

Critical analysis of micro-plastics and the environment

[Environment](#), [Ecology](#)



Introduction

Over the decades there has been a growing concern about the escalating amounts of plastic debris found in the marine environment. Plastic debris has been reported worldwide in marine and terrestrial habitats (Thompson et al, 2004). The understanding of micro-plastic spatial, temporal distribution and its abundance in the oceans environment (water, sediment, and biota) is still in its infancy (Le, 2010; NOAA, 2011). Larger plastic fragments have been persistently recorded since the 1960's in environments from the poles to the equator (Derraik, 2002). Smaller plastics have been recorded but with less attention. Though the presence of micro plastics is evident, the impacts they may have on the environment is uncertain (GESAMP, 2010). Public, governmental, and institutional awareness is limited. This has allowed for industrial and commercial practices and their processes to go on largely unregulated (Thompson et al, 2009). There is also inadequate awareness amongst the public. That post consumer plastic items and packaging, once in the environment breakdown, generating significant quantities of microscopic plastic debris over time.

Microscopic plastics (<5mm) in the marine environment constitute for a significant environmental pollutant (Derraik, 2002). Pieces have been found in the digestive tracts from a multitude of organisms ranging from microscopic plankton, sea birds, and cetaceans (Teuten et al, 2009). Upon digestion, it is possible for smaller fragments of plastic to present a physical hazard. This can happen through clogging feeding appendages or the digestive system (Derraik, 2002). The properties of plastics allow them to

contain and adsorb persistent organic pollutants (POP's') (Carpenter et al 1972; Mato et al, 2001). This may facilitate the entry of these chemicals into the food chain, through ingestion from a multitude of marine organisms (Mato et al, 2001, Teuten et al, 2007, 2009).

Previous studies by Thompson et al; 2004; 2006, Brown 2009; Scontus, 2011, Travis, 2011; Colton, 1974; indicated that microscopic plastics are present worldwide particularly in shallow shores and sediment. This demonstrates that through current knowledge, no area is free from plastic pollution.

This study investigates the presence and distribution of microscopic plastics from Marazion and Carbis Bay. This research survey is also the first survey to be performed at these sites. Consequently contributing to the register of surveyed sites previously conducted. This will also continue to build evidence that microscopic plastics are a global scale pollution problem.

Section 1: Literature Review

1.1 The Marine Environment

The earth is covered with 70% water of which 97% is marine salt water (Pidwirney 2010). This environment includes a variety of diverse landscapes which comprise of many different habitat types such as estuarine and rocky shores to coral reefs and the deep oceans. The suites of habitat within the landscapes of the marine environment consistently interlink and occur together, for example: salt marsh; inter-tidal mud-flats; rocky shores and sub-tidal mussel beds which are all present in estuaries (JNCC, 2011). Many

of these marine habitats provide important ecosystem services such as provisioning of food and water resources. They also regulate and support functions including: flood control; waste management; water balance and climate regulation (Pinet, 2009). Human reliance on these ecosystem services is fundamental, as it also includes many imperative economically and culturally key organisms (NCEAS, 2010). Around 40% of the global population presently inhabit the coastal band areas which take up 5% of the total land mass. There is an estimated 2.75 billion people living within 100km of the coastline, (LOITZ, 2011) where many communities depend directly upon the marine resources for their livelihood (Kaiser et al, 2008). Human dependence on coastal systems is increasing, particularly in wetlands, reefs, and estuaries. With an estimated increase of 35% by the year 2025 (MARES, 2009).

Research by (Barnes et al, 2009; Lavender-Law et al, 2010), has indicated that contamination of pollutants is much more concentrated in coastal systems, ocean surfaces, and gyres. This can be driven by: ocean circulation, local wind, oceanic current conditions, coastline geography, and the location of discharge points.

1.2 Pollutants in the Marine Environment and their impacts

Pollution is the introduction of substances or energy into the marine environment (Pinet, 2009). Pinet (2009) states that pollutants can be found in three parts of the ocean:

The first is the seabed. Pollutants accumulate here by one of two main ways: They either settle as solid particles directly to the seabed where benthic

organisms can mix them into the sediment; or they chemically attach to particles such as silt and clay.

The second part of the ocean is where pollutants are concentrated in the pycnocline. This is the layer that separates water masses at different densities, commonly occurring in estuaries.

The neuston layer (sea surface microlayer) is the part of the ocean where solid wastes can accumulate. It is a thin interface of 0.1-10mm between air and sea. The chemicals and solids that collect here tend to aggregate and can affect the plankton and other invertebrates that use this layer as a temporary habitat (Pinet, 2009).

UNEP (2009) reports an estimated 80% of all polluting substances in the marine environment derive from a multitude of direct or indirect human land based activities. Shipping and sea dumping are thought to contribute to the remaining 20% (Karua, 2003). This also includes exploration and production from the offshore oil and gas industry, including the transportation of marine oil.

Direct inputs of pollution include either discharge of solid wastes e. g. plastics, or effluent from sewage sources such as industrial, municipal or coastal (Pinet, 2009).

Indirect inputs come from either land runoff where pollutants are transported mainly by rivers, or atmospheric fallout of pollutants entering the surface layer of the ocean (Clark, 2001).

When pollutants enter the marine environment they are broken down or degraded by oceanic and biological processes (Pinet, 2009). Pinet (2009) states that crude oil and petroleum spills in the marine environment are spread through advection caused by currents and winds. The hydrocarbons within the oil undergo evaporation, dissolution, emulsification, vertical mixing, and sedimentation. Pinet (2009) continues that biological process such as degradation to carbon dioxide by microbes and its ingestion by organisms. Have been shown to alter the composition of pollutants and disperse the spill further (Pinet, 2009). Municipal and industrial effluent comes in two forms: ' natural' such as sewage, and ' artificial' such as plastic (Pinet, 2009). These have entered the marine environment as mentioned above mainly by rivers. As pollutants enter the coastal waters, they are rapidly diluted by natural ' self cleansing' mixing processes, however, due to population increase, the volume of untreated wastes exceed the natural capacity of these coastal environments (Woodford, 2006). The natural mobility of water in contrast with land sourced pollution, allows pollutants to disperse over greater distances from the sources of input (Morales-Ojeda et al, 2010). Anthropogenic activities have led to ecosystem degradation, but the speed at which this occurs depends on local and regional characteristics (Morales-Ojeda et al, 2010).

The impacts pollutants have on the marine environment are diverse. At the extreme level of impact, the effects on marine life are acute and lethal to all biota. Organism populations are damaged, altering the structure of the community (Eisler, 1985). Eisler (1985) continues to state that this equates

to the lethal amount of a polluting substance, when given in a single dose. This is termed acute toxicity. At this level Eisler reported the most sensitive species of fauna are eliminated, with a consequent distortion within the biological community. A lower sub-lethal level may occur before the concentration of toxic substances reaches a lethal level; this can be used as an early warning of pollution (Eisler, 1985). At the next level, mobile marine animals e. g. fish and birds, can escape by moving away from the contaminated areas as they can detect a stressor change in environmental conditions. Those unable to escape can either adapt to the stress or perish. Sessile organisms like barnacles and vegetation fall into this unfortunate category.

