DERELICT FISHING GEAR MANAGEMENT SYSTEM IN THE ADRIATIC REGION (DEFISHGEAR)

DeFishGear

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Pilot assessment on microplastic in sea surface and beach sediment potential accumulation zones

Report for WP5

September, 2016

DeFishGear

Derelict Fishing Gear management system in the Adriatic Region

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Acronyms

ABS - Acrylonitrile butadiene styrene

ATR FT-IR - Attenuated total reflection Fourier transform infrared spectroscopy

EVA - Ethylene vinil acetat

LMP - large microplastic particles (1–5 mm)

MUF - Melamine urea formaldehyde resine

NIR - Near Infrared spectroscopy

NY - Nylon

OCl - Organochlorine

PA - Polyamide

PAN - Polyacrylonitrile

PCB - Polychlorinated biphenyls

PE - Polyethylene

PET - Polyethylene terephthalate

PO - Polyolefine

PP - Polypropylene

PS - Polystyrene

PU - Polyurethane

PVA - Polyvinyl acetate

PVC - Polyvinyl chloride

PVS - Polyvinyl stearate

SMP - small microplastic particles (<1 mm)

WWTP - Waste Water Treatment Plant

Summary

This report summarises findings of part of the work carried by work package 5 (WP5) of the project DeFishGear, refered to microplastic pollution on the sea surface and beach sediment accumulation zones in Adriatic region. The aim of this part of WP5 was to investigate the level of pollution in water and sediments of the Adriatic Sea, on which basis the program of measures for microplastic was prepared in the document "Strategic recommendations for improving marine litter management in the Adriatic Sea in the field of microplastic pollution" (Kovač Viršek, 2016).

The main objectives of the output "Pilot assessment on microplastic in sea surface and beach sediment potential accumulation zones" were:

- Determination of accumulation zones of marine litter in Adriatic region.
- Development of harmonized sampling and sample analysis methodology for the sea surface and sediment samples, usable for Adriatic region and realization of activities related to developed methodology in all countries of Adriatic region.
- Estimation of microplastic concentration on the sea surface and in beach sediments of Adriatic region.
- Analysis of Organochlorine and Polychlorinated biphenyls on plastic pellets from beaches of Adriatic region.

Methodology

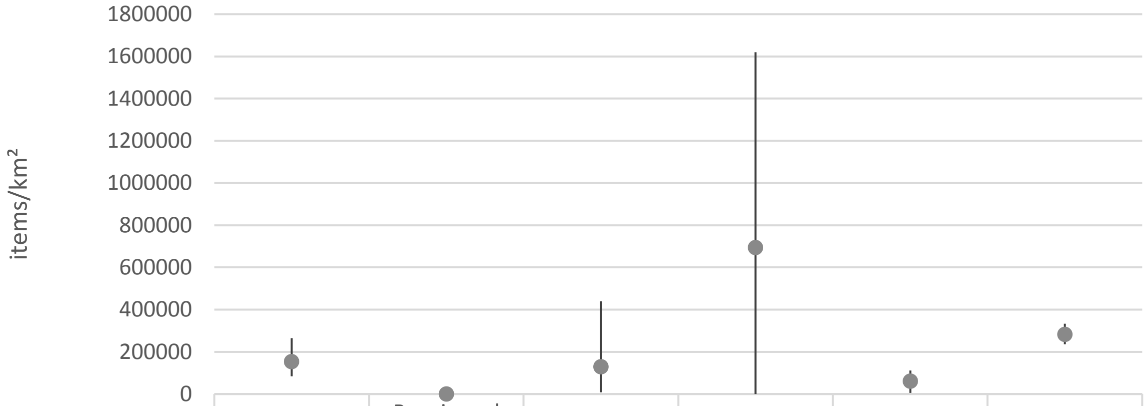
Microplastic sampling and sample analysis on the sea surface were done according to the "Recommendation on regional approach to monitoring and assessment of microplastic in the marine environment" developed within the project DeFishGear. Microplastic was sampled on 44 sea surface transects by the use of manta net (mesh size ~300 µm) in Italy (Cesenatico – 8 transects), Slovenia (from Koper to Piran – 4 transects), Croatia (Split region – 10 transects), Albania (Durres – 5 transects), Bosnia and Herzegovina (Neum – 2 transects) and Greece (Corfu island – 15 transects). Samplings were performed in the summer and autumn 2014 and winter 2015. Microplastic separation from the sea surface samples were done by the use of stereomicroscopes. Microplastic particles were counted, weighted, categorized into 6 categories (fragments, filaments, foams, granule, pellets and other) and analysed for their chemical structure. At the end estimation of density of microplastic pollution for each country and all Adriatic region were calculated.

Microplastic sampling in the beach sediments and sample analysis were also done according to the "Recommendation on regional approach to monitoring and assessment of microplastic in the marine environment" developed within the project DeFishGear. Microplastic was sampled on 9 beaches (Italy – Cesenatico beach; Slovenia – Lazaret beach; Croatia – Bačvice, Zaglav and Neretva beach; Albania – Velipoje beach; Greece – Halikounas, Issos and Arachavi beach on Corfu Island) by the use of two different protocols, one for large microplastic particles (LMP: 1 – 5 mm) and one for small microplastic particles (SMP: <1 mm). LMP were separated only by the use of naked eyes and stereomicroscopes, while SMP were separated from the sand by density separation technique. Microplastic particles were counted, weighted, categorized into 6 categories (fragments, filaments, foams, granule, pellets and other) and analysed for their chemical structure. At the end estimation of density of microplastic pollution for each country and all Adriatic region were calculated.

Plastic pellets founded on beaches were analysed for OCI and PCBs by the use of a pressurized fluid extractor. The developed methodology focuses on 11 OCPs and related compounds including DDT and its two main metabolites DDE and DDD, lindane and two production isomers, as well as the two biologically active isomers of technical endosulfan.

Results

Microplastic concentrations on the sea surface varied among transects from 0 – 1,619,000 items/km^2. The mean concentration for all Adriatic region was calculated as 233,732 ± 278,060 items/km^2.

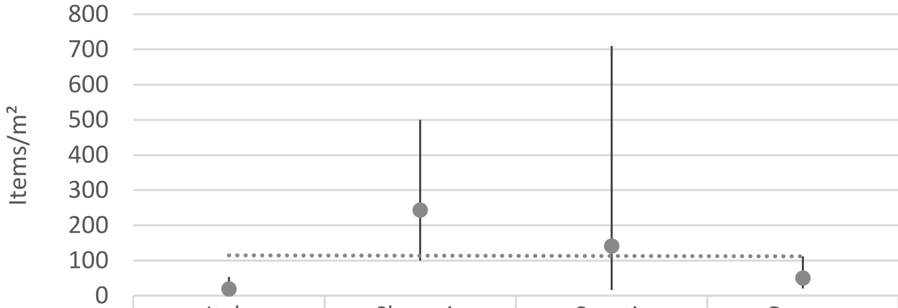


	Albania	Bosnia and Hr	Croatia	Greece	Italy	Slovenia
min (items/km2)	84236	75	8631	0	5747	235642
max (items/km2)	264501	250	439787	1619658	112057	333766
● average	153667	171	129236	694035	62046	283172

min (items/km2) max (items/km2) ● average

Comparison of average and range of microplastic concentrations among countries of the Adriatic region.

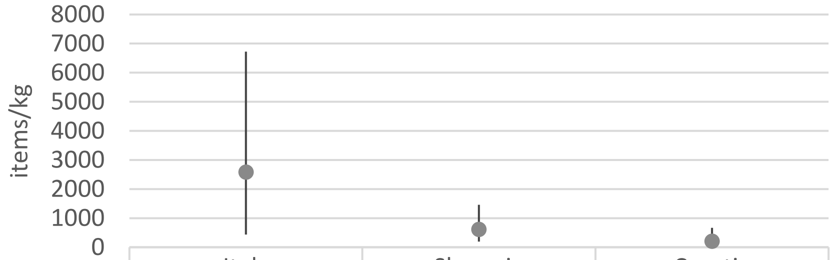
Microplastic concentrations of LMP in beach sediments ranged from 11 – 710 items/m^2 and for SMP from 70 – 6724 items/kg of dry sediments. The mean concentration for all Adriatic region was calculated as 113 ± 101 items/m^2 for LMP and 1133 ± 1271 items/kg of dry sediments for SMP.



	Italy	Slovenia	Croatia	Greece
min	11	100	16	20
max	53	500	710	112
average	19	243	141	50

min max average Linear (average)

Comparison of average and range of LMP concentration on beaches of countries of the Adriatic region.



	Italy	Slovenia	Croatia
min	440	196	70
max	6724	1460	670
average	2581	616	202

min max average

Comparison of average and range of SMP concentration on beaches of the countries of the Adriatic region.

Chemical identification of microplastic particles were not possible for all particles, due to fragmentation of particles and possible losing and due to biofilms that in most cases covered particles and therefore FT-IR spectrophotometer could not provide the true results. However chemical identification of microplastic particles show that polyethylene (PE) is the most abundant plastic material among microplastics, followed by polypropylene. Among the sea surface samples, PE was presented in 32 – 93%, while among beach sediment samples PE was presented in 38 – 67%.

Results of analysis of PCBs and OCPs on plastic pellets, gathered on beaches, show that PCBs and OCPs were detected in all samples from all sampling locations. Total concentrations of the studied OCPs range from 1.9 to 14.9 ng/g, where the sites Greece 2 and Italy 2 showing the highest concentrations (>14 ng/g). Concentrations of DDTs range from 0.2 to 10.0 ng/g. The predominance of the degradation products DDE and DDD over DDT reflects a background pollution from past treatments rather than a recent use of the insecticide. Concentrations of HCHs are relatively low (<2.5 ng/g) except on 2 sites (i.e. Italy 2 and Greece 2). Overall, there is no clear predominance of the isomer γ-HCH that would suggest a recent application of the pesticide, except eventually for the site Italy 2. Total concentrations of the studied PCBs range from 13.1 to 224.3 ng/g, the sites Croatia 2, Italy 2 and 5 presenting the highest concentrations (> 200 ng/g).

Conclusions

On the basis of this study the following conclusions are presented:

- Adriatic Sea is contaminated by microplastic in all studied regions including all countries of Adriatic region. The mean concentration is ~230,000 items/km^2.
- All studied beaches of Adriatic Sea are also contaminated by microplastic of both size class (LMP and SMP), where is the mean concentration of LMP 113 ± 101 items/m^2 and for SMP 1133 ± 1271 items/kg of dry sediments.
- The most abundant plastic material among microplastic particles is polyethylene in sea surface and beach sediment samples.
- Results of microplastic concentrations on the sea surface and beach sediment show a high variability among samples, while several factors in the process of sampling and sample analysis influence on final results.
- PCBs and OCPs were detected in all samples from all sampling locations, where total concentrations of the studied OCPs range from 1.9 to 14.9 ng/g, and total concentrations of the studied PCBs range from 13.1 to 224.3 ng/g.
- Overall, the concentrations of OCPs and PCBs are consistent with the data obtained by the IPW monitoring programme in similar (i.e. Adriatic and Ionian areas) and surrounding regions (i.e. Mediterranean and Aegean areas);
- The sites Croatia 2, Italy 2 and Italy 5 are the most contaminated with POPs (total concentration >200 ng/g), whereas the sites Greece 1 and Italy 3 present the lowest levels of POPs (total concentration <50 ng/g).

Table of contents

1 Introduction

This report presents the results of monitoring of microplastic and related activities within the DeFishGear project - "Derelict Fishing Gear Management System in the Adriatic Region" (project code: 1°STR/ 00010), which was funded by IPA Adriatic Cross-border Cooperation Programme 2007 – 2013.

The report is focused exclusively on monitoring and assessment of microplastic pollution (plastic particles <5 mm) on the sea surface and in beach sediments accumulation zones of the Adriatic Region. The report is a result of coordinated actions toward sharing knowledge on analysing microplastic pollution, which included application of the joint monitoring methodology in the Adriatic region aiming to determine microplastic types and quantities in coastal and marine departments.

1.1 Objectives

The main objectives of the output "Pilot assessment on microplastic in sea surface and beach sediment potential accumulation zones" were:

- Determination of accumulation zones of marine litter in Adriatic region.
- Development of sampling and sample analysis methodology for the sea surface and sediment samples.
- Sampling in the sea surface accumulation zones by manta net and sample analysis of water samples. Sampling of sea surface samples on 8 transects near Cesenatico in Italy, on 4 transects in Slovenia through the whole coast, on 5 transects in Croatia in Split region, on 2 transects in Bosnia and Herzegovina, on 5 transects in Albania in Durres region and on 15 transects in Greece in Corfu region.
- Sampling in beach sediment accumulation zones and sample analysis of sediment samples. Sampling of beach sediments on 1 beach in Italy (Cesenatico beach), 1 beach in Slovenia (Debeli rtič), 3 beaches in Croatia (near Neretva River, Zaglav beach and Bacvice beach), 3 beaches in Albania (Plepa, Shengjin and Velipoje) and 3 beaches in Greece on Corfu island (Halikounas beach, Issos beach and Acharavi beach).
- Estimation of microplastic concentration on the sea surface and in beach sediments of Adriatic region.
- Analysis of Organochlorine and Polychlorinated biphenyls on plastic pellets from beaches of Adriatic region.

