# Debris balls characteristics, composition and likely source

## Background and summary

The EPA is investigating the potential source of debris balls found on beaches in Sydney and the NSW South Coast from October 2024 to January 2025. This has included sampling and analysis of the debris balls to investigate their physical characteristics and composition and inspections of Sydney's major wastewater (sewage) treatment plants and visiting cruise ships to examine the wastewater treatment systems and collect samples for comparison.

The debris balls included a mix of hair, waste cooking oil, faecal material and hydrocarbons, indicating that a land-based sewage treatment system receiving a mix of grey water, blackwater and trade waste is the most likely source. In contrast, the separate waste management systems used on cruise ships mean they are unlikely to be the source.

Similar beach debris ball incidents elsewhere have also been linked to land-based sewage treatment systems, including in Victoria and overseas in Bermuda.

Based on these multiple lines of evidence, on the balance of probability Sydney's sewage treatment system is the most likely source of the debris balls.

## Sampling and analysis

Debris balls were sampled at beaches around Sydney and two South Coast beaches over five events from October 2024 to January 2025 (Analytes included:

- faecal indicator bacteria
- fatty acids and lipids
- total recoverable hydrocarbons
- nutrients
- metals.

Samples were also analysed using quantitative polymerase chain reaction (qPCR) methods to sequence the DNA and test for microbial source tracking markers.

Table *1*). Several of Sydney's wastewater treatment plants (WWTP's) and visiting cruise ships were subsequently sampled for comparison (Analytes included:

- faecal indicator bacteria
- fatty acids and lipids
- total recoverable hydrocarbons
- nutrients
- metals.

Samples were also analysed using quantitative polymerase chain reaction (qPCR) methods to sequence the DNA and test for microbial source tracking markers.

Table *1*). A regional council also provided samples of similar debris balls removed from the primary screens of one of their WWTPs.

Samples were analysed for a range of analytes to characterise and compare the composition of the debris balls and possible source samples. Analytes included:

- faecal indicator bacteria
- fatty acids and lipids
- total recoverable hydrocarbons
- nutrients
- metals.

Samples were also analysed using quantitative polymerase chain reaction (qPCR) methods to sequence the DNA and test for microbial source tracking markers.

Table 1. Summary of sample types and locations

| Debris ball event | Event date | Sample type | Sampling location | Sample code |
|---|---|---|---|---|
| 1 | Oct 2024 | Beach debris ball | Coogee Beach | CB DB 1 |
| 1 | Oct 2024 | Beach debris ball | Coogee Beach | CB DB 2 |
| 1 | Oct 2024 | Beach debris ball | Congwong Beach | CWB DB |
| 2 | Nov 2024 | Beach debris ball | Bombo Beach | Bombo DB |
| 3 | Dec 2024 | Beach debris ball | Silver Beach | SB DB 1 |
| 3 | Dec 2024 | Beach debris ball | Silver Beach | SB DB 3 |
| 3 | Dec 2024 | Beach debris ball | Silver Beach | SB DB 4 |
| 3 | Dec 2024 | Beach debris ball | Silver Beach | SB DB 5 |
| 3 | Dec 2024 | Beach debris ball | Silver Beach | SB DB 6 |
| 3 | Dec 2024 | Beach debris ball | Silver Beach | SB DB 6 |
| 4 | Dec 2024 | Beach debris ball | 1080 Beach | 10B DB 1 |
| 5 | Jan 2025 | Beach debris ball | Bondi Beach | Bondi DB |
| 5 | Jan 2025 | Beach debris ball | Maroubra Beach | MRB DB 1 |
| 5 | Jan 2025 | Beach debris ball | Maroubra Beach | MRB DB 2 |
| 5 | Jan 2025 | Beach debris ball | Manly Beach | MNB DB |
| 5 | Jan 2025 | Beach debris ball | Dee Why Beach | DWB DB 1 |
| 5 | Jan 2025 | Beach debris ball | Dee Why Beach | DWB DB 2 |
| 5 | Jan 2025 | Beach debris ball | Dee Why Beach | DWB DB 3 |
| 5 | Jan 2025 | Beach debris ball | Palm Beach | PB DB |
| 5 | Jan 2025 | Beach debris ball | Malabar Beach | MLB DB 1 |
| n/a | n/a | WWTP debris ball | Regional WWTP | RWWTP DB |
| n/a | n/a | Sed tank scum - top phase | Malabar WWTP | Mal WWTP 1 |
| n/a | n/a | Sed tank scum - bottom phase | Malabar WWTP | Mal WWTP 2 |
| n/a | n/a | Sed tank scum - top phase | Bondi WWTP | Bon WWTP |
| n/a | n/a | Sed tank scum - top phase | Cronulla WWTP | Cro WWTP |
| n/a | n/a | Sed tank scum - top phase | Warriewood WWTP | War WWTP |
| n/a | n/a | Sed tank scum - top phase | North Head WWTP | NH WWTP |
| n/a | n/a | Oily bilge water separator - solid | Cruise ship 1 | CS1 O/W Sep |
| n/a | n/a | Oily bilge sludge | Cruise ship 1 | CS1 Bilge Sludge |
| n/a | n/a | Waste cook oil liquids | Cruise ship 1 | CS1 Cook Oil Liquid |
| n/a | n/a | Waste cook oil solids | Cruise ship 1 | CS1 Cook Oil Solids |
| n/a | n/a | Waste cook oil liquids | Cruise ship 2 | CS2 Cook Oil Liquid |
| n/a | n/a | Food waste biodigester | Cruise ship 2 | CS2 Food Waste |

