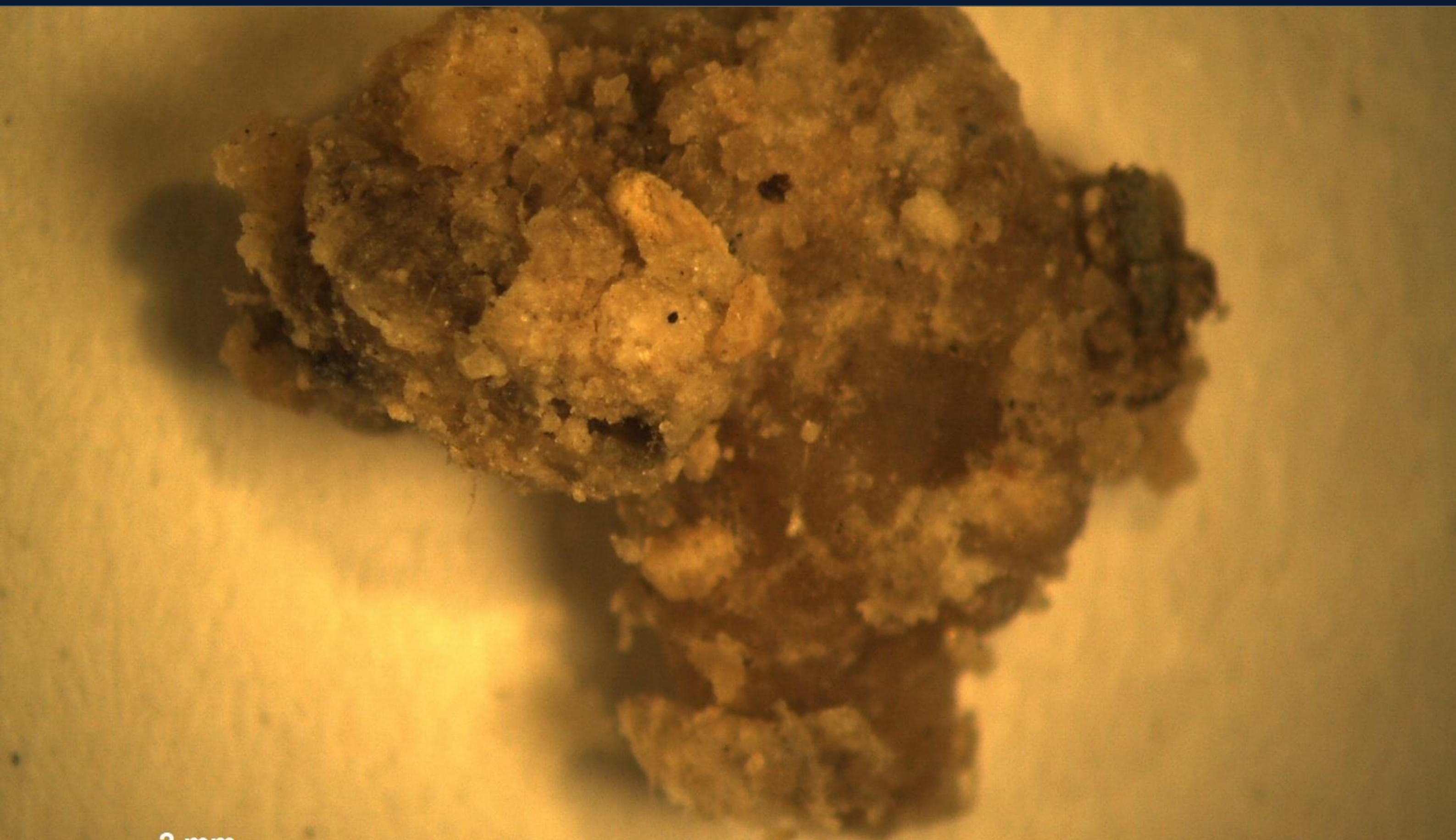
Fatberg Analysis

Museum of London

Department: Cranfield Water Science Institute

Date: January 2018



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Sample composition

The sample was dried at 105°C to remove the water content and calculate the amount of solids contained by the sample (dry weight or total solid). Following this, the samples were placed in a furnace at 550°C to remove all the volatile compounds (e.g. fats, carbohydrates, proteins, lignocellulose). The residual material is referred in the picture as ash/grit. All the analysis were done in triplicate. Sample composition and fatty acids profiling are reported in figure 1. An example of the GC-MS chromatogram of the fatty acids profile is reported in figure 2.