2.3 Description of the teams involved in microplastic research

These targeted actions related to monitoring and assessment of microplastic pollution were performed in 6 eligible countries in the Adriatic Region (Albania, Bosnia and Herzegovina, Croatia, Greece, Italy and Slovenia) by following 7 project partners from the DeFishGear project:

- Regional Agency for Environmental Protection in the Emilia-Romagna region, Cesenatico, Italy;
- Institute for Water of the Republic of Slovenia, Ljubljana, Slovenia;
- National Institute of Chemistry, Ljubljana, Slovenia;
- Institute for Oceanography and Fisheries, Split, Croatia;
- Hydro-Engineering Institute Sarajevo, Bosnia and Hercegovina;
- Agricultural University of Tirana, Albania;
- Hellenic Centre for Marine Research, Greece.

1.1.1 Albania - Agricultural University of Tirana, Tirana

AUT elaborates water management and marine management studies and technical background legal regulations which mainly support the Ministry of Agriculture and the Environment and develops approach to monitoring and management of marine litter pollution, including beach litter and microplastic and has been involved in Clean Coast, Marine Renegades and other NGO projects. The laboratory is involved in marine litter research since 2013 and has the leading role in microplastic analysis in Albanian sea water since 2013. AUT has also experience in socio-economic analysis (SEA).

1.1.2 Bosnia and Herzegovina - Hydro-Engineering Institute Sarajevo, Sarajevo

Prior to investigation of microplastics trends and accumulations in the Adriatic, DeFishGear project partners involved in the microplastic surveys have performed extensive literature review. It was actually the first sub-activity performed within the Working Package 5 dealing exclusively with the microplastics pollution. This initial activity, as well as all the other activities related to the WP5 which took place in the part of the Adriatic Sea pertaining to BIH, were performed by the expert team from the Hydro-Engineering Institute Sarajevo.

The main aim of the literature review was to prepare the stock of data related to the current level of surveys dealing with the assessments and trends of microplastics pollution in the Adriatic Region and abroad. The results of the literature review performed by BIH team and other expert teams, which were involved in this activity in general have shown that microplastics has been recognized as emerging pollution threat all around the globe. Nevertheless, still certain aspects related to its accumulation trends, assessment methodology and exact data related to its quantity and quality remain insufficiently investigated.

Furthermore, literature review has shown that scientific data related to the Adriatic Sea are scattered and sporadic, lacking joint assessment methodology and data base. This was actually the greatest challenge that all the countries involved in the Working Package 5 of the DeFishGear project had to deal with. Moreover, for some countries, like it was the case with Bosnia and Herzegovina, microplastics pollution was completely new scientific field, requiring even more engagement and knowledge acquisition from the partners who were already experienced in these kinds of scientific activities.

Finally, literature review served as the pillar for the preparation of the common guidance documents, i.e. DeFishGear Monitoring Protocols, which have enabled application of the joint assessment methodology in the period, and creation of the first data base for the microplastic pollution in the Adriatic Sea.

1.1.3 Croatia - Institute for Oceanography and Fisheries, Split

The Institute of Oceanography and Fisheries (IOF) is the scientific public institute and it is National Reference Centre for the marine research. Institute employs 116 people of whom 71 are experts in different field of which 50 are professionals with PhD. Scientific activities conducted in the IOF are interdisciplinary including biological, chemical, physical, geological and fishery research. The research vessels Bios and Navicula, owned by IOF, are used for oceanographic and fisheries research activities, designed specifically for surveys and data collection for both coastal and open-sea waters.

The IOF have eight Departments dealing with variety aspects of coastal environment. Information available on the composition and distribution of marine litter, including microplastics in the Croatian marine environment is scarce because surveys to date have mainly focused on biological and hydrological parameters. During our long-term investigations, microplastics have been detected in the tissues of a variety of marine species, as well as in the water column and sediment. However, there is currently a lack of dedicated studies on the bio-ecological effects of various kind of marine litter on the sea life in Croatia. The IOF aims to participate in establishing a framework within which Policy makers and other stakeholders would take measures to achieve or maintain good environmental status in the sea.

The IOF team involved in DeFishGear project are employees of two laboratories; Laboratory of ichthyology and coastal fisheries and Laboratory of fisheries science and management of pelagic and demersal resources. The team includes scientists who are experts in the fields of biology and biotechnology, dealing with the biology and ecology of fishes and their developmental stages, trophic ecology, population dynamics, all aspects of fisheries including stock assessment and management of pelagic, demersal and coastal resources. At the beginning DeFishGear project, two people were hired to be fully involved in the activities assigned by the project and they were sent for training in order to specialize in collection and processing samples of microplastics.

1.1.4 Greece - Hellenic Centre for Marine Research, Anavyssos

HCMR has participated in a number of projects related to the topic of marine litter. In the framework of the FP7 project PERSEUS (2011-2015) the seafloor litter was studied in the Eastern Mediterranean and the Black Sea. The methodology for the analysis of microplastics in sediments was developed in the framework of the FP7 project CLEANSEA (2012-2016). Finally, in the framework of the FP7 SEAS ERA project MERMAID (2012-2015), besides other descriptors, the marine litter descriptor (D10) was studied in the Gulf of Lions (France), Saronikos Gulf (Greece) and the Cilician basin (Turkey), linking the defined targets for marine litter to the corresponding measures.

1.1.5 Italy - Regional Agency for Environmental Protection in the Emilia-Romagna region, Cesenatico

Regional Agency for Environmental Protection in the Emili-Romagna region (ArpaER) carries out research about coastal marine systems with emphasis on multidisciplinary ecosystem complexity: the main activities include research, development and application of monitoring programme to comply with regional, national, EU laws. During the 2013 the ArpaER was involved in sea surface microplastics analysis for the Marine Strategy. In the 2015 they started again the activities about marine Strategy and we are involved in sea surface microplastics analysis. In Italy the microplastics analysis in the beach sediment are not take into consideration until now.

The team is composed from marine biologists and technicians that are involved in sampling activities and laboratory analysis with a couple years of experience in this skill.

1.1.6 Slovenia - Institute for Water of the Republic of Slovenia, Ljubljana

Institute for water of the Republic of Slovenia (IWRS) implements common European water policy and international strategies and conventions, participates in expert working groups of the Common Implementation Strategy process of directives at the DG Environment of the European Commission and activities of the European Environment Agency. IWRS elaborates water management and marine management studies and technical background legal regulations which mainly support the Ministry of Agriculture and the Environment and develops approach to monitoring and management of marine litter pollution, including beach litter and microplastic and has been involved in Clean Coast, Marine Renegades and other NGO projects.

The Institute is involved in marine litter research since 2010 and has the leading role in microplastic analysis in Slovenian sea water since 2011. The team is composed from biologists and ecologist that are involved in sampling activities and laboratory analysis with a couple years of experience in this skill.

The National Institute of Chemistry, Ljubljana

The National Institute of Chemistry (NIC) is a public research institution active in all areas of chemistry. It was the first research institution in Slovenia to obtain ISO 9001 standards in 2003. It offers high-level research equipment such as NMR spectrometers, ultra-high resolution microscopes, chromatography systems etc. and is routinely involved in national and international research frameworks. The Department for Polymer Chemistry and Technology (D07) with its 17 members is specialized in synthesis and characterization of polymers and plastics. It provides a full array of chemical polymer/plastics characterization expertise: spectroscopy, chromatography, thermal methods, as well as an excellent staff including 9 Ph. D. experts.

The laboratory has a history of activity in the broad area of environmental aspects of plastics and polymers including plastic waste management, plastics recycling, biodegradability of plastics, biobased plastics and bionanocomposites. Through its project involvement D07 has expertise in plastics sustainability issues from its strong involvement in bioplastics as well as the legal, standardization/certification and strategic aspects of plastic waste management, plastic pollution in the environment and environmental solutions such as biodegradable plastics.

Through the waste management and biodegradability issues the team lead by dr. Andrej Kržan has had exposure to the issue of marine litter and microplastics. In cooperation with the University of Nova Gorica dr. Kržan lead the first studies of microplastics occurrence in the Adriatic sea (Slovenian part), which started in 2011 (two studies finished by 2015). The results of these exploratory studies were included in the national reporting as part of fulfilling the requirements for the Marine Strategy Framework Directive.

1.2 Literature review

1.2.1 History of microplastic research in the Adriatic region

Microplastic pollution is newly recognized and defined threat to environment. It was first identified and documented from 1970s onwards, when three different researches published findings about polystyrene spherules less than 2 mm in diameter (Carpenter et al., 1972; Colton et al., 1974; Kartar et al., 1973). In September 2008 was "International Research Workshop on the Occurrence, Effects, and Fate of Microplastic Marine Debris" which brought microplastics into broader attention of the scientific and political community (Allsopp et al., 2009).

Unfortunately, before the end of the DeFishgear project, just two studies of microplastics pollution in beach sediments were published and none for microplastic pollution on the sea surface in the Adriatic Sea. The first research on microplastic occurence in the sea sediments was performed in the Venice Lagoon and published in 2013. The abundance of microplastic particles varied from 2175 to 672 microplastic particles per kg of dry weight and the most abundant types of plastic were polyethylene and polypropylene (Vianello et al., 2013). The concentration of microplastics on the Slovenian coast was identified as much smaller in comparison with Italian concentrations and were 155.6 particles per kg of sediments in the infralittoral area and 133.3 particles per kg of sediments in the shoreline area (Laglbauer et al., 2014).

In Greece also one study of microplastic pollution on the sea surface and one from the beach sediments were published, but both of them were performed in Aegean Sea. Kornilios et al. (1998) assessed for the first time in Greek waters the distribution of floating microplastics. The tows were performed in the Cretan Sea using nylon net (500 µm mesh). Plastics were found in 90% of the tows at a density ranging from 1 to 1160 $\mu g/m^2$, consisting primarily of fishing lines, cellophane and small plastic pieces as eroded fragments of larger items. The first assessment of the concentration of microplastics in beach sand was done by Kaberi et al. (2013). They assessed the microplastics densities along the shoreline of Kea Island (Aegean Sea, Eastern Mediterranean). The microplastics varied among beaches ranging from absence of plastic items at the eastern beaches to more than 300 items per m^2 at the northern beaches, demonstrating a direct relation to beach orientation and wind regime rather than to proximity to land based sources. Microplastics were categorized according to origin (fragments or pellets), size, and colour and polymer type. The majority of microplastics were identified by FT-IR spectroscopy as polyethylene.

Therefore the study of microplastic particles within the DeFishGear project represents the first thorough study in Adriatic Sea and its coastal area. It was the first time that the data on presence, quantity and type of microplastic particles on the sea surface and beach sediment was analyzed.

1.2.2 Plastic pellets as vector of organic pollutants

1.2.2.1 Plastic pellets

Plastic resin pellets (Figure 1) are small granules generally with the shape of a cylinder or a disk and with a diameter of a few mm (i.e. 2 to 7 mm) (Ogata et al., 2009; Andrady, 2011), therefore they fall in the category of microplastics.

These plastic granules are industrial raw material from which final plastic products are manufactured through re-melting and moulding at high temperature (Antunes et al., 2013). They can be unintentionally released to the environment during manufacturing and transport. For instance, they can be directly introduced to the ocean through accidental spills during shipping (Derraik, 2002; Takada, 2006; Ogata et al., 2009) or they can be carried from land to oceans by surface run-off, streams and rivers.

Because of their environmental persistence, plastic pellets are distributed widely in the oceans and found on beaches all over the world (Ogata et al., 2009). They can negatively affect marine organisms and can cause the death of some species by ingestion (Moore, 2008; Antunes et al., 2013). In addition, they can enter the food chain, where their effects are unpredictable (Derraik, 2002; Antunes et al., 2013).

Figure 1: Plastic pellets. Photo: M. Pflieger, UNG.

1.2.2.2 Persistent organic pollutants

Persistent organic pollutants (POPs) are chemical substances that persist in the environment, bioaccumulate through the food chain, and pose a risk of causing adverse effects to human health and the environment. This group of priority pollutants consists of pesticides (e.g DDT-dichlorodiphenyltrichloroethane), industrial chemicals (e.g. PCBs - polychlorinated biphenyls -) and unintentional by-products of industrial processes (e.g. dioxins). POPs can undergo a long-range transport and contaminate non-target regions located far from areas of production or use. Consequently, they pose a threat to the environment and to human health all over the globe (Stockholm Convention, 2009).

In this study, 24 PCBs congeners, as well as 11 organochlorine pesticides and related degradation compounds were investigated (OCPs).

Polychlorinated biphenyls (PCBs – Figure 2) are liposoluble organic chlorine compounds which are thermally and chemically stable. Because of their physical-chemical properties, they had been widely used in industrial processes usually as dielectric fluids in transformers and capacitors, lubricants, hydraulic oils, paints and adhesives (Antunes et al., 2013). Although their production had been banned already in the 1970s in several countries (e.g. Japan, USA), they can still be found in circulation (Antunes et al., 2013).

