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REPORT

North-east England (Coastal Cell 1) Regional Coastal Monitoring Programme - Microplastics Study

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1 INTRODUCTION

The issue of microplastic pollution has seen an increasing focus over the last decade, both as a research and media topic. Plastic is an unavoidable material and its presence in the marine environment has been identified on a global scale. Plastic is estimated to account for 60-80% of marine debris (Moore, 2008) with an estimated five trillion pieces of plastic in surface waters globally (Eriksen *et al.*, 2014). It has been estimated that throughout one year coastal countries could contribute between 4.8 to 12.7 million metric tons of plastic waste to the ocean (Jambeck *et al*., 2015). As part of the Great British Beach Clean in September 2018, approximately 15,000 volunteers across beaches in the UK cleared 8,550kg of marine litter in 4 days, of which plastic was the most dominant material (Marine Conservation Society, 2018). On UK beaches, the presence of small plastic fragments (less than 25mm) increased by 230% between 2005 and 2014 (Nelms *et al.*, 2017). Using modelling tools, it is estimated that the accumulated number of microplastics particles in 2014 ranges from 15-51 trillion particles in surface waters, which is only approximately 1% of global plastic waste estimated to enter the ocean in the year 2010 (Sebille *et al*., 2015). Between 80,000 and 219,000 tonnes of microplastics are estimated to be entering the sea from Europe per year (UK Parliament, 2016).

The Cell 1 Regional Coastal Monitoring Programme covers approximately 300km of the northeast England coastline, from the Scottish Border (just south of St. Abb's Head) to Flamborough Head in East Yorkshire. As part of this monitoring Programme, subtidal sediment samples were taken from the sea bed and have been analysed for microplastic presence. This report presents the results of this analysis along with a literature review of the sources, movements and concentration of microplastics.

2 LITERATURE REVIEW

2.1 Introduction

Ubiquitous across the global marine environment (Bergman *et al*., 2015), microplastics have been found in a wide range of marine sediments from surface sediments on beaches (Lots *et al.*, 2017) to the deep sea (Van Cauwenberghe *et al*., 2013). The impacts of this scale of microplastics on the marine environment are not yet fully understood; microplastics can be ingested by marine organisms and transferred up the food chain (Andrady, 2011) and harmful substances can leach from or adhere to microplastic debris (Cole *et al*., 2011).

Research topics have rapidly expanded to establish baselines (Maes *et al.*, 2017), sampling methodologies (Qui *et al.*, 2016) and to investigate sources and impacts of microplastic pollution (Auta *et al.*, 2017). Marine impacts have remained the focus, but an increasing number of studies are considering impacts on freshwater and terrestrial habitats (Horton *et al*., 2017b). This increasing interest in plastic pollution is reflected in the growing number of bans on certain types of microplastics such as microbeads in multiple countries, including the UK. Additionally, the Marine Strategy Framework Directive (MSFD) requires the UK to provide specific information in relation to trends, amount, distribution and composition of microplastics.

2.2 Definition and sources of microplastics

The term microplastics was established by Thompson *et al*. (2004) to describe microscopic pieces of plastics in European waters and sediments. The most common size description of microplastics is that of Arthur *et al.*, (2009) defining microplastic particles as those less than 5mm. There are, however, a range of definitions used, with less than 1mm being another favoured definition (Frias and Nash, 2019).

While there is no definition of a minimum size of microplastics, a 0.33mm mesh size is commonly used to collect microplastic samples (Masura *et al.*, 2015). With the large amount of attention being given to microplastics in the environment, several researchers have begun to consider the fragmentation of plastics down to lower scales (i.e., the sub-micrometer scale). The term “nanoplastics” is still under debate, and different studies have set the upper size limit at either 1000 nm or 100 nm (Gigault *et al*. 2018). A review of the current opinion by Gigault *et al*., (2018) defines nanoplastics as particles unintentionally produced (i.e. from the degradation and the manufacturing of the plastic objects) and presenting a colloidal behaviour, within the size range from 1 to 1000 nm.

Microplastics are commonly split into three different categories (Cole *et al.*, 2011; Barnes *et al.*, 2009):

- **Microbeads** – Primary microplastics which have been manufactured to be microscopic in size, such as those in exfoliation cosmetics and plastic pellets used for the production of other plastic products.
- **Microfragments** - Secondary microplastics fragmented from larger plastics usually as a result of mechanical abrasion, photo-oxidative processes by UV radiation, and thermo-oxidative or biological processes.
- **Microfibres** – Secondary microplastics in the form of synthetic fibres, such as those broken down from textiles.

Microplastic abundance within the marine environment is increasing. Claessens *et al.* (2011), whilst investigating sediment cores, found that microplastic concentrations in beach sediments in Belgium tripled between 1993 and 2008. Degradation of plastic objects can take several hundred years (Avio *et al.*, 2016) so increasing fragmentation is expected to continually increase microplastic concentrations.

2.3 Previous Studies

Studies have increasingly been looking at quantifying the concentrations of microplastics. However, varying sampling techniques, metrics and even definitions of microplastics make direct comparisons between these studies difficult. A selection of microplastic concentration studies are provided in **Table 2.1**. These studies have been selected where the definition of microplastics as less than 5 mm is used and results are shown in number of microplastic particles per kilogram of sediment (p/kg), rounded to the nearest decimal place.

Table 2.1 Mean and Max concentration (particles per kilogram of sediment (p/kg)) of microplastics in sediment of different areas. All studies identified microplastics as <5 mm.

Study Location	Mean (p/kg)	Max (p/kg)	Reference
Tunisia, Mediterranean	316	461	Abidli *et al.*, 2018
Balearic Islands, Mediterranean	-	900	Alomar *et al.*, 2016
Orkney, Scotland	730-2300	-	Blumenroder *et al.*, 2017
Bohai Strait, China	102	256	Dai *et al.*, 2018
Canada	6656	25,368	Kazmiruk *et al.*, 2018
Europe (13 countries)	131-387	1,512	Lots *et al.*, 2017
Belgium	585	3,146	Maes *et al.*, 2017
France	481	1,509	Maes *et al.*, 2017
Netherlands	222	561	Maes *et al.*, 2017
English Channel, UK	306	643	Maes *et al.*, 2017

Study Location	Mean (p/kg)	Max (p/kg)	Reference
Halifax, Canada	-	8,000	Mathalon and Hill, 2014
Singapore	36.8	63	Nor and Obbard, 2014
Changjian Estuary, China	121	340	Peng *et al.*, 2017
Wanning, China	6922.8	8714	Qiu *et al.*, 2015
Baltic Sea	34	48	Zobkov and Esiukova, 2017

In the majority of studies in **Table 2.1**, microplastic pollution was found in all samples taken. Notably, a study taking 5 replicate samples from 23 beach locations across 13 different countries in Europe found microplastics in every sample, the lowest of which was 72 p/kg in Norway (Lots *et al.,* 2017). However, this could also be an artefact of studies specifically selecting sample locations with high anthropogenic inputs (see Abidli *et al.*, 2018; Alomar *et al.*, 2016; Dai *et al.*, 2018; Peng *et al.,* 2017 and Qiu *et al.*, 2015). Indeed, Maes *et al*. (2017) found 3 out of 27 sample sites containing no microplastic contamination when comparing sediments from four European countries. The samples containing no microplastics were found in subtidal sediments in the English Channel and the Netherlands. Conversely, a study specifically comparing sample locations in mangroves near and far from centres of human activity (Nor and Obbard, 2014) found microplastics in all samples.

2.3.1 UK Studies

Studies with sample locations in the UK are represented by two entries in **Table 2.1** (Blumenroder *et al*., 2017 and Maes *et al.* 2017). Further studies include Thompson *et al.* (2004), which found microplastics in sediments for 23 of 30 estuarine, beach and subtidal samples in Plymouth, identifying them as fibres and fragments typically derived from clothing, packaging and rope. Browne *et al.* (2010) identified 952 microplastic items in 30 sediment samples throughout the Tamar estuary. However, in both cases a definition of less than 1mm was used and so these studies have not been included in **Table 2.1**.

Additional UK studies cover a wider number of topics, freshwater sediment studies have been completed in the River Thames, finding an average of 660 particles p/kg of sediment using a definition of 1-4mm for microplastics (Horton *et al*., 2017a) and a shallow eutrophic lake in central Birmingham, finding 250-300 particles p/kg of sediment using a definition of 1.0 - 0.5mm (Vaughan *et al.*, 2017). A study has also been undertaken on the presence of microplastics in the water column in the Solent estuarine complex (Gallagher *et al.*, 2016), finding an average of 172 particles within 16 ten minute trawls. The highest number of microplastics in a single trawl was 937 particles, found in the Itchen.

2.3.2 Sources

There are multiple pathways for microplastics to enter the marine environment. Drainage systems bring microplastics from cosmetics and clothing into the marine environment (Auta *et al.*, 2017). Recently, in one of the biggest Wastewater Treatment Plants in Northern Italy, despite 84% of microplastics being removed by the treatment system, it was estimated that 160 million microplastics particles were released daily into freshwater environments (Magni *et al*., 2019). Sewage sludge produced by Wastewater Treatment Plants is often used as fertilizers for agriculture, and the same treatment plant produced 30 tons of sludge containing 3.4 billion microplastic particles each day.

There are various mechanisms for the movement of microplastics from freshwater and terrestrial sources to the marine environment. Locally, run-off and wind are pathways for movement, as well as direct flows from storm drain systems (Auta *et al.*, 2017) and even the atmospheric fallout of microplastic fibres (Dris

et al., 2016). Horton *et al.* (2017a) identified that microplastic fragments of paint from road markings were present in River Thames basin sediments, likely from run-off through storm drains.

Riverine input is an important factor (Siegfried *et al*., 2017). When comparing harbours of different types, Claessons *et al.* (2011) found the highest microplastic concentrations in a harbour exclusively used for pleasure craft. However, the source of microplastics in this area was identified as commercial sources, of which the harbour had none, while the harbour that was selected for its commercial and industrial uses had lower microplastic contamination. It was concluded the source was likely from the high level of riverine input (6 rivers) that fed into the harbour rather than the activities present.

Common anthropogenic sources are centres of human activity, like cities, industrial activity and harbours. Within the marine environment activities of tourism, recreation, fishing, aquaculture and marine vessels can all contribute to the input of microplastics (Cole *et al*., 2011). Abidli *et al.* (2018) investigated sites along the Tunisian coast finding microplastic concentrations higher near human and industrial activity. Peng *et al.* (2017) sampled the wider Changjian Estuary in China, finding the highest values in a geographical area with riverine inputs, a sewage treatment plant and near to Shanghai, the most populated city in China.

The highest maximum value for microplastic pollution in the studies identified in Table 1 was that found by Kazmiruk *et al.* (2018) in Canada. The high result was contributed to by both the geography of the area, a shallow coastal bay surrounded by tidal estuaries and inshore marshes, and the intense levels of shellfish aquaculture near the sampling site. The release of microfibres from fishing nets is a well-known source and Kazimuruk *et al.* (2018) hypothesised microbeads were likely to be sourced from the aquaculture industry as well. It has been suggested that fisheries-related activities are responsible for large amounts of the marine debris present in UK waters and beaches (Unger and Harrison, 2016).

Conversely, in a similar study sampling low energy (mangrove) areas near high levels of aquaculture, results found the second lowest concentrations in **Table 2.1** (Nor and Obbard, 2014). In a study comparing sites in an urbanised and highly populated coastal bay with two different Marine Protected Areas (MPAs) on the Balearic Islands in the west Mediterranean, it was found the highest microplastic concentration was in the MPA with the highest level of restrictions (Alomar *et al.* 2016). Additionally, Laglbauer *et al.* (2014) found no significant difference in microplastics between tourist and non-tourist beaches in Slovenia.

From the studies discussed, it is clear there is not always a clear correlation between microplastic concentration and proximity to anthropogenic sources. This variation in values can often be attributed to geographical conditions affecting the transport of microplastic particles.

2.3.3 Transportation and Sedimentation

Once within the marine environment, microplastics can be transported on a far-field scale. Due to their size and low density, currents can distribute microplastics across large distances leading to widespread transport (Eriksson *et al*., 2013). Winds, waves, tides and tsunamis can all contribute to transportation (Wang *et al.*, 2016; Zhang, 2017).

Studies selecting areas for their relative remoteness, such as Orkney in Scotland, found that microplastic contamination levels were comparable with mainland UK values in areas with much higher anthropogenic activity (Blumenroder *et al.,* 2017). It was found that microplastic concentration was significantly higher in remote Iceland when compared to wider European values (Lots *et al.*, 2017), noting the potential travel of plastic debris on the North Atlantic current.

Dai *et al*. (2018) sampled the Bohai sea, a semi-enclosed inner sea surrounded by one of the most densely populated and industrialised zones in China with multiple riverine inputs including the Yellow River – the second largest river in the world for sediment load. However, as seen in **Table 2.1**, microplastic concentration was comparably low. This could relate to strong tidal and wind driven currents within the sample area (Dai *et al.,* 2018).

In general, the low density of plastic means that a large proportion of plastic debris floats on the surface of the marine environment (Maes *et al.*, 2017). However, where they are denser than seawater some, such as PVC, may settle on the sea floor (Engler, 2012). Plastics that float can be entrained in marine sediments through biofouling, gaining weight and sinking to the seafloor (Ye and Andrady, 1991). Additionally, microplastics can become entrained in sediments through the ingestion and egestion of microplastics in faecal pellets by zooplankton (Auta *et al.*, 2017). It has also been shown that the polychaete *Arenicola marina*, a marine worm species common in high numbers across coasts in Britain (Tyler-Walters, 2008), promotes the burial of microplastics in sediment at up to 20 cm depth as a result of ingestion and bioturbation (Gebhardt and Forster, 2018). Marine sediments have been found to act as sinks, areas of long-term burial, for microplastic pollution in areas like the deep sea and submarine canyons (Pham *et al.*, 2014; Woodall *et al.*, 2014).

There is a difference between the transport of microplastics to areas and the entrenchment of the microplastics into marine sediments. It was found in Dai *et al*. (2018) that the concentration of microplastic particles in the water column was not consistent with concentration within sediments, with areas with the highest water column microplastic concentrations having the lowest sediment concentration and vice versa. A study looking at the different beach environments in Halifax Harbour in Canada found no statistical difference in the average number of microplastic particles between different beaches. There was a significant difference in where those particles were found however, with more exposed beaches having higher values in the strand line in the upper shore and low energy beaches having increased concentrations on the lower shore (Mathalon and Hill, 2014).

It appears that the factors that determine sedimentation of fine sediment particles may similarly govern the settlement of microplastics. Maes *et al*. (2017) found that in samples with a smaller median grain size a higher number of microplastic particles were found. Similar results had been found in Vianello *et al.* (2013), looking at microplastic presence in a lagoon in Italy.