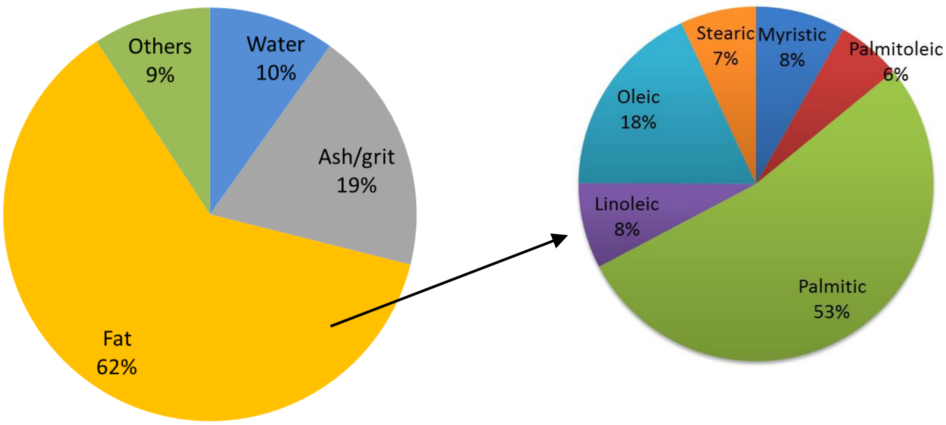

Figure 1. (a) Whitechapel sample composition and (b) Speciation of the fatty acids contained in the fat fraction of the sample.

The distribution of the identified six acids in the main common fats is reported in table 1.
The main fatty acids identified in the fat fraction of the sample include, in decreasing order:

- **Palmitic acid 53%** (C16:0), unsaturated fat, found mainly in palm oil, olive oil, as well as butter, cheese, milk and meat. It can be also used as flavouring agent in food, as surfactant in laundry, dishwashing products, personal care products and cosmetics.
- **Oleic acid 18%** (C18:0), unsaturated fat, is the most widely distributed and abundant fatty acid in nature. Major constituent of plant oils e. g. olive oil (about 80%), almond oil (about 80%) and many others. It ca be used as food additive and as emulsifying agent. Oleic acid is also used in manufacturing of surfactants, soaps, plasticisers.

- **Myristic acid 8%** (C14:0), found in some foods and oils such as coconut oil, pal oil and nutmeg. It is used to synthesise flavours and as an ingredient in soaps and cosmetics.
- **Linoleic** 8% (C18:2), polyunsaturated essential fatty acid found mostly in plant oils. Same uses as oleic acid.
- **Stearic 7%** (C18:0), saturated fat, is found in various animal and plant fats, and is a major component of cocoa butter and shea butter. It can be also used as flavouring agent in food, as surfactant in laundry, dishwashing products, personal care products and cosmetics.
- **Palmitoleic acid 6%** (C16:1), unsaturated fat, found naturally in macadamia oil (*Macadamia integrifolia*) and Sea Buckthorn oil (*Hippophae rhamnoides*), containing 22 and 40% respectively. It can be used for lubricants and lubricant additives or surface active agents.

A variety of cosmetic creams, cakes, soaps and pastes contains fatty acids and mixtures of fatty acids such as stearic acid, oleic acid, lauric acid, palmitic acid and myristic acid.