The present investigation focused on the following congeners: 28, 31, 52, 77, 95, 99, 101, 105, 110, 118, 126, 128, 138, 146, 149, 151, 153, 156, 169, 170, 177, 180, 183, and 187.

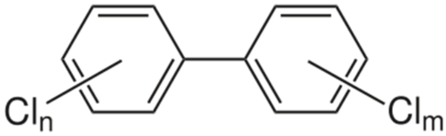


Figure 2: Chemical strusture of PCBs. Source: https://en.wikipedia.org/

The studied organochlorine pesticides are broad-spectrum insecticides, chemically stable and hydrophobic.

DDT (dichlorodiphenyltrichloroethane – Figure 3) molecule was first synthesized in 1874. However, its insecticide property was only discovered in the late 1930's. The technical product is a mixture of two isomers: about 85% of 4,4'-DDT (or p,p'-DDT) and 15% of 2,4'-DDT (or o,p'-DDT). DDT degrades into two primary metabolites, DDE (dichlorodiphenyldichloroethylene; 4,4'- and 2,4'-DDE) and DDD (dichlorodiphenyldichloroethane; 4,4'- and 2,4'-DDD) produced through aerobic and anaerobic processes, respectively (Ogata et al., 2009). DDT was banned in many countries in the 1970's for all uses except for malaria control.

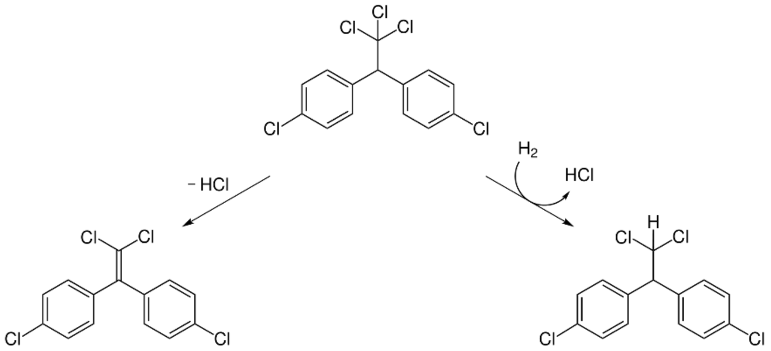


Figure 3: 4,4'-DDT and its metabolites 4,4'-DDE and 4,4'-DDD. Source: https://en.wikipedia.org/

Lindane (Figure 4) is mainly (about 99%) composed of the isomer γ-HCH (gamma-hexachlorocyclohexane). Originally synthesized in 1825, its pesticidal action was discovered in the 1940's. Its production unintentionally generates high amounts of the isomers α-HCH and β-HCH (i.e. 6 to 10 times higher than the quantity of γ-HCH produced) considered as more toxic than lindane itself (Stockholm Convention, 2009; ATSDR, 2005). Internationally banned for agricultural application by the Stockholm Convention in 2009, lindane can still be used as pharmaceutical treatment for control of head lice and scabies.

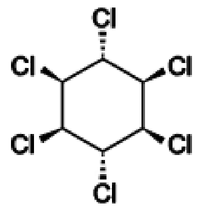


Figure 4: Lindane (γ-HCH). Source: www.pops.int

Technical endosulfan, consisting of two biologically active isomers endosulfan I (or α-endosulfan; ENDO I; Fig. 5a) and endosulfan II (or β-endosulfan; ENDO II; Fig. 5b), has been used since the 1950's (Stockholm Convention, 2009). Although banned or phase out in about 60 countries (including European Union), it is still in use in many other countries such as India, Brazil and Australia.

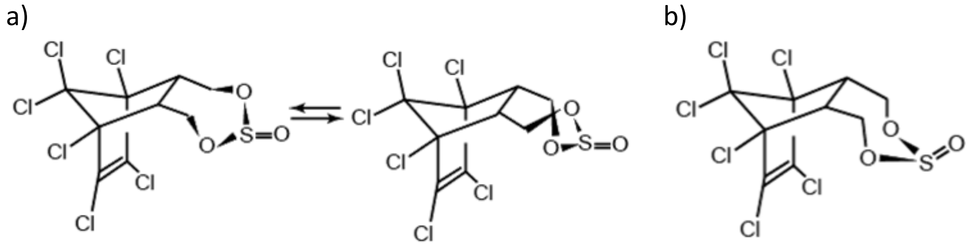


Figure 5: a) Endosulfan I and b) Endosulfan II. Source: www.pops.int.

1.2.2.3 Plastic pellets and POPs

Microplastics carry compounds which may penetrate into cells and be biochemically active (Teuten et al., 2009). These compounds are either additives (e.g. PBDEs - polybrominated diphenyl ethers) that are incorporated into plastics during manufacturing or hydrophobic chemicals (e.g. PCBs, organochlorine pesticides) which adsorb from the surrounding environment (e.g. seawater). This investigation focuses on the second category of compounds.

Several studies have revealed the presence of contaminants adsorbed onto plastic pellets found in coastal environment worldwide, which then act as vector of these potentially toxic chemicals (Ogata et al., 2009; Teuten et al., 2009; Heskett et al., 2012). Most of investigations reported in the literature focus on PAHs (polycyclic aromatic hydrocarbons) and POPs, mainly PCBs, DDTs and HCHs (Teuten et al., 2009). Actually, the available results are mostly provided by the International Pellet Watch program (IWP).

Launched from Japan in 2006 (Takada, 2006), the International Pellet Watch (IPW) is a global monitoring program for POPs based on the sampling of plastic resin pellets by volunteers (Yeo et al., 2015). Thus, the primary goal of IWP is to assess POP levels worldwide with low sampling costs in order to better assess their environmental fate and remediation. Besides, the obtained results bring valuable information in the field of microplastics.

Briefly, the method consists in sorting the collected plastic pellets by plastic type applying infrared spectroscopy and by yellowness (pigmented pellets are excluded) (Ogata et al., 2009). Only yellowing polyethylene (PE) pellets are subjected to POPs analysis. In fact, it has been shown that aged PE pellets adsorbed higher concentration of POPs than other categories of pellets (Takada, 2006).

According to the IPW program and several independent studies carried out worldwide (Endo et al., 2005; Ogata et al., 2009; Teuten et al., 2009; Frias et al., 2010; Karapanagioti et al., 2011; Heskett et al., 2012; Antunes et al., 2013; Mizukawa et al., 2013; Gauquie et al., 2015; Yeo et al., 2015), the concentrations of POPs associated to plastic pellets range from sub ng g^{-1} to hundreds of μg g^{-1}. Overall, the concentrations of PCBs are 1 to 2 order(s) of magnitude higher than the ones of HCHs and DDTs.

Table 1 presents the levels of POPs measured in plastic pellets collected on beaches located in the Adriatic and Ionian regions, which correspond to the DeFishGear project study area. For comparison, the concentrations of POPs determined in plastic pellets sampled in the Mediterranean and Aegean regions are given in Table 2.

Table 1: Concentrations of POPs (ng/g) obtained from IWP program in Adriatic and Ionian regions. Source: http://www.pelletwatch.org/.

Country	Location, year	PCBs[a]	HCHs[b]	DDTs[c]	DDT[d]	DDD[d]	DDE[d]
Albania	Durres, 2011	112	2.1	1080.5	489.9	89.6	481
Croatia	Island Ilovik, Beach Przine, 2013	70	1.1	8.3	4.6	0.6	3.1
Greece	Beach of Kato Achaia, 2008	5	1	2.4	0.8	0.8	0.8
	Kato Achaia, 2008[e]	4.8	1.0	12.0	1.2	0.8	10.0

Table 2: Concentrations of POPs (ng/g) obtained from IWP program in Mediterranean and Aegean regions. Source: http://www.pelletwatch.org/.

Country	Location, year	PCBs[a]	HCHs[b]	DDTs[c]	DDT[d]	DDD[d]	DDE[d]
Israel	Achizu beach, 2011	33	n.a.	16.9	11.5	n.a.	5.4
	Sdot Yam Beach, 2012	38	0.4	5	4	1	n.a.
Italy	Beach at Trapani, Sicilia, 2006	94	n.a.	n.a.	n.a.	n.a.	n.a.
	Caorle, 2012	136	n.a.	n.a.	n.a.	n.a.	n.a.
	Laconella beach, 2010	177.2	0.5	8.6	3.1	0.8	4.7
	Pellestrina, 2012	212	n.a.	n.a.	n.a.	n.a.	n.a.
Greece	Aegina island, 2014	299	0.8	27.6	12.2	2.5	12.9
	Aegina island, 2008	258	2	42	24.8	2.1	15.1
	Loutropyrgos Beach, Attica, 2008	250	1.9	18.1	9.9	2.2	6
	Loutropyrgos Beach, Attica, 2004	302	0.8	34.7	16	2	16.7
	Palaio Faliro, Athens, 2010	209	0.2	263.2	180	7.8	75.4
	Vatera Beach, Lesvos, 2008	6	2.2	12	0.6	0.3	0.3
	Vatera Beach, 2008[e]	5.4	2,2	1.1	0,6	0.3	0.2
	Loutropyrgos Beach, 2008[e]	248.6	3.5	18.1	9.9	2.2	6.0
	Aegena island, 2008[e]	223.3	3.0	42.1	25.0	2.1	15.0
Turkey	Izmir, 2003	53	0.8	27.6	8.2	3.5	15.9

[a] PCBs: sum of congeners 101, 110, 149, 118, 153, 138, 128, 187, 180, 170 and 206

[b] HCHs: sum of isomers α, β, δ and γ

[c] DDTs: sum of 4,4'-DDT, 4,4'-DDD and 4,4'-DDE

[d] DDT, DDD and DDE refer to 4,4'-DDT, 4,4'-DDD and 4,4'-DDE, respectively

[e] Results taken from Karapanagioti et al., 2011

The presence of organic contaminants adsorbed to plastics raise concerns about their possible effects on wildlife. There are evidences from laboratory works suggesting that chemicals can bioaccumulate in tissues of organisms after having been released from ingested plastic fragments (Besseling et al., 2013; Rochman et al., 2013).

1.3 Description of the Adriatic Sea by country

1.3.1 Albania

The coastline of Albania borders Montenegro's coastline in the north and Greece's coastline in the south. The length of the coastline is 472.3 km.

In average the sea surface salinity in Albanian bay is the highest from the surface salinity of the rest of the Adriatic sea, and usually have values from 42 to 45‰ but can drop down to 38‰ in the summer time due to the increased inflow of rivers.

Although most part of Adriatic Sea has a Mediterranean climate, on the north the climate is more sub Mediterranean and moderate continental. Adriatic sea is known as warm that has distinct seasonal oscillations. Average year temperature in Durres in 2013 was 15.9 °C.

1.3.2 Bosnia and Herzegovina

Geographical features

The coastline of the Adriatic Sea pertaining to Bosnia and Herzegovina (BIH) is 25.6 km long. It is situated in the south-eastern part of the Adriatic basin. It circumcises Neum Bay, a micro locality within the Malostonski Bay situated in the south-eastern part of the Adriatic Sea. It is defined by the continental border line of the Republic of Croatia and Bosnia and Herzegovina and Klek peninsula from the other side.

The typical geographic features of the coastline are the pebble and rocky beaches. However, due to intensive activities related to the urbanization of the mainland coastal area, significant percentage of the coast has been covered with the concrete. Unlike the mainland, Klek peninsula is almost unpopulated and not urbanized. It has conserved its natural geographic features (rocky coastline and coverage with the typical Mediterranean flora) thanks to the fact that it was proclaimed protected area according to the relevant law in 1980s.

The main sea currents are directed northwards and mostly weak due to the fact that the entire coastline and Adriatic Sea basin area pertaining to BIH could be practically described as "bay within the bay", and thus protected from the strong sea currents typical for this part of the Adriatic Sea. The average sea depth is 27 m and salinity typical for the southern Adriatic. The relief of the sea bottom is rather dynamic and by its structure it is mostly sludge.

Pollution sources

There is only one urban agglomeration, i.e. Neum on the coastline of the Adriatic Sea pertaining to BA with population of over 4000 inhabitants. However, the number of inhabitants during the touristic season (June-September) increases up to 3-4 times, and thus amounts to 12000-16000 of inhabitants in the aforesaid period.

It is important to highlight that in the BIH coastal area, more precisely in Neum urban and suburban area, the sewage network and WWTP (even though it needs certain improvements) are well developed and in operation from 1980s. Moreover, the sewage network is one of rare examples of trans-border sewage network systems, since certain segments of the same pass through the area of Republic of Croatia.

With regards to industry, besides intensive aqua culture activity for such a short coastline amounting to more than 2 tones/year, there is practically no industrial activity. Fishing activity is poorly developed, resulting in practical inexistence of the sea fishermen associations, and just a small number of fishermen who fish only for private purposes.

Thus, in relation to the pollution sources, one could conclude that neither waste water management system nor industrial activity represent significant pressure on the state of the environment of the investigated area. However, contrary to this, inexistence of the effective solid waste management (no separation of the waste, no reuse, and no recycling) represents one of the major pollution pressures, which needs to be tackled in sustainable and effective manner in due time. Only one legal landfill with unsatisfactory sanitary features is in operation for the entire investigated area, whereas 11 illegal landfills have been identified in the Neum macro region. Furthermore, negative impact of the ineffective solid waste management is magnified during the touristic season.