## Debris ball composition

In summary the faecal indicator bacteria, fatty acids and hydrocarbon content of the debris balls are consistent with a land-based mixed sewage source. The fibrous and oily/fatty nature of the debris balls and the presence of hair, litter and other debris is also typical of fat, oil and grease deposits (fatbergs) found in sewer systems. The beach debris balls were also similar in appearance to the debris balls found in the pre-screen at the regional WWTP.

### Faecal indicators and microbial source tracking

Several beach debris ball samples were analysed for faecal indicator bacteria (*Escherichia coli*, enterococci and faecal coliforms), with these indicator bacteria being detected in all samples. This indicates that the debris balls had been in contact with and/or contained faeces, consistent with having originated from sewage treatment systems.

Debris ball, WWTP and cruise ship samples were also sent to the CSIRO for genetic sequencing using quantitative polymerase chain reaction (qPCR) methods to test for four microbial source tracking markers:

- Bacteroides HF183: Highly abundant in untreated sewage and absent in animal faecal samples, indicative of recent faecal contamination.
- Bac-V6-21: A Bacteroides sewer pipe (urban infrastructure) marker found in urban sewer infrastructure and considered unlikely to be present in wastewater from cruise ships.
- CrAssphage: A sewage-associated viral marker that is highly abundant in sewage and absent in animal faecal samples.
- GFD: A marker of avian faeces.

All three sewage-associated markers were detected in all debris ball samples, indicating that they most likely originate from a sewage source.

The avian marker was detected in some debris ball and WWTP samples, but generally at much lower levels than the sewage markers. This indicates that avian faecal contamination is not a major contributor to the debris ball composition and sewage remains the most likely primary source.

Bac-V6-21 was detected in all samples, indicating that the marker was not specific to urban sewage infrastructure and could not be used to differentiate between vessel- and land-based sewage sources.

### Fatty acids

All the debris ball samples contained substantial concentrations of fatty acids, ranging from 9% to 37% weight per weight (w/w) (Figure 1). These fatty acids likely originate from waste fats and oils draining from kitchens to sewers.

Palmitic acid was the dominant fatty acid in the beach debris balls (Figure 2) consistent with the composition of fat, oil and grease (FOG) deposits and balls that accumulate in sewerage systems (Keener et al., 2008; Rizkianto et al., 2024; Williams et al., 2012).

Palmitic acid also comprised a substantial proportion of the fatty acids in the regional WWTP debris balls and Sydney WWTP samples, but proportions of longer chain fatty acids such as oleic acid and linoleic acid were generally higher than in the beach debris balls (Figure 2).

The cruise ship waste cooking oil and food waste samples generally had higher proportions of oleic acid and/or linoleic acid than palmitic acid (Figure 2).

The greater predominance of palmitic acid in the beach debris balls likely relates to processes of FOG deposit formation and aging and weathering in sewerage systems and the environment, with higher ratios of palmitic to oleic acid promoting the accumulation of deposits (Yusuf et al, 2023) and this ratio increasing with distance and time from source (Williams et al., 2012).

In this context:

- the cruise ship waste oil fatty acid profiles are likely reflective of waste fats and oils from kitchens (vessel or land based) before aging and weathering
- the WWTP fatty acid profiles are likely reflective of material that has undergone some aging and transformation in the sewerage system

- the debris ball fatty acid profiles are consistent with further aging and weathering of fats and oils from the sewage treatment system after release to the marine environment.