Pollutants can have detrimental effects on marine organisms, communities, and ecosystems. Depending on the type of impact they have, they can be grouped into one of the following categories of increasing hazard, detailed by Patin (n. d) as being:

Substances causing mechanical impacts (suspensions, films, solid wastes) that damage the respiratory organs, digestive system, and receptive ability. Substances provoking eutrophic effects (e. g., mineral compounds of nitrogen and phosphorus, and organic substances) that cause mass rapid growth of primary producers and disturb the balance, structure, and functions of the marine ecosystem.

Substances with saprogenic properties (sewage with a high content of easily decomposing organic matter) that cause oxygen deficiency followed by mass mortality of biota, and appearance of specific microflora.

Substances causing toxic effects (e. g., heavy metals, chlorinated hydrocarbons, dioxins, and furans) that damage the physiological processes and functions of reproduction, feeding, and respiration.

Substances with mutagenic properties (e. g., benzo(a)pyrene and other polycyclic aromatic compounds, biphenyls, radionuclides) that cause carcinogenic, mutagenic, and teratogenic effects.

These categories show the abundance of sub-lethal affects which are strong indicators of pollutant induced stress. This also highlights the negative impacts of pollutants on the marine environment.

1. 3 Plastic debris and the Marine Environment

Plastic debris can be found in seas in all areas of the globe (Clarke, 2001) indicating that this is an international concern. The manufacture of plastic produces millions of tons per year (Thompson et al, 2004). The worldwide production has significantly increased over the last 60 years expanding from 1. 5 million tons to 245 million tons per annum (Zarfl and Matthies, 2010). The type of plastic produced in the current markets are chemically engineered to be highly durable and designed to support a slow biodegradation rate (Sudhaker et al, 2007). This type of manufacturing could result in plastic being one of the most profuse contaminants for centuries (Shaw et al 1994; as cited in Lavender-Law et al 2010). Considering the design and high production of plastic, there is growing concern for the risk of accumulation in marine habitats. There is evidence to suggest that plastic debris can account for between 50-80% of plastics reported on beaches, ocean surfaces and the seabed (Zarfl and Matthies, 2010).

Today's current market has made plastic highly accessible and transformed it into society's everyday lives (Thompson, 2009). Due to the versatile use and low cost of manufacture, it has helped make significant advances in all areas such as energy savings, human health, and lower costs in transportation (Zarfl and Matthies, 2010). Of all plastic produced, one third is used for single use items that are disposed of within a year (Knoblauch 2009). Packaging is a major component (Zarfl and Matthies 2010), who continues to state that plastic litter accounts for 10% of municipal waste worldwide. On the sea and coasts, plastic litter is mainly primary or secondary packaging consisting mainly of plastic bags, cups, bottles, feminine hygiene products and polystyrene (Clark, 2001). In 2009 a research project was performed on 'every day' commodities which contain micro plastics, revealing that a majority of facial cleansers now contain polyethylene micro plastics (Fendall and Sewell, 2009). The five main high production plastics that constitute for 90% of the total demand are: Polyethylene (LDPE and HDPE), Polypropylene (PP), Polyethylene Terephthalate (PET), Polyvinylchloride (PVC) and Polystyrene (PS) (Andrady and Neal, 2009).

Identifying the source of plastic debris is a complicated task due to the considerable amount of ways it could have entered the beach sediment. The source of some items can be accurately identified, and may be attributed with a high level of confidence to one of six specific sources: public, fishing, sewage related debris (SRD), shipping, fly tipped, or medical (MCA, 2009). An additional category is used for items that are unidentifiable (non-sourced).

This is because these items have either degraded too much, or have come from a multitude of sources.

1. 4 Micro-plastic fibres and the Marine Environment

Plastics that are <5mm are classified as micro-plastic fibres (Brown et al 2009). This was first introduced in September 2008 where the first International Conference of the newly recognised microplastic concern was sponsored by the U. S National Oceanic and Atmospheric Administration. Six countries were involved and agreed to define the term micro plastics as “ plastic pieces or fragments smaller than 5 millimetres” (Betts , 2008)

Micro plastics are usually the remains of macro plastics that are impervious to biodegradation (Thompson, 2004). Mechanical processes such as photodegradation by UV rays and wave abrasion can breakdown plastics into smaller particles (Klemchuck, 1990). Some plastics are susceptible to biodegradation due to containing matter such as starch which degrades but still leaves the micro-plastic fragments behind (Thompson et al, 2004). Micro plastic fibres can be from a number of sources. In a research project by Thompson et al (2004) FT-IR spectroscopy was used which discovered 9 conclusive polymers recognized as: acrylic, alkyd, poly (ethylene: propylene), polyamide (nylon), polyester, polyethylene, polymethylacrylate, polypropylene and polyvinyl-alcohol. They were present in marine sediment, including estuarine, sub-tidal, and sandy beaches. These types of polymers can be associated with larger macro plastics such as rope, clothes, and packaging. This further suggests according to Thompson et al (2004) that micro plastics are the result of mechanical breakdown.

In addition to mechanical breakdown, micro plastics enter the marine environment through accidental loss. This can happen during manufacturing and transport before entering the production phase such as in resin pellets and powders (Moore et al 2008). A study by Ashton et al (2010) found that in SW England, pellets were generally 3-5mm in diameter, out of 30 resin pellets identified, 29 were of polyethylene origin, with the remaining pellet being nylon. Plastic particles (fragments, fibres, and pellets) have been found in a study by Doyle et al (2010) to be widely distributed in the surface waters of the North East Pacific coastal ecosystems. Temporal and spatial variability in the quantities sampled were evident. The study also found that plastic fragments < 2.5mm were identified as the main contaminant in the pelagic ecosystems. These were assumed to be related to the mechanical breakdown from larger fragments with a widespread distribution due to ocean currents. These studies and various others such as Thompson et al (2004); Moore (2008) have shown the presence of micro plastic debris in the marine environment. However, to date there are no standardized methods for collecting, identifying, and quantifying micro-plastics in environmental samples. There is also no consistent terminology used to describe the issue between individual marine species and the encounter rates with plastic particles (Doyle et al, 2010).

1.5 The Chemical Effects of Plastic on Marine Biota

The most evident impact plastic has on marine organisms from birds to plankton is physical entanglement and ingestion of plastic resulting in suffocation and starvation (Laist, 1987, Clark, 2001 and Thompson et al, 2004). Evidence of fragmented plastic in the marine environment allows for

ingestion by a broader range of organisms (Barnes et al, 2008). Research on Great Shearwaters as mentioned by Zarfl and Matthies (2010) indicated a relationship between chemical burden and ingestion. This research led to the theory that the consumption and ingestion of plastic debris may transfer toxins through biota (Teuten et al, 2009).