1.3.3 Croatia (Sampling area: Split region)

Geographical features

The length of the coastline of Croatian mainland is 1777.3 kilometres, with a coastline of all the islands, Croatia has a total of 5835.3 km of coastline. The research area of the project covered the coastal and marine area of Split-Dalmatia County. Split-Dalmatia County, with a total area of 14,106.40 km^2, is the largest of the 21 counties existing in Croatia and is located in the central part of the Adriatic coast. Mainland area, including the area of islands, is 4,523.64 km^2, while marine area is 9576.40 km^2 (30.8% of total marine area of Croatia). The coastal area and islands occupy about 40% of the total area of the County. Coastal area makes a narrow strip between the mountains and the sea and is highly urbanized and economically developed, in contrast with the islands that are sparsely populated due to permanent emigration of the inhabitants. The island area of the county consists of 74 islands and 57 islets and reefs. Due to its size and population, we could point out the islands Čiovo, Šolta, Brač, Hvar and Vis, with a total population of about 33,500. The whole County has around 455,000 inhabitants, while Split as the second largest city in Croatia has a total number of inhabitants around 178,000. Split is an important cultural, touristic, industrial, commercial, administrative centre of Dalmatia. Its port has an exceptional geographical position in the Mediterranean, and is one of the most important centres for local and international maritime traffic. Because of the unique historical heritage and its 1700 years of tradition, the city and port of Split have become an unavoidable destination for cruising tourism in the Mediterranean.

In recent years due to increased traffic, the southern part of the Port of Split near the town centre is used for passenger traffic, while freight traffic is displaced to the industrial zone in the northern part of the port (Kaštela Bay). According to data on passenger traffic, Port Split is today the first in Croatia with over 4 million passengers per year. According to data on freight transport is in third place, after the ports of Rijeka and Ploče, with about 3.2 million tons of cargo per year.

Climatic features

Split-Dalmatia County is located in the zone of the Adriatic type of Mediterranean climate with hot and dry summers and mild, wet winters. Adriatic Sea, as a natural reservoir of relatively warm water with a temperature of 10 to 26^{0}C, is the most important indicator of good climate in the wider area of the county.

Coastal area is characterized by maximum precipitation in the cold winter months and hot, dry, extremely bright summers. The island area is characterized by a warm climate with plenty of sunshine, temperatures that rarely fall below zero and with little rainfall.

The temperature of the coldest month is between -3°C and + 18°C, while the mean temperature of the warmest month is higher than 22°C. The average summer temperature in Split is 26°C, and winter around 7°C. The average annual temperature is 17.3°C. Prevailing winds are bura (NE) and jugo (SE) with frequency of 35 to 55% through year.

Pollution sources

In recent decades urbanization of the coast exert strong pressure on the environment and shows increasing degradation due to human activities (Marcus, 2004). Environmental degradation effects coastal water quality through the impact of excess nutrients and the presence of organic pollutants originating from the industrial discharge and domestic sewage (Avanzini, 2009).

Rapid urbanization of the Split region in the 1970s, industrialization (cement, vinyl chloride, metallurgy, ship building and food processing), affected water properties of the surrounding coastal waters by receiving large quantities of untreated municipal and industrial effluents for decades (Marasović et al., 1991). In order to improve the environmental status, a new sewage treatment system for more than 300,000 inhabitants, comprising a network of pipelines, pumping stations and a tunnel with treatment plants and submarine outfalls was constructed and the outflow was moved to the wider area of the Brač Channel at the end of 2004.

In the past, almost the entire confluence of the Jadro and Žrnovnica was sparsely populated area with a relatively small amount of wastewater. The construction of roads, development of tourism and industry, and the construction of municipal infrastructure has increased the amount of wastewater, especially in the karst areas. Since there is no natural surface receivers of wastewater, it is common that wastewater is discharged into the ground, and usually in morphological depressions, caves and sinkholes. Specific features of karst areas prevent natural way of waste treatment (dispersion, sorption, degradation, etc.). If the waste is discharged into the karst area over a long period, there is a deterioration in the quality of groundwater, and thus spring water.

Most of the housewarmings in the area have no sewage infrastructure, though it is their construction is planned. For now, the settlements represent the biggest pressure on groundwater quality, especially in the hydrologically wet periods preceded by long dry periods when accumulated contaminants in septic tanks washed underground.

1.3.4 Greece (Sampling area: Corfu Island)

The study of microplastics on the sea surface and the beach sand was carried out in Corfu Island, in the Ionian Sea. It is the second largest of the Ionian Islands and, including its small satellite islands, forms the northwesternmost part of Greece. Corfu's coastline spans 217 kilometres, its area is estimated at 588 km^2 and the population at 39,000 inhabitants. Corfu has a typical Mediterranean climate, with an average high of 21.8°C, an annual average low of 11.7°C and an annual average rainfall of 1097 mm. The island is one of the main touristic destinations in Greece, which makes tourism the main sourse of litter on the beaches as well as in the marine environment. The only river carrying garbage in Kerkyraikos gulf is Kalamas which flows in the Greek mainland and affects only the eastern part of Corfu. The other parts of the island are exposed to litter coming from the land (tourism) as well as the open sea (maritime traffic).

The research area of the project covered three beaches for the analysis of microplastics. Halikounas beach and Issos beach, which are located on the W-SW side of Corfu Island, and Acharavi beach on the north part.

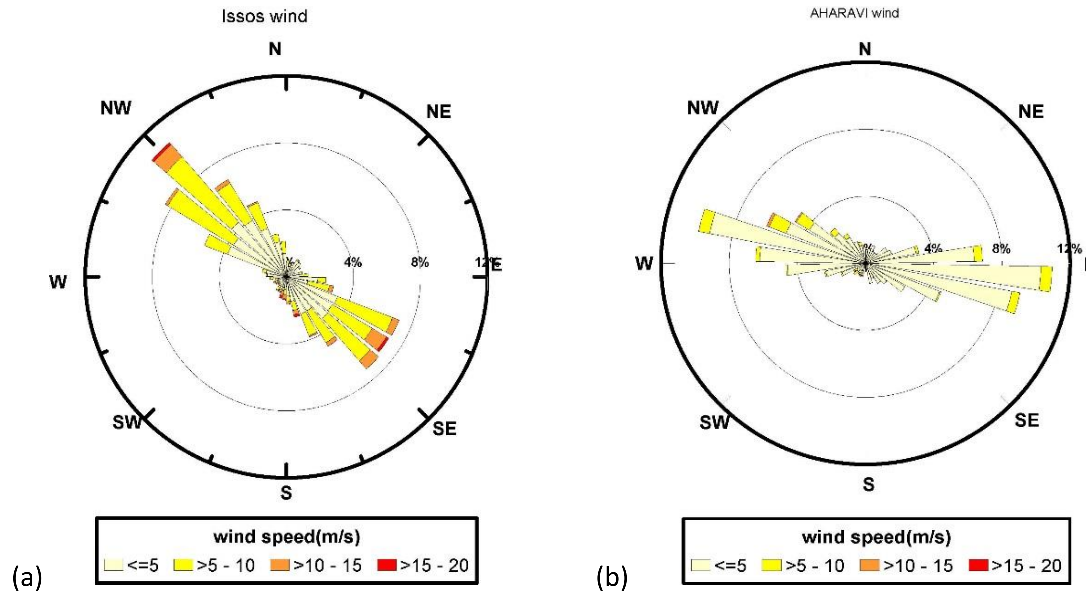


Figure 6: Prevailing winds in a) Issos and b) Acharavi beaches, Greece.

Halikounas beach faces south-west; it is 2659 m long, 20 m wide, 98% fine sand (500-63 μm) and is visited by tourists mainly during August. The surrounding coastal area is not residential and so the main sources of litter are the tourists and the open sea. The mistral (NW) is the prevailing wind.

Issos beach faces south, it is 2360 m long, 20 m wide, 92% fine sand and touristic during August mostly. The mistral is the prevailing wind (Figure 6a).

Acharavi beach faces north, it is 5107 m long and 17 m wide, and the east-west winds prevail. It is touristic with summer houses at the back. Only one sample was collected due mainly to the coarse character of the sand (26% coarse sand and 71% medium sand) (Figure 6b).

Sea surface microplastics (<300 μm) were sampled from 15 locations around Corfu island. In the South Adriatic –Otranto Straits, four manta net transects were conducted. Further to the south, in the North Ionian waters, five manta net transects were done starting from within the current towards the coast. Finally, in Kerkyraikos Gulf microplastic samples were collected from six manta net transects, about 4-5 km away from the mouth of the river Kalamas.

1.3.5 Italy (Sampling area: Porto Garibaldi and Cesenatico region)

The Northern Adriatic Sea, being a semi-enclosed and very shallow marine region, is strongly influenced by meteorological conditions and Po river runoff. The river runoff is a significant component of the basin hydrological cycle and its responsible for the basin net freshwater gain (Raicich, 1994), implying an average estuarine thermohaline circulation.

The shallow northern Adriatic Sea (NA) is characterized by marked seasonal and long-term fluctuations of oceanographic and biological conditions, mainly due to atmospheric forcing, freshwater discharges, variable intrusion of high salinity waters, and a very variable and complex circulation (Orlić et al., 1992; Poulain et al., 2001). The Padano Adriatic Basin (an area extended from 7° to 15° in longitude and 44° to 46° in latitude) synoptic meteo-climatology influences northern Adriatic Sea conditions. The North Adriatic receives large quantities of freshwater mainly from the Po River, one of the two largest in the Mediterranean area that, with the Rhone River, accounts for a third of the total freshwater input to the sea (UNEP/MAP/Med POL, 2003). The water mass characteristics and dynamics of the NA, particularly in the surface layer, as well as the chemical and biological processes are greatly influenced by Po river discharges (about half of the total water input and 70% of the nutrient contributions in the region, Degobbis and Gilmartin, 1990). The Po River is the most important river of the Northwest Adriatic basin, largely influencing nutrient load and sediment texture patterns of the coastal zone (De Wit and Bendoricchio, 2001). Direct nutrients load includes water from households and industry and all emissions that enter the surface water in a diffuse manner at intermittent intervals as a results of meteorological events; indirect emissions are inputs to the river network that are routed via the soil/groundwater system, including erosion and subsurface runoff. The most evident effects consist of significant haline stratification and high trophic state (eutrophication), particularly along the North-western side. Eutrophication is a complex set of phenomena ultimately triggered by the increase of limiting nutrients from terrestrial source (Justic et al., 1995). The direct consequence of strong eutrophication processes is the onset of hypoxic/anoxic conditions in the bottom sediments (Vollenweider et al., 1992).

The two major wind regimes are the Bora (NNE) and the Scirocco (SE). The Bora blows over the Adriatic is intense episodic bursts. Its field over the Adriatic Sea is strongly influenced by the orography of the eastern Adriatic land margin (Vilibic, 2003), giving rise to a strong spatial variability (Orlic et al., 1992). The Scirocco is connected with the passage of low-pressure system over the basin, causing the relative increase in sea level in this region due to the inverse barometer effect and to the direct sea level set up by the wind. This effect is particularly strong in the northern Adriatic (Orlic et al., 1992).

Porto Garibaldi is a small residential and touristic town with a population of 5000 inhabitants. Generally, a strong increase of habitants are registered during summer months. Porto Garibaldi fishing harbour is characterized by a Nord West orientation and usually presents approximately 50 number of ships/year.

Cesenatico is a small residential and touristic town with approximately 26,000 inhabitants. Generally, a strong increase of habitants are registered during summer months. Cesenatico is a fishing harbour characterized by a 100 number of ships/year with a Nord East orientation.

1.3.6 Slovenia

Geographical features

Slovenia is located in the very north of the Adriatic Sea. The coastline of Slovenia borders Italy's coastline in the north and Croatia's coastline in the south (Exploring the..., 2011), its length is 46.6 km with 403 km^2 of territorial waters, which are part of the shallow Gulf of Trieste. From 2005 Slovenia established an Ecological Protection Zone in 2005 which covers 406 km^2 (Exploring the..., 2011; NUMO, 2014). The Slovenian Coast is a dynamic, heterogeneous and unique area. 40% of the sea is shallower than 10 m and only 3% are deeper than 25 m with the maximum depth of 38 m (GIS, 2016).

Sea currents in Trieste bay and Slovenian sea are side branch of enclosed, permanent, and cyclonic sea currents of the Adriatic Sea. They are running in direction up from Croatia's coast to the north by the Slovenian sea and towards north-west and back to the south by the coast of Italy (GIS, 2016). In average the sea surface salinity in Trieste bay is the lowest from the surface salinity of the rest of the Adriatic sea, and usually have values from 37 to 38‰ but in the summer time can drop down to 30‰ due to the increased inflow of rivers (GIS, 2016). Sea surface density is the factor, dependent from sea surface temperature and sea salinity. Extreme values were measured right here, on the north of Adriatic sea, and were in range from 1022 kg/m^3 in the summer and up to 1030 km/m^3 in the winter (GIS, 2016).