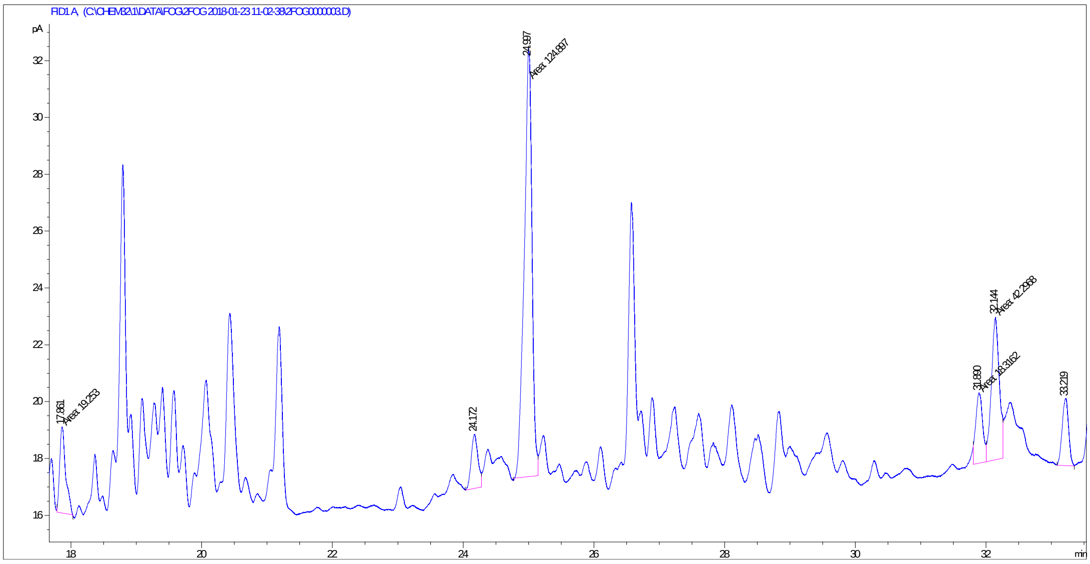

Figure 2. Whitechapel fatty acids composition, GC-MS chromatogram.

Table 1. Fatty acids composition of some commons fats and the fatberg:

	***Myristic acid* C14:0**	***Palmitoleic acid* C16:1**	***Palmitic acid* C16:0**	***Linoleic acid* C18:2**	***Oleic acid* C18:1**	***Stearic acid* C18:0**
Sunflower oil	0.1	nd	6	62	28	3
Rapeseed oil(canola)	nd	nd	5	26	56	2
Olive oil	nd	nd	10	7	78	2
Coconut oil	16	nd	9	2	7	2
Palm oil	nd	nd	44	10	40	4
Beef fat	3	11	27	2	48	7
Butter	12	3	26	2	28	11
Chicken/turkey fat	1	6	22	20	37	6
Lard	2	4	27	11	44	11
Salmon	3	5	11	5	25	4
Fatberg	**8**	**6**	**53**	**8**	**18**	**7**

Extracted from: Gunstone, F. *Fatty Acid and Lipid Chemistry*; Blackie: London, 1996.

Metal content

Metal analysis was done on acid digested sample, using ICP-MS. The results of the analysis are reported in table 2, together with indicative levels of metals in primary sludge (range across different sites). The metals levels, and the type of metals, found in the fatberg relate to those found in different samples of sludge entering the water treatment plant.

Table 2. Metal content of the fatberg sample and primary sludge metal levels from literature:

	Fatberg mg/kg (solid)			***Primary sludge mg/kg(solid)***
Sodium	116	±	17	
Magnesium	49	±	6	
Aluminium	293	±	56	6442-11002
Silicon	345	±	73	
Phosphorus	154	±	20	
Potassium	85	±	16	
Calcium	785	±	307	17.8-1286
Titanium	11	±	2	44.9-73.1
Vanadium	2	±	0	
Chromium	4	±	7	36.1-239
Manganese	2	±	0	103-297
Iron	407	±	70	4472-13847
Cobalt	0	±	0	1.99-5.49
Nickel	0	±	0	14.3-21.7
Copper	12	±	3	131-256
Zinc	44	±	5	633-997
Arsenic	0	±	0	
Selenium	0	±	0	
Molybdenum	0	±	0	3.52-10.2
Cadmium	0	±	0	1.89-6.03
Tungsten	0	±	0	
Lead	28	±	16	72.5-222
Mercury	1	±	1	nd

Faecal indicators

Coliforms/presumptive *E.coli* were extracted from the sample by agitating 5g sample into 45ml of maximum recovery diluent using a Stomacher 400. This suspension, along with serial dilutions, were plated on to Brilliance *E.coli*/Coliform selective agar (Oxoid) and incubated at 37°C. The colonies took a long time to grow and express the colour changes on the agar, indicating that the bacteria were distressed/damaged, or that the sample was relatively old. The results are summarised in table 3. The microbial load measured in the sample are comparable to those found in sanitised sludge.