However, both Peng *at al.* (2017) and Alomar *et al.* (2016) found no significant relationship between sediment grain size and microplastic concentrations, and similar results have been found in a number of studies (Thompson *et al.*, 2004; Nor and Obbard, 2014). Browne *et al.* (2010) proposed that other processes may be playing a more important role, such as the aggregation of microplastic particles with organic material, consequently demonstrated by Strand *et al.* (2013).

2.3.4 Microplastic Types

More information on the complex relationships influencing microplastic concentration and spatial variation can be found when looking at the types of microplastics found. Secondary microplastics, specifically fibres are the predominant type of microplastics found with the least common being primary microbeads / granules (Abidli *et al.*, 2018; Claessens *et al.*, 2011; Laglbauer *et al.*, 2014; Nor and Obbard, 2014; Peng *et al.,* 2017). Lots *et al*. (2017), when sampling 23 locations over 13 European countries, found only one particle that could have been a primary microplastic granule. However, this is contradictory with Maes *et al.* (2017) who predominantly found spheres in four European countries, though the difference here could be to do with the higher proportion of subtidal sampling in the second study. Similarly, the high microplastic concentration in Kazmiruk *et al.* (2018) was attributed to high numbers of microbeads but in a

further difference of results, on beaches on Geoje Island in South Korea fragments dominated (Song *et al.,* 2015).

These differences could be attributed to the difference in how the types of microplastic can be transported. Alomar *et al.* (2016), comparing urban and marine protected area (MPA) microplastic concentrations, found fibres were higher in urban areas and MPAs had higher fragments. Indeed, fibres are the main output from sewage and waste water treatment plants, with an estimated 1,900 fibres released into the environment from washing a single piece of clothing (Browne *et al.* 2011). Alomar *et al.* (2016) concluded that plastic debris would be transported into the area and then break down into fragments. Zobkov and Esiukova (2017) compared the types of microplastics on a transect from the coastline to offshore in Baltic Sea bottom sediments. Here, microfragments were only found near coastlines, films only found offshore and microfibres slowly deceased as sample sites moved offshore.

2.4 Conclusions

The relationships between microplastics and their spatial abundances are therefore complex and not yet fully understood. Multiple and varied sources as well as a number of varied factors govern movement, sedimentation and accumulation of microplastics. Factors range from geographical, biological to chemical and contradicting results from studies are common.

This confusion could be increased due to several factors, however. Comparing results of microplastic concentrations in studies in Greece between 2013 and 2017 shows an increase from 1.5 - 15 p/kg (Kaberi *et al.*, 2013) to 232 p/kg (Lots *et al.* 2017). But when looking more closely the 2013 study only sampled microplastics below 1mm, while the majority of microplastics found in 2017 were above 1mm. Varying sampling techniques can over- or under-estimate different types of microplastic (Song *et al.*, 2015) and cross-contamination is still a significant issue (Prata *et al.*, 2019). Additionally, there is a wide range of sediment sampling depths used throughout studies, such as 1cm (Browne *et al.,* 2011), 3cm (Mathalon and Hill, 2014), 5cm (Van Cauwenberghe *et al*., 2013) and 10cm (Ng and Obbard, 2006). Differences in sampling depth may not produce an accurate estimation of microplastic concentrations as the top 1 - 5cm has higher concentrations than the top 10cm (Prata *et al.,* 2019). There are also differences in the separation methodologies used depending on the nature of the samples (i.e. seawater, benthic sediment, aquatic). Separation strategies for microplastics include floatation, evaporation, filtration, sieving, and visual sorting (Herrera *et al*., 2018)). These techniques are useful for isolating microplastics from sediments, but isolating them from biological material requires a different treatment.

While certain irregularities may be a result of varying sampling techniques, undoubtedly the main constraint is the lack of available information. Further evidence from a wider number of studies is required to be able to show the wider state of microplastic pollution. As noted earlier within this section, many microplastic studies target areas known for plastics contamination sources or plastic debris accumulation, further studies with wider scopes are therefore needed to provide a more holistic view.

3 SAMPLING AND ANALYSIS METHODS

3.1 Overview

Sampling for microplastics is a relatively new subject, with the definition of microplastics only being put forward approximately 10 years ago. The novelty of the subject has meant a wide variety of methods have been used to assess microplastic concentrations, providing incomparable results due to methodological differences, some of which have been discussed in the literature review section of this report.

In 2015, the National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program produced a technical memorandum providing recommendations for quantifying microplastic particles in marine waters and sediments (Masura *et al.*, 2015). The aim of the technical memorandum was to provide simple and standardised methods to provide robust and reproducible assessments of microplastic concentrations.

The NOAA technical memorandum sets out standardised methods for taking and assessing microplastic abundance within samples taken from sea bed, beach and water column samples.

While there are some minor differences in the methods for sea bed and beach samples, the general procedure is similar. The process starts with 400g of wet sediment, to be dried in a drying oven (usually 90°C). The dried sample is weighed and the sample disaggregated, if required, before being sieved on a mesh to remove items larger than 5mm and smaller than 0.3mm. The remaining materials are subjected to wet peroxide oxidation which digests organic matter but leaves plastic materials unaltered. Microplastics must then be separated from the sediment. Given the differences in density between plastics (0.8-1.6g cm^{-3}) and sediment (2.7g cm^{-3}), this is generally achieved by mixing the sediment with salt saturated solutions (Prata *et al.*, 2019). There are various solutions that can be used, but the NOAA technical memorandum uses sodium chloride (NaCl). This floats the microplastics away from the sediments and floating materials are collected. NaCl is noted not to be the most efficient or accurate method (Quinn *et al.*, 2016), and is used most commonly as it is freely available, cheap and environmentally friendly (Prata *et al.*, 2019). The floating solids are separated from the denser undigested mineral components using a density separator and a dissecting microscope at 40X magnification is used to confirm the samples collected as microplastics and characterise them.

Water column sampling methodology is again similar, but does not include as much pre-treatment work given the lack of sediment fraction (such as the disaggregation of sediments).

4 CURRENT STUDY

4.1 Methodology

Surface sediment samples (0.1m) were taken using a Van Veen grab in subtidal sea bed sediments as part of the Cell 1 Regional Coastal Monitoring Programme. A total of 41 sites were sampled in December 2017 and January 2018 from Runswick Bay (3 samples) and off the coast between south Sunderland and Redcar, comprising County Durham, Hartlepool and Tees Bay (38 samples). Where sampling was not possible or where returned samples were not suitable for particle size analysis, these sites were not included in further analysis. Samples from the remaining 24 sites were sent to SOCOTEC for particle size analysis and then analysed for microplastics. As a quality control, a blank sample was carried out using baked sand to ensure external contamination is controlled. To ensure extraction efficiency, a sample of baked sand spiked with a known level of microplastics is analysed along with samples. The methodology used to identify and characterise microplastics was in line with that of the NOAA technical memorandum and a full description of the method along with results can be found in SOCOTEC's report in Appendix A. The location of all sample locations is displayed in **Figure 4.1**.

4.2 Results

All samples analysed contained microplastics, and values have been presented in **Table 4.1**. The number of microplastic particles (per kg of sediment) found in a single sample ranged from 6 particles (D2_3, Tees Bay) to 532 particles (Runswick 4, Runswick Bay). The result at Runswick 4 accounted for 27.7% of the total microplastics found across all samples. The average number of microplastic particles found was 80 p/kg, however when excluding the relatively high Runswick 4 result the average is 60 p/kg.

440000

460000

540000

N

A1_3
A2_1
A1_1
A2_2
A1_2
A4_2
A4_3
A4_1
A3_1
B1_1
B2_2
B1_2
B2_1
B4_1
B4_2
B3_1
C2_1
C2_2
C1_1
C2_3
C4_1
C3_1
C4_2
D2_1
D2_2
D1_2
D2_3
D4_1
D1_1
D4_2
D3_2
D3_1
E2_2
E4_1
E2_1
E4_2
E1_1
E3_1

Runswick 5
Runswick 3
Runswick 4
Runswick Bay
Kettleness

Earrington
Middle Herrington
New Silksworth
Tunstall
Ryhope
Colliery
East Herrington
Sourmilk Hill
Moorside
Doxford Park
Burdon
Ryhope
Seaton
Northlea
Seaham
Westlea
Dalton-le-Dale
Dawdon
Broom Hill
Hetton Downs
Hetton-Le-Hole
Lyons
Easington Lane
Elemore Vale
Hetton le Hill
Murton
Haswell
Haswell Plough
Ludworth
Shotton Colliery
Peterlee
Horden
Easington
Little Thorpe
South Hetton
Hawthorn
Thornley
Wheatley Hill
Cassop
Old Thornley
Wingate
Castle Eden
Hesleden
High Hesleden
Monk Hesleden
Blackhall Colliery
Blackhall Rocks
Shotton
Town Kelloe
Deaf Hill
Trimdon Colliery
Trimdon Grange
Station Town
Hutton Henry
Hart Station
Hart
Sheraton
Trimdon
Hurworth Burn
Fishburn
Elwick
Dalton Piercy
Rift House
Brierton
West Park
Hartlepool
Stranton
Bellevue
Longhill
Throston
Throston Grange Estate
Dyke House
Middleton
West View
Seaton Carew
Owton Manor
Greatham
Newton Bewley
Wynyard Village
Wolviston
Cowpen Bewley
Butterwick
Sedgefield
Thorpe
Foxton
Tees Bay
Tees Mouth
Warrenby
Coatham
Redcar
West Dyke

A690 A19 A182 A1018 A1086 A181 A179 A1049 A178 A689 A177 A1185

0 5 km

Legend

△ Sample Number

▲ Analysed Samples

▲ Samples Unsuitable for Analysis

Client:	Project:
Scarborough Borough Council	Cell 1 Monitoring Programme

Title:

Cell 1 Monitoring: Microplastics Sample Locations

Figure: 4.1

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
0	30/01/2019	TC	CG	A3	1:110,000

Co-ordinate system: British National Grid

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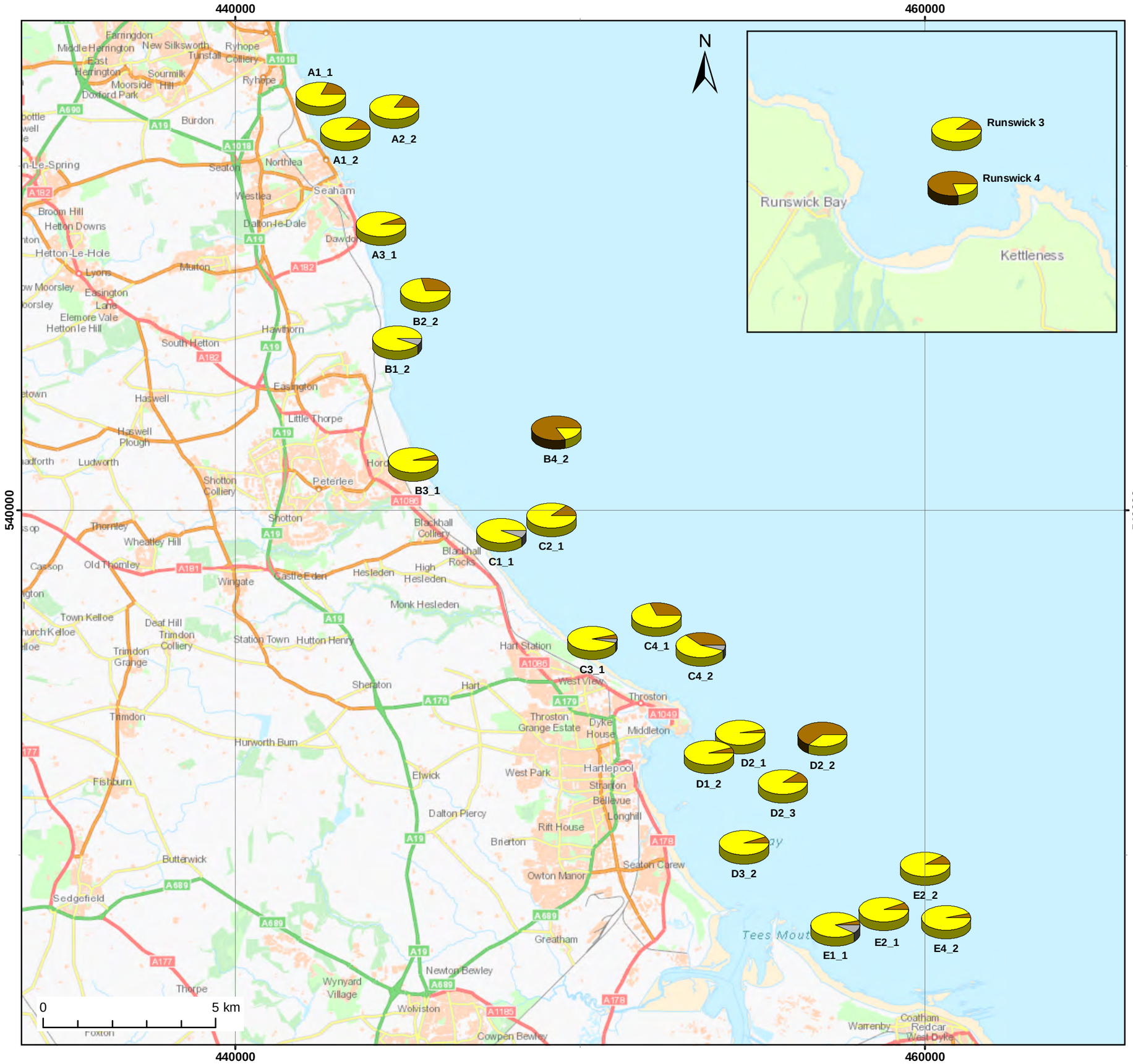
The most common microplastic type was microfibres, accounting for 54% of the microplastic particles found and all samples contained microfibres. Microfragments accounted for 41% of microplastics and were present in all examples except one (D2_1). Microbeads were the least common microplastic type (accounting for the remaining 5%) and were present in only 10 of the 24 samples.

Table 4.1 Microplastic particles per kg sediment, by microplastic type, and sediment fractions and sorting coefficients.

