

# Biosolids and FOGO pyrolysis trials – Fate of contaminants

Emerging Contaminants Workshop, 21 November 2024

Aravind Surapaneni

# Biosolids problem & solution

1. Rapidly changing regulatory environment
2. Land application is becoming challenging
3. Thermal treatment is the only viable and matured PFAS destruction method
4. PYROCO - a novel Fluidised bed pyrolysis technology could be a solution

# Our Biochar Journey

1. Started in 2015
2. Pyroco Mark 1 trials in 2021: 2 feedstocks
3. Pyroco Mark 2 Phase 1 trails in 2023: 6 feedstocks
4. Pyroco Mark 2 Phase 2 trails in 2025: 8 feedstocks

# Project Partners & Funding

Contributor	Cash	In-Kind
DEECA	\$100,000	
Intelligent Water Networks (IWN)	\$100,000	\$10,000
South East Water	\$130,000	\$20,000
East Gippsland Water	\$17,000	\$5,000
Westernport Water	\$16,000	\$5,000
Barwon Water	\$32,000	\$10,000
RMIT University	\$10,000	\$20,000
Victorian Higher Education Seed Innovation Fund (VHESIF)	\$650,000	
Greater Western Water	\$10,000	\$50,000
<b>TOTAL</b>	<b>\$1,065,000</b>	<b>\$120,000</b>



Energy,  
Environment  
and Climate Action



intelligent  
water  
networks  
10+  
Years

South East  
Water



Greater Western  
Water

BarwonWater



WESTERNPORT  
WATER™



# Materials and Methods

# Feedstocks Trialied

Feedstock	Code	Initial Bulk density (kg/m <sup>3</sup> )	Final Bulk density (kg/m <sup>3</sup> )	Final particle size (mm)	Final particle shape	Total mass processed per feedstock (kg)
<b>Metropolitan biosolids</b>	Source 1 <sup>1</sup>	800	Non-Pelletised	1-2	Spherical	234
	Source 2 <sup>2</sup>	800	Pelletised- 658	3 x 20	Cylindrical	118
<b>Canola Straw</b>	CS	153	Mixed with biosolids and pelletised (80 % CS:20 % Source 2 biosolids)			-
<b>Source 2 biosolids (20 wt.%) + Canola straw (80 wt.%)</b>	Source 3		Pelletised- 575	3 x 20	Cylindrical	124
<b>FOGO</b>	Source 4	394	Pelletised- 865	3 x 20	Cylindrical	177
<b>Regional biosolids 1</b>	Source 5	832	Pelletised- 813	3 x 20	Cylindrical	172
<b>Regional biosolids 2</b>	Source 6	815	Pelletised- 1000	3 x 20	Cylindrical	98