Table 3. Faecal indicators in the fatberg sample:

Sample	Coliforms (cfu/g)	*E.coli* (cfu/g)
Whitechapel replicate 1	1.7×10^4	<10
Whitechapel replicate 2	3.4×10^2	<10

Optical microscope analysis

An initial microscopic analysis done on the sample showed a granular structure, with harder solid particles or sewers' debris encased into a 'soap' like softer matrix (Figure 3). The main constituents of the fatberg being saponified free-fatty acids.

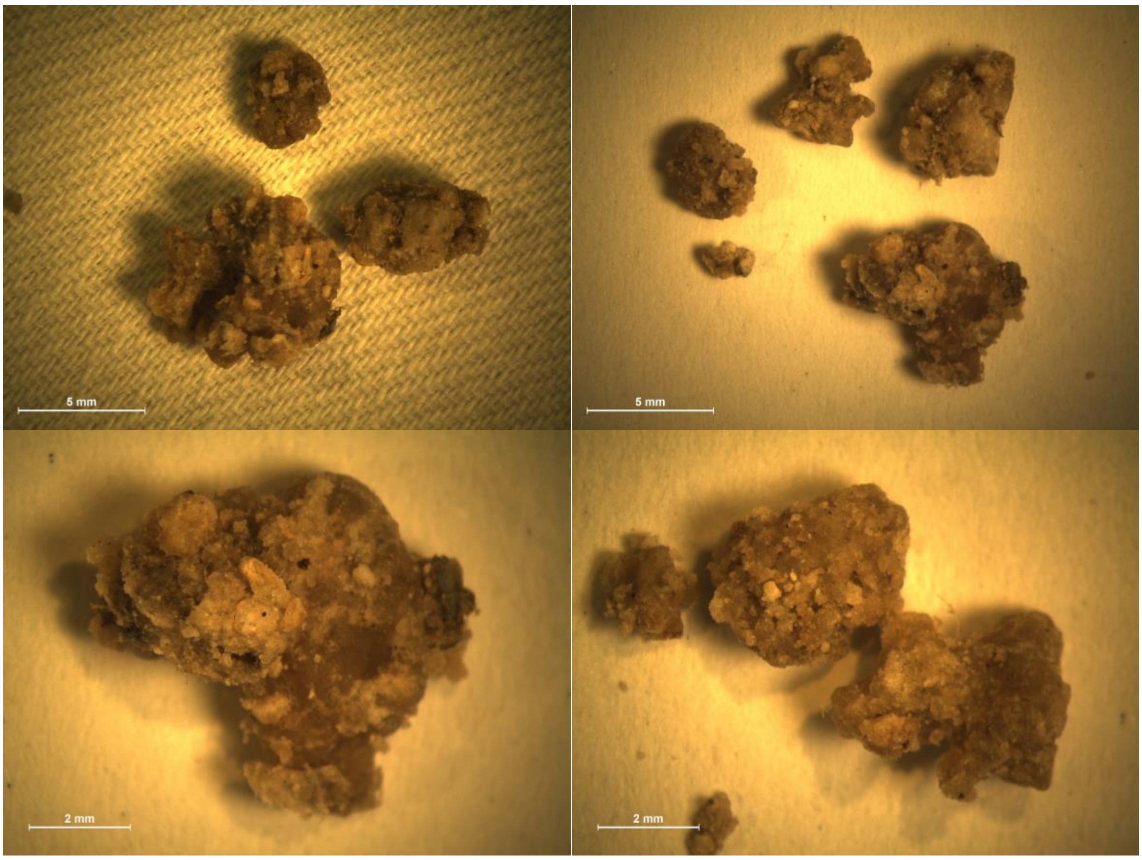

Figure 3. Optical microscope analysis of the fatberg.

