THERMAL DESORPTION TREATMENT OF PFAS AND GALAXOLIDE FROM BIOSOLIDS

Qi Bi, *Project and Innovation Engineer,* Veolia
Tai Truong, *Facility Manager at Earthsure,* Ventia
Glen Stewart, *Operations Manager at Ballarat North Water Reclamation Plant,* Veolia
John Lucas, *Head of DePollution,* Veolia

ABSTRACT

Biosolids contaminated with PFAS and emerging contaminants like galaxolide face increasing regulation under Australia's NEMP 3.0. This study evaluated thermal desorption technology for treating PFAS and galaxolide in biosolids at the Earthsure facility in Dandenong, Victoria.

Approximately 15 tonnes of thermally dried biosolids from Central Highlands Water's Ballarat North Water Reclamation Plant were blended with PFAS contaminated soil and processed through a direct fired thermal desorption unit operating at gas treatment temperatures exceeding 930°C. The demonstration trial, conducted in October 2025, aimed to validate treatment effectiveness for achieving EPA Victoria Fill Material classification standards.

Thermal desorption treatment achieved successful treatment of PFAS (including short-chain (C4-C8), medium-chain, and long-chain (C9-C16) perfluoroalkyl carboxylic acids and sulfonic acids, fluorotelomer sulfonates, sulfonamides), and galaxolide, reducing concentrations to below detection limits across all samples. The treated material met EPA Victoria Fill Material classification criteria, validating thermal desorption as a scalable solution for biosolids management. With processing capacity up to 100,000 tonnes contaminated soil annually, this technology has the potential to provide a viable pathway for the Victorian water industry to address NEMP 3.0 requirements while preserving beneficial reuse options and supporting circular economy objectives.

1.0 INTRODUCTION

Australia produces approximately 300,000 tons of dry biosolids annually, which have been beneficially used in agriculture and landscaping since the early 1990s (DCCEEW 2021; NSW Department of Primary Industries 2009). However, contamination with per- and polyfluoroalkyl substances (PFAS) and galaxolide, a synthetic musk fragrance widely used in consumer products, presents significant management challenges (NSW EPA 2016). The PFAS National Environmental Management Plan 3.0 (NEMP 3.0), released in March 2025, mandates that approximately 60% of biosolids will require treatment to meet new regulatory standards for beneficial use applications (HEPA 2025).

Following technical evaluation of multiple technologies (pyrolysis, gasification, incineration, supercritical water oxidation), Veolia identified thermal desorption as one of the feasible treatment options. While the Earthsure facility has successfully treated PFAS contaminated soil commercially, PFAS distribution differs significantly between soils (surface bound) and biosolids (homogeneously distributed), necessitating dedicated validation trials. This trial, conducted with Central Highlands Water biosolids generated at Ballarat North Water Reclamation Plant, aims to validate thermal desorption effectiveness for achieving EPA Victoria Fill Material acceptance levels and establish fundamental understanding of galaxolide treatment mechanisms.

2.0 METHODOLOGY

2.1 Trial Scope

This trial evaluated thermal desorption effectiveness for treating PFAS and galaxolide in biosolids. The scope included:

- Assessment of PFAS destruction through sampling and analysis of feed material and treated output
- Analysis of galaxolide levels in feed material and treated output
- Evaluation of treated residue characteristics for potential beneficial use applications

2.2 Materials and Trial Setup

Approximately 15 tonnes of thermally dried biosolids (95% dryness) were sourced from Central Highlands Water's Ballarat North Water Reclamation Plant and transported to the Earthsure facility in Dandenong, Vic under an existing trial permit. The trial was conducted on 22 October 2025.

Biosolids were blended with PFAS contaminated soils to facilitate processing through the thermal desorption system.

2.3 Thermal Desorption Process

The Earthsure thermal desorption unit utilises direct heated thermal technology to volatilise and separate contaminants.

Key specifications include:

- Processing capacity: 12 tonnes per hour
- Operating temperature: 450 °C at the thermal desorption drum, > 930°C at the oxidation chamber.
- Integrated thermal oxidiser and air pollution control system
- Real time monitoring of temperature, residence time, and emissions

2.4 Sampling and Analysis

Samples were collected at two critical points:

- Feed material (input biosolids & soil blend)
- Product material (treated output)

At each sampling point, the following samples were collected:

- 11 sample (including 1 duplicate sample) analysed by ALS (NATA accredited) for EPA Victoria Waste Classification Guidance 1828.3 suite (including PFAS) and galaxolide
- One sample for galaxolide analysis by Envirolab (NATA accredited)

Sampling Frequency and Protocol:
A set of 1 feed and 1 treated sample was collected per hour. The treated material was sampled 20 minutes after feed sampling to account for processing time. Duplicate and split samples (galaxolide QC samples) were collected at the same time as the primary sample to ensure quality control and verification.

3.0 RESULTS AND DISCUSSION

3.1 PFAS Treatment

The feed material (biosolids blended with contaminated soil) contained detectable levels of multiple PFAS compounds across 11 samples. The trial FPAS data of the feed material and the treated products are summarised in the table below.