# FEEDSTOCK PREPARATION



Dryer



Pin Mill



Hammer Mill



Shredder

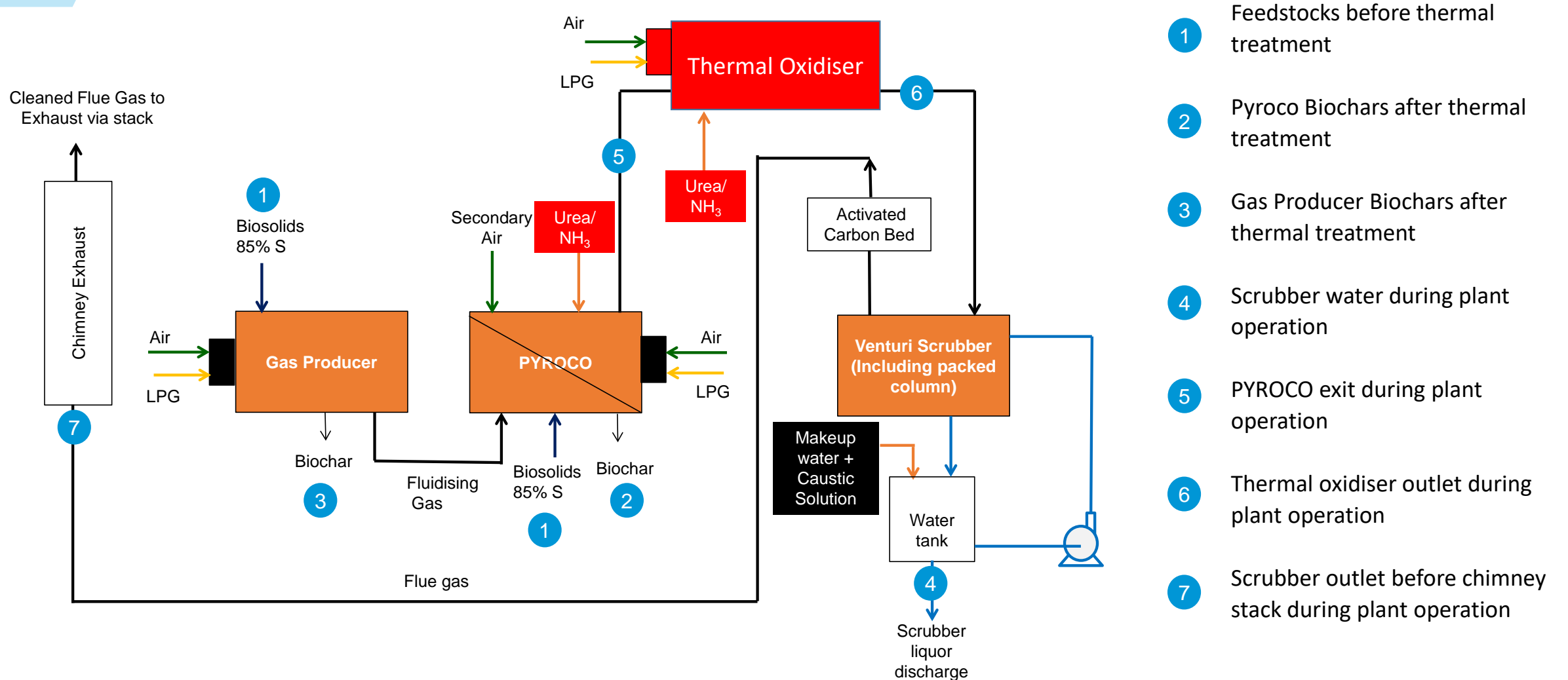


Pelletiser



Only for canola straw

# SAMPLING POINTS

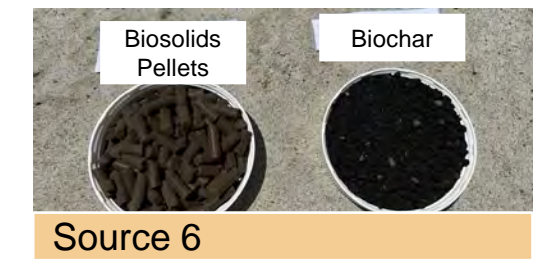
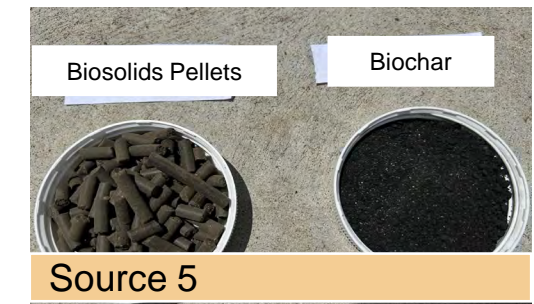
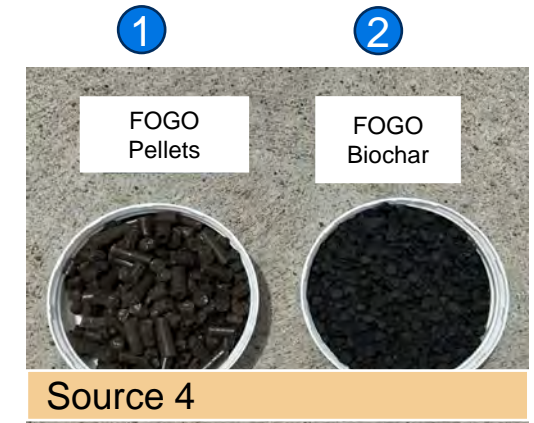
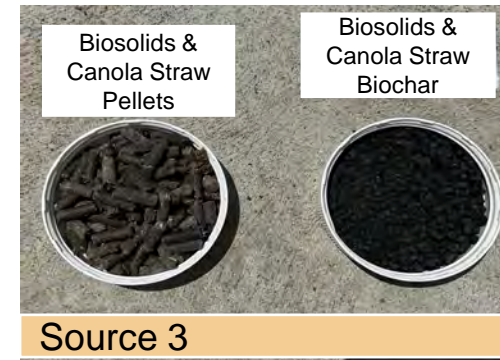
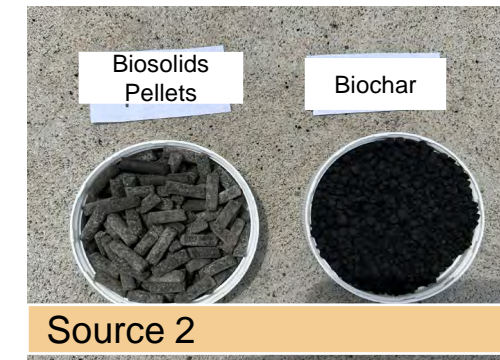
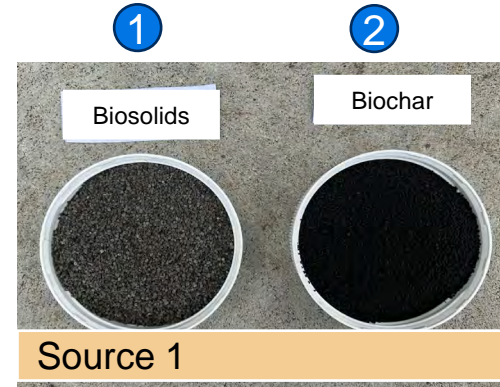
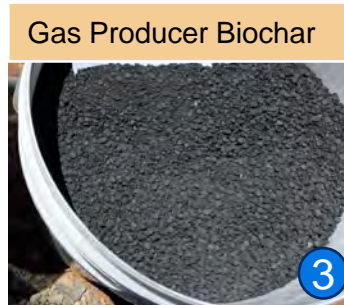
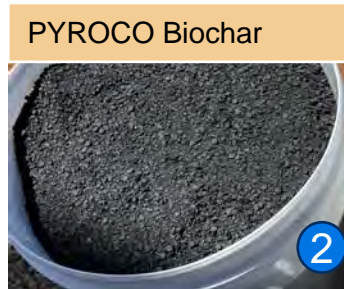