Reference	Microfibre	Microbead	Microfragment	Total Microplastics	%Gravel	%Sand	%Mud	Sorting Coefficient
A1_1	20	5	165	190	0.00	0.81	0.19	1.06
A1_2	3	0	31	34	0.00	0.87	0.13	1.07
A2_2	5	0	5	10	0.00	0.84	0.16	1.01
A3_1	9	0	9	18	0.00	0.93	0.07	0.85
B1_2	16	0	19	35	0.07	0.93	0.00	0.77
B2_2	40	0	22	62	0.00	0.71	0.29	1.48
B3_1	16	6	16	38	0.00	0.95	0.05	1.25
B4_2	45	3	27	75	0.00	0.17	0.83	2.31
C1_1	7	7	7	21	0.07	0.93	0.00	0.97
C2_1	14	0	23	37	0.00	0.88	0.12	1.20
C3_1	10	0	17	27	0.04	0.92	0.04	1.06
C4_1	191	10	57	258	0.00	0.69	0.31	2.11
C4_2	58	5	48	111	0.05	0.57	0.38	2.98
D1_2	10	0	13	23	0.00	0.95	0.05	0.76
D2_1	20	0	0	20	0.00	0.97	0.03	0.85
D2_2	97	17	46	160	0.00	0.37	0.63	2.72
D2_3	3	0	3	6	0.00	0.89	0.11	1.30
D3_2	13	0	31	44	0.00	0.94	0.06	0.75
E1_1	12	0	16	28	0.09	0.88	0.04	1.68
E2_1	21	4	14	39	0.00	0.93	0.07	0.63
E2_2	21	6	21	48	0.00	0.90	0.10	0.77
E4_2	20	0	4	24	0.00	0.96	0.04	0.47
Runswick 3	56	0	25	81	0	0.88	0.12	1.54
Runswick 4	329	31	172	532	0	0.20	0.80	2.12
Total	**1,036**	**94**	**791**	**1,921**				

Particle size analysis showed the majority of sites sampled were predominantly sand with some mud fractions (**Figure 4.2**). **Table 4.1** also presents the sorting coefficient of the samples, where the higher the value the more variation of particles sizes within the sediment sample.

Figure 4.3 and **Figure 4.4** show the microplastic content by site, values split between microplastic types, revealing that sites predominantly contained values below 50 microplastic particles per kg sediment, with some isolated sites showing hotspots of microplastic contamination. **Figure 4.5** and **Figure 4.6** appear to present some correlation between the fine sediment fraction, sorting coefficient and total microplastic content, and **Figure 4.7** shows a similar correlation with the microfragments, microfibres and microbeads.



Legend

Sediment composition (%)

Sample Number

- Mud
- Sand
- Gravel

Client:	Project:
Scarborough Borough Council	Cell 1 Monitoring Programme

Title: Sediment composition per site

Figure: 4.2

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
0	30/01/2019	TC	CG	A3	1:110,000

Co-ordinate system: British National Grid

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440000

460000

540000

N

A1_1
A2_2
A1_2
A3_1
B2_2
B1_2
B4_2
B3_1
C2_1
C1_1
C4_1
C4_2
C3_1
D2_1
D2_2
D1_2
D2_3
D3_2
E2_2
E2_1
E4_2
E1_1

Runswick 3
Runswick 4
Runswick Bay
Kettleness

Sunderland
Seaham
Peterlee
Hartlepool
Stockton-on-Tees
Redcar
Saltburn-by-the-Sea
Middlesbrough
Loftus
Guisborough
Whitby

Legend

Microplastics content (p/kg)

Sample Number

- Microfibre
- Microbead
- Microfragment

Client:	Project:
Scarborough Borough Council	Cell 1 Monitoring Programme

Title: **Microplastics content per site**

Figure: 4.3

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
0	30/01/2019	TC	CG	A3	1:110,000

Co-ordinate system: British National Grid

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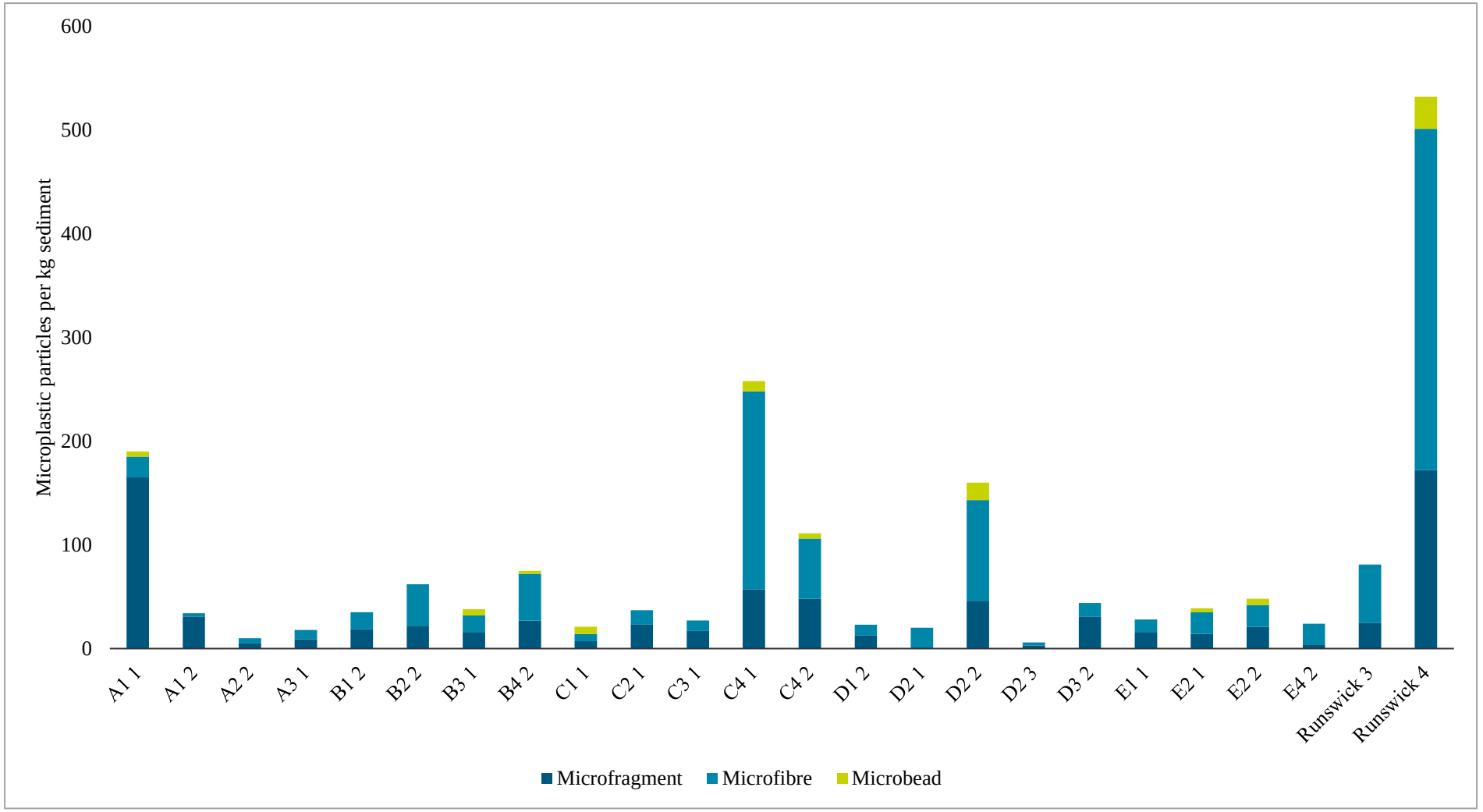


Figure 4.4 Microplastic content by site

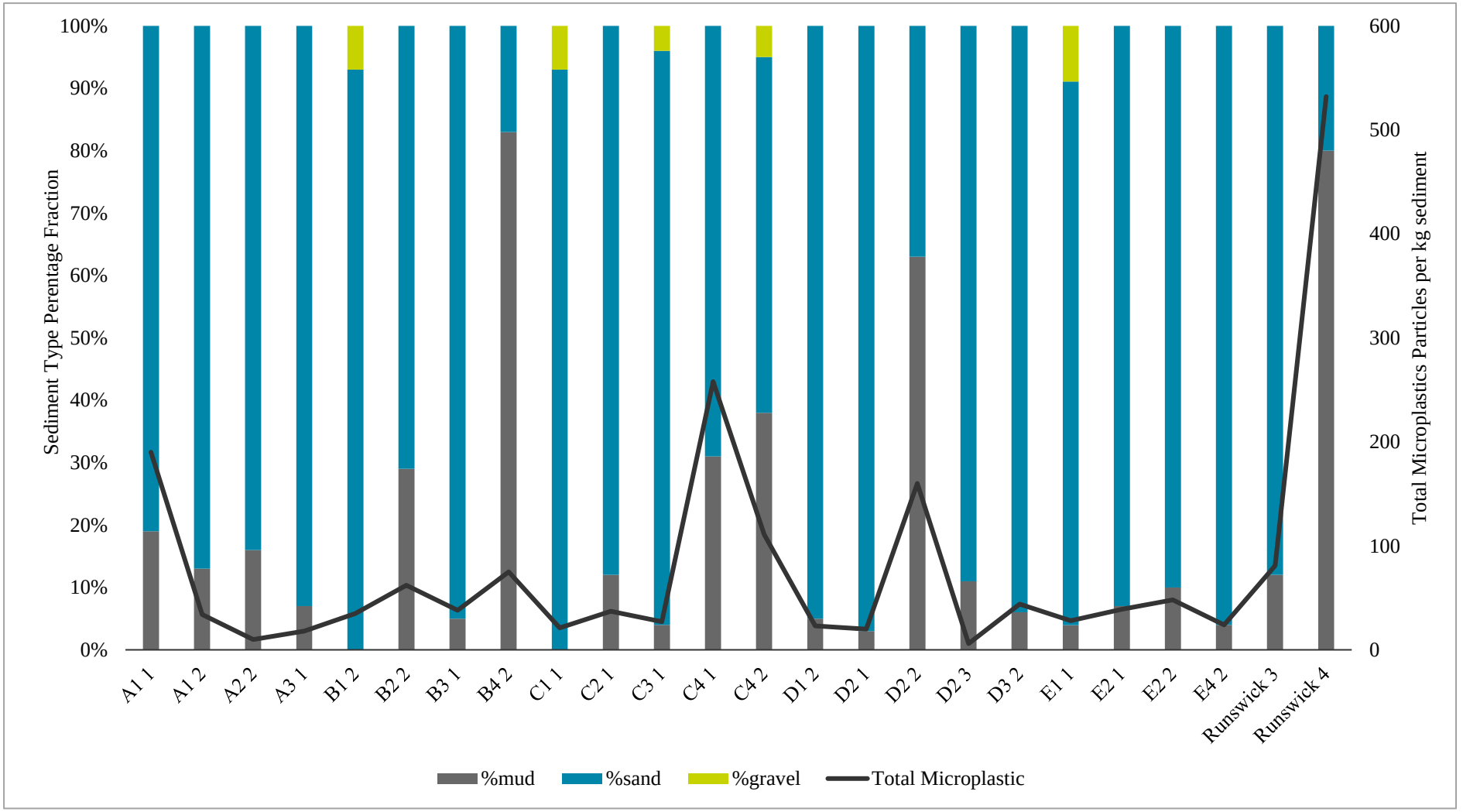


Figure 4.5 Total microplastic content (particles per kg sediment) and percentage sediment fractions by site

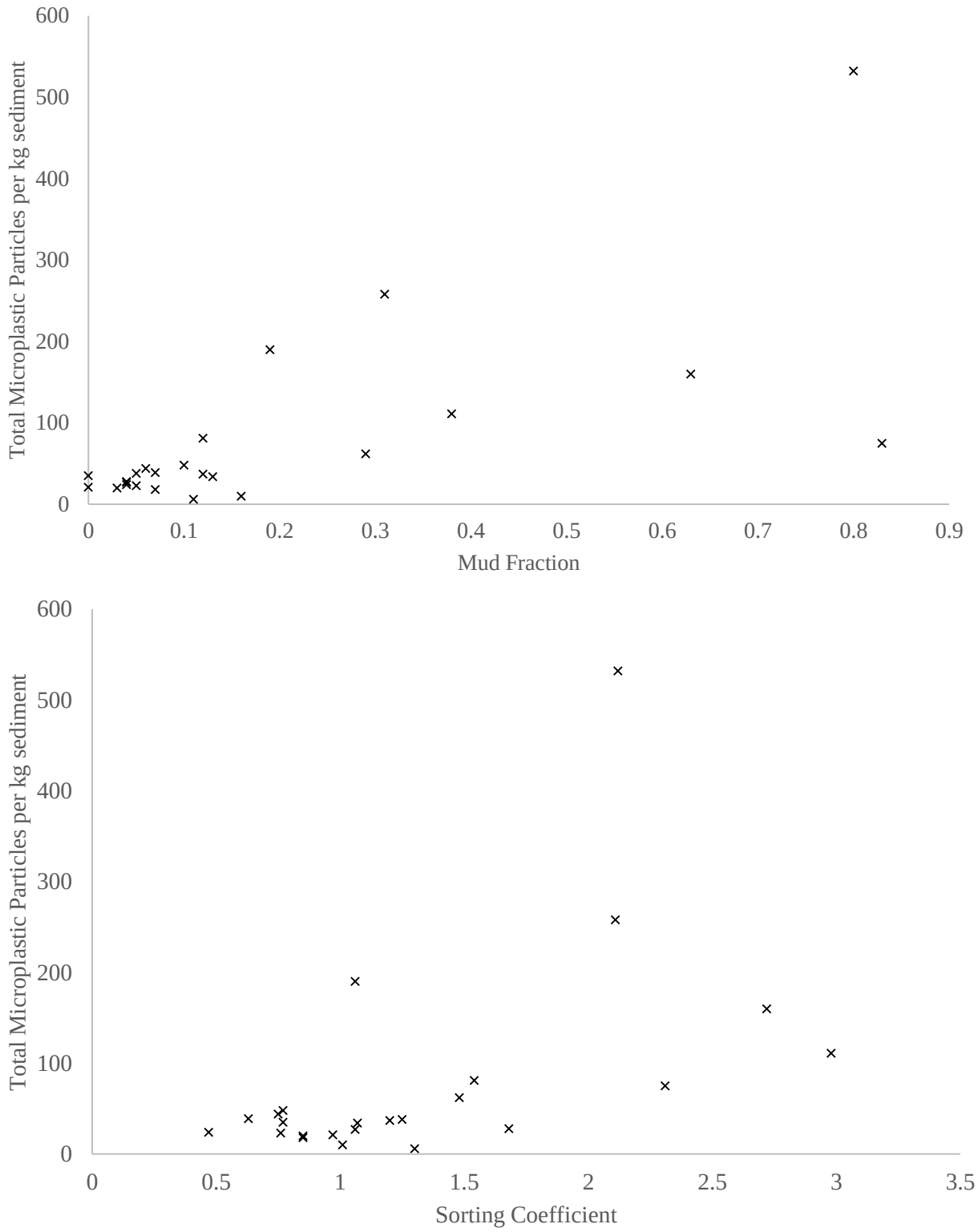


Figure 4.6 Total microplastic particles per kg sediment vs Fine Sediment fraction (top) and sediment sorting fraction (bottom)