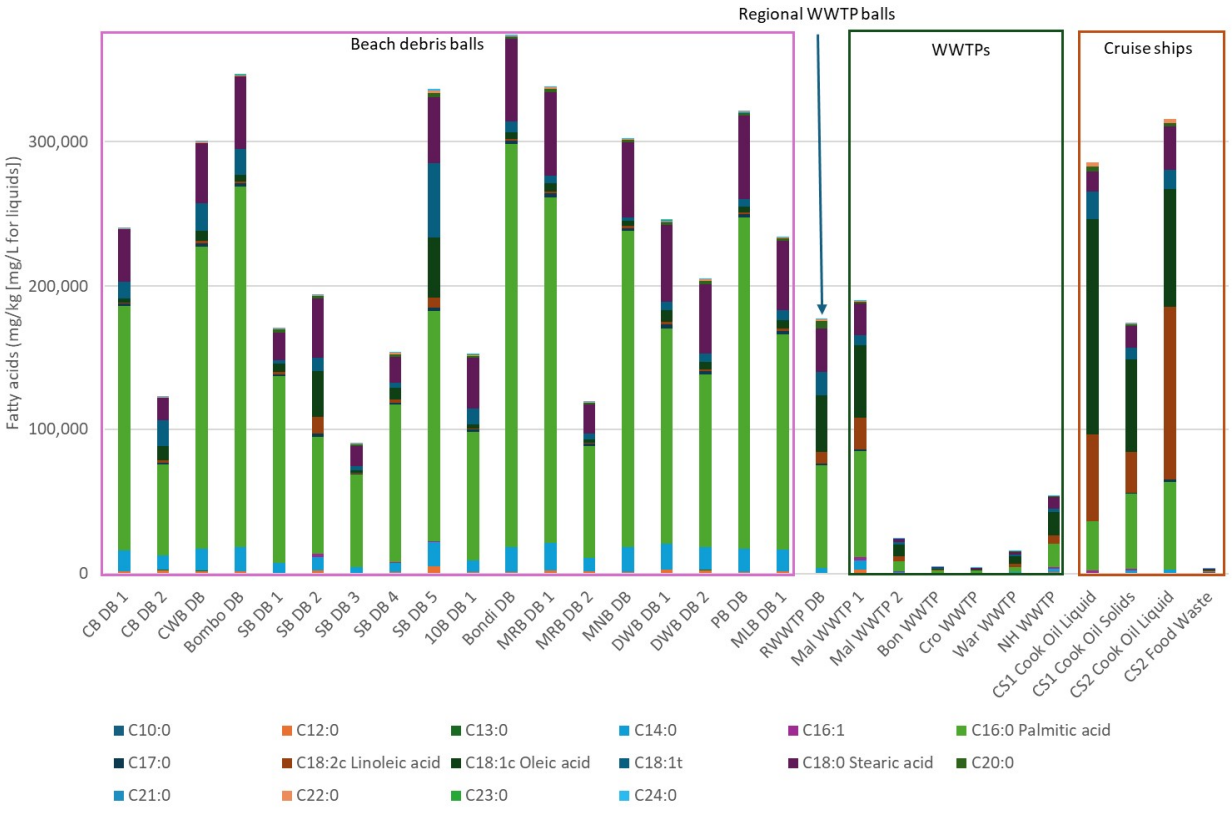


*Figure 1. Fatty acids concentrations*

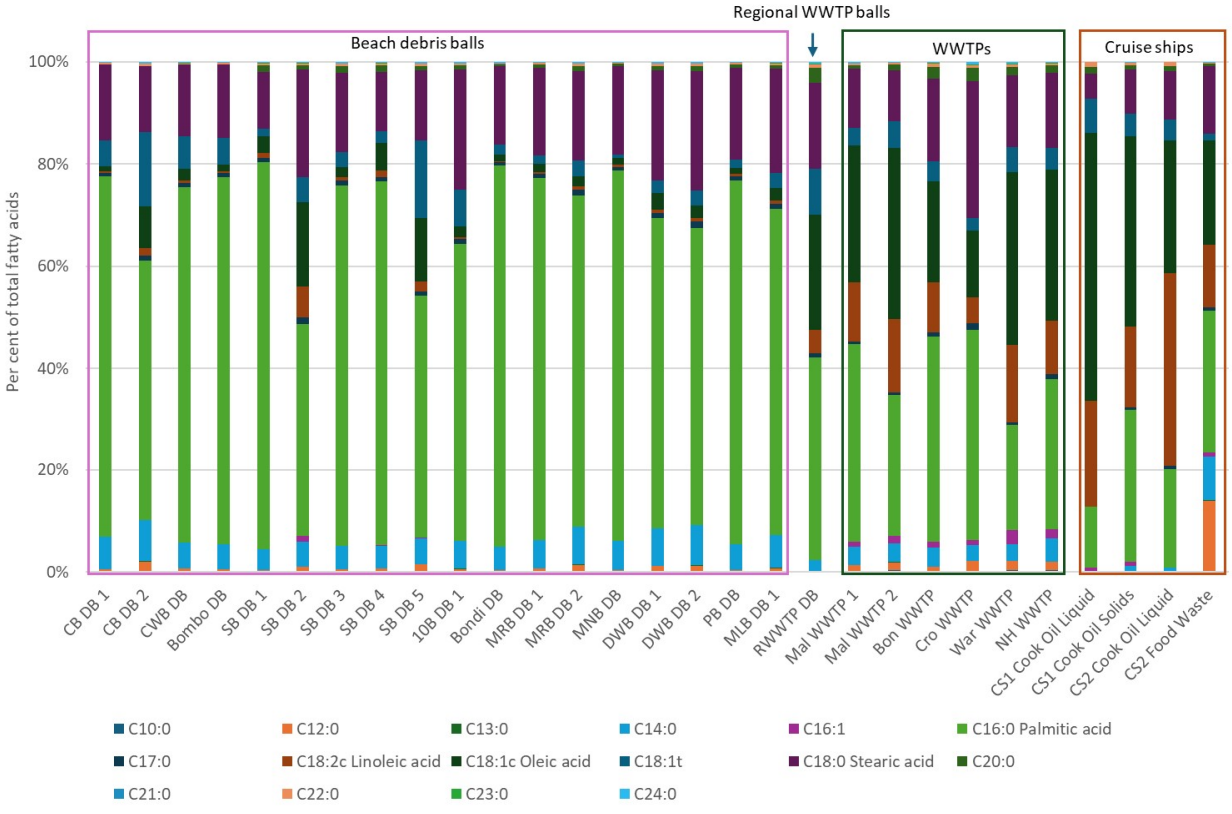


*Figure 2. Fatty acids profiles*

## Lipids

Beach debris ball, WWTP and cruise ship samples were also sent to the CSIRO for lipids (fatty compounds) analysis. The CSIRO carried out a range of statistical analyses on the lipids results. These analyses show similar patterns to the fatty acids results above, with the beach debris ball samples generally grouping separately from the wastewater treatment plant and cruise ship samples.

The principal component analysis also groups the Bondi WWTP (R-250353) and the regional WWTP debris ball (T-250357) samples with the beach debris ball samples, indicating similarities in the lipids composition (Figure 3).

The dendrogram plot groups samples based on relative similarities of the lipids profiles, with the horizontal distance between each pair of samples and their joining node representing the relative difference compared to other sample pairs (Figure 4). Beach debris ball samples are grouped within the same branch as the regional WWTP debris ball sample (T-250357) in the dendrogram (Figure 4). The other WWTP and cruise ship waste cooking oil and sewage samples are grouped on a separate branch, including the Bondi WWTP sample (Figure 4). This indicates that the lipids profiles of the beach debris balls were most similar to that of the regional WWTP debris ball sample. This could potentially reflect the more solid nature of the regional WWTP debris ball sample compared to the other WWTP and cruise ship samples.