Although most part of Adriatic Sea has a Mediterranean climate, on the north and on the north-west the climate is more sub Mediterranean and moderate continental. Adriatic sea is known as warm that has distinct seasonal oscillations. Average year temperature in Koper in 2011 was 16.4°C and it was 0.6 lower when compared to average of the last ten years (ARSO, 2012).

Economy and population

The use of sea environment is intensive and versatile. The most important maritime activities in Slovenia are (marine) tourism, fisheries and maritime transport. The country has three coastal municipalities namely Koper, Izola and Piran (located in South Primorska, which is a statistical region and has no legal basis) (Country report - Slovenia, 2011).

The port of Koper is an important international port in Central Europe. In 2015, the port handled more than 20 million tonnes of cargo (Port of Koper, 2016). The entire north-western part of Slovenia's territorial sea (on the border with Italy) is intended as a routing corridor in the traffic separation scheme which was reconciled between Slovenia, Italy and Croatia in 2000. It is expected that maritime traffic in the Northern Adriatic will further increase (Country report - Slovenia, 2011).

Tourism is an important activity in the coastal municipalities, especially in the municipality of Piran. Tourist activities account for close to 10% of the Slovenian GDP and the coastal areas are estimated to host around 26% of all tourists in the country. Moreover, the Slovenian coast hosts four tourist harbours: Marina Koper, Marina Izola, Marina Portorož and Laguna Bernardin. There are also two salt-making areas on the coast of Slovenia, Sečovlje and Strunjan. Those are the northern still operational saltpans in the Mediterranean region (NUMO, 2014).

At the last inventory of population in Slovenia in 2011 there were 86,270 people or 4% of entire population of Slovenia living in the coastal region. The density of population is 2-times higher than the rest of the Slovenia. In addition to this number, each summer come here almost 600,000 tourist from Slovenia and abroad.

Pollution sources

Main sources of littering of the sea environment are from mainland activities: tourism and recreation, river outflows, sewage disposals, landfills near coast, incorrect waste management in coastal cities, industry). In addition to this, marine activities as sea traffic, fishery and mariculture also contribute its part to the pollution. Thoroughly 74% of all pieces of waste on the coast of Slovenia are from plastic (NUMO, 2014). And if we know that secondary microplastics are plastic fragments derived from the breakdown of larger plastic debris, we have a lot of input sources.

For example there are several wastewater treatment plants (WWTP) near sea shore in Slovenia, and two of them are channelled directly into waters that flows into the sea: WWTP Koper is channelled into the river Rižana, and WWTP Seča is channelled into "Jernejev kanal", which is channel directly into the sea. In addition to this there is WWTP Piran which is drained directly into the sea, on the sea bottom away from the shore (Atlas okolja, 2015).

2 Materials and Methods

During the DeFishGear project protocols for the assessment of microplastic pollution on the sea surface and beach sediments were developed and composed in final dokument: “Recommendation on regional approach to monitoring and assessment of microplastic in the marine environment” (Kovač Viršek et al., 2015).

These DeFishGear protocols were developed by the DeFishGear project partners based on existing recommended methods for microplastics sampling and analysis. These recommended methods strongly rely on different relevant marine Directives and Conventions applied in the Mediterranean and abroad (Marine Strategy Framework Directive, various guidance documents for the common implementation of MSFD, OSPAR-Convention for the Protection of the Marine Environment of the North-East Atlantic, etc.).

Some of the partners made some modifications of the protocol and they are specified in each section on the sampling and sample analysis.

2.1 Sea surface sampling and sample analysis

In addition to detailed description of methodology, general features of monitoring strategy have also been defined in the relevant DeFishGear Monitoring Protocols. Therefore Albania, Croatia, Greece and Italy sampled sea surface microplastics in the predetermined locations according to the mathematical model for litter accumulation developed by CMCC (Mediterranean Centre for Climatic Change), whereas Bosnia and Herzegovina and Slovenia performed their sea surface monitoring activities on randomly chosen locations.

2.1.1 Sampling

2.1.1.1 Albania

Sampling was performed on 5 sampling transects near the city of Durres (Figure 7). Sampling was done on 25th January 2016. Other technical data referred to this survey are described in Appendix 1, Table A - 1. The sampling was conducted with manta net according to the recommendations from chapter “2.2 Sea surface sampling” from the protocol “Recommendation on regional approach…” (Kovač Viršek et al., 2015). There were no adaptations of the protocol.

Figure 7: Sea surface sampling transects in Albania. Source: Google Earth.

2.1.1.2 Bosnia and Herzegovina

Sampling activities related to the assessment of sea surface microplastics in Bosnia and Herzegovina were performed in Neum aquatorium (Neum bay) on randomly chosen locations. They were performed in 3 cycles (December 2014, December 2016, and March 2016). Within each cycle, 2 transect were sampled (Figure 8). Sampling data are presented in Appendix 1, Table A - 2, Table A - 3.

There were no adaptations of the protocol "Recommendation on regional approach…" (Kovač Viršek et al., 2015).

Figure 8: Sea surface sampling transects in Bosnia and Hercegovina. Source: Google Earth.

2.1.1.3 Croatia

In Croatia, sea surface was sampled for microplastics in 3 areas from Split to Island Vis (Splitski kanal, Viški kanal, Biševski kanal). Sampling was performed in October and December 2014. The protocol "Recommendation on regional approach…" (Kovač Viršek et al., 2015), within the DFG project, was followed. In both seasons samples were collected from 10 sea surface transects (Figure 9), on the same locations, 4 in Splitski kanal, 4 in Viški kanal and 2 in Biševski kanal. The locations were predetermined according to the possible litter accumulations caused by sea currents. Within the area covered by surface sampling were included locations near urban places near the coast as well as the channel waters and the open sea. Sampling data are described in Appendix 1, Table A - 4, Table A - 5.

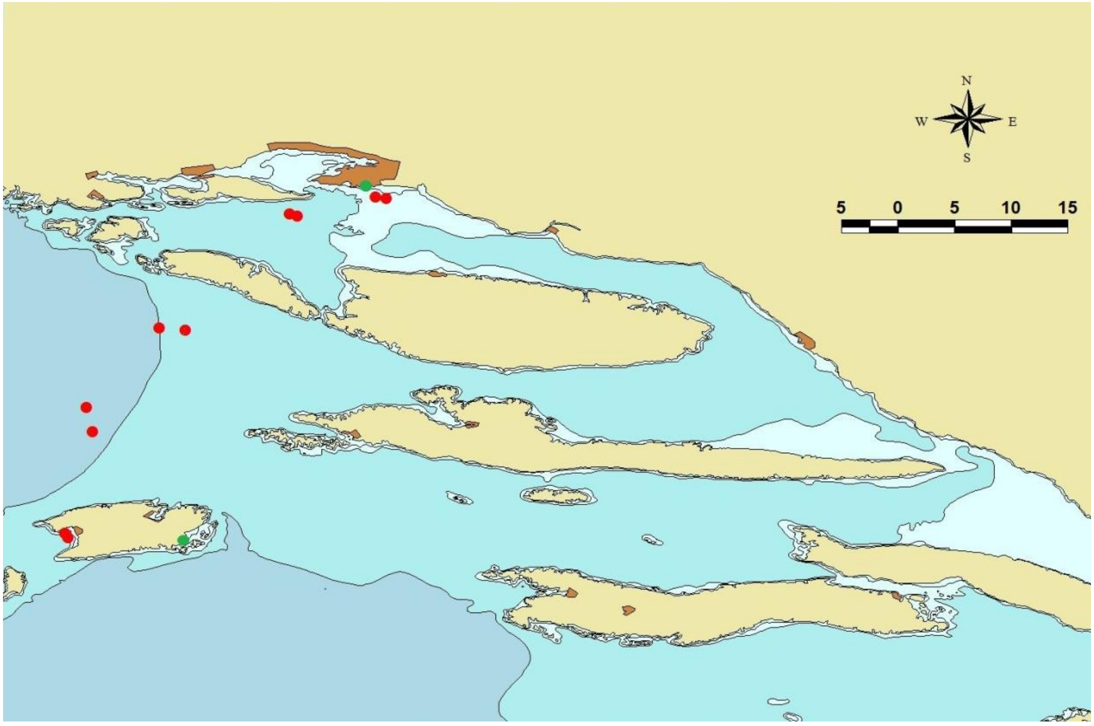


Figure 9: Sea surface sampling transects in Split region (red labels), Croatia. Source: Google Earth.

2.1.1.4 Greece

In Greece, sea surface was sampled for microplastics on 3 areas around Corfu Island (Otranto Straits, North Ionian waters, Kerkyraikos Gulf) in October 2014. The protocol "Recommendation on regional approach…" (Kovač Viršek et al., 2015) within the DFG project, was followed.

In Otranto Straits, the South Adriatic, four manta net transects were conducted following the forecast on the presence of surface currents as indicated by the CMCC group. Further to the south, in the North Ionian waters, five manta net transects were done starting from within the current towards the coast. Finally, in Kerkyraikos Gulf microplastic samples were collected from six manta net transects (Figure 10) (Appendix 1, Table A - 6, Table A - 7, Table A - 8, Table A - 9).

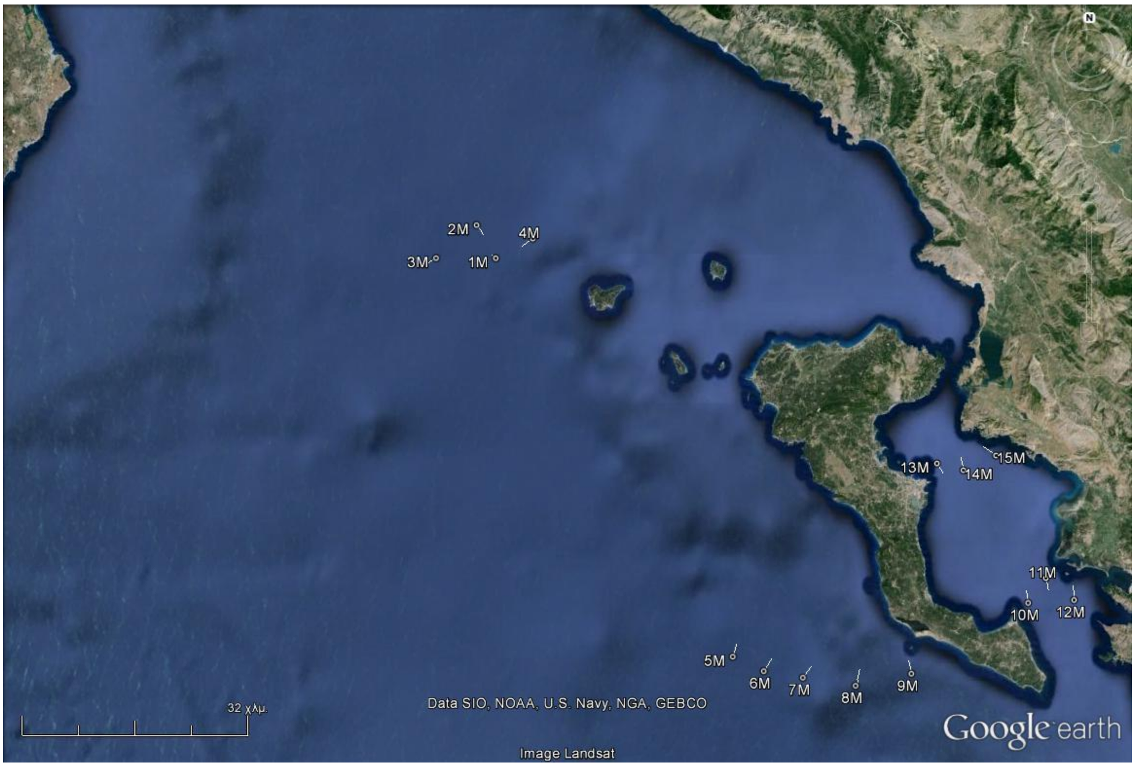


Figure 10: Sea surface sampling transects in greece, near the Corfu Island, Greece. Source: Google Earth.

2.1.1.5 Italy

In Italy, 2 transects perpendicular to the coast on the Northern Adriatic Sea were selected (Figure 11). In each transect 3-4 sampling stations were located at different distance from the coast (0.5, 3, 10 and 20 km). The samplings were carried out in October 2014.

Porto Garibaldi transect

Porto Garibaldi transect was constituted from 4 sampling stations (PG4_S, 304_S, 1004_S, 2004_S). The sampling stations are strongly influenced by Porto Garibaldi River. Porto Garibaldi site is characterized by sandy beach with Nord East coast orientation. The stations were sampled in October 2014 (sampling data in Appendix 1, Table A - 11).

Cesenatico transect

Cesenatico transect was constituted from 4 sampling stations (PG14_S, 314_S, 1014_S, 2014_S). Cesenatico site is characterized by sandy beach with Nord East coast orientation. The samplings were carried out in October 2014 (sampling data in Appendix 1, Table A - 10).

In Italy a few modifications of the protocol "Recommendation on regional approach…" (Kovač Viršek et al., 2015) was used: 1) manta net aperture: 25 x 50 cm; 2) mesh size 330 µm; 3) duration of sampling was 20 min.