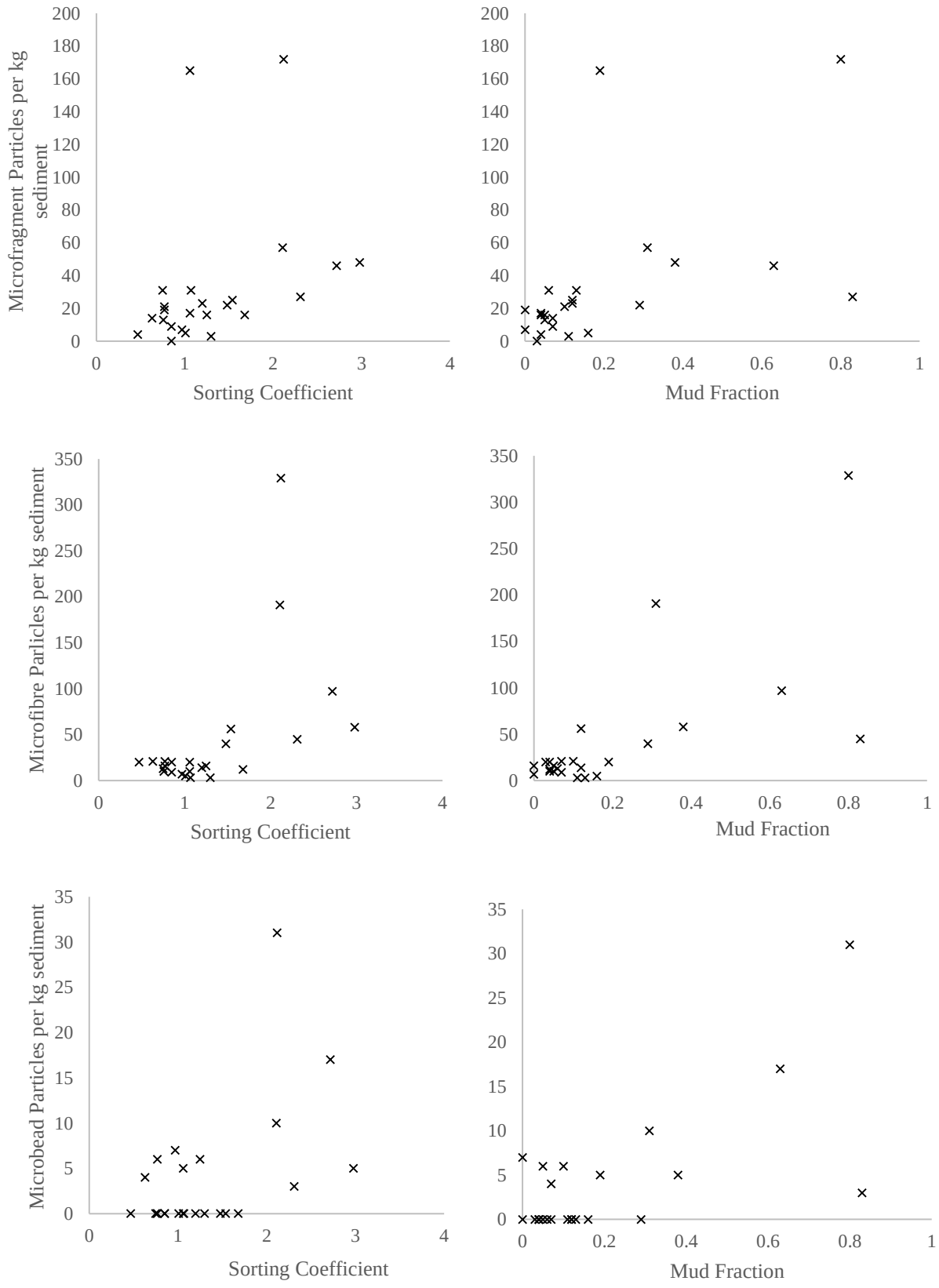


Figure 4.7 Microplastic particles per kg sediment by type (Microfragment – top; Microfibre – middle; Microbead – bottom) vs sediment sorting fraction (left) and fine sediment fraction (right).

4.3 Discussion

Comparing the results found in **Table 4.1** to the summary of projects with results using the same metrics in **Table 2.1**, the concentrations sampled are comparatively low. The lack of similar UK studies, however, prevents effective comparison. As noted previously, many of the comparative studies target areas expected to have high concentrations, potentially making the current results appear relatively lower than a realistic baseline. Additionally, many of the studies in **Table 2.1** sample beach sediments, when the current study contains subtidal sea bed sediments only.

A comparative methodology in Zobkov and Esiukova (2017) sampling subtidal coastal sediments found lower values that identified in the present study. The mean value of samples (80 p/kg) in the present study was much lower than the mean of samples taken in the English Channel (306 p/kg) in Maes *et al.* (2017), though the maximum values identified were comparable, 643 p/kg in Maes *et al.* (2017) compared to 532 in the present study.

Direct comparisons should not be accepted without consideration of the further processes that impact microplastic contamination. For example, the study with the most comparable values to the present study in **Table 2.1** are results from a study in a semi-enclosed sea surrounded by the most densely populated and industrialised zones in China with multiple riverine inputs (Dai *et al.*, 2018). However, in that study it was noted that the low concentrations of microplastic particles in the sediment was not consistent with higher concentrations within the water column sediments, indicating high currents in the area prevented the settlement of microplastics within the sediment.

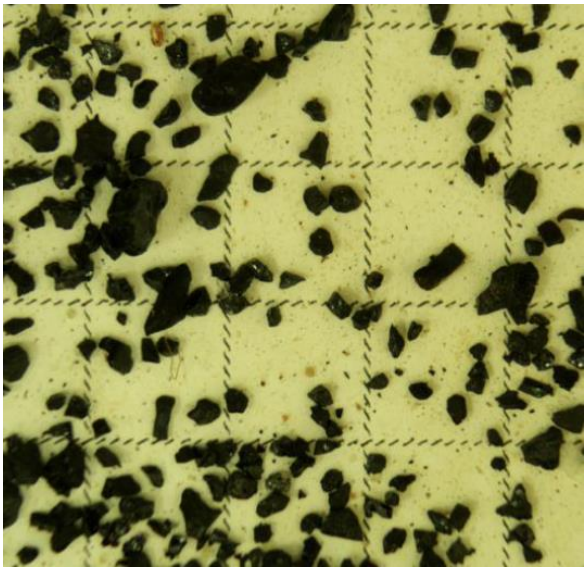
It appears that there is a weak positive correlation between the percentage of mud in the samples with the total microplastic content (**Figure 4.5** and **Figure 4.6** (top)). However, this is not the case in all situations. B4_2 for example has a fine sediment fraction of 83%, but total microplastic is slightly below average (75 p/kg). Similarly, a general trend for an increased sorting coefficient (poorly sorted sediment) increasing microplastic concentration can be seen (**Figure 4.6** (bottom)). Poorly sorted sediment tends to relate to lower energy environments, so this may indicate that the high levels found in Runswick Bay could be due to the sheltered nature of the area. Similar patterns are seen when comparing the same plots but separating microplastics types (**Figure 4.7**), however, without statistical analysis, it is unconfirmed whether these potential relationships have is a significant correlation or not, and as noted within the literature review there are many other factors that influence sedimentation of microplastics.

When reviewing the types of microplastics found in the sample results, the results matched wider findings of low primary microplastics (microbeads) and of microfibres being the most common. Samples with comparatively high microfibres included C4_1, C4_2 and D2_2 (Figure 4.3), grouped to the north of Tees Bay. However, samples to the north of Seaham indicated a source of microfragments, specifically for sample points A1_1 and A1_2.

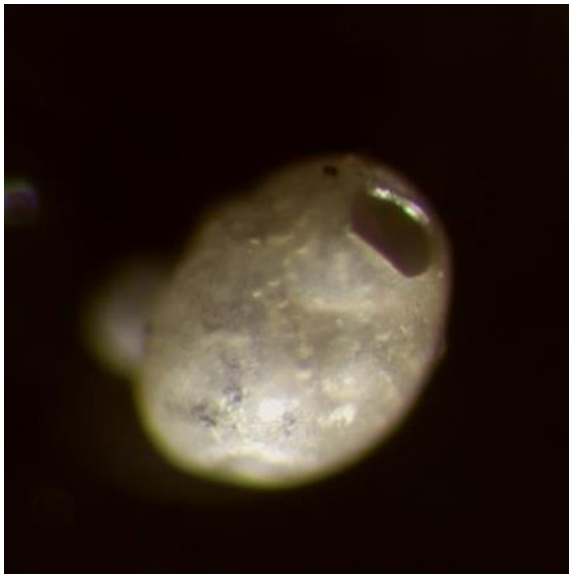
Reviewing the data, no clear spatial pattern is immediately apparent. This is likely to be due to the multiple factors that influence microplastic spatial distribution. Local sources are likely to include the riverine input from the River Tees, run-off from the urban areas of Hartlepool and Seaham, waste water treatment plants along the coast and fishing activities within the area. The factors that govern movement once entering the marine coastal environment and eventual settlement further confuse aspects, indeed if microplastics can be found in high concentrations in Orkney despite a lack of local plastics sources (Blumenroder *et al.,* 2017), then there is no guarantee that sources on this coastline contribute to concentrations of microplastics in local sediments. Even microplastics within the sediments can be subject to further disturbance, with sample points D3_2 and D2_3 within a regularly dredged channel.

Within the samples, a high number of spherical coal particles and fly ash were identified. In some samples over 1,000 coal particles were identified within the sample. This is mentioned here for two reasons.

- Firstly, sediment samples that contain significant amounts of coal fragments can cause major interference issues with the analysis of microplastics. One of the main isolation stages for microplastics is the density floatation. This is designed to float-away the microplastics from the heavier material such as sand and gravel. Plastics have a variety of densities and density floatation is carried out using a liquid solution at 1.6 g/cm^3 which will float all common plastics. However, coal has a density between 1.2 – 1.8 g/cm^3 (depending on type) and thus also becomes floated-away with the microplastics during the floatation process if it is present within the sample. Whilst it is possible to use a floatation liquid of 1.15 g/cm^3 to float Polyethylene and Polypropylene away from coal particles, this will result in some other plastics being lost from the analysis. For the present study, SOCOTEC undertook a detailed search of each sample under the microscope to identify and remove individual coal particles from the microplastics within the sample. An important part of this process is to recognise that fly ash within the samples (derived from burnt coal) looks like spherical balls, which can be misidentified by an untrained microscopist as microbeads of plastic.



Coal particles
recovered from a sediment sample



Fly ash particle
recovered from isolated coal particles (this could be misidentified by an untrained microscopist as a microbead of plastic)

- Secondly, the presence of coal particles and fly ash within the samples is highly likely to be associated with the legacy of colliery spoil tipping which occurred along the County Durham coastline and has previously been discussed in detail in the Cell 1 Sediment Transport Study (Royal HaskoningDHV, 2014). Tipping began around 1900 and continued until 1993 with the closure of the last colliery. At the peak of tipping over 2.5 million tonnes of spoil were tipped in one year (1983) and in total it is estimated that around 100 million tonnes were tipped, both at foreshore tipping sites and at offshore disposal grounds. This tipping despoiled the beaches and resulted in significant progradation of the shore. Since cessation, there has been a tendency for ongoing erosion of the spoil beaches.

Colliery spoil beach at Horden, County Durham

It is concluded from the literature review that the high number of factors that could be impacting the concentration, distribution and type of microplastics within marine sediments within the study area does not allow for attribution of the results found to any specific factors. However, this study does present a first baseline assessment for the area. The nature of the sampling means that there is no targeted approach to identify high microplastic concentrations, contributing a more complete picture of microplastic pollution to existing literature.

5 CONCLUSIONS AND RECOMMENDATIONS

It is clear from the literature review and the results from the study that a multitude of factors govern the sources, movement and sinks of microplastics in marine sediments. Further statistical analysis and data on these factors, such as interpretation of local currents and sediment movements, areas of erosion and accretion, fishing effort and the location of waste water treatment plants and storm drains, may provide further detail and interpretation of the results.

The current study presents a baseline for the sea bed between south Sunderland and Redcar, and in Runswick Bay, for subtidal marine sediments. Repeat surveys from other sea bed areas within cell 1 as well as further data from beach sediments and water column samples could present a wider understanding of the movements of microplastics within the study area. Interpretation of available data on microplastic debris on local beaches could also provide further understanding of the wider plastic influences on the environment.

Given the apparent localised hotspots of microfragment pollution north of Seaham, and that it has previously been shown that microfragments are the least likely to be transported further distances (Zobkov

and Esiukova, 2017) it may be more possible to identify a potential source for the microfragments through further data collection and analysis for this area.

There is also the potential for further Fourier-transform infrared spectroscopy (FTIR) analysis, which could provide further information on the types of plastics the microplastics were originally made from. However, given the prevalence of the multitude of plastics in the environment and the limited number of samples to the north of the study area, it is unlikely that there would be much benefit in this information and the cost of FTIR analysis is £25.00 excluding VAT for each microplastic particle examined.

Additionally, while not within the scope of this review, another important topic to consider would be the impact of microplastics upon the environment. In just the UK alone, a number of studies have investigated the impacts of microplastics on various organisms. Reviewing impacts of waste water treatment works on freshwater macroinvertebrates in South Wales, Windsor *et al*. (2019) found concentrations of up to 0.14 microplastic particles per mg of tissue. Microplastic presence in macroinvertebrates was found at all sites with largely similar concentrations both up and downstream from the treatment works. Similarly, microplastic presence has been found in the roach (*Rutilus rutilus*), a freshwater fish in the River Thames (Horton *et al*., 2018), pelagic and demersal fish from the English Channel (Lusher *et al*., 2013), the brown shrimp *Crangon crangon* in coastal waters of the Southern North Sea and Channel area (Devriese *et al*., 2015) and even in supermarket mussels (Li *et al*., 2018).

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Appendix A

Microplastics Results Report

TEST REPORT ASC/36266

Customer:	Royal Haskoning DHV UK Ltd Marlborough House Marlborough Crescent Newcastle upon Tyne United Kingdom NE1 4EE
Testing Facility:	Specialist Chemistry SOCOTEC Etwall Building Bretby Business Park Ashby Road Burton Upon Trent DE15 0YZ
Purchase Order Number:	PB5237-112-107
Date Samples Received:	19 November 2018
Condition of Samples:	Ambient and Satisfactory
Approved by:	
Approver's name:	Paul Walker
Job Title:	Senior Development & Technical Specialist
Test Report Date:	18 January 2019

Sample and Method Descriptions

Number of Samples Received	Matrix / Sample Description	Method ID	Description
24	Sediment	IHM	**IHM – ISOLATION AND COUNTING OF POTENTIAL MICROPLASTICS** Up to 400g of sample 'as received' is dried to give a dry sample weight. The sample is wet sieved to isolate the 0.3mm-5mm fraction. This fraction is subjected to a density flotation and the material with a density below 1.6g/ml is taken and a wet peroxide oxidation digestion carried out. The material from the digestion is filtered and prepared for microscopic examination. Particles that pass the visual 40x magnification examination are removed, counted and the total weight determined by microbalance weighing. Samples containing high levels of coal should be treated with caution to ensure coal particles, and those of fly ash are not taken into account with the final microplastic isolation. Potential microplastics are solids that have a size between 0.3mm and 5mm, are resistant to a wet peroxide oxidation extraction, floats in a density flotation liquid (density 1.6g/ml) and passes a visual inspection under a microscope at 40x magnification. Number counts and weights were determined on the 'as received' wet fraction of sample taken for analysis and expressed as per kg of dried sample. This assumes a uniform distribution of microplastics throughout the sample. As a quality control, a blank sample is carried out using baked sand to ensure external contamination is controlled. To ensure extraction efficiency, a sample of baked sand spiked with a known level of microplastics is analysed along with samples.