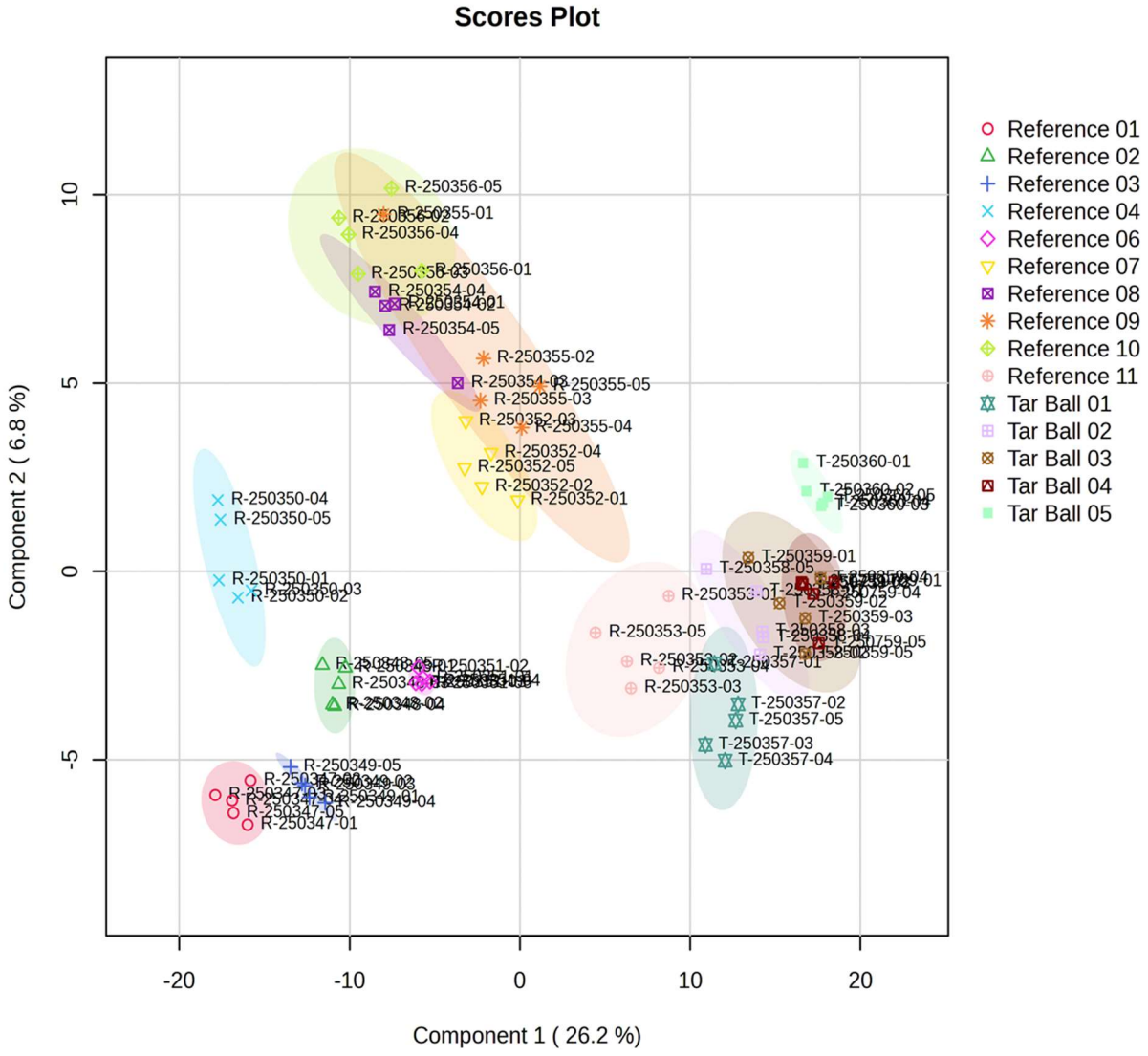


*Figure 3. Principal component analysis of the lipids profile results (prepared by CSIRO).*

Note: Sample codes starting with “R” indicate WWTP and cruise ship samples. Sample codes starting with “T” indicate beach debris ball samples, except T-250357 which was the regional WWTP debris ball.