Table 1: ***PFAS Treatment Performance - Feed Material vs Treated Product (n=11 samples)***

PFAS Compound	Feed Material Range (mg/kg)	Feed Material Mean (mg/kg)	Treated Product (mg/kg)	LOR (mg/kg)	Destruction Efficiency	Fill Material (EPA VIC 1828.3) (mg/kg)	VIC EPA Cat D Waste limit (mg/kg)
Total PFAS	0.129 - 0.196	0.165	<0.0002	0.0002	>99.88%	-	-
PFOS	0.0842 - - 0.128	0.109	<0.0002	0.0002	>99.82%	0.002	-
PFHxS	0.0043 - 0.006	0.0051	<0.0002	0.0002	>96.08%	0.001	-
Sum of PFHxS + PFOS	0.0885 - 0.134	0.114	<0.0002	0.0002	>99.82%	-	1
6:2 FTS	0.0134 - 0.0206	0.0177	<0.0005	0.0005	>97.18%	-	-
PFOA	0.0055 - 0.0095	0.0075	<0.0002	0.0002	>97.33%	0.001	10
PFBS, PFPeS, PFHpS	0.0023 - 0.0037	0.003	<0.0002	0.0002	>93.33%	-	-
PFPeA, PFHxA, PFHpA	0.0043 - 0.0069	0.005	<0.0002	0.0002	>96%	-	-
Long-chain PFAS (C9-C16)	0.0004 - 0.0014	0.0009	<0.0002	0.0002*	>77.78%	-	-
Most sulfonamides	0.0124 - 0.0237	0.0176	<0.0002	0.0002**	>98.86	-	-

*LOR for PFTeDA is 0.0005 mg/kg
**LOR for MeFOSA, EtFOSA, MeFOSE, EtFOSE is 0.0005 mg/kg

The feed material had moderate levels of PFAS contamination with total PFAS concentrations ranging from 0.129 to 0.196 mg/kg (mean: 0.165 mg/kg). PFOS was the dominant contaminant (mean: 0.109 mg/kg), followed by 6:2 FTS (mean: 0.0177 mg/kg) and PFOA (mean: 0.0075mg/kg). The presence of multiple short chain compounds (PFBS, PFPeS, PFHpS, PFPeA, PFHxA, PFHpA) alongside other PFAS compounds indicated a diverse contamination profile typical of biosolids from wastewater treatment processes.

The thermal desorption process demonstrated successful performance, achieving >99.88% destruction efficiency for total PFAS. All 40 PFAS analytes tested were reduced from measurable concentrations to below their respective limits of reporting across all 11 treated samples. This represents the treatment of PFAS, including the most persistent and environmentally significant compounds (PFOS, PFHxS, PFOA). The consistent treatment

outcomes despite feed concentration variations (Total PFAS: 0.129 -0.196 mg/kg) demonstrate process robustness and reliability.

The feed material significantly exceeded NEMP 3.0 thresholds, with PFHxS + PFOS at 0.114 mg/kg (>100 times of the unrestricted reuse threshold of 1.1 µg/kg and >3.5 times of the restricted use threshold of 31 µg/kg) and PFOA at 0.0075 mg/kg (2.5 times of the unrestricted threshold of 3 µg/kg). The thermal treatment successfully reduced PFAS concentrations to below detection limits (<0.2 µg/kg), well below both unrestricted and restricted reuse thresholds, enabling beneficial reuse pathways that would otherwise be prohibited.

The analytical results confirm successful thermal treatment, with the treated material classified as Fill Material according to EPA Victoria Waste Classification Guidance 1828.3, meeting the trial's primary objective of achieving regulatory acceptance levels and converting previously restricted material into material suitable for unrestricted beneficial reuse.

3.2 Galaxolide Treatment

The trial galaxolide data of the feed material and the treated products are summarised in the table below.

Table 2: ***Galaxolide Treatment Performance - Feed Material vs Treated Product***

Sample Type	Number of Samples	Feed Material Concentration	Treated Product Concentration	LOR
Primary Analysis ALS	10	Range: <1.0 to 1.1 mg/kg Detectable: 1.0, 1.0, 1.0, 1.1 mg/kg (n=4) Below detection: <1.0 mg/kg (n=6)	All samples <0.5 mg/kg	Feed: 1.0 mg/kg Product: 0.5 mg/kg
QC Sample Envirolab (NATA accredited)	1	0.28 mg/kg	<0.1 mg/kg	Feed: 0.1 mg/kg Product: 0.1 mg/kg

Galaxolide was present in the feed material at low to moderate concentrations. ALS analysis detected galaxolide in 4 of 10 samples (1.0-1.1 mg/kg), with 6 samples below the 1.0 mg/kg detection limit. The NATA accredited Envirolab QC sample, utilising a lower detection limit (0.1 mg/kg), confirmed galaxolide presence at 0.28 mg/kg, below the ALS reporting threshold.