Results

Customer Sample Reference: **A1 1**
Laboratory Sample Reference: **ASC/36266.001**

Table 1: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
A1 1	ASC/36266.001	1.7	165	5	20

ND Denotes None Detected

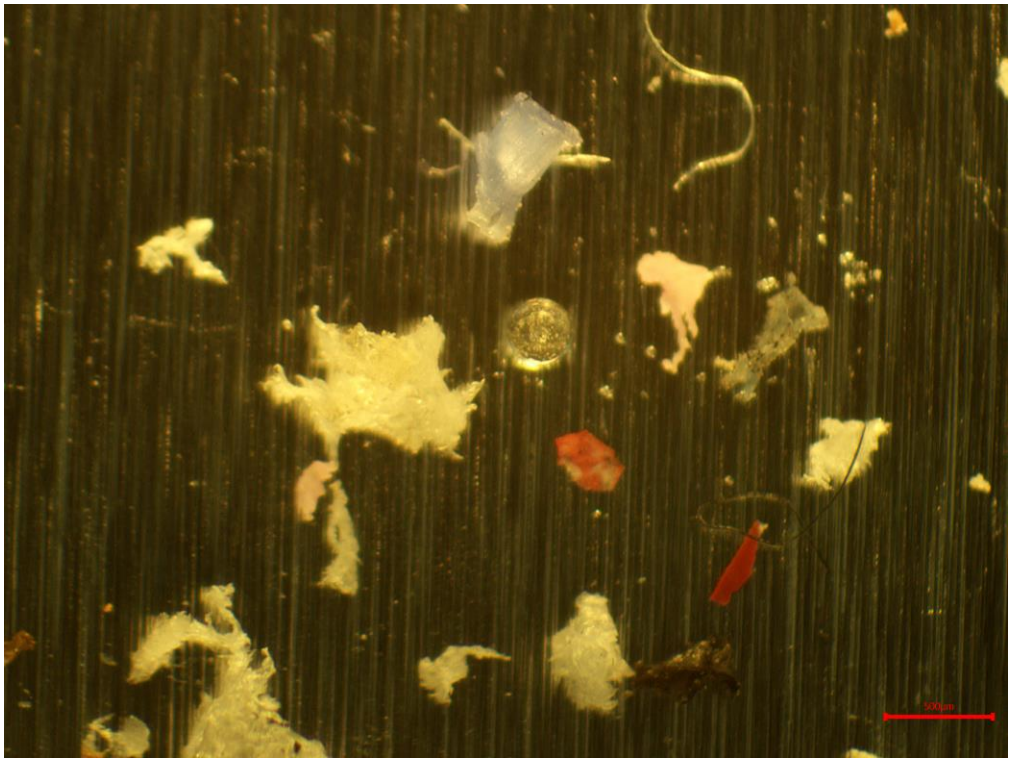

Figure 1. Overview image of potential microplastics recovered from sample ASC36266.001 (A1 1)

Results

Customer Sample Reference: **A1 2**
Laboratory Sample Reference: **ASC/36266.002**

Table 2: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
A1 2	ASC/36266.002	0.13	31	ND	3

ND Denotes None Detected

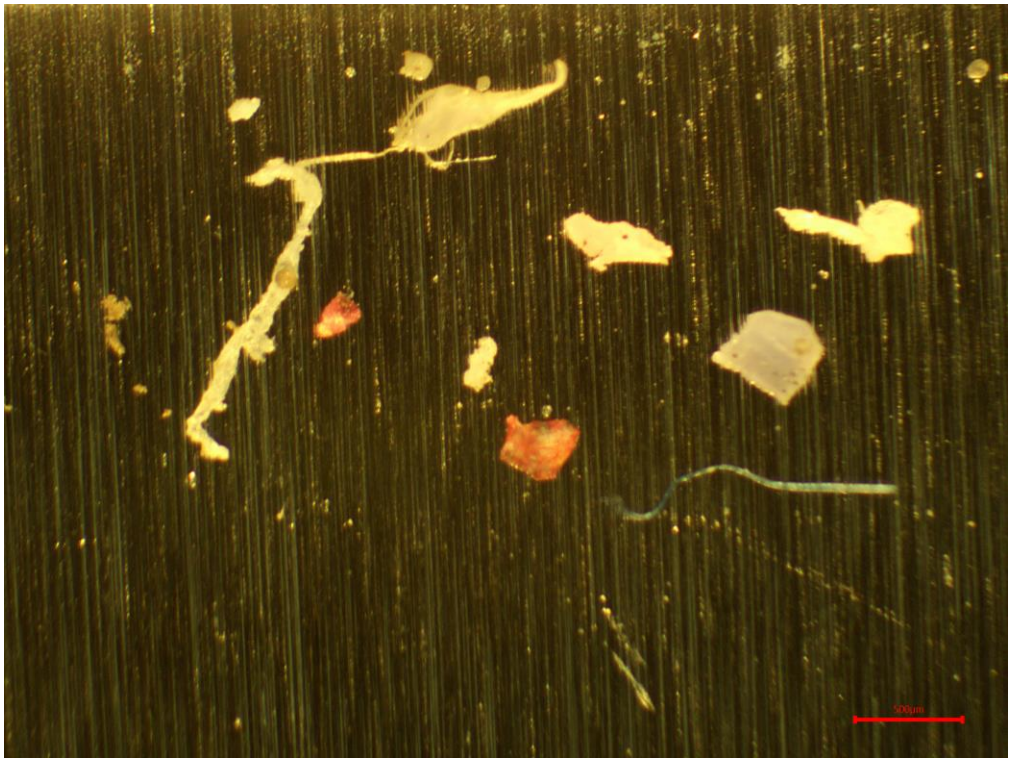

Figure 2. Overview image of potential microplastics recovered from sample ASC36266.002 (A1 2)

Results

Customer Sample Reference: **A2 2**
Laboratory Sample Reference: **ASC/36266.003**

Table 3: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
A2 2	ASC/36266.003	0.02	5	ND	5

ND Denotes None Detected

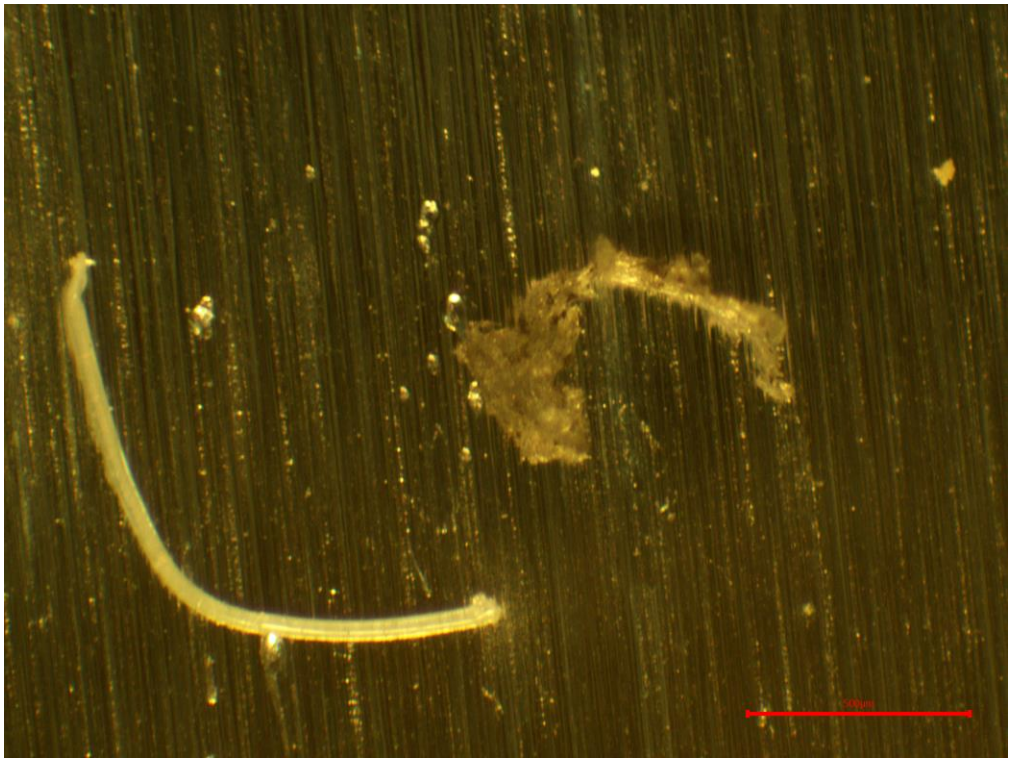

Figure 3. Overview image of potential microplastics recovered from sample ASC36266.003 (A2 2)

Results

Customer Sample Reference: **A3 1**
Laboratory Sample Reference: **ASC/36266.004**

Table 4: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
A3 1	ASC/36266.004	0.09	9	ND	9

ND Denotes None Detected

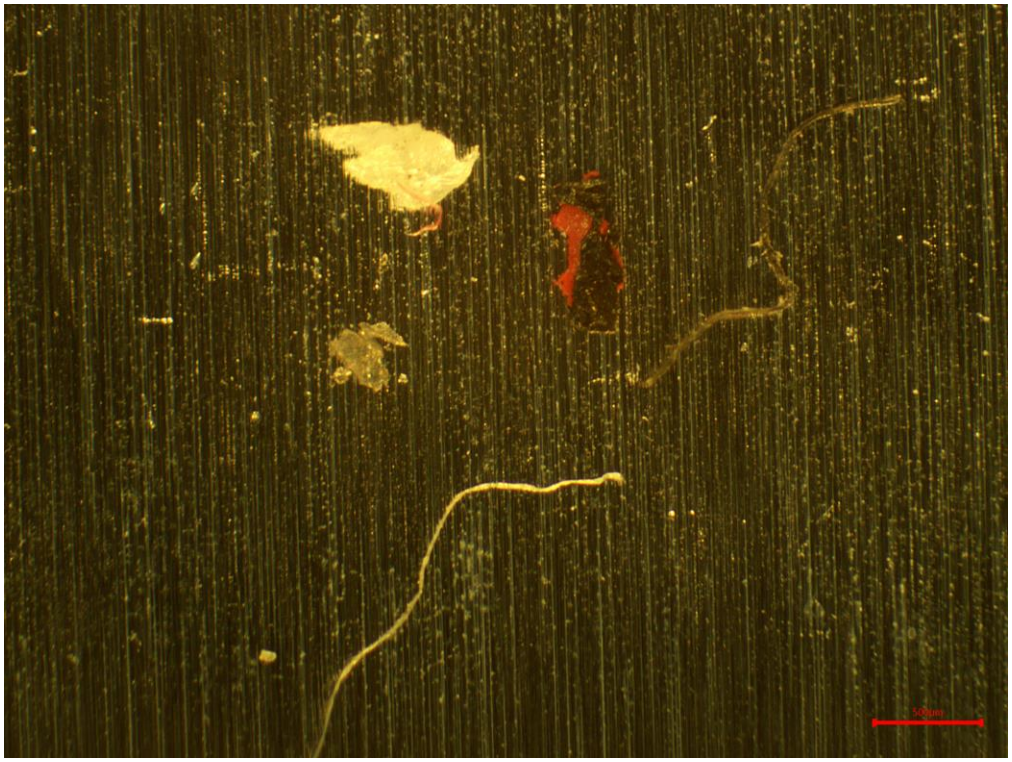

Figure 4. Overview image of potential microplastics recovered from sample ASC36266.004 (A3 1)

Results

Customer Sample Reference: **B1 2**
Laboratory Sample Reference: **ASC/36266.005**

Table 5: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
B1 2	ASC/36266.005	0.04	19	ND	16

ND Denotes None Detected

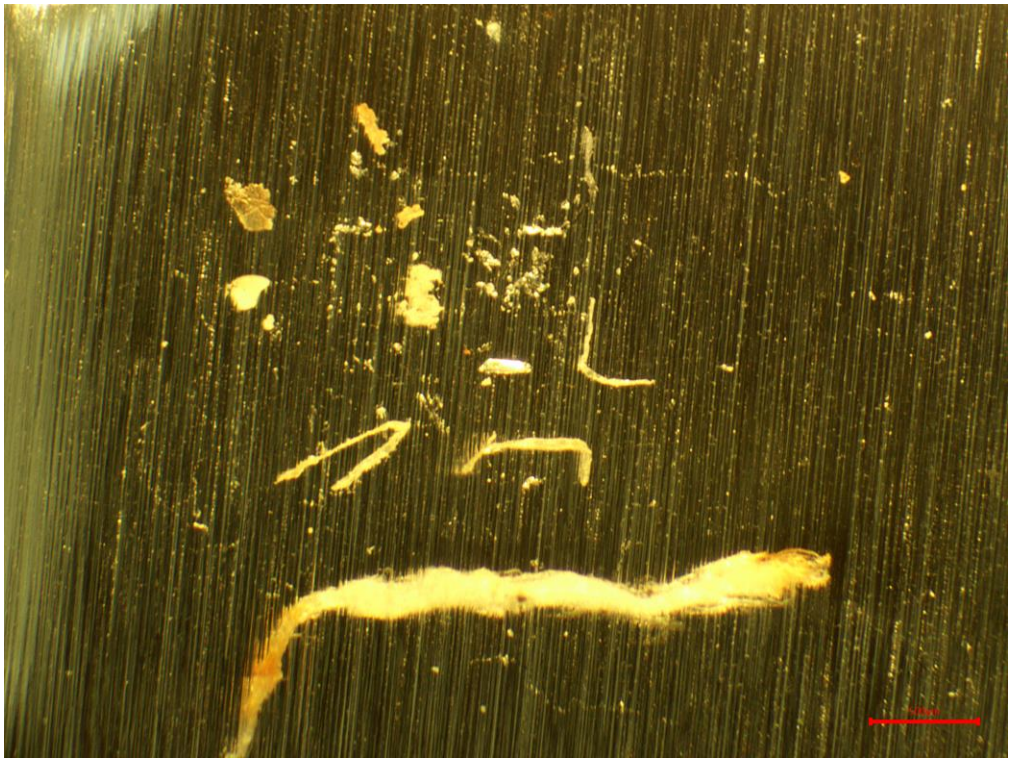

Figure 5. Overview image of potential microplastics recovered from sample ASC36266.005 (B1 2)

Results

Customer Sample Reference: **B2 2**
Laboratory Sample Reference: **ASC/36266.006**

Table 6: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
B2 2	ASC/36266.006	0.31	22	ND	40

ND Denotes None Detected

Figure 6. Overview image of potential microplastics recovered from sample ASC36266.006 (B2 2)

Results

Customer Sample Reference: **B3 1**
Laboratory Sample Reference: **ASC/36266.007**

Table 7: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
B3 1	ASC/36266.007	0.47	16	6	16