Figure 11: Sea surface sampling transects in Italy. Source: Google Earth.

2.1.1.6 Slovenia

In Slovenia, sea surface was sampled for microplastics almost in all Slovenian coast from Piran to Koper in August 2014. Other sampling data referred to this survey are described in Appendix 1, Table A - 12. The sampling was conducted with manta net according to the recommendations from chapter "2.2 Sea surface sampling" from protocol "Recommendation on regional approach…" (Kovač Viršek et al., 2015). There were no adaptations of the protocol.

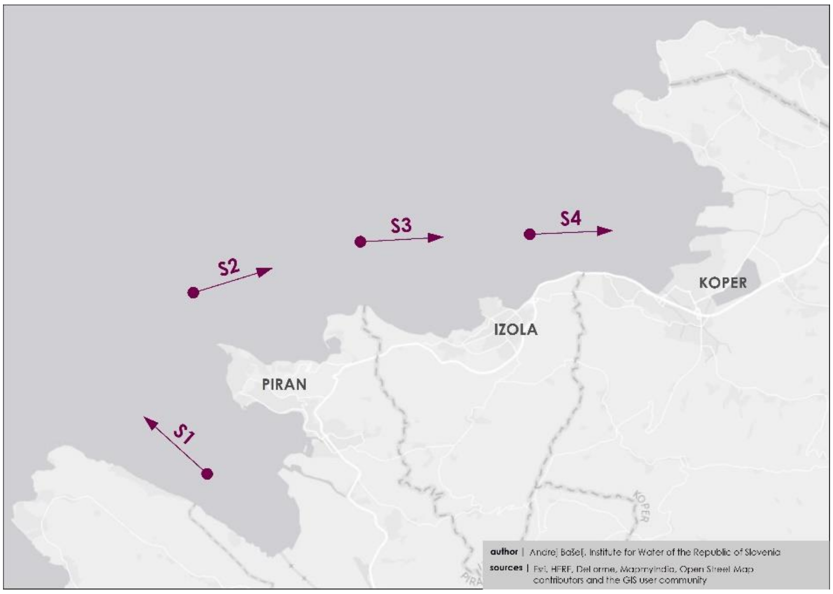


Figure 12: Sea surface sampling transects in Slovenia. Photo: IWRS.

2.1.2 Microplastic separation from the sea surface

Microplastic separation from the sea surface samples were performed according to the document "Recommendation on regional approach…" (Kovač Viršek et al., 2015). Modifications to the protocol from above mention document were developed by Greece and Croatia. In Greece, the problem with large amounts of organic matter was present and for this reason two sieves were used in the faze of cleaning the sample, a 1 mm and a 300 µm sieve (one on top of the other), in order to separate small particles from the large gelatinous lumps or the seaweeds. Samples were always rinsing with seawater in order to facilitate separation. One sample in Kerkyraikos Gulf during April 2015 was exceptionally dense in floating seaweed and its treatment included also several times of flotation. In Croatia image analysis of particles and measure of weight of microplastic was not perfomed due to the lack of appropriate equipment.

2.2 Beach sediment sampling and sample analysis

2.2.1 Beach sediment sampling

Microplastics in beach sediments was researched by the use of two different protocols, for large microplastic particles (LMP) (1-5 mm) and for small microplastic particles (SMP) (<1 mm). Microplastics in beach sediments was sampled in Croatia (3 beaches), Greece (3 beaches), Italy (1 beach) and Slovenia (1 beach). Sampling was done two times for each beach (except 2 beaches in Greece), in touristic and non touristic season and for LMP and SMP. The assessment of beach sediment microplastic pollution has not been performed in Bosnia and Herzegovina due to the lack of sandy beaches.

In Albania, beach sediment samples were sampled on three beaches: Pleba, Shengjin and Velipoje in January, February, March and June 2015 (sampling data in Appendix 2, Table A - 13).

In Croatia, two beaches that are placed in rather touristic area were investigated in aim to compare results during and after touristic season. One is located in the centre of Split (Bačvice beach), representing one of the most popular touristic beaches in the area while other beach (Zaglav beach) is located on the island of Vis, one of the most distant islands from the Croatian coast, exposed to southern winds and influenced by open sea currents. Additionally, 5 transects from the beach placed in vicinity of the Neretva river outflow were collected. On Bačvice beach samples were collected in September and December 2014 and on Zaglav beach in July and October 2014. The samples from beach on Neretva outflow were taken in October 2014 (sampling data in Appendix 2, Table A - 14, Table A - 15, Table A - 16, Table A - 17, Table A - 18).

In Greece, sampling of beach sediments was performed on Corfu Island. The Halikounas beach was sampled twice (7/2014 and 7/2015). The Issos beach was sampled once (6/2015). No samples were taken from Acharavi beach in 2014 due to bad weather conditions; the sediment samples in Acharavi beach were collected during September 2015. Sediment samples were collected from a) the high strandline, b) the middle, and c) the back of the beach (sampling data in Appendix 2, Table A - 19, Table A - 20, Table A - 21).

In Italy, sampling was perfomed on Cesenatico beach, representing one of the most popular touristic beaches in Emilia Romania region. This region is influenced also by Po River, which is less than 100 km north from Cesenatico (sampling data in Appendix 2, Table A - 22).

In Slovenia sampling can be done just on one place, named Lazaret, which is located near the border with Italy. Because this beach is narrow and short, just 3 replicates was sampled per LMP and SMP. Beach is not very touristic and near the beach is mussle farm. Sampling was peformed in September 2014 and January 2015 (sampling data in Appendix 2, Table A - 23).

Figure 13: Beach sediment sampling sites in Slovenia, Italy, Greece, Albania and Croatia. Source: Google Earth.

In all countries sampling of microplastic from beach sediment for LMP and SMP was done according to the method in recommendations from chapter "3.2.2 Sediment sampling of large microplastic (LMP) (1 mm – 5 mm)" and "3.2.4 Sampling of small microplastic (SMP) (20 µm – 1 mm)" from the protocol "Recommendation on regional approach to monitoring and assessment of microplastic in the marine environment" (Kovač Viršek et al., 2015). There were adaptations of the protocol just in Slovenia, where only 3 replicates per beach were sampled with a 3 m distance between each replicate.

2.2.2 Microplastic separation from the beach sediment samples

Microplastics separation from the beach sediment samples was performed according to the methods described in document "Recommendation on regional approach to monitoring and assessment of microplastic in the marine environment" (Kovač Viršek et al., 2015) in chapter "4.3 Microplastic separation from the beach sediments".

In Croatia and Greece a few modifications of the protocol were applied. In Croatia image analysis of particles and measure of weight of microplastic was not perfomed due to the lack of appropriate equipment. In Greece all LMP samples were analyzed for microplastics according to the protocol mention above, except samples from the Acharavi beach, which were coarse sand and so the method of density separation was found to be more efficient.

In Greece protocol was improved in order to avoid the contamination from air transported fibers. For this reason the separation of the SMP was carried out in a glove bag as working area and the filters were covered with glass lids during observation under the stereomicroscope (Figure 6). To monitor air contamination, procedural blanks were used.

Figure 14: Separation of SMP in the laboratorium in Greece, where chamber were used to protect the sample before air born microplastic contamination. Photo: HCMR.

2.3 Chemical identification of microplastic

Chemical identification of microplastic particles were done by the use of ATR FT-IR microscopy and Near IR spectroscopy. An FTIR microscope combines the function of a microscope and an infrared spectrometer. This allows recording a spectrum on a very small area suitable for analysis of microplastics smaller than 1 mm. Microplastics particles were placed on a glass filter and the ATR germanium crystal was cleaned using 80% alcohol and lint free cloth. The filter with the microplastic was placed on the automatic scanning table and the joystick was used to locate the sample and to record an optical image. The measured area was 20 x 20 µm in size. Spectra of sample area was compared with the spectrum in spectral database to identify the composition of the sample.

Chemical analysis of pellets and other particles larger than 2 mm was performed using near infrared spectroscopy (NIR) (SIROGRAN, GUT environmental technologies, GmbH, Germany). We applied a new approach to the identification using a NIR spectrometer with an automated XY scanning facility. A sample plate with 625 set positions each able to contain one particle was used. Identification of polymer type was achieved by comparing collected NIR spectra with a built-in spectral database through an automated chemo metric procedure.

By the use of above described methods, microplastic from the Bosnia and Herzegovina (sea surface), Croatia (sea surface and beach sediments), Italy (sea surface and beach sediments) and Slovenia (Sea surface) were analyzed.

In Greece, microplastic were analyzed by the use of Fourier transform infrared spectroscopy (FT-IR). This technique was used to confirm the synthetic polymer origin of microplastic that were large enough to handle with forceps and analysed on an Agilent Cary 630 FTIR spectrometer using a self generated polymer library. However, FT-IR microscopy is required to analyze the majority of microplastic found in mussels and fish. FT-IR microscopy of microplastic is in process by LB.

The chemical identification of a random sample of large microplastics from Halikounas beach and of all the microplastic fragments was done with FTIR.

In Slovenia, microplastic from sediment samples were analyzed by the use of Fourier transform infrared spectroscopy (FT-IR) (Spectrum Two, Perkin Elmer) using a Hummel spectra library.

2.4 Organochlorine (OCI) and polychlorinated biphenyls (PCB) analysis

The main steps of the methodology applied in this study are briefly described in this section. Overall, a strict cleaning protocol was applied throughout experiments in order to avoid background contamination. The procedure was adapted from IWP monitoring (Mato et al. 2001; Endo et al., 2005; Ogata et al., 2009).

Sampling of plastic pellets: Plastic pellets were collected from the beach with solvent-rinsed stainless steel tweezers and wrapped in solvent-rinsed aluminium foil. Paper bag could be used as an alternative. Wet samples were dried in the darkness and at ambient temperature prior to shipment.

Shipment and storage: The pellets, wrapped in solvent–rinsed aluminium foil, were placed in zip-lock bags and sent to the partner responsible of the analysis. Prior to analysis, the samples were stored in freezer at -18°C.

Sorting: For each sampling event, pellets were sorted by naked eyes according to the following categories of colour (Figure 15): white, yellowish, yellow, orange, amber, brown, dark and pigmented (e.g. red, pink, violet, green, blue). One sample consisted in a pool of 10 pellets of similar colour randomly selected (i.e. plastic type not considered).

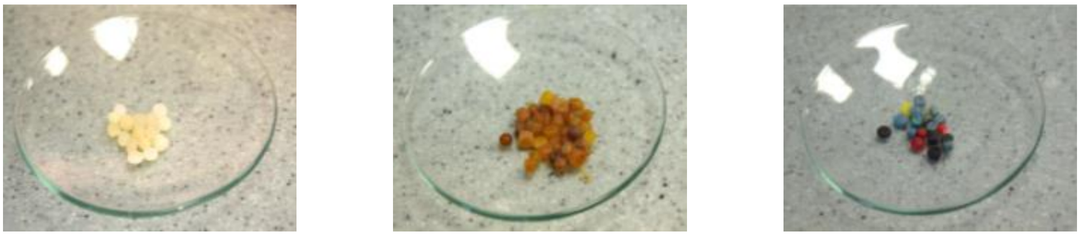


Figure 15: Sorting of plastic pellets by colour. Photo: UNG.

Extraction: First, the sample was soaked in hexane overnight (extract 1). Then, the pellets were transferred into an Inox cell and extracted in a pressurized fluid extractor (Figure 16) with hexane at 60°C under 100 bar and for 25 min (extract 2). Finally, both extracts were mixed.

Figure 16: Pressurized Fluid Extractor (acquired from the DeFishGear project). Photo: UNG.

Concentration: The obtained extract was concentrated to 1 mL in a concentrator at 40°C for 20 min.

Clean-up step: The concentrated extract was cleaned up on a Florisil sorbent by solid-phase extraction (SPE – Figure 17) (EPA method 3620C). First, the sorbent was activated with 4 mL of hexane. Then, the 1 mL of sample was loaded on the sorbent and passed through the cartridge bed at a low flow rate. A first fraction was eluted with 4 mL of hexane and contained PCBs and DDE. A second fraction was eluted with 6 mL of acetone/hexane (10/90, v/v) and contained the remaining pesticides, being HCHs, DDT, DDD, ENDO I and II.

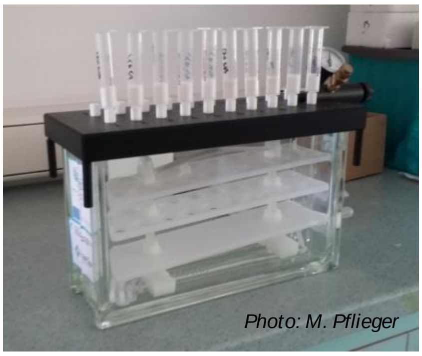


Figure 17: Solid-Phase Extractor (acquired from the DeFishGear project). Photo. UNG.