- 1 Feedstocks before thermal treatment
- 2 Pyroco Biochars after thermal treatment
- 3 Gas Producer Biochars after thermal treatment
- 4 Scrubber water during plant operation
- 5 PYROCO exit during plant operation
- 6 Thermal oxidiser outlet during plant operation
- 7 Scrubber outlet before chimney stack during plant operation

# PFAS Sampling Points 1, 2 & 3

- ① Feedstocks before thermal treatment (x6 Samples)
- ② Pyroco Biochars after thermal treatment (x6 Samples)
- ③ Gas Producer Biochars after thermal treatment (x5 Samples)

	Feedstock type
Source 1	Biosolids – Metro
Source 2	Biosolids - Metro
Source 3	Biosolids (Metro) + Canola Straw mix
Source 4	Food Organics & Garden Organics (FOGO)
Source 5	Biosolids – Regional
Source 6	Biosolids – Regional





# Sampling Points 4, 5, 6 & 7

4

## Scrubber Water

3 Metros  
(Source 1,  
Source 2 and  
Source 3)



5

## PYROCO exit during plant operation

1 Metro  
(Source 1)



6

## Thermal oxidiser outlet during plant operation

1 Metro  
(Source 1)



7

## Scrubber outlet before chimney stack during plant operation

1 Metro (Source 1)



# Sampling and analysis

---

- **Feedstocks and biochars** - Project team and Australian Laboratory Services (ALS), Leeder Analytical Lab and Eurofins
- **Scrubber water** – Project team and Leeder Analytical Lab
- **Emission testing** – sampling and analysis by Eurofins
- All Labs are accredited by National Association Testing Authorities (NATA) Australia.
- However, there is no lab in Australia that uses NATA accredited PFAS testing method for stack emission.
- 28 targeted PFAS components were analysed.
- Limits of reporting (LOR) ranged from <2.5 to <10 µg/kg

# PFAS Sampling and analysis in emission testing

---

- Sampling date - 23 Nov 2023
- PFAS sampling recommended method - Isokinetic sampling into 90 mm Glass Fiber Filter & PFAS free deionised water impingers in accordance with **USEPA Method 13B** (Non-NATA Endorsed method).
- PFAS Analysis according to Eurofins accredited method LTM-ORG-2100 PFAS by LC-MS/MS based on **USEPA Method 537**. Measurement Uncertainty is  $\pm 28\%$ .

# Biosolids & Biochar Results

1. Biosolids & Canola Straw Pellets

3. Gas Producer Biochar from #1.



2. PYROCO Biochar from #1.

4. Biochar process fines from #1

## Heavy Metals (mg/kg) – Total

	Source 1		Source 2		Source 3		Source 4		Source 5		Source 6	
	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar
Arsenic	<5	5	<5	<5	<5	<5	10	12	6	<5	<5	<5
Cadmium	1.1	2.2	1.1	2.4	0.2	<0.2	<0.2	<0.2	1.1	1.1	0.6	0.6
Chromium	21	40	27	36	7	20	31	67	36	31	120	120
<b>Copper</b>	<b>1000</b>	<b>1600</b>	<b>880</b>	<b>1400</b>	<b>180</b>	<b>440</b>	<b>24</b>	<b>53</b>	<b>350</b>	<b>340</b>	<b>230</b>	<b>170</b>
Mercury	1.2	<0.05	1.1	<0.05	0.14	<0.05	<0.05	<0.05	0.53	<0.05	0.37	<0.05
Nickel	17	60	17	26	<5	21	18	100	14	17	35	59
Lead	18	87	18	55	<5	21	23	57	27	43	17	25
Selenium	6	9	6	8	<3	3	<3	<3	7	5	4	<3
<b>Zinc</b>	<b>1100</b>	<b>1900</b>	<b>1000</b>	<b>1800</b>	<b>190</b>	<b>550</b>	<b>120</b>	<b>170</b>	<b>600</b>	<b>570</b>	<b>370</b>	<b>290</b>