ND Denotes None Detected

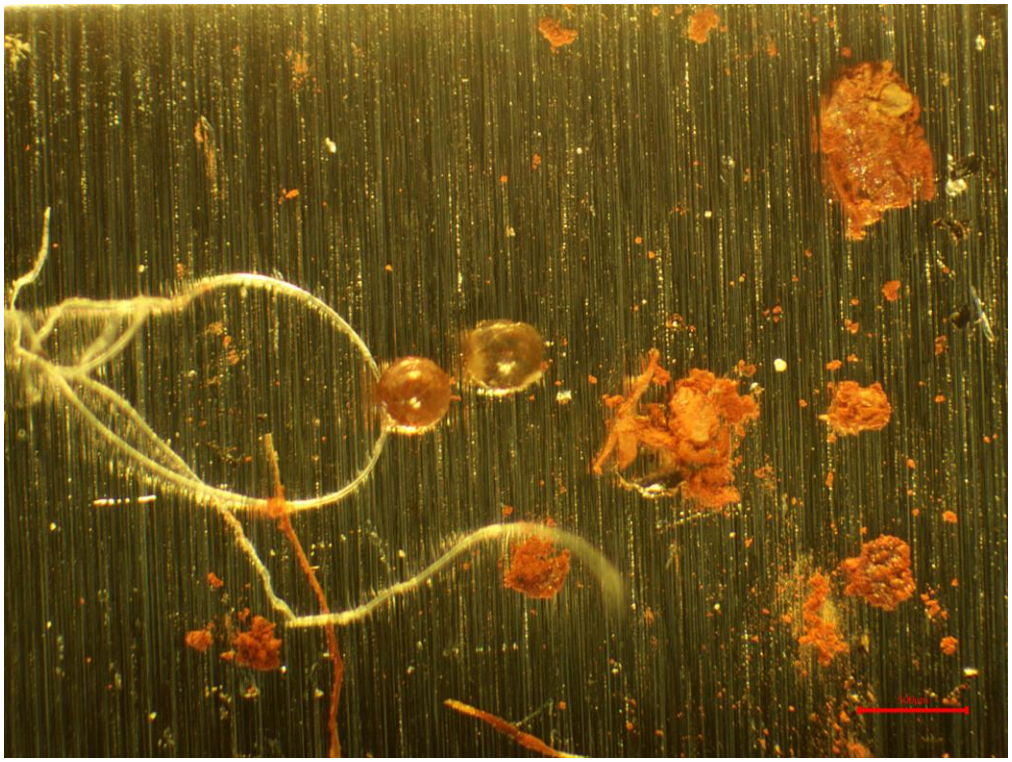

Figure 7. Overview image of potential microplastics recovered from sample ASC36266.007 (B3 1)

Results

Customer Sample Reference: **B4 2**
Laboratory Sample Reference: **ASC/36266.008**

Table 8: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
Method ID (ASC/SOP/xxx)		IHM	IHM	IHM	IHM
UKAS		NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
B4 2	ASC/36266.008	6.2	27	3	45

ND Denotes None Detected

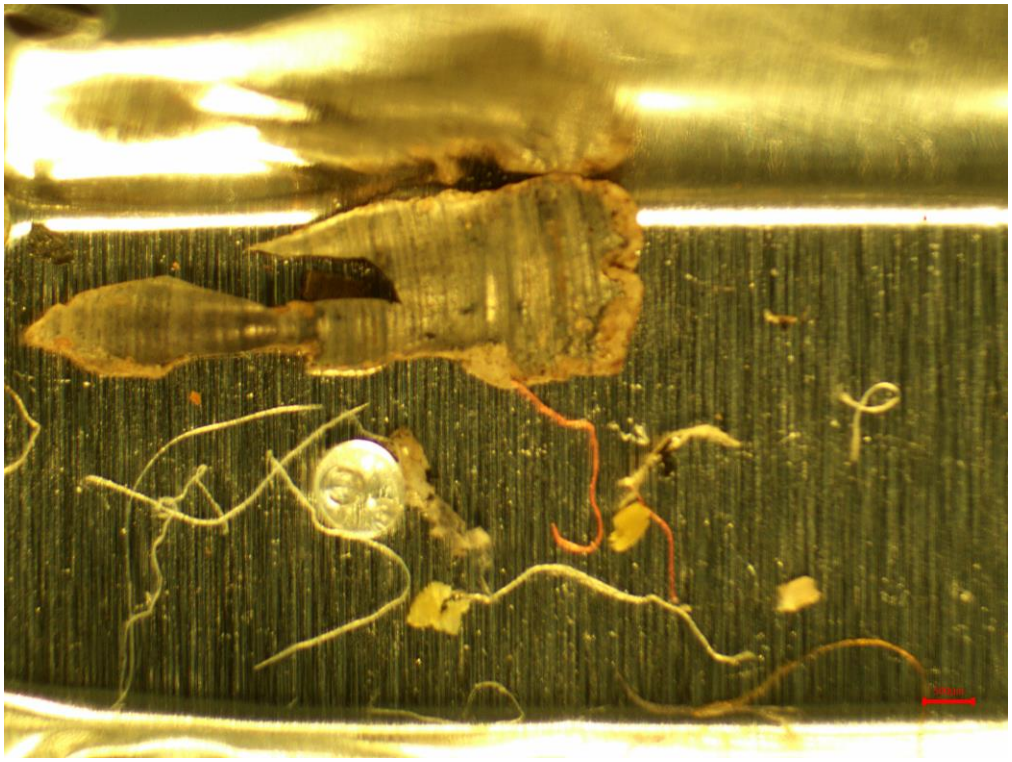

Figure 8. Overview image of potential microplastics recovered from sample ASC36266.008 (B4 2)

Results

Customer Sample Reference: **C1 1**
Laboratory Sample Reference: **ASC/36266.009**

Table 9: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
C1 1	ASC/36266.009	0.04	7	7	7

ND Denotes None Detected

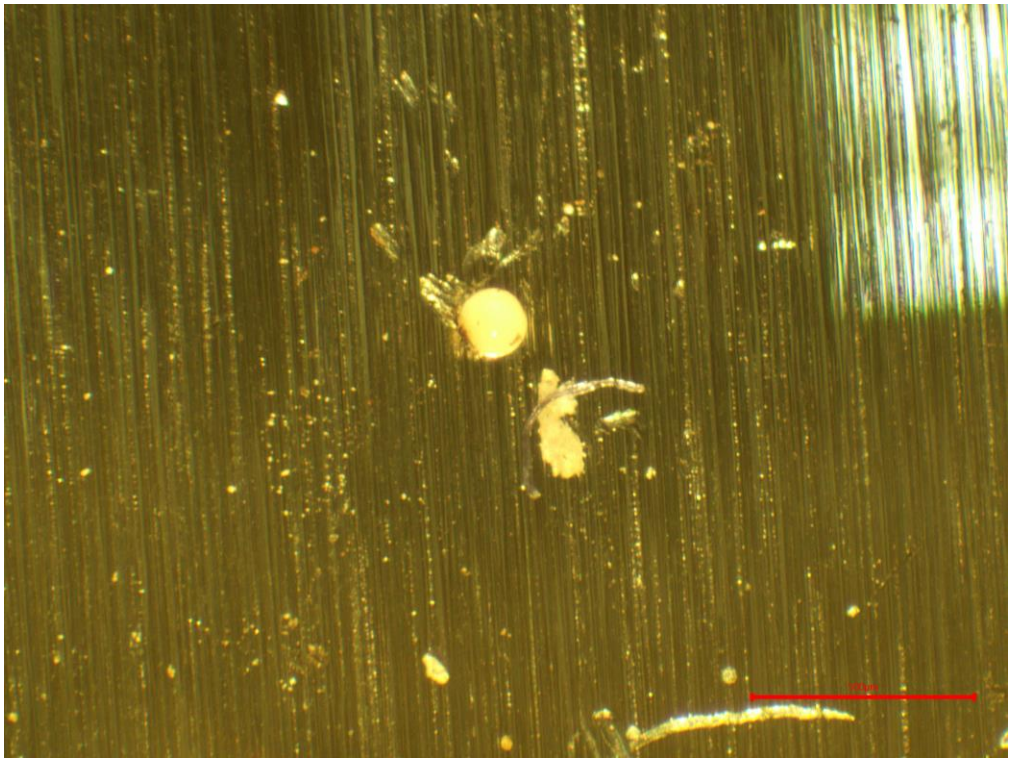

Figure 9. Overview image of potential microplastics recovered from sample ASC36266.009 (C1 1)

Results

Customer Sample Reference: **C2 1**
Laboratory Sample Reference: **ASC/36266.010**

Table 10: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
C2 1	ASC/36266.010	0.28	23	ND	14

ND Denotes None Detected

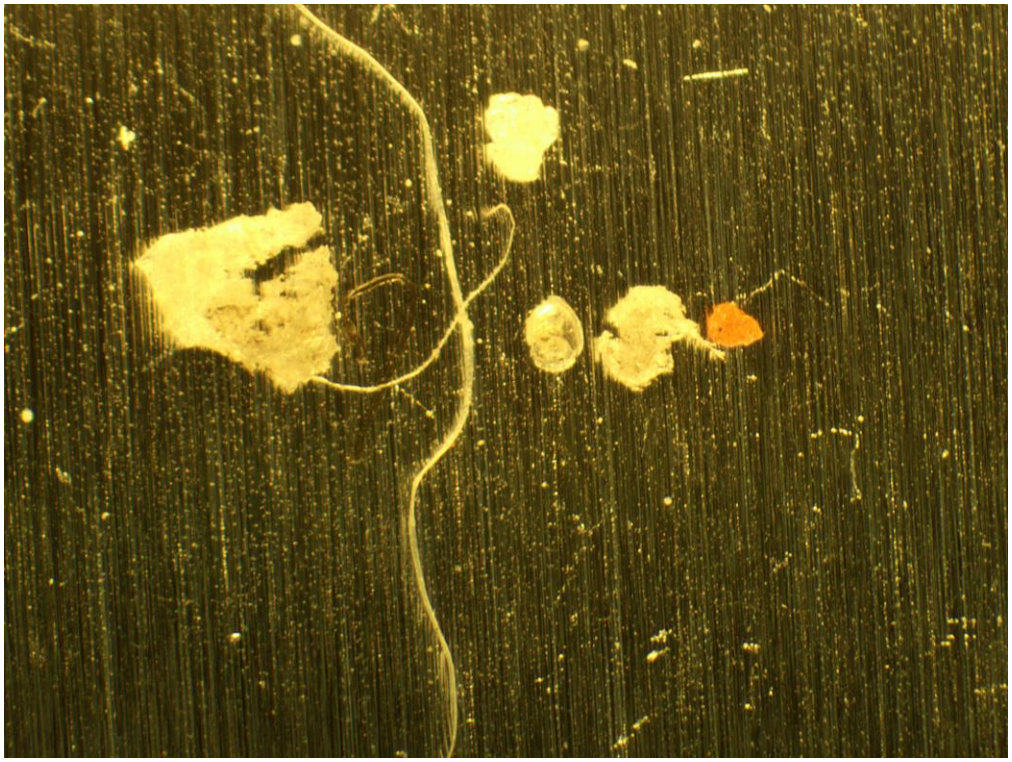

Figure 10. Overview image of potential microplastics recovered from sample ASC36266.010 (C2 1)

Results

Customer Sample Reference: **C3 1**
Laboratory Sample Reference: **ASC/36266.011**

Table 11: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
C3 1	ASC/36266.011	0.15	17	ND	10

ND Denotes None Detected

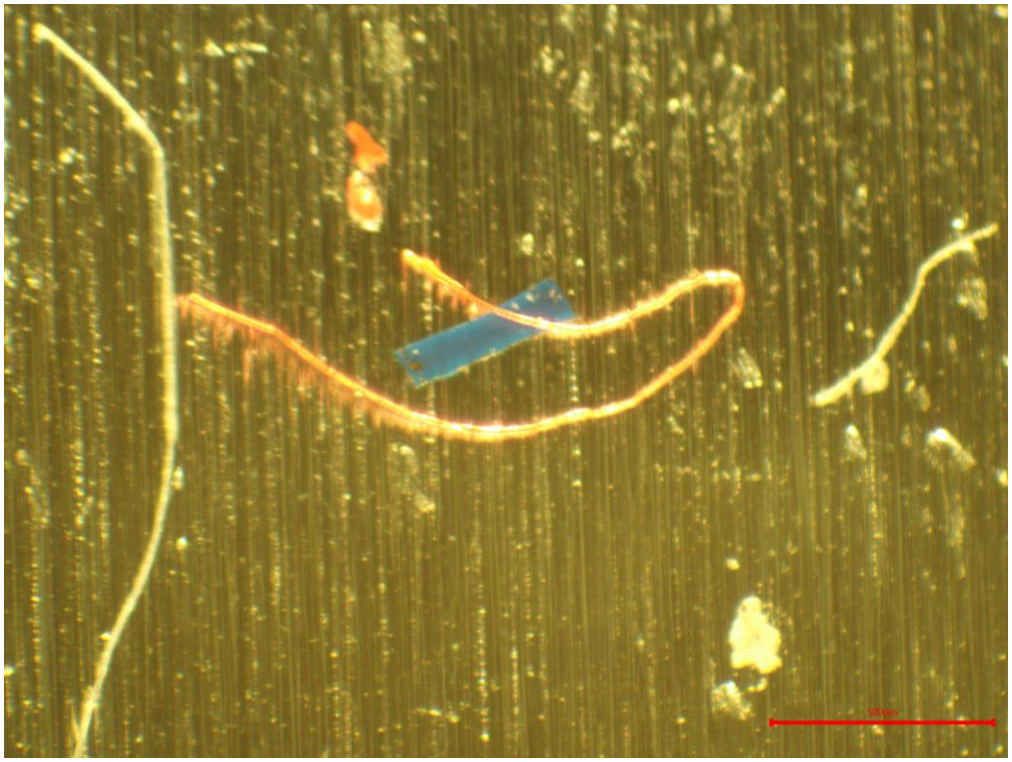

Figure 11. Overview image of potential microplastics recovered from sample ASC36266.011 (C3 1)

Results

Customer Sample Reference: **C4 1**
Laboratory Sample Reference: **ASC/36266.012**

Table 12: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
C4 1	ASC/36266.012	1.5	57	10	191

ND Denotes None Detected

Figure 12. Overview image of potential microplastics recovered from sample ASC36266.012 (C4 1)

Results

Customer Sample Reference: **C4 2**
Laboratory Sample Reference: **ASC/36266.013**

Table 13: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
C4 2	ASC/36266.013	2.5	48	5	58

