Microwave Pyrolysis of Biosolids

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Objectives

- Smart Water Fund Project
- A scoping study of microwave assisted pyrolytic decomposition of biosolids

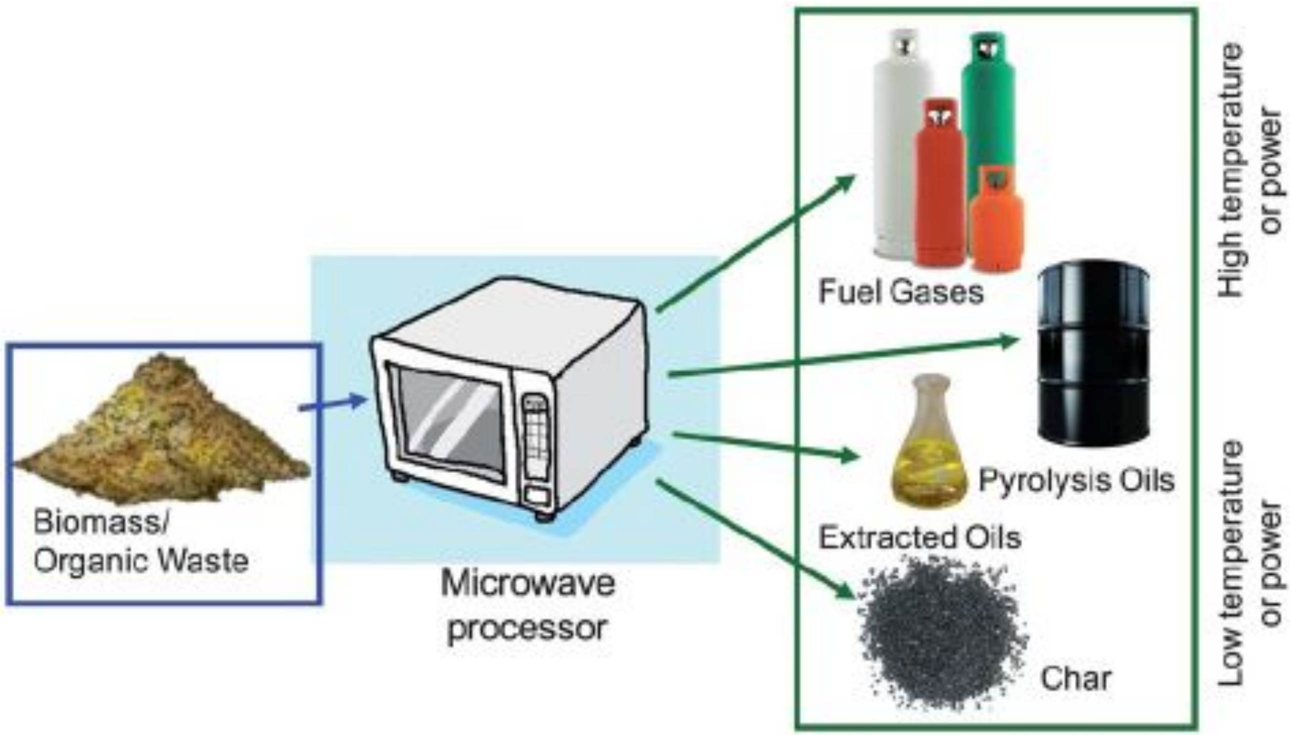

Figure 1: Microwave pyrolysis concept

Problems with Dry Material

- Dielectric properties of dry biosolids = 1.6 + j 0.08
  - Almost transparent to microwave fields
  - No microwave absorption
  - Heating almost stops

- Dielectric properties of dry carbon = 23.0 + j 15.0
  - Good microwave absorber
  - Rapid heating