## Heavy Metals (mg/kg) – DTPA Extractable

	Source 1		Source 2		Source 3		Source 4		Source 5		Source 6	
	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar
Silver	0.001	0.001	0.004	<0.0006	0.003	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
Arsenic	0.08	0.04	0.06	0.03	0.12	0.02	0.04	0.03	0.35	0.01	0.007	0.10
Beryllium	0.001	0.001	0.002	0.001	0.001	0.000	0.001	0.000	0.000	0.001	0.001	0.000
Cadmium	0.04	0.03	0.04	0.02	0.07	<0.0001	0.03	0.02	0.02	0.00	0.02	<0.0001
Cobalt	0.08	0.02	0.03	0.01	0.06	0.03	0.20	0.009	0.11	0.76	0.04	0.005
Chromium	0.010	<0.003	<0.003	<0.003	0.003	<0.003	<0.003	<0.003	0.048	<0.003	0.008	<0.003
<b>Copper</b>	<b>38.7</b>	<b>5.6</b>	<b>32.2</b>	<b>1.7</b>	<b>43.4</b>	<b>0.7</b>	<b>21.1</b>	<b>1.4</b>	<b>3.3</b>	<b>6.8</b>	<b>2.2</b>	<b>0.1</b>
Iron	19.6	57.0	16.4	29.6	26.1	51.5	158.7	24.7	49.3	85.2	42.6	26.0
Manganese	13.0	2.1	5.4	1.6	9.0	0.6	8.5	1.4	1.3	1.8	6.7	1.1
Nickel	0.4	0.1	0.26	0.04	0.6	0.3	0.9	0.02	0.67	66.1	0.2	0.04
Lead	0.3	0.7	0.2	0.4	0.3	0.02	0.3	0.3	0.1	0.04	0.02	0.01
Selenium	0.03	0.01	0.01	0.01	0.04	<0.004	0.03	0.01	0.04	0.04	0.01	0.02
<b>Zinc</b>	<b>28.4</b>	<b>20.0</b>	<b>29.1</b>	<b>7.0</b>	<b>57.3</b>	<b>0.1</b>	<b>21.0</b>	<b>5.8</b>	<b>23.8</b>	<b>1.2</b>	<b>16.1</b>	<b>0.3</b>

## Heavy Metals (mg/L) – Australian Standard Leaching Procedure (ASLP)

	Source 1		Source 2		Source 3		Source 4		Source 5		Source 6	
	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar
Antimony	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	0.04	<0.01	0.04	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	<0.01	<0.01
Barium	0.02	<0.01	0.03	<0.01	0.13	<0.01	0.03	<0.01	0.09	0.1	0.02	0.03
Beryllium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	<0.2	0.5	<0.2	0.6	0.2	<0.2	0.4	0.4	<0.2	<0.2	<0.2	0.3
Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.012	<0.002	<0.002	<0.002
<b>Copper</b>	<b>1.1</b>	<b>&lt;0.01</b>	<b>1.3</b>	<b>&lt;0.01</b>	<b>0.55</b>	<b>&lt;0.01</b>	<b>0.04</b>	<b>&lt;0.01</b>	<b>0.14</b>	<b>&lt;0.01</b>	<b>0.14</b>	<b>&lt;0.01</b>
Lead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	0.05	<0.01	0.09	<0.01	0.25	<0.01	0.14	<0.01	2.1	0.02	1.1	0.14
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum	0.06	0.02	0.07	0.02	0.01	<0.01	0.01	0.01	<0.01	0.04	<0.01	0.03
Nickel	0.04	<0.01	0.03	<0.01	0.02	<0.01	0.02	<0.01	0.08	<0.01	0.02	<0.01
Selenium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
<b>Zinc</b>	<b>0.21</b>	<b>&lt;0.01</b>	<b>0.29</b>	<b>&lt;0.01</b>	<b>0.33</b>	<b>&lt;0.01</b>	<b>0.14</b>	<b>&lt;0.01</b>	<b>16</b>	<b>&lt;0.01</b>	<b>0.98</b>	<b>&lt;0.01</b>