In the marine environment, micro plastics are known to absorb and concentrate contaminants (Mato et al. 2001). These can become several orders of magnitude more concentrated on the surface of the debris than in the surrounding seawater (Mato et al. 2001). Plastic contains organic contaminants which include: polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons, petroleum hydrocarbons, organochlorine pesticides (2, 2'-bis(p-chlorophenyl)-1, 1, 1-trichloroethane, hex chlorinated hexanes), polybrominated diphenylethers, alkyl phenols and biphenyl A (Teuten et al, 2009). A number of these additives are known to be, submitted during the manufacturing process. These antioxidants, stabilizers, flame-retardants and phthalate plasticizers create a unique property to each plastic (Thompson et al, 2009, Teuten, 2009). Additives and organic compounds can also be absorbed into the plastic from the immediate seawater (hydrophobic chemicals) (Thompson et al, 2009, Teuten, 2009). Plasticizers end up in the environment as they are not especially stable in the plastic product and leach out (Staple et al 1997). Biphenyl- A (BPA) degrades rapidly. However due to its frequent appearance in aquatic ecosystems through point discharges such as landfill leachate and sewage treatment plant effluent, it is continually released into the environment (Oehelmann et al 2009).

Reports have indicated that BPA and phthalates bio concentration factors (BCF) in invertebrates are typically higher than those in vertebrates. A study carried out by the European Union in 2003. Found that the Bis(2-ethylhexyl)phthalates (DEHP) bioaccumulation factor is between 42 and 82 in variety of fish species, but in the amphipod *Gammarus psuedolimnaeus* BFC was 3600. In *Mytilus edulis* BFC was 2500 and up to 5380 in the copepod *Acartia tonsa*. This indicated that suspension feeders that are fixed to their habitats are more likely to consume pollutants.

The effects phthalates had on biochemical pathways such as antioxidant and proximal marker enzymes in *M. edulis* and *M. galloprovincialis* showed that exposure to diallyl phthalate (DAP) reduced phosphor-protein levels and raised micronuclei frequency. This was a marker for genotoxicity and fragmented - apoptic cells in the gills (Barsiene et al, 2006). Furthermore in a study carried out by Tagatz et al (1986) Di-n-butyl phthalate (DBP) altered community structure and colonisation profiles of zoomicrobenthos in both laboratory and field conditions with up to a 49-97% reduction in the density of molluscs and echinoderms.

Studies of the impacts of BPA on bivalves particularly in *Mytilus* species has shown increased; phosphor-protein levels, induced spawning in both sexes, damaged oocytes and ovarian follicles (Aarab et al, 2006) and increased micronuclei frequency in gill cells (Barsiene et al, 2006). BPA also caused a significant effect in the haemolymph. That initiates a lysomal membrane destabilization in extracted haemocytes in *M. galloprovincialis* (Canasie et al 2007). BPA has furthermore caused alterations in phosphorylation of MAP

kinases, which is essential in embryogenesis, cell growth, differentiation, and apoptosis (Canasie et al 2007). The outcome of these studies may suggest considerable implications for the health of mussel species (Oehelmann et al 2009).

The majority of past literature which has been published on plastic debris concentrates on the distribution of plastics and classification. Research by Mato et al (2001) found that contaminants adsorb to plastics. This illustrates potential for indirect effects of debris ingestion. Microplastics have recently been identified as marine pollutants of significant concern, due to their persistence, ubiquity and potential act as vectors to transfer and expose persistent organic pollutants (POP's) to marine organisms (Obard and Ng, 2005).

1. 6 Transfer of Contaminants from Plastics to Lower Trophic Organisms

Research was conducted on lugworms, *Arenicola marina* by Thompson et al (2004). They assessed the ability of micro plastics to transport contaminants to benthic organisms. The experiment exposed a priority pollutant phenathrene (a PAH), tetrabromodiphenyl ether (a PBDE), triclosan (antimicrobial) and NP to microscopic PVC particles, at environmentally appropriate concentrations. Sediment containing these plastics was exposed to *A. marina*. The result of the trial indicated that the contaminant concentrations were significantly higher than in the sediment. This demonstrated that contaminants can be transported from plastic to organism. However the mechanism remains unclear (Thompson 2004–2007, unpublished data). Additional research by Thompson et al (2004) shows that

a variety of organisms with differing feeding habits (sediment feeders, filter feeders), have all shown to ingest plastic fragments/ fibres. The results of these trials indicates that ingestion of contaminant-sorbed plastics, have the potential to be a pathway of contaminant transport to benthic organisms.

Studies conducted by Brown et al (2009) revealed that micro plastics that were ingested by the bivalve *M. edulis* persisted in the circulatory system > 48 days. Larger numbers of smaller plastics were discovered in the actual circulatory tissue. It is important here to highlight the scarcity of research and the rarity of studies concentrating on the biological impacts of marine micro plastic on invertebrates. Thompson et al (2005) stressed the importance that further research is needed to focus on micro plastic ingestion and bioaccumulation in food chains. This could help to better appreciate the effects of interactions on the level of organism impacts, before extrapolating to ecosystem level impacts of micro plastics (Arthur et al, 2008).

A study undertaken by Teuten et al (2007) investigated the potential for plastics to; transport hydrophobic contaminants and establish the importance that plastics may play in the global distribution of hydrophobic contaminants. It was discovered that there is potential for plastics to transport contaminants to organisms. A priority pollutant phenanthrene was also observed to be ingested by the common lugworm *A. Marina*, which is a benthic deposit feeder. Given the high capacity of plastics to sorb phenanthrene and that *A. Marina* is at the base of the food chain, eaten by numerous other species. The contamination of *A Marina* presented high

potential to transfer contaminants through the food web (Thompson et al 2004). The presence of small amounts of plastic fibres could also result in a large increase of concentrations of hydrophobic contaminants in the sediment (Teuten et al, 2007). The sea surface microlayer (SML) or neuston layer where hydrophobic contaminants can be concentrated by up to 500 times that of the underlying water column (Mato et al, 2001), it is also one of the main parts of the ocean in which micro plastics accumulate (Mato et al, 2001). Plastics could therefore become an important factor in contaminant transport at a global scale.