- Include some carbon in biosolids
  - Initiate the pyrolysis process

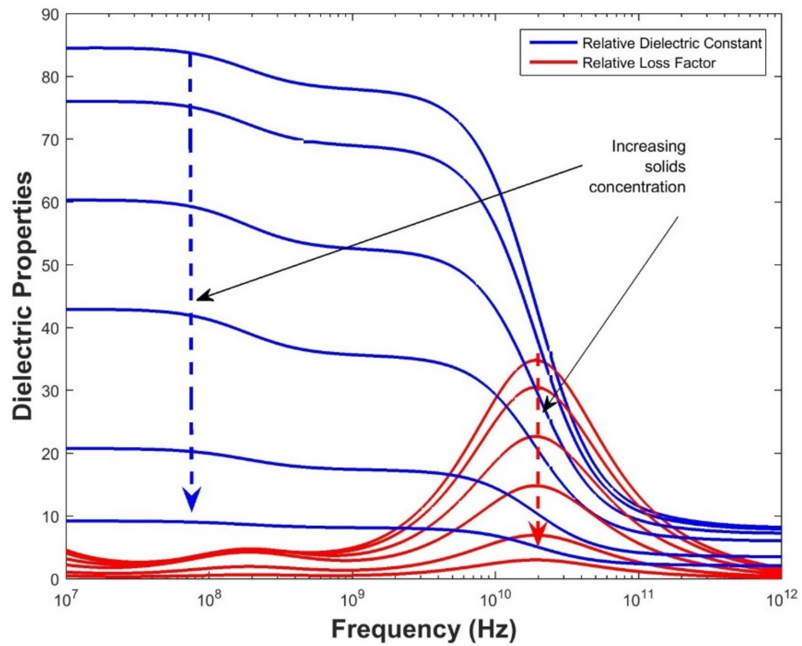

Figure 1: Dielectric properties of sewage sludge as a function of frequency and solids concentration

First Step Towards Scale Up

- Multi-mode Multi-magnetron Chamber
  - 2.45 GHz
  - 1 m^3 capacity
  - 6 by 1 kW Magnetrons

