with an in-situ solvent system (water or ethanol) and formic acid (FA). Non-dried DSS, water or ethanol and FA is added to a reactor, which is then closed and heated to 280 – 380 °C for 2 – 6 hours. The oil is collected after cooldown, and separated from the gaseous-, solid- and aqueous product phases.

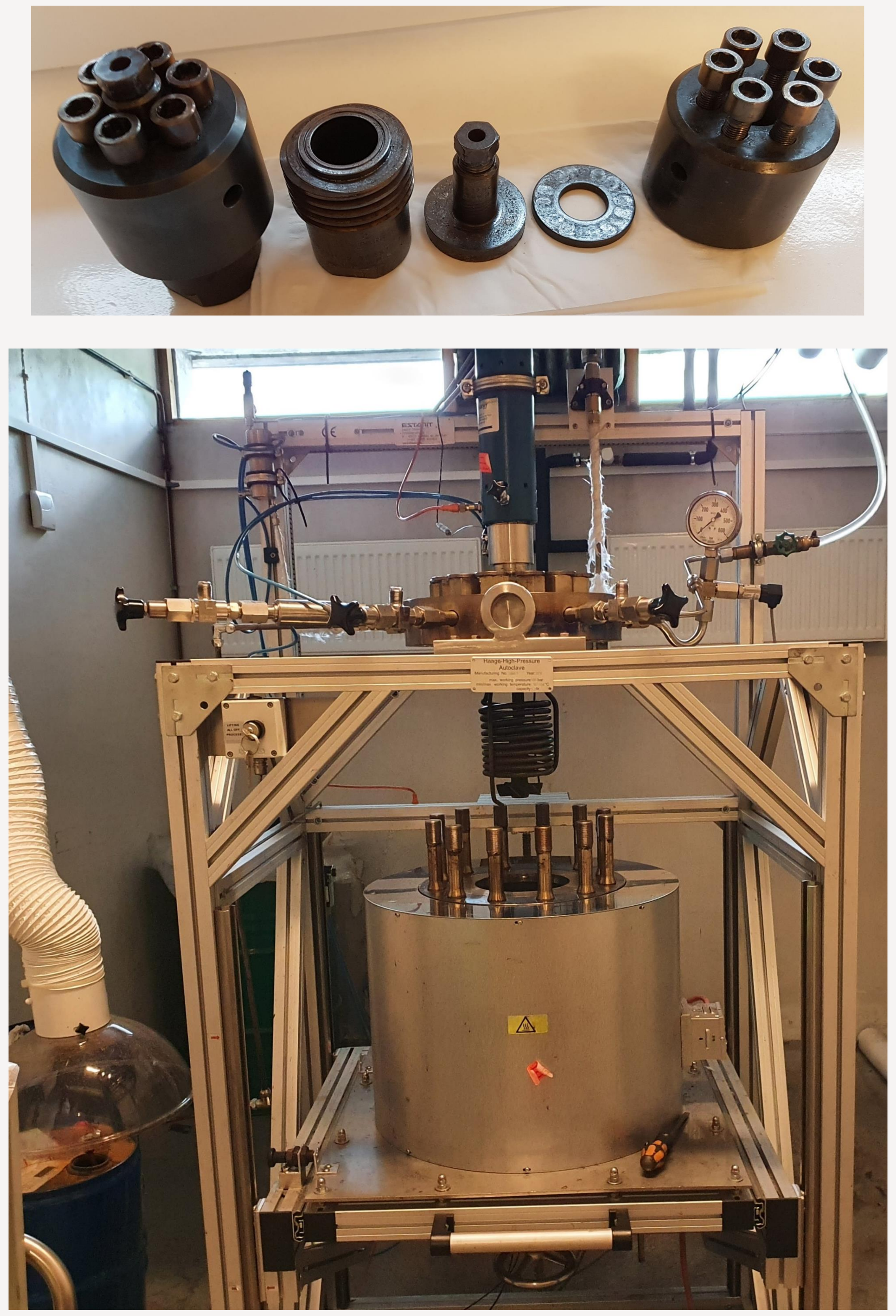

Figure 2: 25 mL reactor (top) and 5.3 L reactor (bottom)

RESULTS AND DISCUSSION

Oil Yields:

In the 25 mL reactor (Figure 2, top), the dry, ash free *(daf)* oil yield reached 29 – 73 %. The 5.3 L reactor (Figure 2, bottom) provided *daf* oil yields of 29 – 67 %. Table 1 shows the experimental conditions providing the highest oil yield for each reactor.