1. 7 Floating micro plastics: Global Transportation for POP'S, Invasive/Alien Species

Depending on the polymer type and additives the micro plastics position in the water body either; floats on or near the ocean surface, suspended at mid- depth or sinks to the sea bed. The density of the water is also a variable (Gordon 2006). As many plastics are less dense than water they float on the surface micro layer (SML). The high concentrations of POP's in this layer are available > 500 times greater than the underlying water column (Teuten et al 2007). The potential impacts of POP's have been discussed however micro plastics due to their buoyant nature may also provide a transport mechanism for contaminants globally (Derraik, 2002; Thompson et al 2004). There are reports that plastic debris including micro plastics could also transport invasive and alien species (Derraik, 2002; Moore, 2001) species such as bacteria, diatoms, algae, barnacles, serpulids, hydroids, tunicates and bryozoans (Winston, 1982; Derraik, 2002). These species could pose serious harmful impacts on native biodiversity on a global scale to intertidal and

shoreline ecosystems (Gordon 2006). A report by Derraik (2002) suggests a possible decrease of 58% in global marine species biodiversity, if the worldwide biotic mixing continues to rise. An example is of the bryozoans *Membranipora tuberculata* which has been transported from the Tasman Sea (Australia) to New Zealand on plastic pellets (Gregory, 1978). The same species has been discovered on plastics which have been stranded on the shores of the USA, Derraik (2002) states their abundance has increased worldwide. Though in a study by Moore et al (2001) in the North Pacific Central Gyre <10% of micro plastics researched was host to the bryozoan *Membranipora tuberculata*. Floating plastics combined with other sources of debris can also cause severe issues regarding water quality, obstructing the growth of marine vegetation, decreasing spawning areas and habitats for marine organisms (Gordon, 2006).

1. 8 Transport and Distribution

The understanding of micro-plastic spatial, temporal distribution and its abundance in the oceans environment (water, sediment, and biota) is still in its infancy (Le, 2010; NOAA, 2011). Larger plastic fragments have been persistantly recorded since the 1960's in environments from the poles to the equator (Derraik, 2002). Smaller plastics have been recorded but with less attention and understanding in methods such as how to quantify the full spectrum of micro-plastic materials present (Thompson, 2004). In the UK on South Wales sedimentary beach habitats Williams and Turner (2001) reported that 63% of debris was represented by plastics (Derraik, 2002). In comparison Thompson et al (2004) reports that the beaches surrounding Plymouth using FT-IR spectroscopy identified ~60% of debris were synthetic

polymers which included acrylic, alkyd, poly (ethylene: propylene), polyamide (nylon), polyesters, polyethylene, polymethacrylate, polypropylene and polyvinyl-alcohol.

The physical qualities of plastics floatation and hydrodynamics (discussed in section 1. 8) advocates that plastic debris can be transported and distributed through the oceans surface currents. Oceanic effects are important controls of the movement and weathering of plastic debris. The properties and durability of the polymers are also variables (Pichel et al, 2008). The haline and cooling properties of the ocean interfere with the UV degradation process. Which indicates that plastics have a longer degradation time in the marine environment (Barnes et al, 2011). The fouling of organisms happens relatively quickly therefore plastic debris become sheltered from UV light making it more persistent (Barnes et al, 2011). This was highlighted in a report by Wiess et al (2006) where plastic by an albatross had originated from a plane which had been shot 60 years prior over 9600 km away.

The abundance of plastic debris in a study by Brown et al (2011) shows that location is a significant factor. Brown et al (2011) reported values of 0-7290 plastic items per hectare in the south West Atlantic and Atlantic sector of the Southern ocean. The Mediterranean showed the greatest densities. They concluded this is due to densely populated coastlines and shipping lanes. This combined with a poor dispersion of the plastics due to the limited tidal flow or water circulation (Brown et al, 2011). In comparison in areas of low circulation bottom plastic debris becomes trapped in high concentrations of sediment. This gathers in frontal areas. The debris could have travelled

extensive distances only sinking under weight of fouling by a diversity of bacteria, algae, animals and accumulative sediment (Brown et al, 2011). Plastic debris can also be consumed by organisms. This undigested in faecal matter in turn settles to the bottom (Doyle, 2009). Doyle (2009) reported that fisheries could be an example of this. A report by GESAMP (1990) suggested that 80% of marine pollution is sourced from land based activities and the majority of beaches near population centres are contaminated with a variety of plastic remains that are washed up from the ocean, contributed by rivers, ships and outfalls, dumped by illegal garbage operators or left behind by beach users.

It is liable that the majority of plastics that have entered the marine environment have continually occurred as polymers. Few of which can fully degrade in the marine environment (Andrady 2009). Despite this the absolute quantities and distribution are uncertain due to the inconsistency of verified samples and analytical methods.

1. 9 Marine Debris: Control and Legislation

Marine pollution is a local, national, regional and international concern therefore management and policy needs to be implemented at these varying levels. These also need to be adopted to the appropriate systems such as terrestrial and marine based sources of pollution. The United Nations Convention on the Law of the Sea was opened for signature at Montego Bay, Jamaica, on 10 December 1982. It went into force on 14 November 1994 and is presently binding for 154 States, as well as the European Community. Its objective was to protect and preserve the marine environment which

established a complete framework governing principles and responsibilities for land and sea based pollution (GESAMP, 2010) to protect human health and the environment.

The Ship and platform-based litter MARPOL 73/78 Annex V which is a section of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (IMO, 2010) it is an international treaty which provides a comprehensive approach to dealing with ocean dumping. It has creating international guidelines for pollution prevention from ships. Annex V prohibits the disposal of plastic and regulates the disposal of other types of rubbish at sea. This convention as of the 31st July 2010, has support of 140 countries which have ratified annex V controlling the disposal of plastics and garbage in the ocean. MARPOL Annex V has also designated ' Special Areas' depending on the sites unique oceanographic, ecological or traffic conditions. Where all overboard discharges and garbage are prohibited with the exception of ground up food waste. To date MARPOL has enlisted 9 special areas which include; Mediterranean Sea, Baltic Sea, Black Sea, Red Sea, Persian Gulf, Gulf of Aden North Sea, Antarctic area and the wider Caribbean (GESAMP, 2010). A revision of Annex V commenced in 2006 and MEPC produced a submission containing a new draft proposal which was labelled " IMO's Marine Environment Protection Committee 61st session in October 2010". This overview could adopt a strengthening in regulations (GESAMP, 2010).

The Global Environmental Facility, Transboundary Water Assessment Programme (GEF-TWAP) is expected to begin in 2011-2014. The objectives

are to develop an indicator based methodology for assessment of transboundary water systems. Which include open oceans, large marine ecosystems, rivers, lakes and groundwater. In addition, to develop partnerships with UN and other agencies and the arrangements for the conduct of a global assessment of transboundary waters. If conducted this project would also allow for the prioritization of interventions and allocation for financial resources (GESAMP, 2010).

The 1996 Protocol refers to the 1972. Convention on the Prevention of Marine Pollution by Dumping of Wastes or Other Matter. It is also known as the London Convention.