Mechanisms of FOG deposit formation

The current hypothesis on FOG deposit formation has been described in detail in a review by Hen et al (2017).[1] When free fatty acids are produced from FOG hydrolysis and discharged into sewer pipelines they would preferentially partition into an oily layer and flow on the wastewater surface. In the presence of calcium the saponification process can occur at a fast rate and the saponified solid acts as a primary attachment point to the sewer pipe wall. The unreacted FFAs would then tend to accumulate around the core and draw additional calcium and other cations toward the solid core matrix. Different sources of calcium and fat in sewer systems also produced different colour and texture of FOG deposits. The authors also suggest an intermittent and alternate deposition of layers of sewer debris and saponified and aggregated fatty acid, due to the lack of continuously fed FOG or calcium.

The Whitechapel deposit is mainly constituted of palmitic acid, found in nature in palm oil as well as butter, beef and chicken fat (see table 1). This suggests that the free fatty acids forming the saponified deposits mainly come from cooking residues and cooking activities.

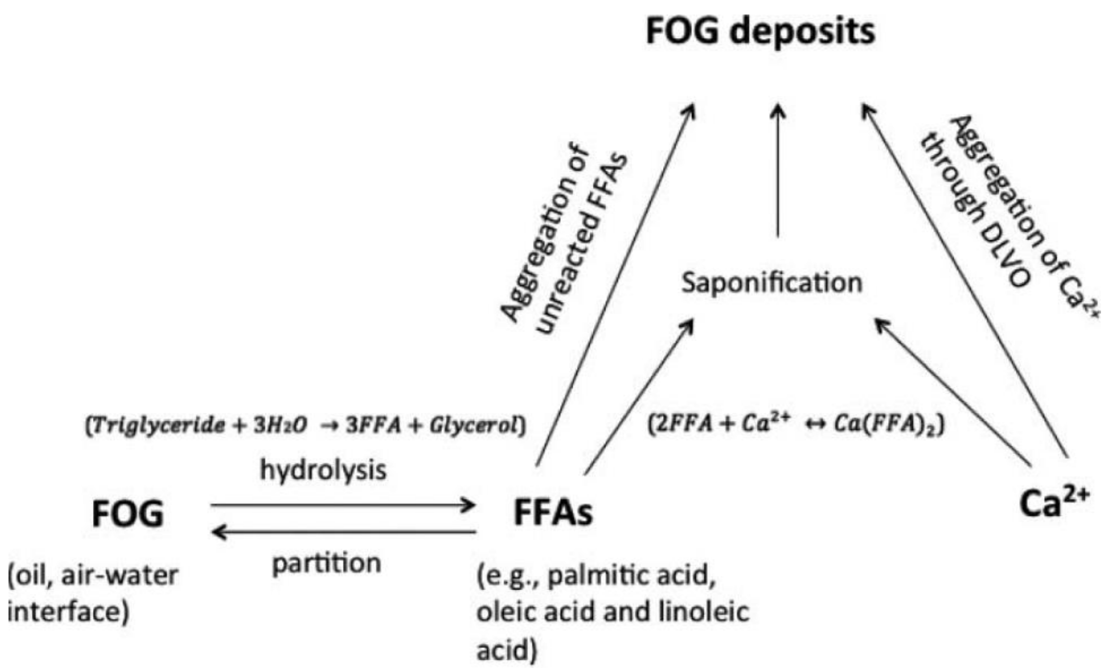

Figure 4. General understanding of FOG deposit formation in sewer pipelines, from He et al. 2017[1].

[1] Xia He, Francis L. de los Reyes III & Joel J. Ducoste (2017) A critical review of fat, oil, and grease (FOG) in sewer collection systems: Challenges and control, Critical Reviews in Environmental Science and Technology, 47:13, 1191-1217

Scanning electron microscope (SEM) analysis

The sample was treated with acetone overnight and the remaining solids analysed by electron microscope. The samples images are reported in figure 5.