ND Denotes None Detected

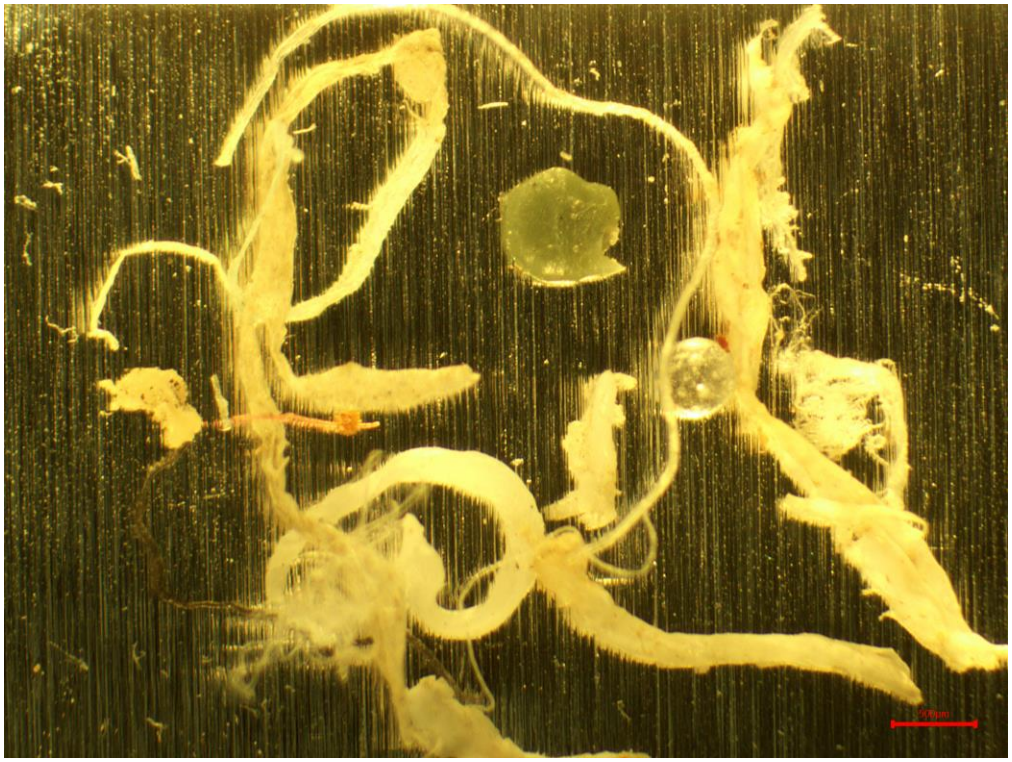

Figure 13. Overview image of potential microplastics recovered from sample ASC36266.013 (C4 2)

Results

Customer Sample Reference: **D1 2**
Laboratory Sample Reference: **ASC/36266.014**

Table 14: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
D1 2	ASC/36266.014	0.89	13	ND	10

ND Denotes None Detected

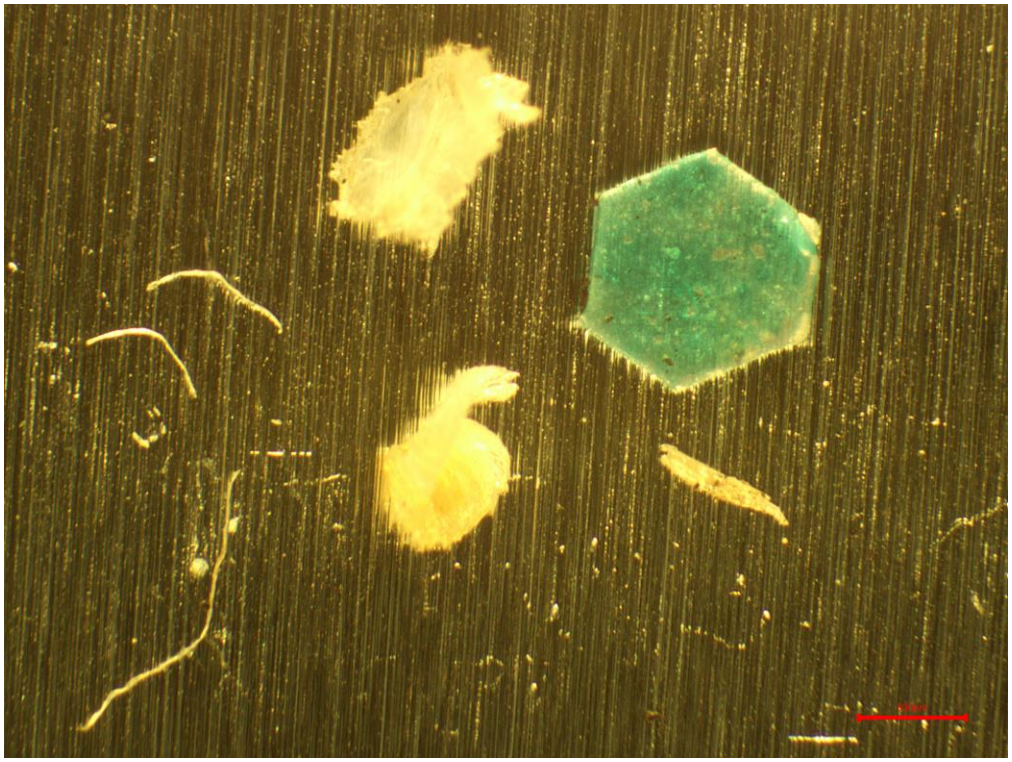

Figure 14. Overview image of potential microplastics recovered from sample ASC36266.014 (D1 2)

Results

Customer Sample Reference: **D2 1**
Laboratory Sample Reference: **ASC/36266.015**

Table 15: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
D2 1	ASC/36266.015	0.03	ND	ND	20

ND Denotes None Detected

Figure 15. Overview image of potential microplastics recovered from sample ASC36266.015 (D2 1)

Results

Customer Sample Reference: **D2 2**
Laboratory Sample Reference: **ASC/36266.016**

Table 16: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
D2 2	ASC/36266.016	2.9	46	17	97

ND Denotes None Detected

Figure 16. Overview image of potential microplastics recovered from sample ASC36266.016 (D2 2)

Results

Customer Sample Reference: **D2 3**
Laboratory Sample Reference: **ASC/36266.017**

Table 17: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
D2 3	ASC/36266.017	0.07	3	ND	3

ND Denotes None Detected

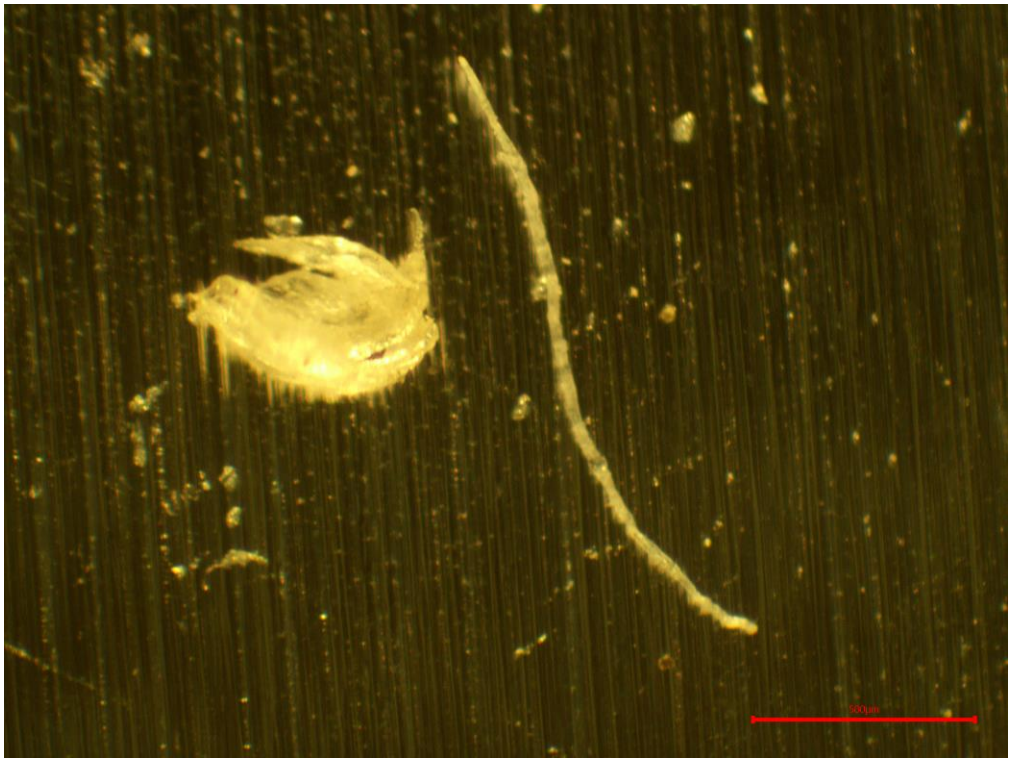

Figure 17. Overview image of potential microplastics recovered from sample ASC36266.017 (D2 3)

Results

Customer Sample Reference: **D3 2**
Laboratory Sample Reference: **ASC/36266.018**

Table 18: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
D3 2	ASC/36266.018	0.08	31	ND	13

ND Denotes None Detected

Figure 18. Overview image of potential microplastics recovered from sample ASC36266.018 (D3 2)

Results

Customer Sample Reference: **E1 1**
Laboratory Sample Reference: **ASC/36266.019**

Table 19: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
E1 1	ASC/36266.019	0.03	16	ND	12

ND Denotes None Detected

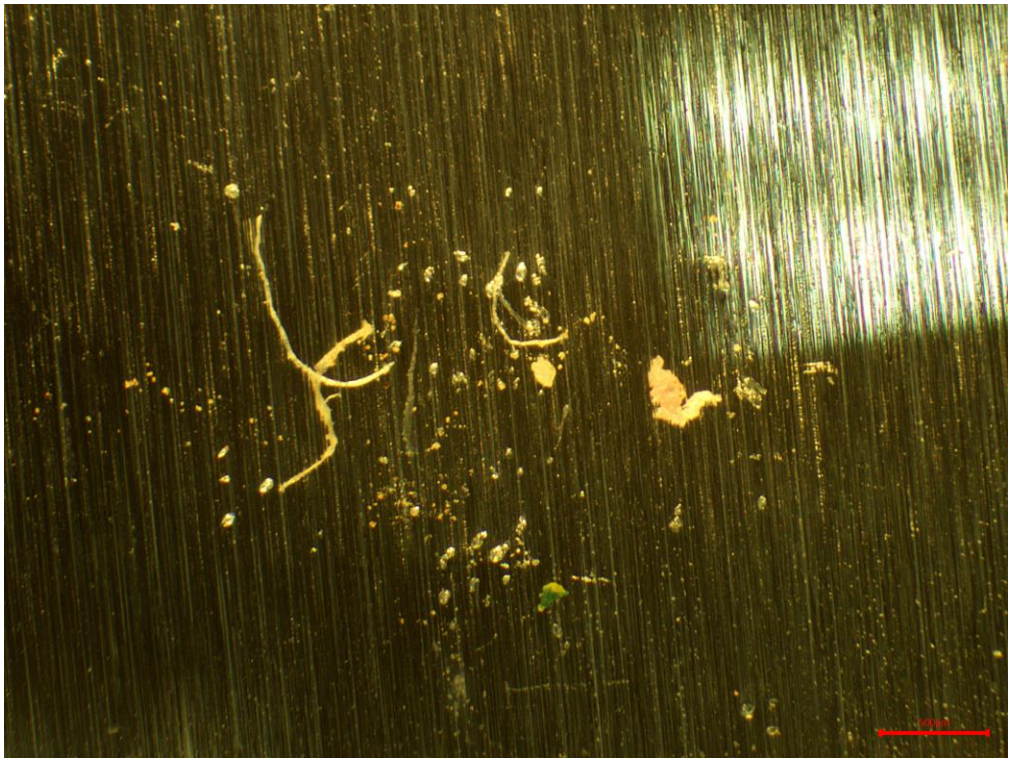

Figure 19. Overview image of potential microplastics recovered from sample ASC36266.019 (E1 1)

Results

Customer Sample Reference: **E2 1**
Laboratory Sample Reference: **ASC/36266.020**

Table 20: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
E2 1	ASC/36266.020	0.34	14	4	21

ND Denotes None Detected

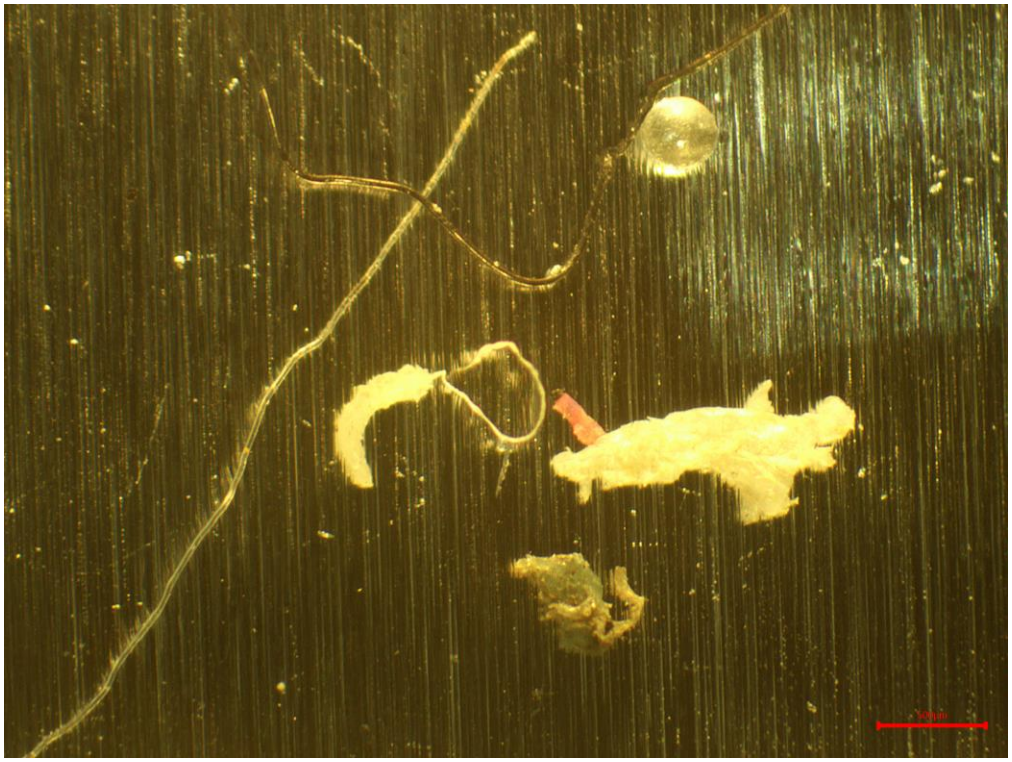

Figure 20. Overview image of potential microplastics recovered from sample ASC36266.020 (E2 1)

Results

Customer Sample Reference: **E2 2**
Laboratory Sample Reference: **ASC/36266.021**

Table 21: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
E2 2	ASC/36266.021	1.1	21	6	21