# Nutrients

Nutrients	Units	Source 1		Source 2		Source 3		Source 4		Source 5		Source 6	
		Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar
Total Kjeldahl Nitrogen (TKN)	mg/kg	60000	31000	54000	31000	13000	15000	17000	7100	16000	4400	12000	3100
Ammonia (NH <sub>3</sub> )	mg N/kg	4800	98	4300	82	1300	31	260	27	500	20	210	89
Nitrite (NO <sub>2</sub> )	mg/kg	<0.5	<0.2	<1	<0.05	<0.5	<0.05	<1	<0.05	0.5	<0.05	0.7	<0.05
Nitrate (NO <sub>3</sub> )	mg/kg	<0.5	0.4	<1	0.2	<0.5	0.3	<1	0.2	350	<0.2	210	<0.2
NO <sub>x</sub>	mg N/kg	<0.5	0.5	<1	0.2	<0.5	0.3	<1	0.2	350	0.2	210	0.1
<b>Total Nitrogen</b>	mg N/kg	<b>60000</b>	<b>31000</b>	<b>54000</b>	<b>31000</b>	<b>13000</b>	<b>15000</b>	<b>17000</b>	<b>7100</b>	<b>16000</b>	<b>4400</b>	<b>13000</b>	<b>3100</b>
<b>Total Phosphorus</b>	mg/kg	<b>27000</b>	<b>70000</b>	<b>31000</b>	<b>79000</b>	<b>6900</b>	<b>18000</b>	<b>3200</b>	<b>5700</b>	<b>4300</b>	<b>7100</b>	<b>5500</b>	<b>5100</b>
<b>Olsen Phosphorus</b>	mg/kg	<b>1400</b>	<b>88</b>	<b>310</b>	<b>62</b>	<b>39</b>	<b>19</b>	<b>160</b>	<b>20</b>	<b>17</b>	<b>24</b>	<b>47</b>	<b>25</b>
<b>Total Potassium</b>	mg/kg	<b>6300</b>	<b>12000</b>	<b>6900</b>	<b>12000</b>	<b>3200</b>	<b>8400</b>	<b>12000</b>	<b>19000</b>	<b>870</b>	<b>2100</b>	<b>960</b>	<b>1500</b>
OESEXTRA / Sulfur	mg/kg	12000	6900	13000	6600	3800	3200	2400	2200	8300	5500	4600	3900
Total Sulfur	%	0.79	0.67	0.67	0.69	0.16	0.34	0.14	0.2	0.88	0.21	0.38	0.32
Total Calcium	mg/kg	42000	89000	55000	94000	13000	38000	18000	33000	5600	9500	6800	6800
Total Magnesium	mg/kg	6200	10000	8100	12000	3000	6900	5700	8600	1300	1800	2700	4600
Total Sodium	mg/kg	4300	8200	5200	8700	1100	3400	2700	5000	1400	890	1000	1600

# EC, pH, Total solids, Total volatile solids, Total organic carbon

	Units	Source 1		Source 2		Source 3		Source 4		Source 5		Source 6	
		Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar
Electrical Conductivity (EC)	uS/cm	4900	990	3200	670	1300	930	4200	7100	1400	850	870	980
pH	pH Units	7.5	11.2	8	10.2	7.3	11.2	8.1	11.6	4.9	9.2	5.3	7.3
Total Solids	% w/wet wt	76	100	81	100	83	100	92	100	93	100	88	100
Volatile Total Solids	%	58	23	55	14	71	18	41	5	26	8	16	4
Total organic carbon	% Carbon	35	32	34	31	40	57	20	24	14	3	9	5

## PFAS (µg/kg)

	Unit	Source 1		Source 2		Source 3		Source 4		Source 5		Source 6	
		Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar
PFHxS	ug/kg	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
PFOA	ug/kg	6.8	<2.5	5.3	<2.5	<2.5	<2.5	<2.5	<2.5	6.1	<2.5	26	<2.5
PFOS	ug/kg	23	<2.5	17	<2.5	4.5	<2.5	<2.5	<2.5	5.8	<2.5	19	<2.5
PFBA	ug/kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
SUM OF PFAS	ug/kg	58.1	<2.5	44.8	<2.5	4.5	<2.5	<2.5	<2.5	44.8	<2.5	114.3	<2.5

## Microplastics (Polymers - Particles Detected in the fraction < 500µm)

	Source 1		Source 2		Source 3		Source 4		Source 5		Source 6	
	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar
Polyethylene (PE)	20	1	49	2	4	0	8	0	24	0	5	0
Polypropylene (PP)	34	4	160	2	10	1	56	0	93	0	14	0
Polystyrene (PS)	0	0	10	0	1	2	4	0	7	0	2	0
Polyvinylchloride (PVC)	2	0	5	0	2	0	3	0	10	0	2	0
Polyethylene Terephthalate (PET)	14	10	33	1	9	2	7	2	17	2	58	2
Polycarbonate (PC)	1	1	5	0	0	0	0	3	0	1	0	4
Polymethylmethacrylate (PMMA)	34	0	30	0	1	0	27	0	19	0	3	0
Polymide (PA)	9	5	17	1	4	0	17	0	19	2	2	0
Polyurethane (PU)	148	1	812	0	22	0	257	0	1708	2	56	1
<b>SUM</b>	<b>262</b>	<b>22</b>	<b>1121</b>	<b>6</b>	<b>53</b>	<b>5</b>	<b>379</b>	<b>5</b>	<b>1897</b>	<b>7</b>	<b>142</b>	<b>7</b>