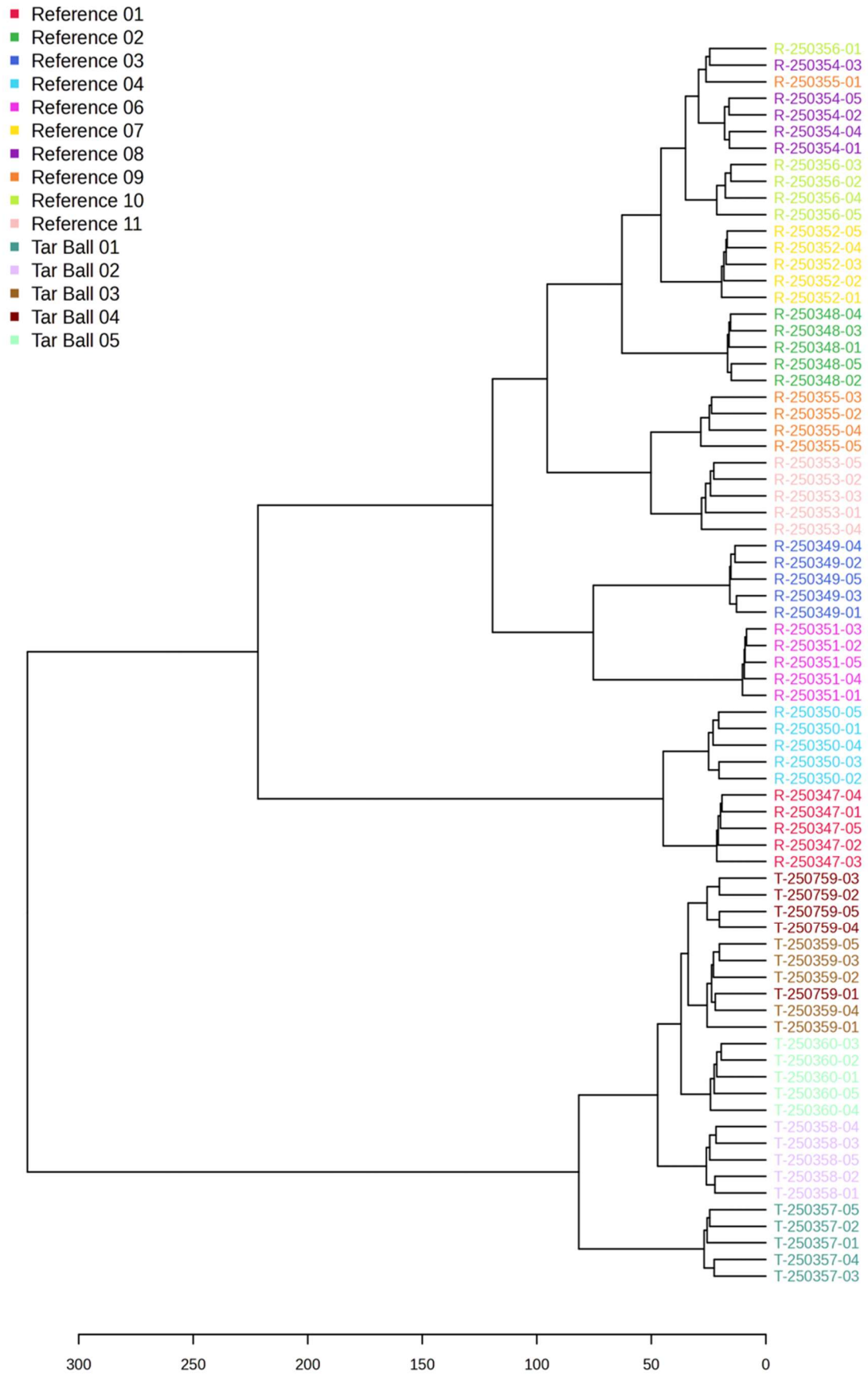


*Figure 4. Dendrogram of the lipids profile results (prepared by CSIRO).*

Note: Sample codes starting with “R” indicate WWTP and cruise ship samples. Sample codes starting with “T” indicate beach debris ball samples, except T-250357 which was the regional WWTP debris ball.

## Hydrocarbons

The presence of hydrocarbons in the beach debris balls is consistent with Sydney's sewage treatment systems being the source of the balls.

The beach debris balls contained hydrocarbon concentrations ranging up to 15% w/w and two samples of solids collected from Malabar WWTP also contained hydrocarbon concentrations within this range (Figure 5). The hydrocarbons in the WWTP samples are likely to originate from trade waste or illegal discharges to Sydney's sewage treatment systems. Minimal hydrocarbons were detected in the debris balls collected from the regional WWTP (Figure 5). It should be noted that the regional WWTP catchment has significantly less industry compared to Sydney's sewage catchments.

The cruise ship oil water separator and oily bilge sludge samples contained substantial hydrocarbon concentrations (Figure 5). This is to be expected as these samples were collected from the ship's oily bilge treatment system, which separates and collects oil and grease from the oily bilge water. Waste oil and grease is collected for onshore disposal, while treated water (<5mg/L of oil) is discharged at sea at least 12 nautical miles from shore.

The Malabar WWTP and the cruise ship oil water separator samples contained proportionally more semi-volatile hydrocarbons (>C10-C16) than the beach debris ball samples, while the cruise ship oily bilge sludge sample had a similar profile (Figure 6). Lower proportional concentrations of semi-volatile hydrocarbons would be expected in the debris balls as these hydrocarbon fractions volatilise more rapidly in the environment than non-volatile hydrocarbons (>C16).