Analysis: Both fractions were quantified separately on GC-ECD in splitless mode by external calibration. The compounds were separated on a fused silica capillary column Zebron ZB-XLB (30 m x 0.25 mm x 0.25 µm). Standard compounds were used to identify the chromatographic peaks. The identification was validated by carrying out a second analysis of the samples on GC-MS. The recoveries and the limits of quantification were ≥ 85% and ≥ 0.03 ng g^{-1} for both fractions, respectively.

<u>Sampling events</u>

A total of 18 field campaigns was carried out in Croatia, Greece, Italy and Slovenia in 2014 and 2015. Details are presented in Table 3 and the 10 sampling sites are shown on the Figure 18. No pellets were found in Albania, Montenegro and Bosnia and Herzegovina, especially due to the stony nature of the beaches.

Table 3: Field surveys for plastic pellet sampling in Croatia, Greece, Italy and Slovenia in years of 2014 and 2015.

Country	Location	Survey number	Sampling dates	Number of pellets analysed
Croatia 1	Otok Levrnaka	1	Apr. 2015	70
Croatia 2	Otok Vis	1	May 2015	70
Greece 1	Issos beach, Corfu	1	Mar. 2015	70
Greece 2	Halikounas, Corfu	1	Mar. 2015	70
Italy 1	Boccassette	3	Apr.-Jul. 2015	90
Italy 2	Rosolina	3	Apr.-Jun. 2015	90
Italy 3	Torre del Cerrano	2	Apr.-Jul. 2015	80
Italy 4	Torre Guaceto	1	Sept. 2015	60
Italy 5	Cesenatico Ponente	2	Oct. 2014-Jan. 2015	80
Slovenia 1	Strunjan	3	Jan.-Mar. 2015	60

Figure 18: Location of the sampling sites for plastic pellet sampling in Croatia, Greece, Italy and Slovenia in years of 2014 and 2015. Source: https://www.zeemaps.com/.

The levels of OCPs and PCBs were determined in the 10 selected sampling sites and expressed as ng of organic pollutant per g of plastic pellets. Concentrations are given as the median value of the measurements.

3 Results

3.1 Sea surface

3.1.1 Quantity of microplastics according to the number and weight

3.1.1.1 Country level

3.1.1.1.1 ALBANIA

The amount of microplastics found in the sea surface samples was in range from 8.4 x 10^4 to 26.4 x 10^4 particles per km^2 (items/km^2) with minimum abundance on sampling site S1 and maximum abundance on sampling site S5 (Figure 19). In average there were 15.4 x 10^4 particles per km^2 in the sea at the coast of Albania.

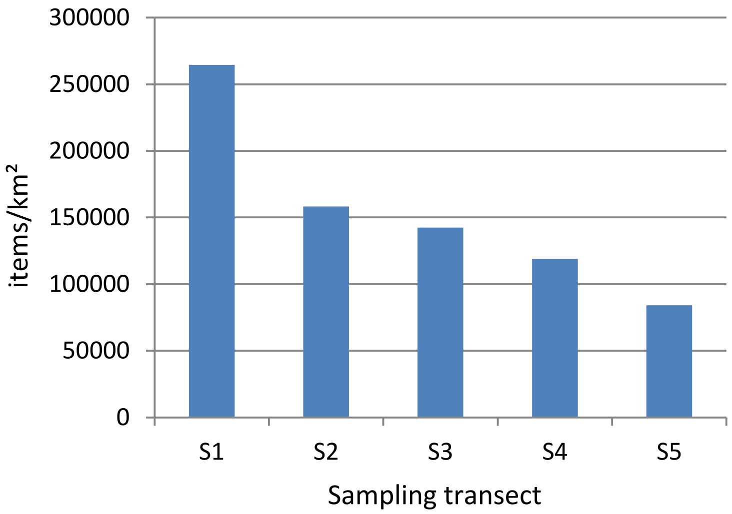
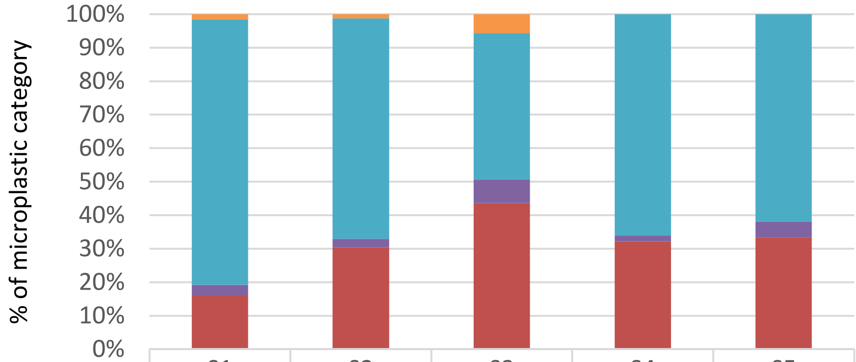


Figure 19: Microplastic concentrations (items/km^2) on the sea surface for each transect in Albania.

In all the sampling sites filaments were predominant type of the microplastic composition, ranging from 43.7% to 79.2% with minimum at sampling site S1 and maximum at sampling site S5. The second most common type of microplastic composition were fragments ranging from 16.2% at sampling site S1 to 43.7% at sampling site S3. Pellets and foams were absent at sampling sites. The films and granules were 5.6% at sampling site S3 to 1.3% at sampling site S2 and granules ranging from 7% at sampling site S3 to 1.7% at sampling site S4 (Figure 20).



	S1	S2	S3	S4	S5
Foam	0,0%	0,0%	0,0%	0,0%	0,0%
Films	1,5%	1,3%	5,6%	0,0%	0,0%
Filaments	79,2%	65,8%	43,7%	66,1%	61,9%
Granules	3,1%	2,5%	7,0%	1,7%	4,8%
Pellets	0,0%	0,0%	0,0%	0,0%	0,0%
Fragments	16,2%	30,4%	43,7%	32,2%	33,3%
Other	0,0%	0,0%	0,0%	0,0%	0,0%

Sampling transect

Figure 20: Microplastic categories for each sampling transect in Albania.

3.1.1.1.2 BOSNIA AND HERZEGOVINA

The amount of microplastic found in the sea surface samples in Bosnia and Herzegovina was in range from 75 and 250 particles per km^2 (items/km^2) with a minimum abundance on sampling transect T2 in December 2015 and maximum abundancy in March 2016 for T1 transect (Figure 21). In average the smallest amount of microplastic particles was caught in December 2015 (137 ± 88 items/km^2) and the maximum in March 2016 (225 ± 35 items/km^2) (Figure 21).

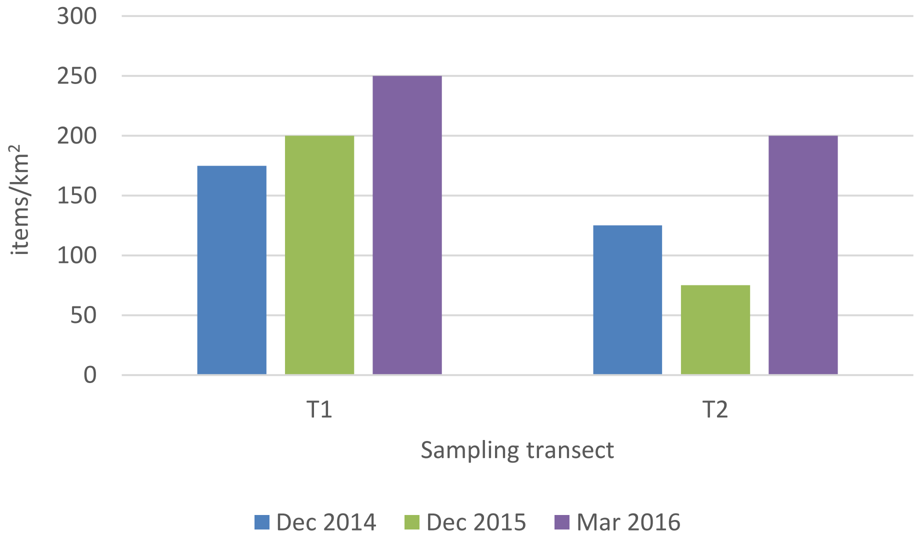
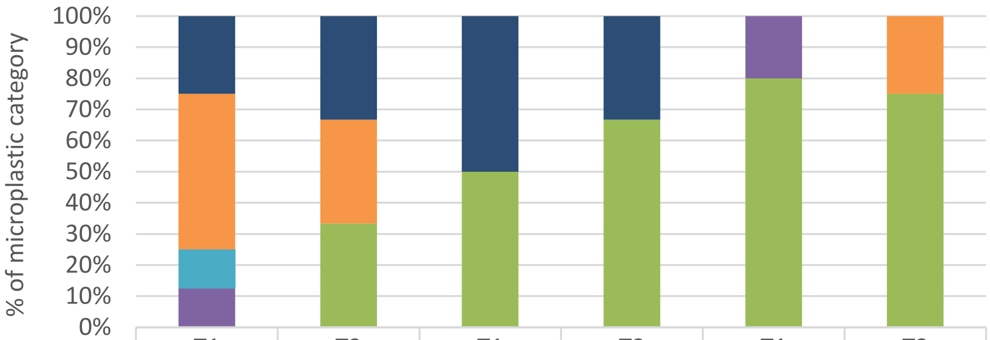


Figure 21: Microplastic concentrations (items/km^2) on the sea surface for each transect in Bosnia and Hercegovina.

The most commonly found microplastic categories are other (33 – 50%) and fragments (33.3 – 80%), followed by filaments (25 – 50%). Films and granules were present only in 1 – 2 samples. No particles of pellets and foam were found (Figure 22).



	T1	T2	T1	T2	T1	T2
	Dec 2014		Dec 2015		Mar 2016	
Other	25,00%	33,33%	50,00%	33,33%	0,00%	0,00%
Filaments	50,00%	33,33%	0,00%	0,00%	0,00%	25,00%
Films	12,50%	0,00%	0,00%	0,00%	0,00%	0,00%
Granules	12,50%	0,00%	0,00%	0,00%	20,00%	0,00%
Fragments	0,00%	33,33%	50,00%	66,67%	80,00%	75,00%
Pellets	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Foams	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%

Sampling transect

Figure 22: Microplastic categories for each sampling transect in Bosnia and Hercegovina.

3.1.1.1.3 CROATIA

In Croatia, from the total of 10 sea surface samples per season, only 5 samples per season were chosen for the analyses. Samples of investigation represented transects from sea surface in coastal waters as well as in the channel area and open sea. During the season 2014 the number of microplastic in collected samples was smaller than 1.3 x 10^4 items per km^2. Exception was SD4 sample where 43.98 x 10^4 microplastic per km^2 was found (Figure 23), as the station is located in vicinity of Split town and contained a bigger amount of organic material. Also all other samples contained organic material mixed with lot of filaments which were the most common category (33.93 - 100%), followed by plastic fragments found in smaller amounts (3.70 – 17.86%). Other categories of microplastic weren't present except the foamed plastic found in SD4 and SD5 samples with 1% and 30.36%, respectively and the films with 3.24% and 17.86% in same transects. According the categories composition, SD5 sample is the most diverse in comparison with other 4 samples. This sample were taken from most distant area from coast, representing fishery area of the open sea (Figure 24).

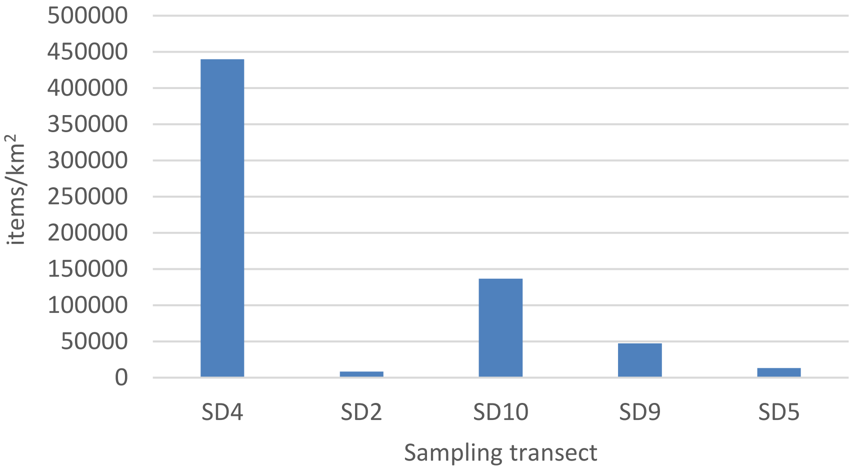
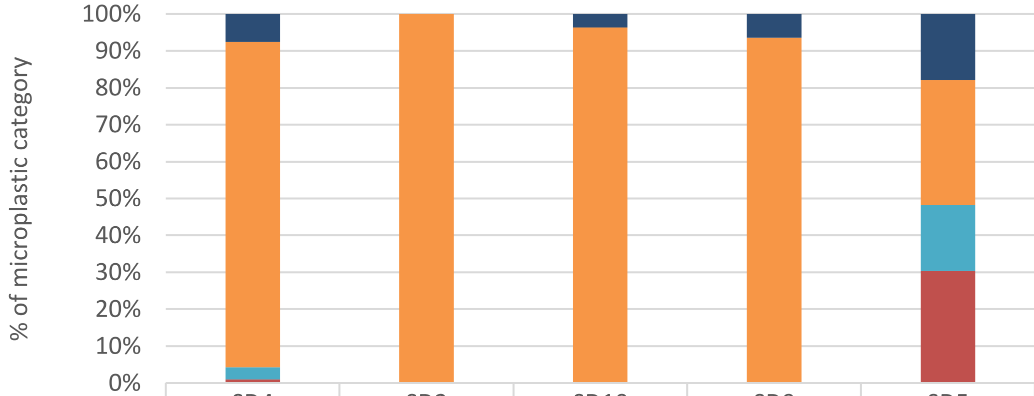


Figure 23: Microplastic concentrations (items/km^2) on the sea surface for each transect in Croatia.