# PPCPs

## Pharmaceuticals and Personal Care Products (µg/kg)

	Source 1		Source 2		Source 3		Source 4		Source 5		Source 6	
	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar
Caffeine	13	<5	<5	<5	<5	<5	470	<5	10	<5	<5	<5
Carbamazepine	110	<5	34	<5	12	<5	<5	<5	16	<5	<5	<5
Cetrazine	30	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Ibuprofen	36	<5	<5	<5	<5	<5	<5	<5	<5	<5	6	<5
<b>Ketoprofen</b>	<b>&lt;5</b>	<b>&lt;5</b>	<b>&lt;5</b>	<b>&lt;5</b>	<b>&lt;5</b>	<b>&lt;5</b>	<b>&lt;5</b>	<b>&lt;5</b>	<b>&lt;5</b>	<b>&lt;5</b>	<b>5</b>	<b>51</b>
Trichlosan	26	<5	21	<5	<5	<5	<5	<5	100	<5	13	<5
Acetaminophen	12	<5	5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Citalopram	140	<5	40	<5	12	<5	<5	<5	45	<5	<5	<5
Doxylamine	18	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Fluoxetine	59	<5	15	<5	5	<5	<5	<5	37	<5	<5	<5
Lamotrigine	23	<5	6	<5	5	<5	<5	<5	<5	<5	<5	<5
Mirtazampine	84	<5	30	<5	12	<5	<5	<5	12	<5	<5	<5
N-DesmethylCitalopram	67	<5	20	<5	<5	<5	<5	<5	26	<5	<5	<5
Nicotine	<5	<5	<5	<5	5	<5	<5	<5	<5	<5	<5	<5
Octinoxate	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Octocrylene	270	<5	140	<5	<5	<5	<5	<5	630	<5	<5	<5
Oxybenzone	10	<5	<5	<5	5	<5	<5	<5	<5	<5	<5	<5
Paraben methyl	15	<5	<5	<5	<5	<5	9	<5	<5	<5	<5	<5
Paraxanthine	12	<5	<5	<5	<5	<5	13	<5	<5	<5	<5	<5
Progesterone	6	<5	<5	<5	9	<5	<5	<5	<5	<5	<5	<5
Sertraline	530	<5	140	<5	41	<5	<5	<5	200	<5	11	<5
Temazepam	16	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Tramadol	7	<5	<5	<5	<5	<5	<5	<5	6	<5	<5	<5
Triclocarban	7	<5	6	<5	<5	<5	<5	<5	640	<5	160	<5
Valsartan	29	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Venlafaxine	11	<5	<5	<5	<5	<5	<5	<5	19	<5	<5	<5
Metoprolol	<5	<5	<5	<5	<5	<5	<5	<5	8	<5	<5	<5

# Polynuclear Aromatic Hydrocarbon (PAH) (mg/kg)

	Unit	Source 1		Source 2		Source 3		Source 4		Source 5		Source 6	
		Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar
ACENAPHTHENE	mg/kg	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1
ACENAPHTHYLENE	mg/kg	<0.3	0.5	<0.3	0.8	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	0.2
ANTHRACENE	mg/kg	<0.3	<0.1	<0.3	0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1
BAP_TEQ_(HALF_LOR)	mg/kg	0.4	0.1	0.4	0.1	0.4	0.1	0.4	0.1	0.4	0.1	0.4	0.1
BAP_TEQ_(LOR)	mg/kg	0.7	0.2	0.7	0.2	0.7	0.2	0.7	0.2	0.7	0.2	0.7	0.2
BAP_TEQ_(ZERO)	mg/kg	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1
BENZ(A)ANTHRACENE	mg/kg	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1
BENZO(A)PYRENE	mg/kg	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1
BENZO(B)FLUORANTHENE	mg/kg	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1
BENZO(GHI)PERYLENE	mg/kg	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1
BENZO(K)FLUORANTHENE	mg/kg	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1
CHRYSENE	mg/kg	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1
DIBENZ(AH)ANTHRACENE	mg/kg	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1
FLUORANTHENE	mg/kg	<0.3	<0.1	<0.3	0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1
FLUORENE	mg/kg	<0.3	0.1	<0.3	0.2	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1
INDENO(123-CD)PYRENE	mg/kg	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1
<b>NAPHTHALENE</b>	mg/kg	<0.3	4.7	<0.3	5.7	<0.3	0.5	<0.3	1.2	<0.3	2	<0.3	3.5
PHENANTHRENE	mg/kg	<0.3	0.2	<0.3	0.6	<0.3	<0.1	<0.3	0.2	<0.3	0.2	<0.3	0.1
p-Terphenyl-d14-SURR	%	96	54	100	88	96	22	96	28	92	78	92	68
PYRENE	mg/kg	<0.3	<0.1	<0.3	0.2	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1	<0.3	<0.1
TOTAL PAHS	mg/kg	<0.3	5.5	<0.3	7.7	<0.3	0.5	<0.3	1.4	<0.3	2.2	<0.3	3.8