This convention prohibits the dumping of all waste except for a restricted group of materials. Then only when it can be established that there are no practical opportunities for reuse or recycling, and that the effects of dumping on the marine environment will be minor (IMO, 2010)

The 1996 protocol classifies pollutants into black and grey lists, where black is substances that are toxic, persistent and bio accumulate, in contrast the grey list are those substances which are non-toxic, are persistent and are able to float or remain suspended in the water column where there is potential interference with the marine environment (GESAMP 2010). These pollutants are controlled and cannot be dumped in the sea other than in trace quantities. Plastic debris according to GESAMP (2010) is enough of a threat to the marine environment to be a black listed pollutant.

The 1998 OSPAR Convention Protection of the Marine Environment of the North East Atlantic safeguarded specific areas. The European Union has

water-protection law (directives) that apply to all of its member states. They include the 1976 Bathing Water Directive, which seeks to ensure the quality of the waters that people use for recreation. Most countries also have their own water pollution laws. In the United States, for example, there is the 1972 Water Pollution Control Act and the 1974 Safe Drinking Water Act (European Commission, 2006).

Section 2: Aims and Objectives

1. To survey the micro plastic fibre distribution in the West Cornwall area (North Coast Carbis Bay and South Coast Marazion).
2. To quantify the abundance and investigate the factors that affect accumulation of microscopic plastic fibres.
3. To identify the types of plastic polymers and potential sources of contamination.
4. Assess the potential environmental consequences of micro plastic fibre contamination within UK beaches.
5. To assess the consistency of existing techniques by:
 - i) Determining the percentage of micro fibres lost during Petri dish storage.
 - ii) Using standard blanks to identify possible contamination routes in the laboratory.

Section 2 Study Area

The county of Cornwall has a temperate Oceanic climate (Koppen Climate Classification: CFB) due to its southerly latitude and the influence of the Gulf Stream (Met Office, 2000a). The mean annual temperature varies between 11.6 °C (53 °F) (Met Office, 2000a). The geographical position Cornwall (Appendice 1) is in, experiences related forcing factors; the North coast is exposed to the Celtic Sea and the South coast is similarly exposed to the English Channel. In both cases the wind direction is predominately blowing in from the Atlantic at a south westerly direction (Met Office, 2000b). The tidal patterns for both the North and South coast follow a related semi diurnal trend. Cornwall's deep water rias that provide sheltered harbours and anchorages along the South coast were shaped from the height of the last ice age where Cornwall's rivers cut long deep valleys and as the ice sheets melted the sea levels rose flooding the estuaries creating rias (Wildlife Trust, 2011). The coastline of the UK covers an area of ~10708 km (Gibson et al, 2001). A 700 km of this coastline belongs to Cornwall's 300 beaches (Cornwall Development Company, 2010). The Southwest sustains over 60% of the UK's Heritage Coast and supports a significant proportion of The UK's designated bathing waters (EA, 2010). The area is also important for rare and endangered habitats (EA, 2010). In addition due to Cornwall's natural and cultural heritage supports significant economic developments in fisheries and tourism (Bradfield et al, 1976). Other local recreation such as surfing and sailing is generic of the coasts in the county.

2.1 Marazion: Top Tieb beach

Grid Reference: SW 52313 3058

Marazion Top Tieb (Plate 1) beach is situated on the South West coast of Cornwall. The South coast is more sheltered and is interrupted by many rias providing deep water harbours. Top Teib beach is east from the main tourist (blue flag) beach of Marazion, it has no parking facilities and is used mainly by dog walkers and anglers. The harbour, known as Top Tieb, was built in the late 1920s to provide a landing place for boats to and from St Michael's Mount. The entrance is difficult to access and is only accessible 1-2 hours either side of high tide in the summer. On observation the beach has a shallow seabed and is a mixture of shingles, rocky pools, and soft fine sand. The ecology of the area is reasonably diverse with many residential birds such as the wader *Haematopus ostralegus* (Oyster catcher) which feeds on bivalves such as *Mytilus edulis*, *Cerastoderma edule* (common cockle) and worms such as *Arenicola marina* (lug worm) which are present in the area.

Plate 1, Marazion Top Tieb beach

The beach is sheltered from the full impact of the Atlantic wind due to the granite outcrops jutting out into the ocean dissipating the strength, however wind action from storms created at sea still create substantial crests. The surrounding cliff which is either occupied on top by farmland or residential gardens is sedimentary which is constantly eroded by high tides and wind abrasion. Plastic pollution was evident on site including; plastic bottles, caps, nets and crates.

2. 2 Carbis Bay

Grid Reference: 52983 38922

The North coast is more exposed to the prevailing winds from the Atlantic Ocean than the South coast and is more uneven, with sheer cliffs and steep valleys. Carbis Bay however is a mile or so to the east of St Ives and is relatively sheltered with a relatively calm sea as result of this and Carbis Bay has good bathing waters and is very popular for windsurfing and water-skiing. The shore is a soft sand sedimentary bay. Though the site does not to appear as diverse in wildlife as Top Teib it is a popular coastal walk to spot basking sharks, grey seals, and bottle-nose dolphins.

Plate 2 Carbis Bay beach

Carbis Bay (Plate 2) is approximately 1 mile length. The centre of the beach homes many facilities such as cafes, shop and a car park. The Carbis Bay Hotel has extensive grounds leading down to the edge of the beach. Being north by northeast facing, the beach rarely gets surf and is mainly a familyfriendly beach. Away from the centre, the beach meanders away to rocky edges. The east side of the beach, at low tide, can dry out to connect with the RSPB bird sanctuary beach of Porthkidney Sands. The beach benefits from an annual beach clean and dog walking is prohibited during the summer period. On site there was no clear plastic pollution, this is most likely due to the annual cleans. For a comprehensive geographical location of Cornwall refer to Appendices 1.

Section 4 Methodology

4.1 Sediment sampling

Using PLASSOP guidelines (Appendices 2) to measure the amount of micro plastic fibres contained in the sub-littoral sediment 5 sample sites were chosen at the strandline of both locations using a metal trowel. The sub sites were set 25 meters apart (Plate 3, Marazion), see Appendices 5 for Carbis Bay, 3 subsamples (450g container) were extracted from each site collecting at random spots within an arm length diameter giving a fair representation of micro plastics from those sites.

Plate 3 Satellite image of top teib beach, illustrating 5 sample sites (25 meters apart), map sourced with permission from Bing (2010) Microsoft Corporation

From each 450g container of sediment the micro plastics were separated from the sediment through a filtration method. Using a saline solution NaCl (260g), 1L deionised H₂O to create buoyancy which aided floatation to micro plastics and other low density materials. Then 50g of the sediment was added to 100ml of the saline solution into a 250ml separation funnel (Figure 1). This was manually oscillated for 1 minute and left to stand for a further minute. After which the sediment was drained from the funnel and collected in a beaker. The remaining supernatant was then filtered using a Buchner funnel and Whatman GF/A filters (Fig 2a; b) with the aid of a vacuum pump to accelerate the process.