ND Denotes None Detected

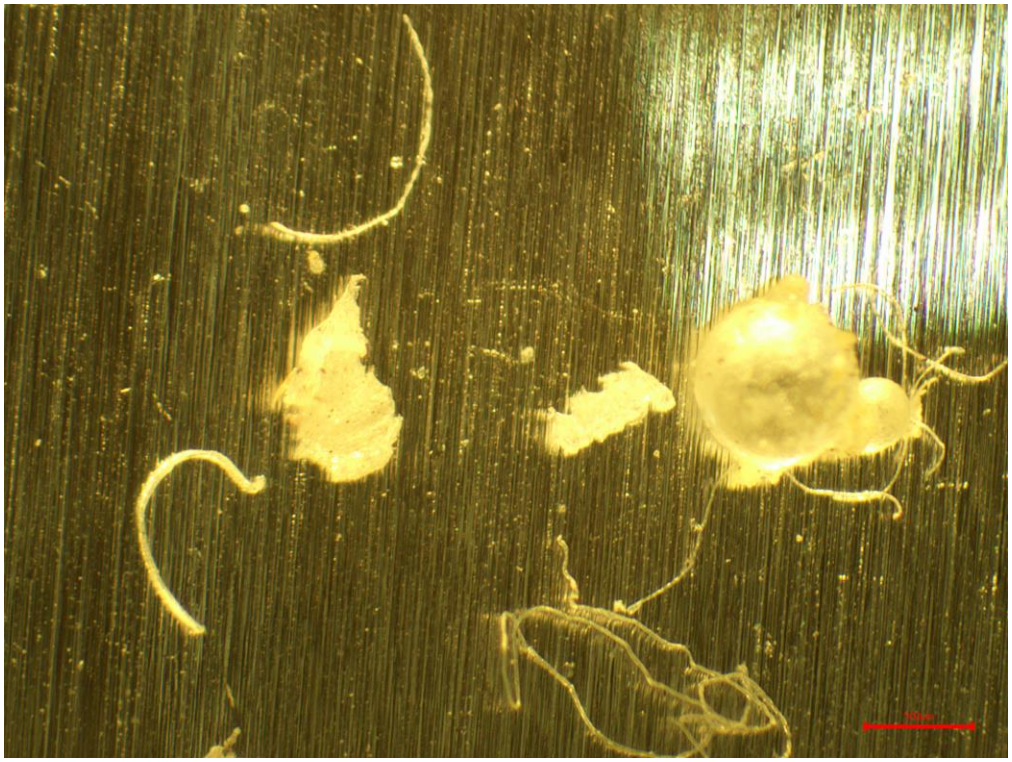

Figure 21. Overview image of potential microplastics recovered from sample ASC36266.021 (E2 2)

Results

Customer Sample Reference: **E4 2**
Laboratory Sample Reference: **ASC/36266.022**

Table 22: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM	IHM	IHM	IHM
	UKAS	NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
E4 2	ASC/36266.022	0.02	4	ND	20

ND Denotes None Detected

Figure 22. Overview image of potential microplastics recovered from sample ASC36266.022 (E4 2)

Results

Customer Sample Reference: **Runswick 3**
Laboratory Sample Reference: **ASC/36266.023**

Table 23: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
Method ID (ASC/SOP/xxx)		IHM	IHM	IHM	IHM
UKAS		NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
Runswick 3	ASC/36266.023	0.27	25	ND	56

ND Denotes None Detected

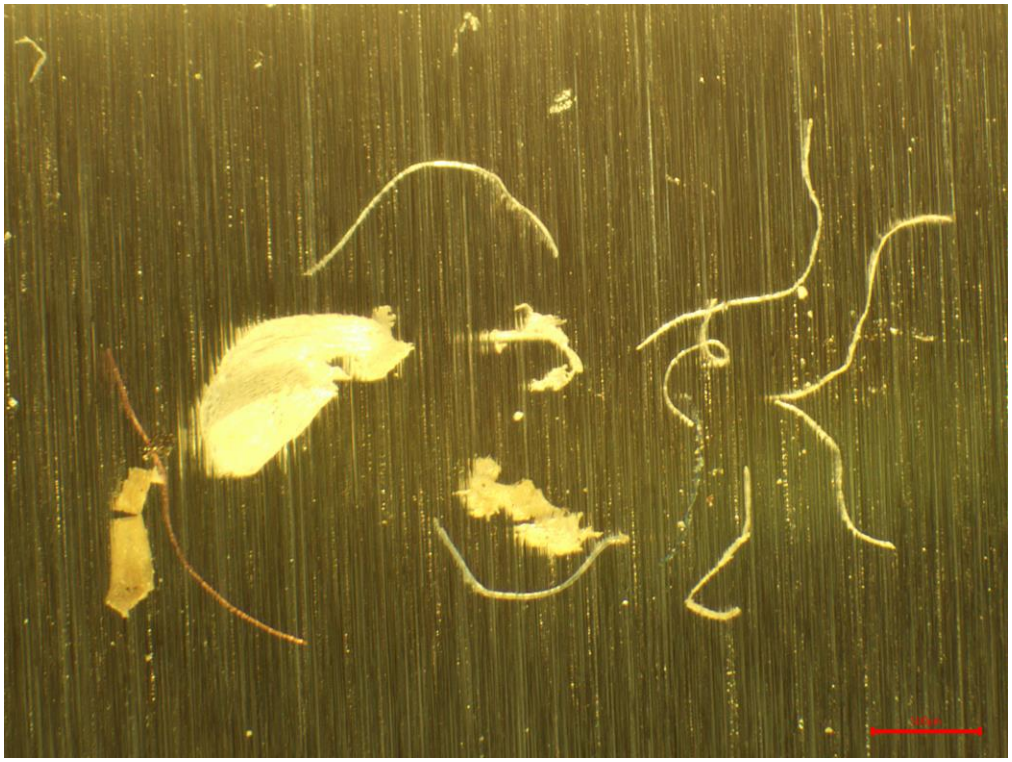

Figure 23. Overview image of potential microplastics recovered from sample ASC36266.023 (Runswick 3)

Results

Customer Sample Reference: **Runswick 4**
Laboratory Sample Reference: **ASC/36266.024**

Table 24: Potential microplastic weight and count

Units		mg/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)	Number/kg (dry sample weight)
Method ID (ASC/SOP/xxx)		IHM	IHM	IHM	IHM
UKAS		NO	NO	NO	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics	Particles	Microbeads	Fibres
Runswick 4	ASC/36266.024	6.8	172	31	329

ND Denotes None Detected

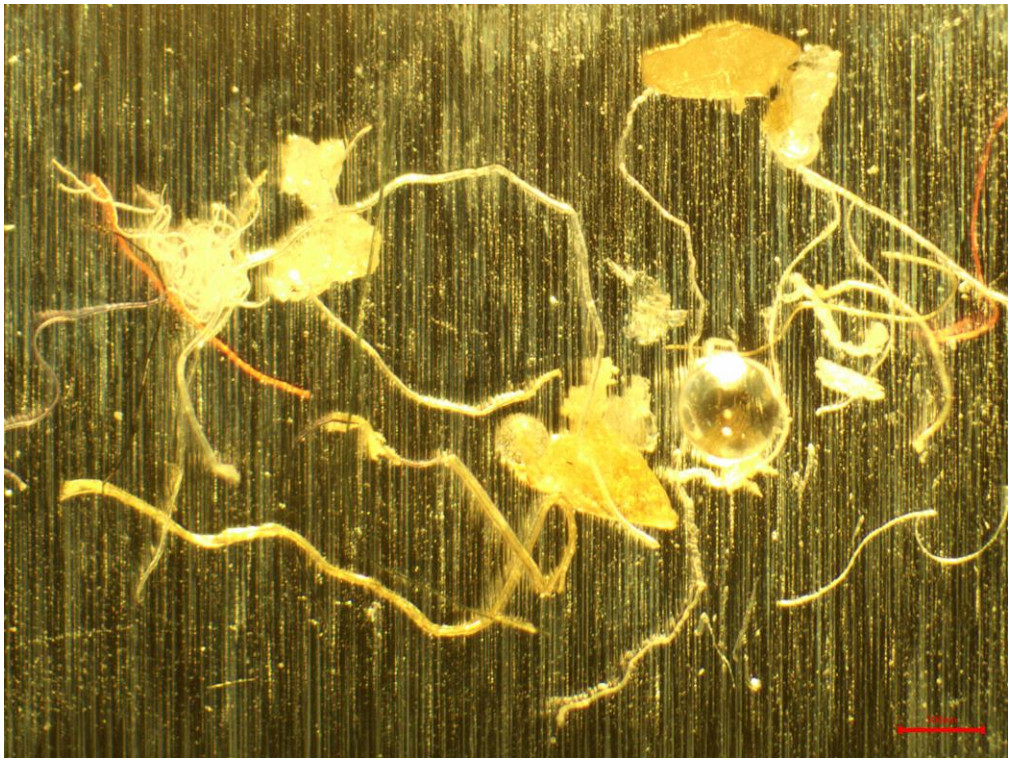

Figure 24. Overview image of potential microplastics recovered from sample ASC36266.024 (Runswick 4)

Quality control Results

Customer Sample Reference: **N/A**
Laboratory Sample Reference: **Laboratory Blank**

Table 25: Potential microplastic weight and count

	Units	mg/kg (dry sample weight)
	Method ID (ASC/SOP/xxx)	IHM
	UKAS	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics
N/A	ASC/36266 Laboratory Blank	ND

ND Denotes None Detected

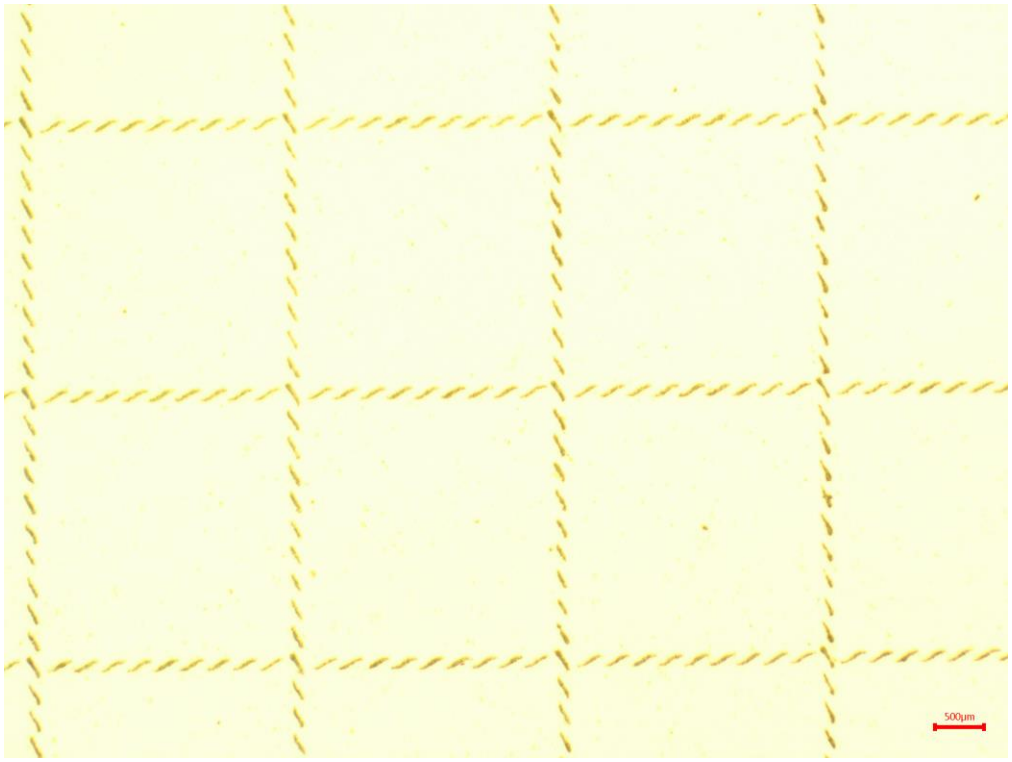

Figure 25. Overview image of potential microplastics recovered from Laboratory Blank

Quality control Results

Customer Sample Reference: **N/A**
Laboratory Sample Reference: **Microplastic Laboratory Spike**

Table 26: Potential microplastic weight and count

	Units	% Recovery
	Method ID (ASC/SOP/xxx)	IHM
	UKAS	NO
Customer Sample Reference	**Laboratory Sample Reference**	Potential Microplastics
N/A	ASC/36266 Microplastic Laboratory Spike	95

ND Denotes None Detected

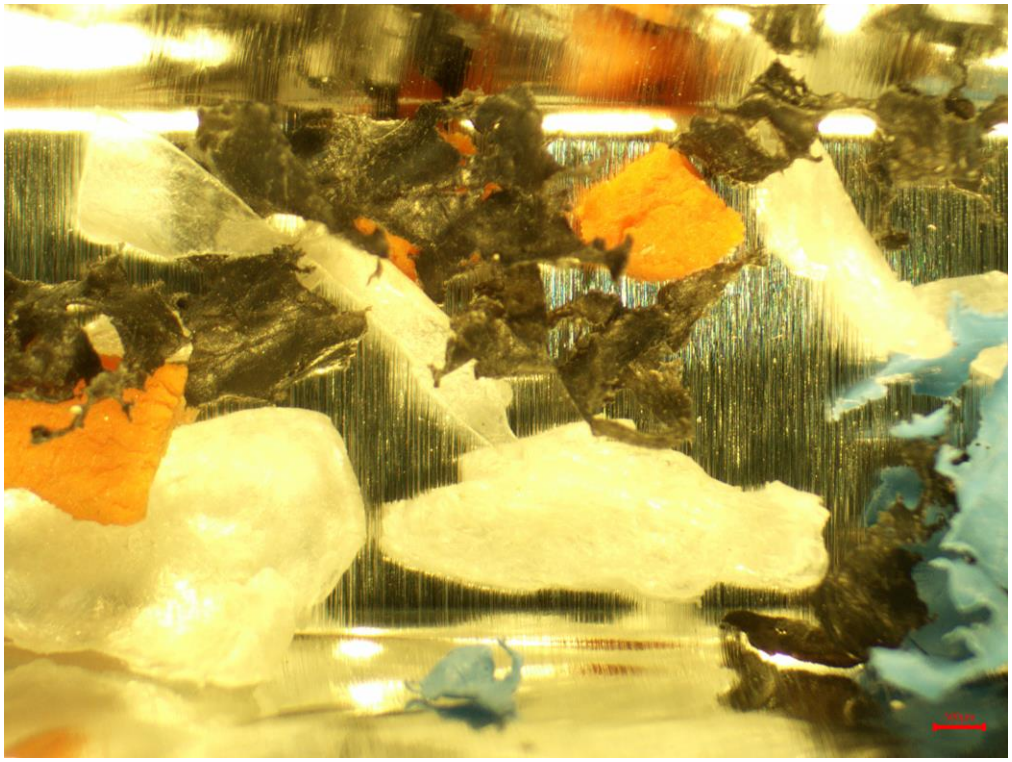

Figure 26. Overview image of potential microplastics recovered from Microplastic Laboratory Spike

END OF TEST REPORT