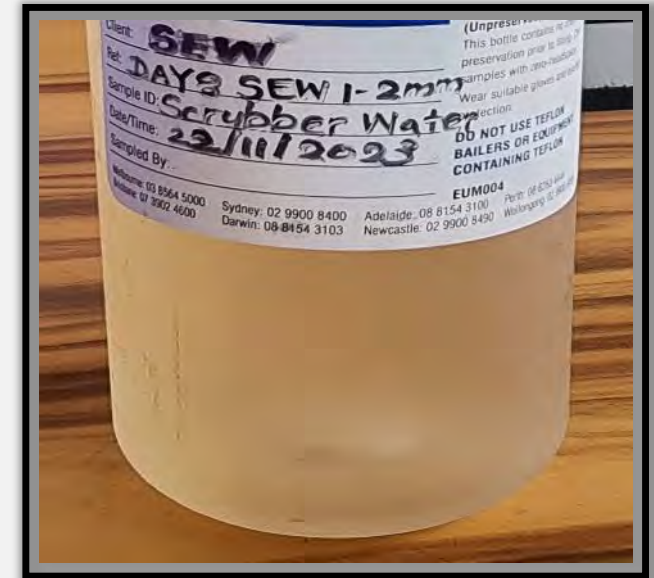
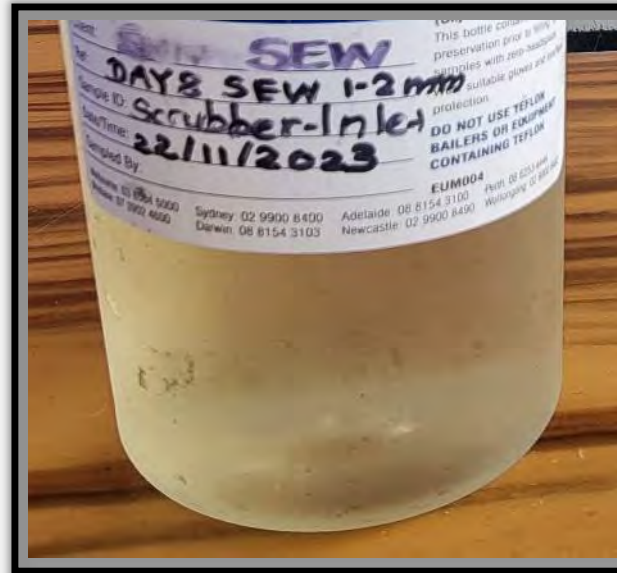
## Estrogens-Endocrine Disruptors (mg/kg)

	Source 1		Source 2		Source 3		Source 4		Source 5		Source 6	
	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar	Feedstock	Biochar
17a-Ethyl estradiol	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
17a-Estradiol	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
17b-Estradiol	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Estrone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Estriol	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Bisphenol A	20	<5	10	<5	<5	<5	11	<5	20	<5	32	<5
Mestranol	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Nonylphenol (tech)	36	<5	87	<5	20	<5	<5	<5	6700	<5	63	<5
tert-octyl phenol	<5	<5	<5	<5	<5	<5	<5	<5	32	<5	<5	<5

# Flue Gas Scrubber Water Results

PFAS below detection limits

PAHs, Phenols, Halides & Metals below acceptable trade wastewater limits



	Scrubber Water Inlet	Scrubber Water Outlet
PFAS Concentration (µg/L)	<0.05	<0.05

# Polynuclear Aromatic Hydrocarbon (PAH) (mg/L)

	Source 1	Source 2	Source 3	Acceptable trade wastewater limits	
				SEW	GWW
Acenaphthene	<0.001	<0.001	<0.001	-	-
Acenaphthylene	<0.001	<0.001	0.015	0.016	0.016
Anthracene	<0.001	<0.001	<0.001	-	-
Benzo[a] anthracene	<0.001	<0.001	0.001	-	-
Benzo[b] fluoranthene	<0.001	<0.001	0.001	-	-
Benzo[k] fluoranthene	<0.001	<0.001	0.001	-	-
Benzo[ghi] perylene	<0.001	<0.001	0.021	-	-
Benzo[a] pyrene	<0.001	<0.001	0.005	-	-
Chrysene	<0.001	<0.001	<0.001	-	-
Dibenz[a,h]anthracene	<0.001	<0.001	<0.001	-	-
Fluoranthene	<0.001	<0.001	0.013	-	-
Fluorene	<0.001	<0.001	0.001	-	-
Indeno[1,2,3-cd]pyrene	<0.001	<0.001	0.004	-	-
Naphthalene	<0.001	<0.001	0.016	1.3	1.3
Phenanthrene	<0.001	<0.001	0.009	-	-
Pyrene	<0.001	<0.001	0.033	-	-
7,12-Dimethylbenz[a]anthracene	<0.001	<0.001	<0.001	-	-
3-Methylcholanthrene	<0.001	<0.001	<0.001	-	-
<b>Sum PAHs</b>			<b>0.12</b>		