The filters were placed and labelled in Petri-dishes and covered to prevent contamination and left to dry at room temperature ($\sim 20^{\circ}\text{C}$). The same sediment was re-suspended a further 2 more times. The process was repeated using the same process resulting in 3 filter papers per sample of sediment. With a fourth control filtration for every set of 3 filters processed. Therefore from each 450g container 3x50g were analysed the labelling strategy was: for Marazion, MZ A1, A2, A3, B1, B2, B3, C1, C2, C3 and similar for Carbis Bay (CB).

Figure 1 (a) Separation funnels

4. 2 Microscopic Analysis and FT-IR spectroscopy

Using a microscope ($\times 30$) plastic fragments / fibres were identified and removed from the petri dish. Using precision forceps and transferred to new filter papers and Petri-dishes to be counted, circled, and stored. The micro-plastic polymers were identified with the use of the Fourier Transform Infrared (FT-IR) spectroscopy. Infrared radiation was passed through the sample where infrared radiation, absorbed and transmitted through the sample. This resulted in a molecular fingerprint represented by absorption and transmission. Similar to a fingerprint no two unique molecular structures generate the same infrared spectrum (Thermo Nicolet Corporation, 2001) which makes it useful in identifying different groups of compounds.

Figure 2 (a) Buchner funnel and vacuum pump, (b) Whatman GF/A filters.

The Bruker IFS 66 (Fig 3a) instrument was used to apply this principle. Micro plastic polymers were identified using the nearest common spectra of known

compound polymers and matching them to the sample spectra polymers in an electronic library database (Thompson, 2004) (Fig 3b).

Figure 3 (a) FT-IR device, (b) Matching the sample spectra polymer in an electronic library database; red line represents the fibre sample being analysed, blue line represents spectra match on library database.

Section 4 Results

4.1 Microplastic abundance

The quantities of micro plastic fibre determined in sediments from both locations are shown below (Table 1). Due to time constraints and lack of access to sufficient equipment and the high numbers of micro plastics discovered in each Petri dish only 2 (A1 and B1) of each 3 sites at Marazion and Carbis Bay could be analysed. The sub sites were analysed for the total micro plastics found, mean and standard deviation.

Table 1 Microplastic fibre count from Marazion and Carbis Bay, showing mean, standard deviation (stdev) and total

MarazionCarbis Bay

Sub sitesSite 1Site 2Site 3Site 1Site 2Site 3

Subsamples(petridish)(50 g-1sediment)

A110861278

B110114948

A114138945

B1111713111310

A11212891112

B16861068

Mean10. 511. 57. 510. 07. 58. 5

Stdev2. 73. 43. 11. 33. 72. 3

Total636945604551

Table 2 Total micro plastic fibre abundance and percentage of fibres at each location

SiteTotal micro plastic fibre abundanceMicro plastic fibre %

Marazion17753. 15

Carbis Bay15646. 84

Total micro plastic fibres333

The microplastic fibres found at both locations as represented in Table 1 and Table 2 show that there is clear microplastic fibre concentrations which contaminate the littoral zone sediment.

4. 2 Micro plastic statistical analysis

A box plot (Fig 4) was created on Minitab15 indicating the mean distribution of micro plastics concentrations of Marazion and Carbis Bay. The box plot shows that there does not seem to be any significant difference in the mean distribution of micro plastic between the two locations nor micro plastic abundance.

Figure 4, box plot indentifying mean micro plastic abundance and spread between M= Marazion and C= Carbis Bay

Firstly; to identify any significant difference in the mean value of spread between each site (Site1, Site 2, and Site 3) on each location an Analysis of Variance (ANOVA) test was performed in Excel using the following Hypothesis:

Null Hypothesis (H0): The underlying population of microplastic concentrations at Marazion follows a normal distribution

versus

Alternative Hypothesis (H1): The underlying population of microplastic concentrations at Marazion does not follow a normal distribution

Anova: Single Factor : Marazion

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	166	310.57	1.87	0.0001
Column 2	266	911.51	3.43	0.0001
Column 3	364	57.59	0.16	0.0001

ANOVA

Source of Variation	SS	df	MS	F	crit
Between Groups	522262.7758	007120	0942633.68232		
Within Groups	140.5159	36666667			
Total	192.517				

Table 3 ANOVA of single factor indicating P value between the sites 1, 2, and 3 taken from Marazion

It was found that the P-value = 0.09426 which is greater than P-value: 0.05: Therefore can conclude that there is not sufficient evidence to reject the null hypothesis indicating that the underlying populations of microplastic concentrations at Marazion are normally distributed.

The same test was performed for Carbis Bay using the following hypothesis:

Null Hypothesis (H0): The underlying population of micro plastic concentrations at Carbis Bay follows a normal distribution in general

versus

Alternative Hypothesis (H1): The underlying population of micro plastic concentrations at Carbis Bay does not follow a normal distribution in general

Anova: Single Factor: Carbis Bay

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	1660	101.6		
Column 2	26457	513.9		
Column 3	36518	55.5		

ANOVA

Source of Variation	SS	df	MS	F	crit
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Between Groups 1929.51. 3571428570. 2872483. 68232

Within Groups 105157

Total 12417

Table 4 ANOVA of single factor indicating the P value between sites 1, 2 and 3 taken from Carbis Bay

It was found that the P-value = 0.28724 which is greater than P-value: 0.05: Therefore it can be concluded, that there is not sufficient evidence to reject the null hypothesis indicating that the underlying populations of micro plastic concentrations at Carbis Bay are normally distributed.

To identify if there was any significant difference in the mean population of micro plastics between the two locations (Marazion and Carbis Bay) a two sampled mean test assuming equal variance (T-test) was performed with the following hypothesis:

H0: There is no significant difference between the mean underlying population of micro plastic concentrations at Carbis Bay and Marazion in general

versus

H1: There is significant difference between the underlying population of micro plastic concentrations at Carbis Bay and Marazion in general.

t-Test: Two-Sample Assuming Equal Variances

MarazionCarbis Bay

Mean9. 8333333338. 666666667

Variance11. 323529417. 294117647

Observations1818

Pooled Variance9. 308823529

Hypothesized Mean Difference0

df34

t Stat1. 147151152

P(T <= t) one-tail0. 129663878t Critical one-tail1. 690924198P(T <= t) two-tail0. 259327756t Critical two-tail2. 032244498

Table 5, T-test of two sample means assuming equal variance indicating the P value between the means of the two locations, Marazion and Carbis Bay

It was found that the P-value= 0. 259327756 which is greater than P-value: 0. 05: Therefore it can be concluded, that there is not sufficient evidence to reject the null hypothesis indicating that the underlying populations of micro plastic concentrations at Carbis Bay and Marazion are not significantly different and in general it can be assumed they are the same. Figure 5 shows the overlap of means which further suggests there is no significant difference between sites.

Figure 5, T-test of two sample means indicating overlap of distribution

4. 2 Polymer Identity

Of the 339 fibres counted, 144 were identified using the Infrared Spectroscopy (FT-IR). This found that 46% of these were true-plastic, 20% part plastic (semi-synthetic), and 34% non-plastic, as indicated in Figure 6a.