Thermal desorption treatment achieved successful treatment of galaxolide across all samples. All ALS analysed treated samples showed concentrations below 0.5 mg/kg, while the NATA accredited Envirolab analysis confirmed treatment to below 0.1 mg/kg. Based on the most sensitive analysis, this represents a reduction from 0.28 mg/kg to <0.1 mg/kg, demonstrating >64% confirmed destruction efficiency, with actual efficiency likely higher given that results are below analytical detection limits. The consistent achievement of below detection results across all treated samples, regardless of feed concentration variability, confirms the robustness of thermal desorption for treating this persistent synthetic musk compound.

3.3 Heavy Metal Contamination

The following table summarises the thermal desorption treatment results for feed materials and

treated materials against VIC EPA 1828.3 fill material limits:

Table 3: ***Heavy Metal Treatment Performance - Feed Material vs Treated Product***

Parameter	Feed Material Range (mg/kg)	Feed Mean (mg/kg)	Treated Material Range (mg/kg)	Treated Mean (mg/kg)	Fill Material (EPA VIC 1828.3) Limit (mg/kg)	VIC EPA Cat D Waste limit (mg/kg)
Arsenic	<5 - 10	5.5	<5 - 8	6.2	20	500
Cadmium	<1 - 1	<1	<1 - 1	<1	3	100
Copper	43 - 62	53.5	36 - 101	53.8	100	5000
Lead	23 - 32	27.1	19 - 30	24.7	300	1500
Molybdenum	<2	<2	<2	<2	40	1000
Nickel	18 - 20	19.3	18 - 24	21.5	60	3000
Tin	<5 - 6	~5	<5 - 8	~5	50	-
Selenium	<5	<5	<5	<5	10	10000
Silver	<2	<2	<2	<2	10	180
Zinc	68 - 96	84.5	61 - 150	85.5	200	35000
Antimony	<5	<5	<5	<5	-	-
Barium	60 - 90	65.5	60 - 90	69.1	-	-
Beryllium	<1	<1	<1	<1	-	-
Boron	<50	<50	<50	<50	-	-

Thermal desorption is designed to remove volatile and semi volatile organic contaminants and is not effective for reducing heavy metal concentrations. The test results show 90% compliance (9/10 VIC EPA regulated parameters) for treated materials, with one marginal copper exceedance in sample DC-08 (101 mg/kg vs 100 mg/kg limit). However, heavy metals remain at similar or elevated levels:

- Copper: Mean stable at 53.5-53.8 mg/kg, but maximum increased 63% (62 to 101 mg/kg)
- Zinc: Mean stable at 84.5-85.5 mg/kg, but maximum increased 56% (96 to 150 mg/kg)
- Nickel: Mean increased 11% (19.3 to 21.5 mg/kg), maximum increased 20% (20 to 24 mg/kg)

The thermal treatment process causes volume reduction through moisture removal and organic matter combustion, resulting in a concentration effect where heavy metals become more concentrated in the remaining solid matrix. This concentration effect is clearly demonstrated by the expanded ranges and elevated maximum values in treated materials.

The trial used a blending of biosolids and contaminated soils. If biosolids were treated alone without blending, accounting for typical 20-30% volume reduction during thermal desorption, the estimated treated biosolids would potentially exceed VIC EPA fill material limits for heavy metals. This makes treated biosolids unsuitable for beneficial reuse as fill material.

4.0 CONCLUSION

This trial successfully validated thermal desorption as an effective, scalable solution for treating PFAS and galaxolide contamination in biosolids. The technology reduced contaminants to below detection limits, enabling treated material to meet EPA Victoria Fill Material standards and NEMP 3.0 requirements. With a commercial processing capacity of 12 tonnes of feed materials per hour, the technology demonstrates robust performance across both regulated PFAS and

emerging contaminants, future-proofing biosolids management against evolving regulations. However, thermal desorption concentrates heavy metals through volume reduction and requires blending for materials with elevated metals intended for beneficial reuse. Overall, this proven technology provides Veolia and the water industry with a compliant, sustainable pathway for biosolids management that preserves beneficial reuse value and supports circular economy objectives.

5.0 ACKNOWLEDGEMENTS

The project team gratefully acknowledges Central Highlands Water for their support and collaboration throughout this trial. Special thanks to Ballarat North Water Reclamation Plant for providing the biosolids materials and funding that made this trial possible.

6.0 REFERENCES

DCCEEW Biosolids snapshot Tuesday 3 October 2021 www.dcceew.gov.au

HEPA PFAS National Environmental Management Plan Version 3.0 Tuesday 4 March 2025 www.dcceew.gov.au

NSW Department of Primary Industries Use of biosolids in agriculture Wednesday 1 April 2009 www.dpi.nsw.gov.au

NSW EPA Use and Disposal of Biosolids Products: Review of Contaminants Wednesday 12 October 2016 hdp-au-prod-app-nswepa-yoursay-files.s3.ap-southeast-2.amazonaws.com

DISCLAIMERS