# Phenol (mg/L)

ANALYTE	Source 1	Source 2	Source 3	Acceptable trade wastewater limits	
				GWW	SEW
1-(1H-pyrrol-2-yl)-Ethanone	<0.001	<0.001	<0.001	-	-
1-methyl-2,5-pyrrolidinedione	<0.001	<0.001	<0.001	-	-
4-Methyl-1H-Benzotriazole	<0.001	<0.001	<0.001	-	-
3-hydroxy Benzonitrile	<0.001	<0.001	<0.001	-	-
o-Cyanobenzoic acid	<0.001	<0.001	<0.001	-	-
2(1H)-Quinolone	<0.001	<0.001	<0.001	-	-
1-Naphthanol,2-amino-	<0.001	<0.001	<0.001	-	-
9H-Pyrido [3,4-B] indole	<0.001	<0.001	<0.001	-	-
<b>LA-13 Phenols</b>					
phenol	<0.001	<0.001	<0.001	-	-
o-cresol	<0.001	<0.001	<0.001	-	-
m-cresol	<0.001	<0.001	<0.001	-	-
p-cresol (4-methyl phenol)	<0.001	<0.001	<0.001	-	-
2-chlorophenol	<0.001	<0.001	<0.001	-	-
2,4-dichlorophenol	<0.001	<0.001	<0.001	-	-
2,6-dichlorophenol	<0.001	<0.001	<0.001	-	-
2,4,6-trichlorophenol	<0.001	<0.001	<0.001	-	-
2,3,4,5-tetrachlorophenol	<0.001	<0.001	<0.001	-	-
pentachlorophenol	<0.001	<0.001	<0.001	-	-
4-chloro-3-methylphenol	<0.001	<0.001	<0.001	-	-
2,4-dimethylphenol	<0.001	<0.001	<0.001	-	-
2-methyl-4,6-dinitrophenol	<0.001	<0.001	<0.001	-	-
2-nitrophenol	<0.001	<0.001	<0.001	-	-
4-nitrophenol	<0.001	<0.001	<0.001	-	-
2,4-dinitrophenol	<0.001	<0.001	<0.001	-	-
hexachlorophene	<0.001	<0.001	<0.001	-	-
dinoseb (DNBP)	<0.001	<0.001	<0.001	-	-
3-Chlorophenol	<0.001	<0.001	<0.001	-	-
4-Chlorophenol	<0.001	<0.001	<0.001	-	-
2,4,5-Trichlorophenol	<0.001	<0.001	<0.001	-	-
2,3,4,6-Tetrachlorophenol	<0.001	<0.001	<0.001	-	-
<b>Total Phenols</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	1	300

## Halides (mg/L)

	Source 1	Source 2	Source 3	Acceptable trade wastewater limits	
				SEW	GWW
pH	7-8			7-8	6-9
Fluoride	1.2	1.6	1.2	30	30
Chloride	75	96	67	N.P	200
Sulphate	240	270	110	N.P	N.P

# Metals (mg/L)

ANALYTE	Source 1	Source 2	Source 3	Acceptable trade wastewater limits	
				SEW	GWG
<b>LA-38 Metals by ICP-MS</b>					
Aluminium (Al)	9.40	29	86	N.P	100
Antimony (Sb)	<2	<2	2	N.P	N.P
Arsenic (As)	0.01	0.011	0.018	1	1
Barium (Ba)	0.032	0.095	0.380	150	5
Beryllium (Be)	<0.5	<0.5	<0.5	30	30
Boron (B)	0.130	0.170	0.210	25	5
Cadmium (Cd)	0.017	0.021	0.011	2	2
Chromium (Cr)	0.08	0.08	0.038	10	3
Cobalt (Co)	2	2	6	10	5
Copper (Cu)	0.120	0.370	0.410	10	5
Iron (Fe)	1.6	3	12	100	10
Lead (Pb)	0.034	0.020	0.140	10	1
Manganese (Mn)	0.090	0.170	0.350	10	10
Mercury (Hg)	0.006	0.001	<0.0005*	1	0.005
Molybdenum (Mo)	0.060	0.041	0.030	10	5
Nickel (Ni)	0.019	0.015	0.060	10	1
Selenium (Se)	0.014	0.020	0.009	10	0.4
Silver (Ag)	0.001	0.002	0.005	5	1
Strontium (Sr)	0.059	0.094	0.940	N.P	N.P
Thallium (Tl)	<0.001	<0.001	<0.001	20	20
Tin (Sn)	0.0014	0.016	0.063	10	5
Titanium (Ti)	0.079	0.270	1.3	N.P	N.P
Vanadium (V)	0.0068	0.0092	0.13	N.P	N.P
Zinc (Zn)	0.17	0.32	0.39	10	1

# Flue Gas Emissions Results

Uncertainty ~+/-28%

Evidence of destruction in Pyroco and below detection limits in flue gases

60 minutes: PFAS Compounds (ng/Nm <sup>3</sup> )			
PFAS Compounds	PYROCO exit	Thermal oxidizer exit	Scrubber exit
Sum (PFHxS + PFOS)	<3.2	<19	<19
Sum of PFASs (n=28)	<32	<40	<29
Sum of US EPA PFAS (PFOS + PFOA)	6.4	<19	<19



# PYROCO Pyrolysis of Biosolids to Biochar

## Pilot Scale Summary

- ✓ PFAS levels were below detection limit in biochar and scrubber water.
- ✓ Gas-phase PFAS in stack emissions and thermal oxidizer exit was below detection limit.
- ✓ Evidence of PFAS destruction in Pyroco reaction which can be optimised



- Improve sampling and flow rates at next pilot trials
- Pilot trials with biosolids with higher PFAS concentration
- Non-targeted PFAS analysis
- Lab-scale spiked PFAS experiments for total fluorine balance



# Conclusion

Our novel pyrolysis technology has huge potential to provide Plan B option for biosolids management in Australia and is likely to enable a circular economy by turning biosolids into a commercial biochar product of value.