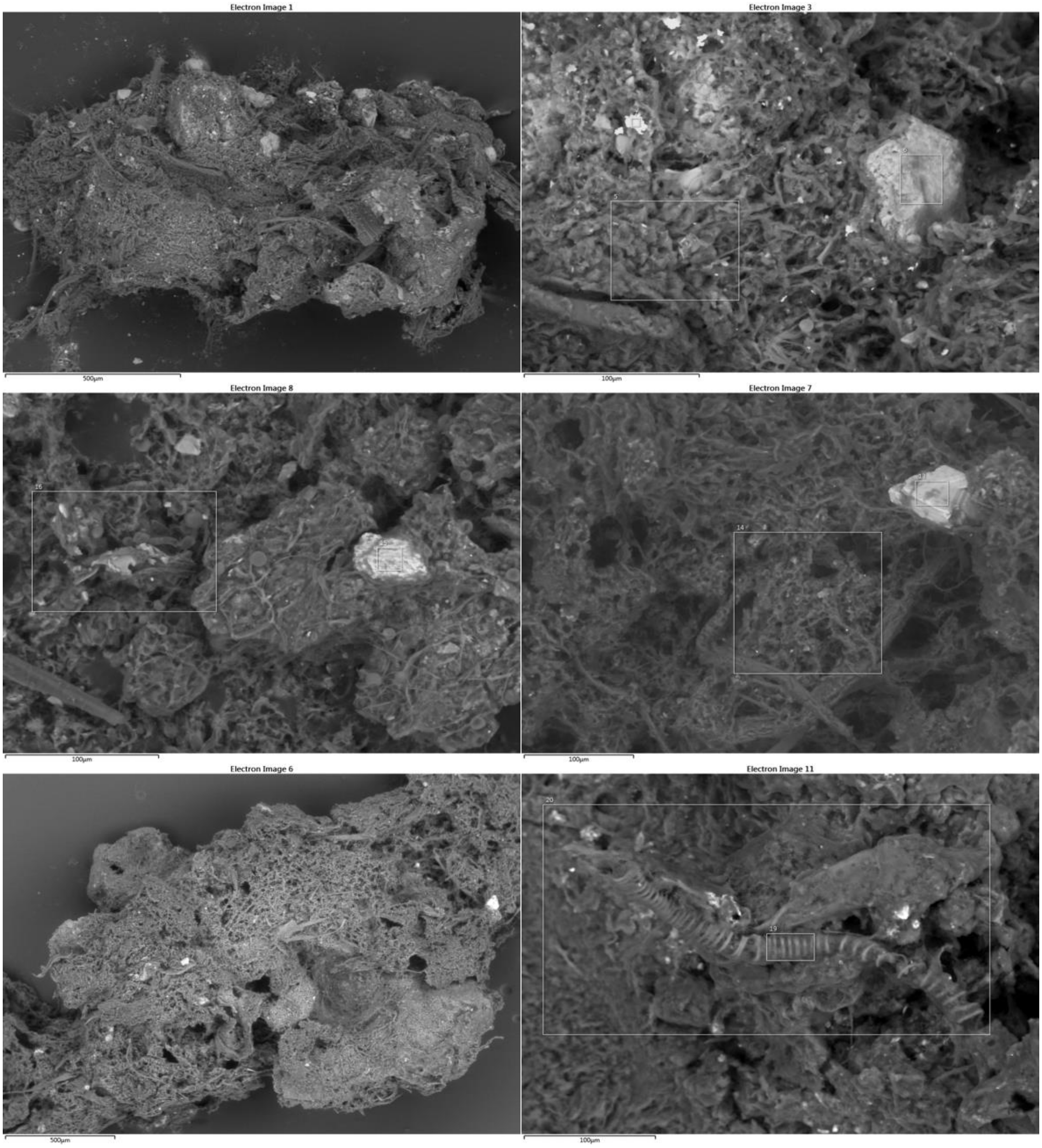

Figure 5. SEM analysis of the fatberg.