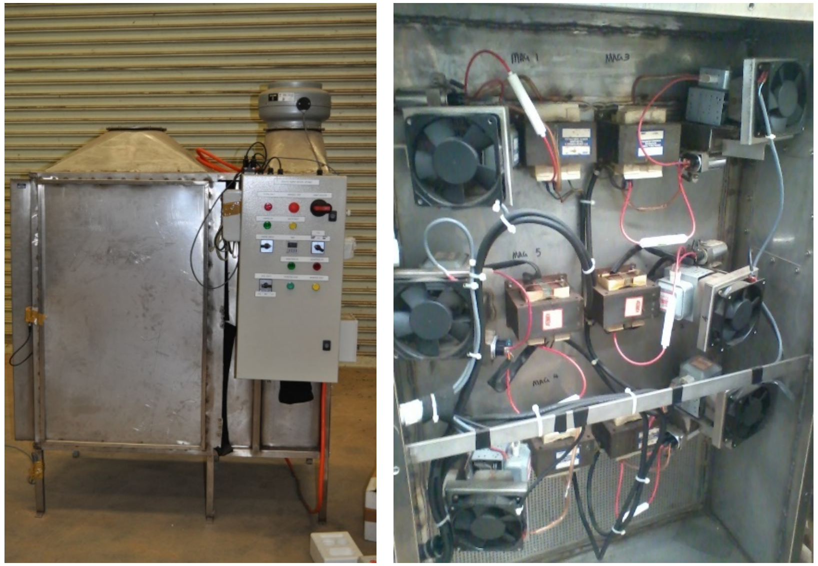

Figure 1: 6 kW Microwave chamber

Products

Figure 1: Oil fraction from pyrolysis of biosolids – about 4.5 % Yield

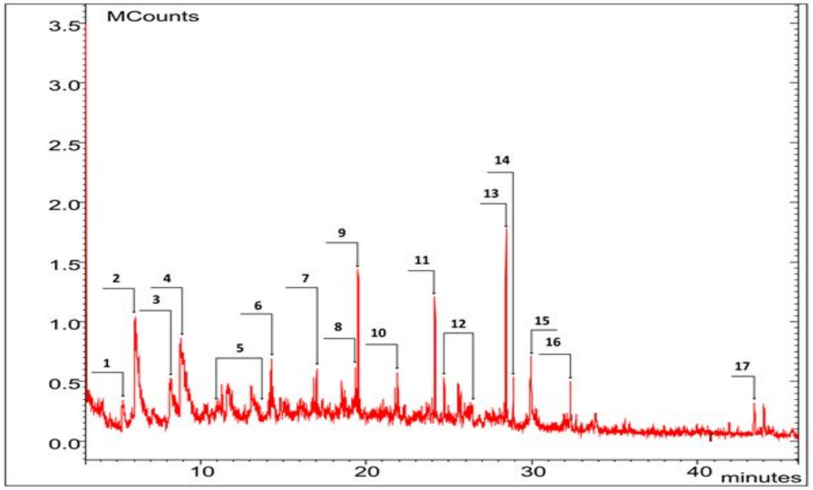

Figure 2: Chromatogram of 700 °C oil samples

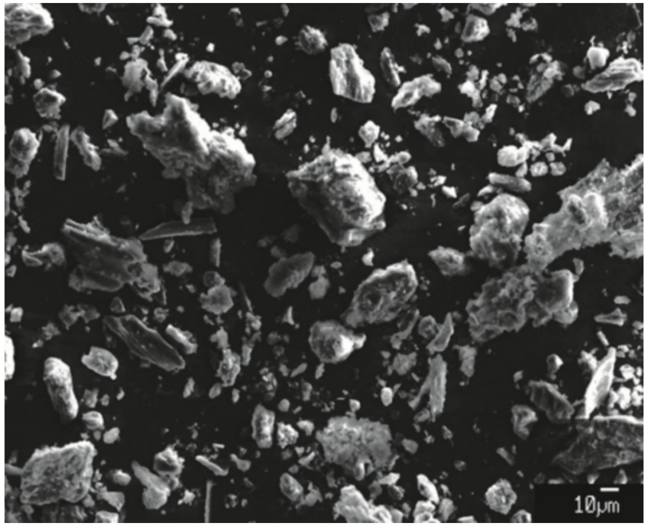

Figure 3: SEM analysis of biochar sample – about 60 % Yield

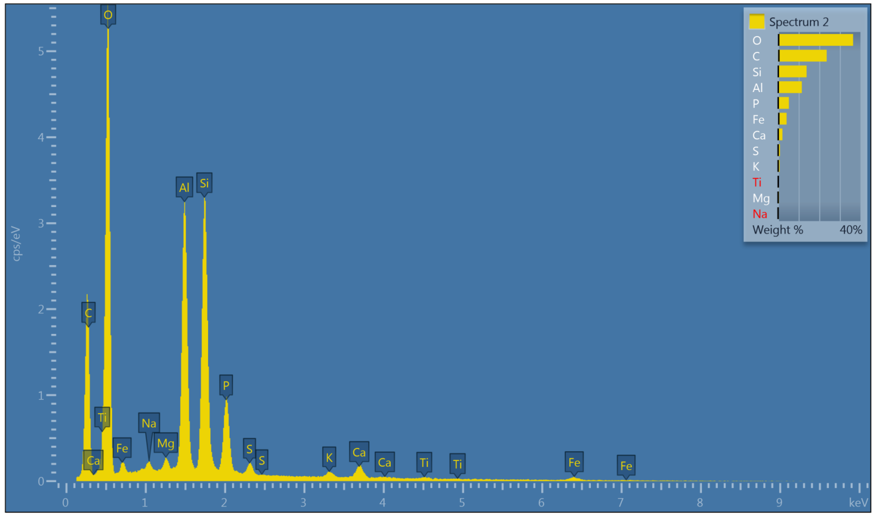

Figure 4: Elemental analysis of biochar

Energy Balance

Table 1: Chemical characteristics and energy values for pyrolysis products

* Determined by mass balance as the difference between biosolids and the combination of biochar and bio-oil.