Table 1: Reaction conditions of the experiments based on fractional design, providing the highest yield in each reactor. + or – indicates whether this was the high or low variable setting:

	25 mL reactor	5.3 L reactor
m_{DSS} [g]	4	600
V_{FA} [mL]	1	150
t [h]	4	4
T [°C]	380 (+)	280 (-)
Solvent	EtOH	EtOH
$V_{solvent}$ [mL]	6 (+)	450 (-)
Stirring [rpm]	n.a.	1000 (+)

Oil Composition:

The oil composition varies, mostly on abundance, somewhat also on which compounds occurs, based on the parameters of the experiment. There are however similarities, such as presence of fatty acids, phenols and glycols, as indicated in Figure 3.

CONCLUSIONS

- In the 25 mL reactor, a yield of 73 % (*daf*) was obtained
- In the 5.3 L reactor, a yield of 67 % *(daf)* was obtained
- The oils consist of compounds such as
    - Fatty acids, which could be turned into biodiesel (fatty acid methyl esters)[3]
    - Glycols and phenols, both of which are useful building blocks for further chemical processes[3]

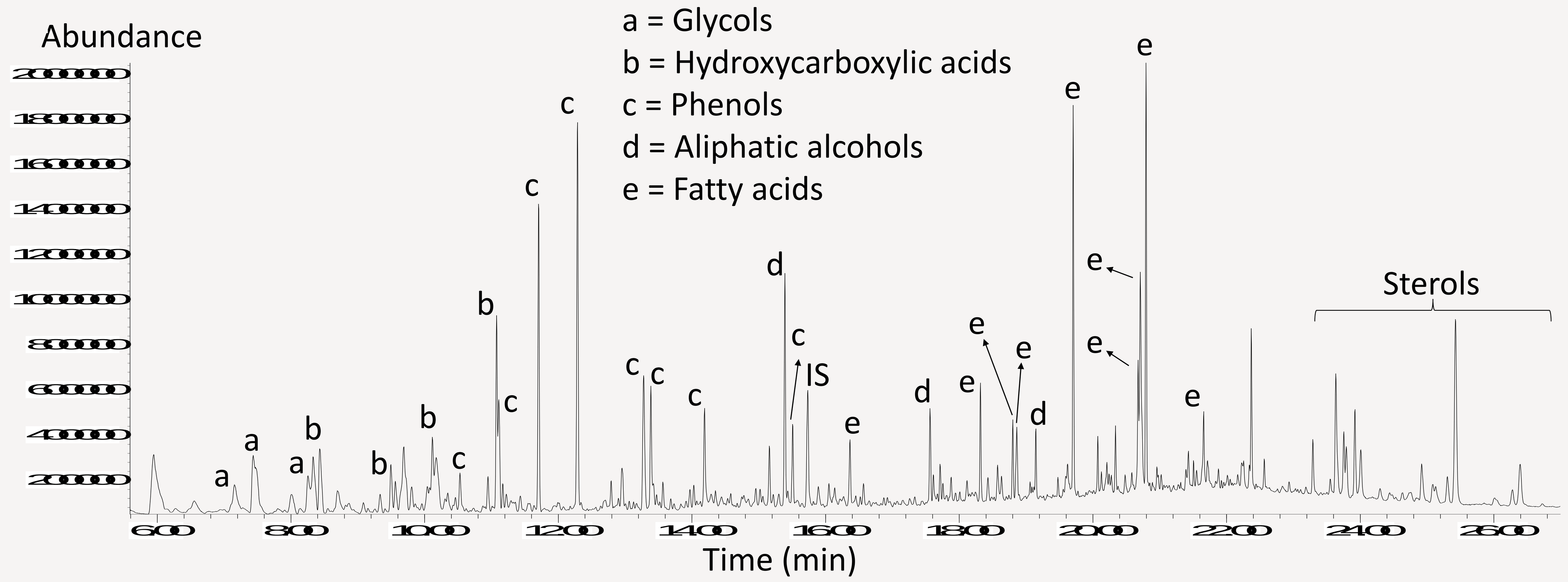

Figure 3: GC chromatogram showing a rough classification of compounds in the bio-oil

References

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3. Clark, J. H.; Deswarte, F. E. I., *Introduction to chemicals from biomass*. Wiley: Chichester, 2008

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