Figure 6. (a) Total percentage of polymer identity broken down between true plastic, part plastic and non-plastic, (b) Total of individual polymers broken down into true plastic, part plastic and non-plastic

Figure 7 (a) Representing the total breakdown percentage of true microplastic fibres found at both locations, (b) A radar chart representing individual microplastic fibres found at both locations

From this data it is clear to identify as a percentage (Fig 6a) and individually (Fig 6b) that the true plastic is the most abundant micro plastic fibre on the littoral zone sediment, followed by non-plastic and semi plastic. True plastic abundance is represented in (Figure 7a; b) where the polymers have been broken down and indentified as acrylic (PMMA), nylon, acetate, polyamide, polyester, polyethylene terephthalate (PET) and Petlon 4630..

The non-plastics were the second most abundant (36%) cellulose rayon fibre as shown in Figure 8a; b was found by far to have the highest concentrations overall. Which included; rayon tire chord 1650, viscose rayon filament, rayon staple, rayon monofilament, solution dyed rayon, and other cellulosic fibres that could relate to feminine hygiene products. Linen which was the second most abundant was recorded as natural pink linen, also identified was 70% rayon 30% rayon blend and white glass.

Figure 8 (a) Percentage of non-plastic polymers identified from both locations
(b) Overall count of non-plastic polymers, from both figures the cellulose rayon fibre is most abundant.

Figure 9 (a) Percentage of overall semi-synthetic polymer fibres found at both locations
(b) Overall count of semi-synthetic polymer fibers found at both locations

Figure 10, indicating the percentage of true plastics at (a) Marazion (b) Carbis Bay

Figure 11 Percentage of Non-plastic polymers found on (a) Marazion (b) Carbis Bay

The third most abundant as shown in Figure 6a; b is the semi-synthetic polymer fibre blend. Which found that the most profuse indicated in Figure 12a; b was the; 73% acrylic 23% wool blend followed by 55% silk 30% nylon 15% angora sweater and the least abundant padded envelope filler. Figure 12 Percentage of semi-synthetic polymers identified at (a) Marazion (b) Carbis Bay

From the data collected the percentage ratio of true plastics was relatively uniform between the sample locations however as shown in Figure 10a; 10b the percentage of polyethylene is significantly higher (almost double) of that found at Marazion. Also illustrated is the high percentage of nylon and acrylic polymer fibres found at Marazion. The percentages of non-plastics between both site locations appear to have no obvious differences between cellulosic

rayon fibre and linen. However the sample site Carbis Bay has concentrations of 70% rayon 30% linen blend and padded envelope filler as indicated in Figure 12a; b. For semi-synthetic polymer fibres the 73% acrylic 23% wool blend appears to be the most abundant at Marazion. Whilst at Carbis Bay the concentrations of 55% silk 30% nylon 15% angora sweater blend and padded envelope filler are greater.

4.3 Control Results

A total of 18 blank control samples were analysed for contamination of polymers from the sample sites. The fibres were found, calculated and recognised using FT-IR spectroscopy therefore confirming risk of contamination and identifying potential sources.

Table 6 Blank controls of polymer identity and abundance Figure 13

Percentage of blank control polymers

The results in Table 6 confirm the risk of contamination during the filtration process; however the blank controls do indicate that the total values were a very small percentage (1. 20%) compared to the typical overall polymer fibres evaluated. As indicated Figure 13 above the main contaminant identified was 70% rayon 30% linen blend which was found with the Carbis Bay blank filtration papers as was the rayon staple. Viscose rayon was identified in relation to the Marazion blank filtration papers.

Section 5 Discussion

5.1 Fibre abundance

Initial results using the ANOVA test as mentioned in section 4 concluded that the total micro plastic fibre abundance throughout each individual location were normally distributed (Table 3, 4) This was also consistent with the follow up t-test analysis (Table 5) supporting the Null hypothesis; The micro plastic fibres between all site locations has no significant difference in distribution.

The most evident explanation for this similarity in distribution may be due to the geographical position of both locations which experience related forcing factors; the North coast is exposed to the Celtic Sea and the South coast is similarly exposed to the English Channel, where in both cases the wind direction is predominately blowing in from the Atlantic at a south westerly direction (Met Office (b), 2000). The tidal patterns for both the North and South coast follow a related semi diurnal trend. Shipping routes throughout the Atlantic Ocean, Celtic Sea and English Channel are habitual of the Cornish coast and consistently increasing (Fig 14) this corresponds with the global trend in the shipping trade (McElvaine, 2009).

Figure 14 indicating the location of major shipping ports and the increase in world imports sourced with permission John Vidal (2008)

Cornwall has significant economic developments in fisheries and tourism (Bradfield et al, 1976). This is generic of the coasts in the county. Illustrated in Figure 15 are the results from the UK Beach Survey (2009), indicating the

major potential sources, of plastic pollution in different regions. It is clear in the Southwest that public and fishing variables are the main factors which attribute to plastic pollution.

Figure 15, Diagram depicts the amounts and sources of pollution found in different regions of the UK sourced with permission from the UK Beach Watch Survey Report (2009)

Similar forcing actions are assumed to be the most fitting explanation for the hypothesis. There is no significant distribution between micro plastic concentrations between the locations. However as only two locations were reviewed the data sets may have been too diminutive for a truthful analysis. The overall amount of micro plastic fibres discovered were a larger percentage of the total microfibrils found (Fig 6). In addition the sample size of 50g of sediment is minute compared to the vast volume of sediment found at any one beach. The method of identification was also initially based on being able to differentiate the fibres by appearance. Which were usually brightly coloured and fibrous, this is thought to represent a small proportion of the micro plastic fibres in the environment. Further research into accurately quantifying the total fibres present is recommended (Thompson et al, 2009). Research carried out by SeaEducationAssociation1986-2008 has reported on plastic micro debris being present in the waters from the British Isles to Iceland (Law, 2010).

Annual accumulation of all marine debris (predominantly plastic) on shores of selected islands with year.

Figure 16 Annual accumulation of all marine debris (predominantly plastic) on shores of selected islands with year. Data for Bird I. and Signy I. are from Walker et al. (1997); Convey et al. (2002) and CCAMLR. Data for Tern I. are from Morishige et al. (2007) and for the UK from Beachwatch 2006 (MCS 2007). Sourced with permission from Barnes D K A et al. Phil. Trans. R. Soc. B 2009; 364: 1985-1998

Figure 7 Update of of Beachwatch Survey (2009) which effectively illustrates beach litter levels have been steadily increasing since 1994, despite yearly variations sourced from with permission Beachwatch 2009 (MCS, 2011)

Studies by Thompson et al; 2004; 2006, Brown 2009; Scontus, 2011, Travis, 2011; Colton, 1974; have also conclusively shown evidence of micro plastic debris in the marine environment. Figure 15 illustrates plastic debris that have been found in the Antarctic, Sub-Antarctic, Tropical Pacific Ocean and the Temporal Atlantic. The Quantities of plastic debris appear to have stabilised. However this could indicate that inputs of plastic debris may be declining but the debris already in the ocean is continually being deposited on the shore or seabed (Brown et al, 2011). Figure 17 illustrates that plastic debris is steadily increasing on the shorelines of the UK despite annual variations (MCS. 2011).