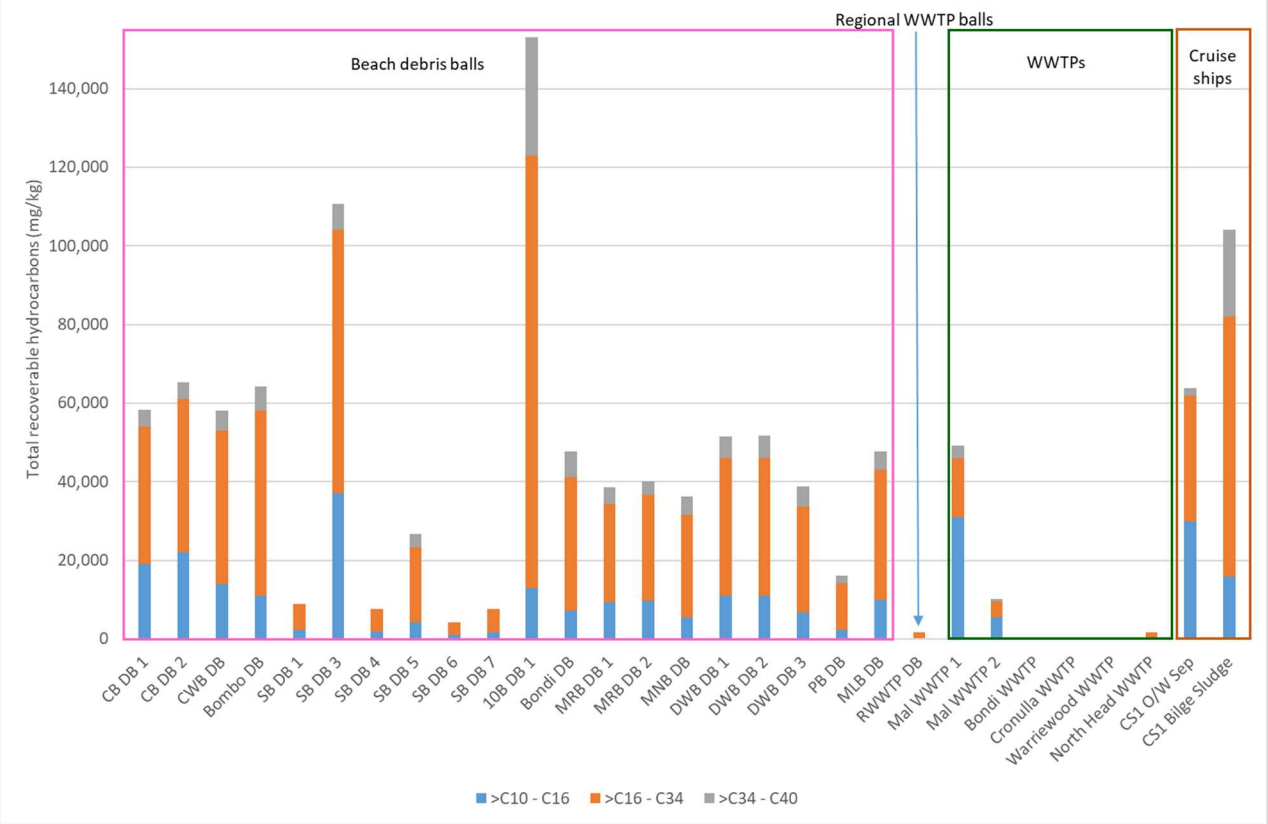


*Figure 5. Total recoverable hydrocarbon concentrations*

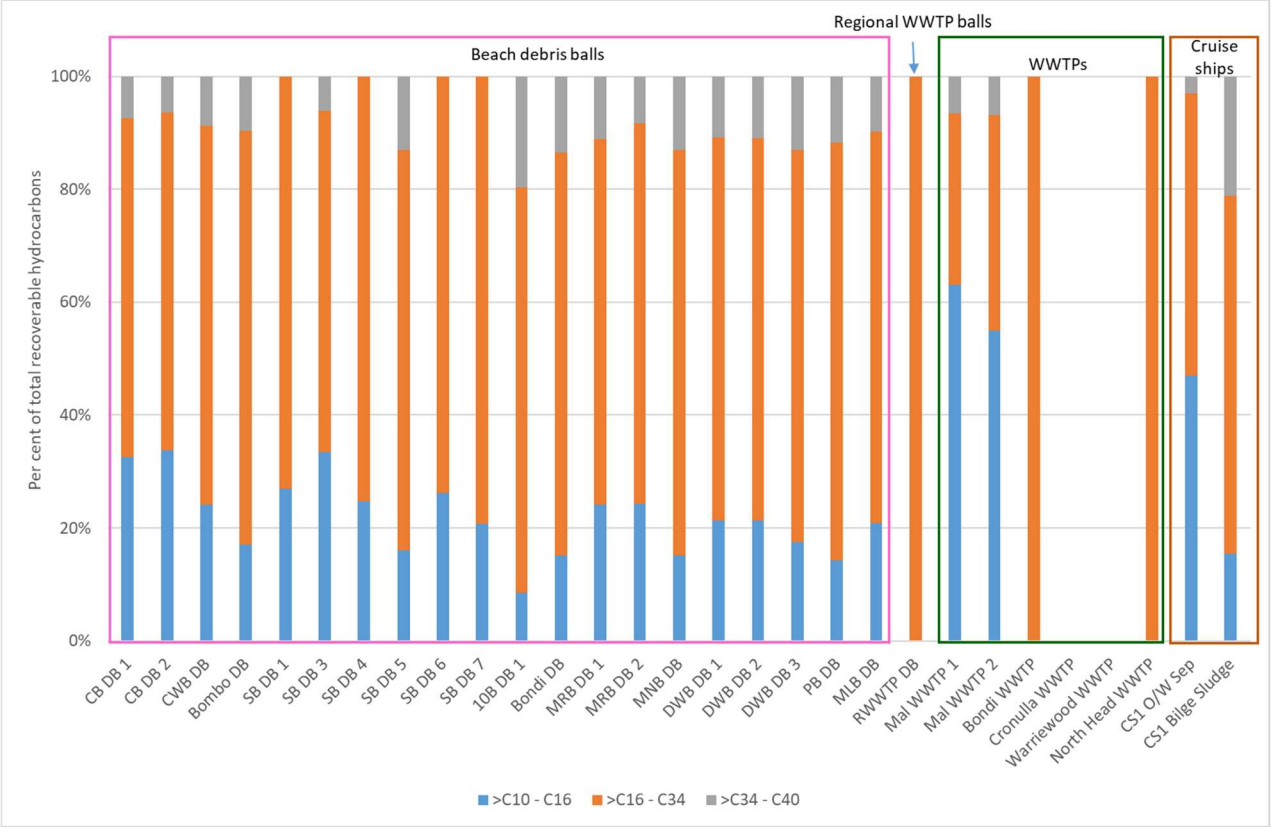


*Figure 6. Total recoverable hydrocarbon profiles*

## Other considerations

While limited amounts of small, weathered debris balls have been reported near Kiama and Narooma, most of the debris balls occurred on Sydney beaches, with the largest amounts at Coogee Beach. This suggests that the source is most likely near Sydney's Eastern Suburbs, with most of the balls washing up near the source and lesser amounts making landfall further away.

Cruise ships are unlikely to be the source of the debris balls as they have separate systems for management, treatment and disposal of grey water, sewage, cooking oils, and oily bilge water.

Sewage treatment systems have been identified as the source of similar debris balls that have been reported on beaches locally and elsewhere. For example:

- Debris balls reported on beaches near Warrnambool were found to originate from the Warrnambool WWTP and be caused by ineffective screening - https://www.abc.net.au/news/2019-12-03/epa-cracks-down-on-fatbergs-and-plastics/11760996
- Repeated incidents of debris balls have been reported on beaches in Bermuda and are linked to discharges of oil and grease with wastewater from an ocean outfall - https://www.royalgazette.com/environment/news/article/20190914/grease-balls-make-a-return/
- Historic "grease ball" events on Sydney's Eastern Suburbs beaches prior to the ocean outfalls being established (Water Board, 1995).

## Conclusions

The sampling results to date do not provide conclusive evidence identifying a specific causal mechanism. However, multiple lines of evidence combine to indicate the likely source. The debris balls were composed of a mix of hair and other debris, waste cooking oil, faecal material and hydrocarbons, indicating that a land-based sewage treatment system receiving a mix of grey water, blackwater and trade waste is most likely the source. In contrast, the separate waste management systems used on cruise ships mean that they are unlikely to be the source.

The source is likely to be near Sydney's Eastern Suburbs given that most of the debris balls occurred on Sydney beaches and the largest amounts of balls were at Coogee Beach.