Product	N%	C%	H%	S%	O%	Ash	HHV (kJ g^{-1} of product)	Yield (g g^{-1} of Biosolids)	Energy Recovery (kJ g^{-1} of Biosolids)
Bio-oil	4.822	73.543	9.838	0.644	11.153	0.000	36.425	0.043	1.55
Biochar	0.700	11.800	0.000	0.530	4.370	82.600	2.342	0.599	1.40
Syngas*	6.674	46.378	10.813	1.849	34.286	0.000	25.684	0.358	8.99
Initial Biosolids	3.050	26.300	4.310	1.030	15.810	49.500	13.324	1.000	

Processing Energy Required – 1.5 to 2.0 kJ g^{-1}

(based on single mode absorbed microwave power data)

Total Energy Recovery = 11.95 kJ g^{-1} = 90 %

Use Syngas to cover/offset energy requirements

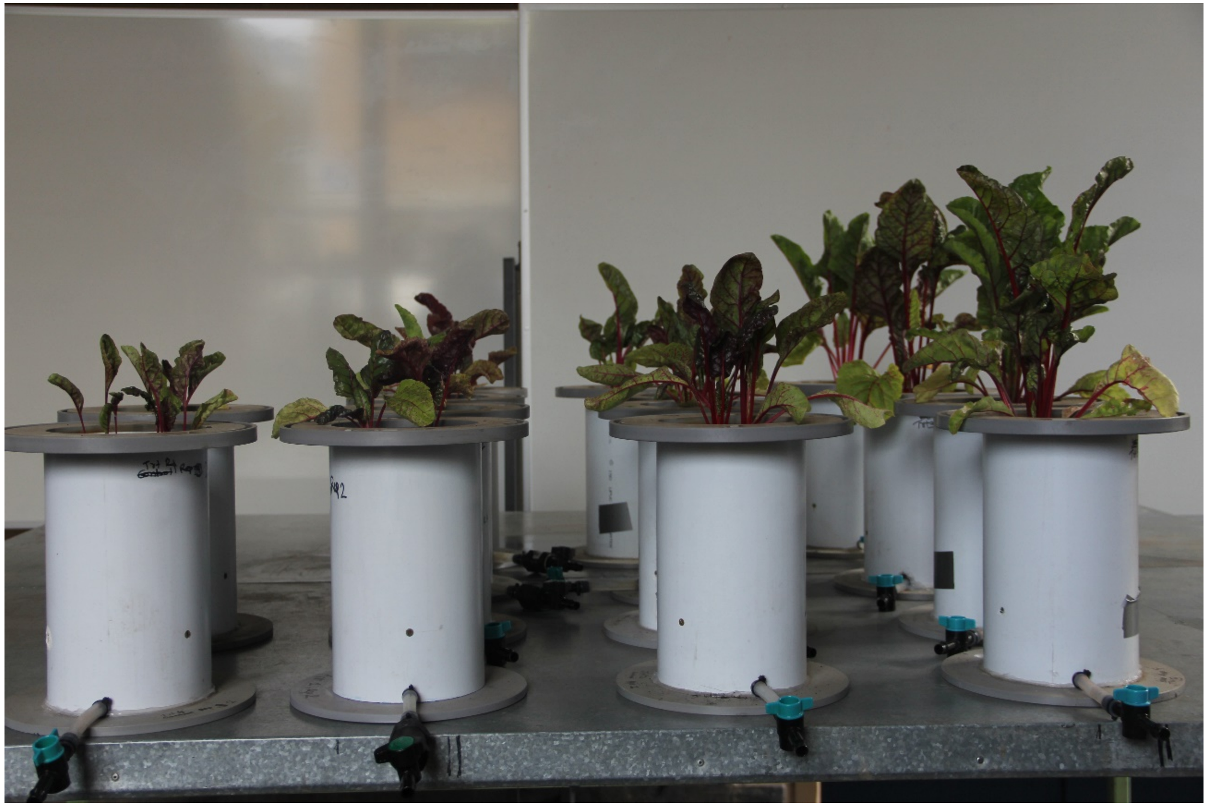

Figure 1: Comparison of plant growth in Silver Beet trial (From left to right – 60% Biochar no fertilizer; Potting mix with fertilizer; 20 % biochar with fertilizer, and 60 % biochar with fertilizer)

Conclusions

- Australia produces 360,000 tonnes of biosolids annually
- Pyrolysis recovers carbon, energy, and chemicals
- Pyrolysis chemicals – value between \$1,200 and \$250,000 per tonne
- A 4 % oil yield from 360,000 tonnes at average of \$1,500 per tonne of oil = \$21.6 million annually
- 3 to 4 fold increased in crop production from incorporated biochar.

Figure 1: Biochar can enhance plant growth and production

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Thank You!

Questions