Despite the vast institution of study sites, irregularity of sampling, differing protocol and observers, has resulted in a very small amount of datasets pning for more than a decade (Barnes & Milner 2005). Therefore the

distribution of plastic particles in the marine environment is fundamentally lacking in research (GESAMP, 2010).

5.2 Microfibre Identity

The majority of microscopic fibres identified using FT-IR spectroscopy demonstrated in Figure 6 showed that true plastics were the most persistent overall with polyethylene contributing to the highest concentrations (35%). Polyethylene was discovered in 1933 by Reginald Gibson and Eric Fawcett at the Imperial Chemical Industries (ICI). Which was evolved into two forms, low density polyethylene (LDPE) and high density polyethylene (HDPE), polyethylene is cheap, flexible, durable, and chemically resistant and is the most widely used plastic. Polyethylene has an annual production of approximately 80 million metric tons (Piringer and Baner, 2008). LDPE is used to make films and packaging materials, including plastic bags while HDPE is used more often to make containers, and automotive fittings.

Concentrations of polyethylene were highest at Carbis Bay. An explanation of this could be related to tourist activities from the use of plastic drinks bottles, plastic food containers, plastic toiletries bottles, plastic caps / lids, cigarette lighters / tobacco pouches, combs / hair brushes / sunglasses, crisp / sweet / lolly / sandwich wrappers, cutlery / trays / straws / cups, pens, plastic shoes / sandals (MCA Beach Report, 2009). The Carbis Bay and St Ives area are holiday hotspots which have a high reliance on the tourist industry for its economy. This is evident by the high number of tourist related shops and food outlets within the area. The tourist industry makes up around a quarter of the economy estimated to contribute as much as 24% of the

County's GDP (Cornwall Tourism Board). Five million tourists visit Cornwall each year, mostly drawn from within the UK.

Fishing in this area is also an economic foundation on which there is local reliance. There are 1, 148 fishermen employed in Cornwall and the Isles of Scilly. Newlyn is the largest fishing port in England, in terms of value. In 2000 landed ? 18. 1 million of fish (Fishing Industry Task Force, 2010). The primary synthetic compounds used in the fishing industry are polyamide (nylon), polyester, polyethylene, and polypropylene (Pruter, 1987). This could also explain the concentrations of nylon concentrations which were highest at Marazion. Other sources of true plastic fibres identified were varied ' acetate'. This has industrial uses such as cigarette and other filters and ink reservoirs for fibre tip pens. Each cigarette filter has more than 12 000 white fibres. That contains the delustrant titanium dioxide. The fibres are made of cellulose acetate, a synthetic plastic-like substance. During production a plasticiser, triacetin (glycerol triacetate), is applied to bond the fibres (Pauly et al 2002). In 2009 the Ocean Conservancy data revealed that over three million (3, 216, 991) cigarette filters were removed internationally from beaches and inland waterways as part of the annual International Coastal Cleanup (ICC, 2009). During the Annual Beachwatch (2009) litter survey a total of 11, 670 cigarette filters were found. Ranking it in the top 10 most littered items nationally. This could therefore be a major source of acetate fibre found on the two locations. Polyester, acrylic and polyamide were found to be relatively uniform at both locations (Fig 10a; b) these polymers are used in apparel including many forms of clothing, home furnishings: carpets,

curtains, draperies, sheets and pillow cases, wall coverings, and upholstery. Other uses are hoses, power belting, ropes and nets, thread, tire cord, auto upholstery and sails (Fibresource, 2010). The potential sources for these polymers as well as from the fishing and tourist industry could be related to shipping (Fig 15) which includes fish boxes, fishing line, fishing net and net pieces < 50 cm, fishing net and net pieces > 50 cm, floats (fishing buoys) / reels, plastic lobster / crab pots and tops rope / cord / string , rubber boots, heavy duty gloves, tyres with holes/rope, fishing weights / hooks and lures (Beach Watch Report 2009). The wide range of sources of identified polymers suggests that the fragments have resulted from the breakdown of larger items (Thompson et al, 2004).

Out of the non-plastic fibres identified rayon deemed most abundant (Fig 11a; b). This could be due to its many applications; clothing, furnishings and industrial uses in medical surgery products, tie chord and other uses such as feminine hygiene products and diapers (Fibresource, 2010). The admiral data charts sourced from Edina marine digimap for Carbis Bay and Marazion illustrated outlet pipes from those immediate areas (Appendices 3a, 4a) and extended areas (Appendices 3b; 4b). However due to the large scale of the coastline the admiral chart could not indicate other possible outlets pipes that could be potential sources for sewage related pollution. Like that of plastics rayon has a highly absorbent quality. That could indicate that it may also have the ability to absorb and transport persistent organic contaminants (Teuten et al, 2007). Rayon manufacture today utilizes the viscose process. This dates to the early 1900s, with most of the growth in production

occurring between 1925 and 1955. In the early stage, production was mainly textile filament. The invention of modifiers in 1947 brought on super tire cords and initiated the beginning of the high-performance rayon fibres (Fibresource, 2010). This extensive time in production may also be a contributing factor for the concentrations found. However despite these possible explanations, there was not sufficient data analysed. To establish if micro plastic fibre distribution shows a discrepancy from that of other fibres (semi-synthetic and non-plastic). The micro fibres identified in the blank controls were of rayon and rayon blend origin. This could be from a number of sources. However clothing is thought to be the most plausible explanation for contamination during the separation filtration process.

5.3 Comparison of other studies of micro fibre identity and distribution

As mentioned in the previous section the amount of available comparative data is limited due to for mentioned factors. However research carried out by Thompson et al (2004) who identified micro plastic fibres in sedimentary habitats ranging from 0.5- 6 fibres 50ml-1sediment. It was found that subtidal habitats have significantly higher concentrations. However the abundance was consistent amongst beaches and estuarine habitat types. Out of all micro fibres identified Thompson et al (2004) reported that one third was of true plastic origin. The results in Figure 6 illustrates that true micro plastic abundance is larger than that discovered by Thompson et al, (2004). Where a significant percentage of the overall fibres collected were of true plastic origin.

To assess long-term trends in abundance Thompson et al (2004) also examined plankton species that have been collected consistently since the 1960's along routes between Aberdeen and the Shetlands; and from Sule Sherry to Iceland. They discovered that plastics were archived with the plankton samples back to the 1960