	SD4	SD2	SD10	SD9	SD5
Fragments	7,56%	0,00%	3,70%	6,47%	17,86%
Filaments	88,19%	100,00%	96,30%	93,53%	33,93%
Films	3,24%	0,00%	0,00%	0,00%	17,86%
Pellets	0,00%	0,00%	0,00%	0,00%	0,00%
Granules	0,00%	0,00%	0,00%	0,00%	0,00%
Foams	1,00%	0,00%	0,00%	0,00%	30,36%
Other	0,00%	0,00%	0,00%	0,00%	0,00%

Sampling transect

Figure 24: Microplastic categories for each sampling transect in Croatia.

3.1.1.1.4 GREECE

In the area of Southern Adriatic and Kerkiraikos Gulf microplastic items ranged from 0 items/km^2 to 1.6 x 10^6 items/km^2 (average 69.4 x 10^4 ± 58.1 x 10^4 items/km^2) during October 2014 (Figure 25). In terms of mass (g) the densities varied from 0 g/km^2 to 2,272 g/km^2 (average 386 ± 556 g/km^2) (Figure 26).

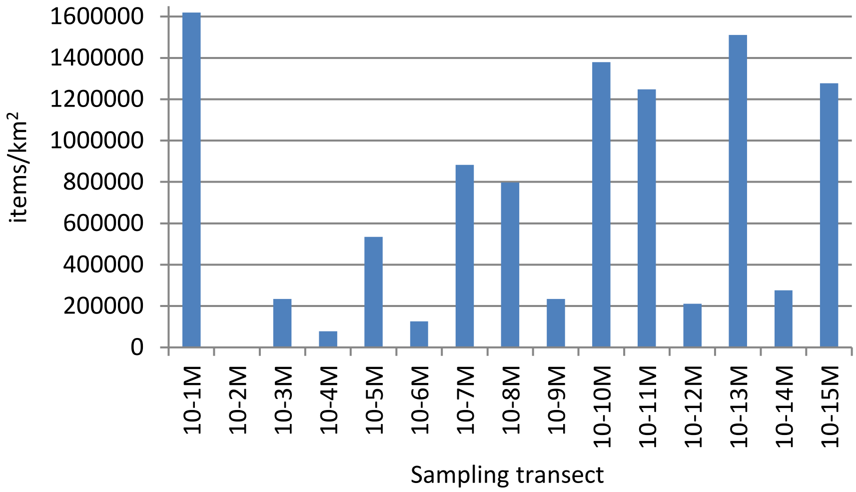


Figure 25: Microplastic concentrations (items/km^2) on the sea surface for each transect in Greece.

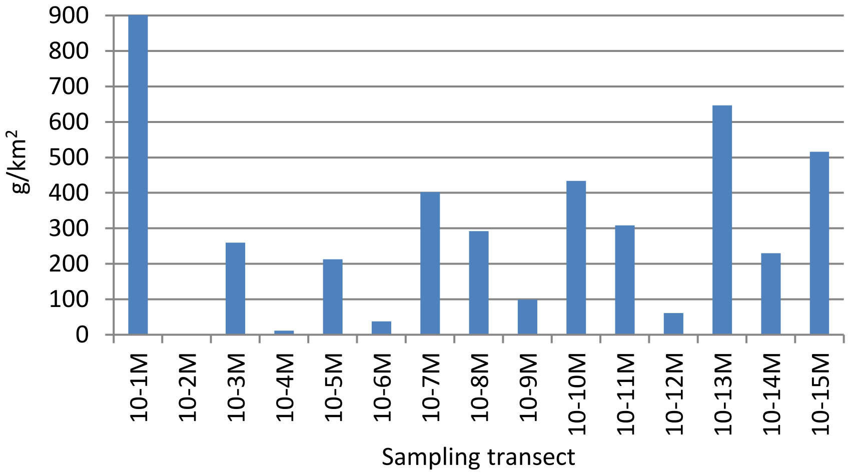


Figure 26: Microplastic concentrations (g/km^2) on the sea surface for each transect in Greece.

The predominant type of microplastics were fragments. We should note here that foams were counted as fragments in the present analysis. Filaments in both size fractions had a very small contribution. Pellets were also absent (Figure 27).

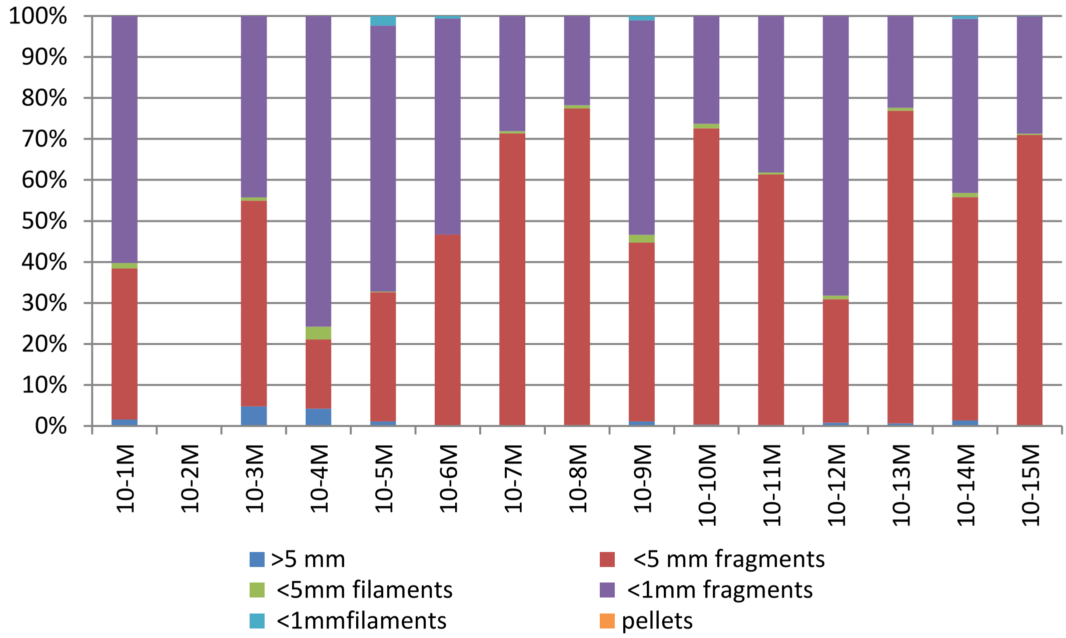


Figure 27: Microplastic categories for each sampling transect in Greece.

3.1.1.1.5 ITALY

The biggest amount of microplastic (items/km^2) was observed in the sampling transect number 14 during October 2014 (Figure 29). In particular, the highest value was recorded in the station 314_S (11.2×10^4 items/km^2) of transect 14, where the quantity of microplastics recorded was 2 times higher compared to the values observed in the station 2014_S of the same transect (Figure 29). While in transect 4, the highest amount of microplastic items were measured in sampling site 2004_S (11.1×10^4 Nr/km^2) (Figure 28).

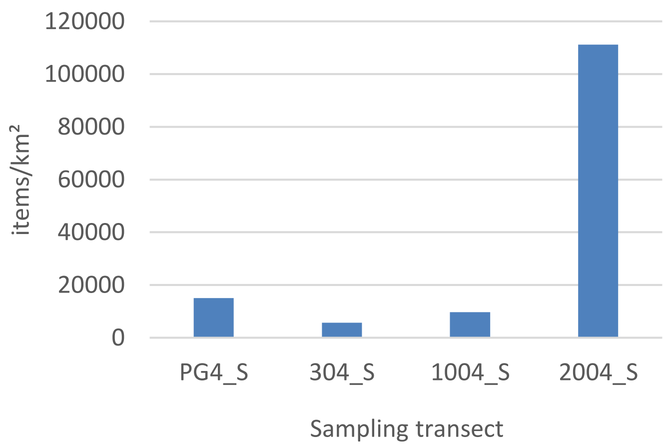


Figure 28: Microplastic concentrations (items/km^2) on the sea surface for samples in transect 4 in Italy.

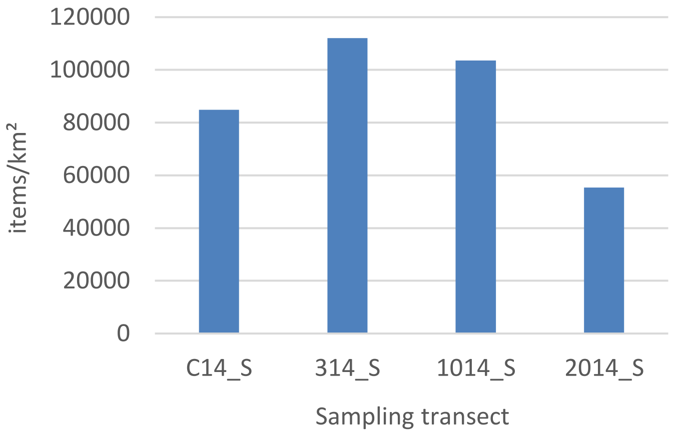


Figure 29: Microplastic concentrations (items/km^2) on the sea surface for samples in transect 14 in Italy.

The weight of the microplastic particles followed the same trends observed for the number of microplastic detected in the sampling transect 4 during October 2014 (Figure 30). On the contrary, different patterns were reported for the transect 14 during October where station 314_S presented high quantity of low weight microplastics (Figure 31).

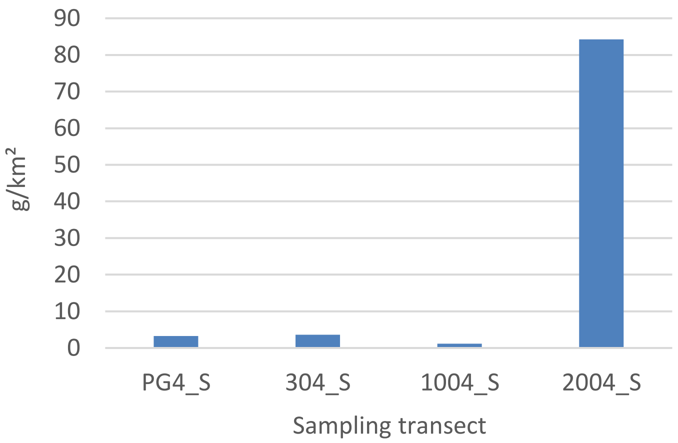


Figure 30: Microplastic concentrations (g/km^2) on the sea surface for samples in transect 4 in Italy.

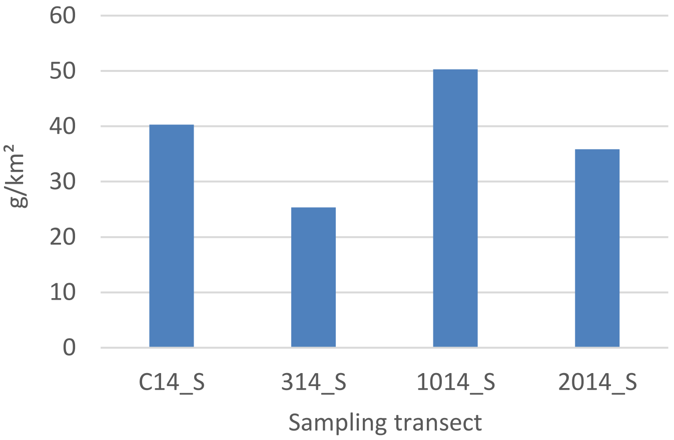
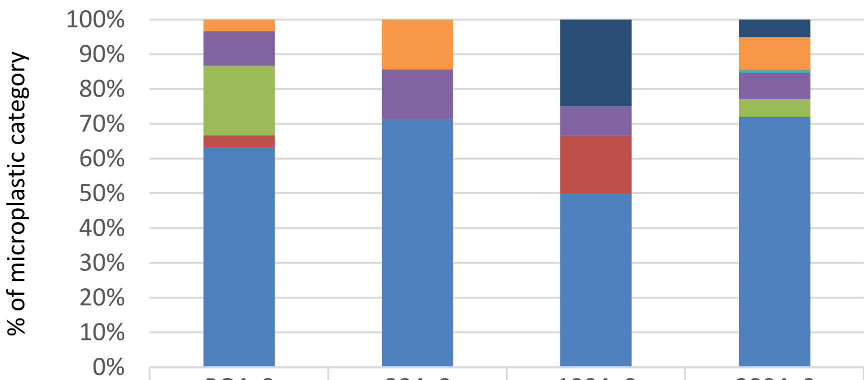


Figure 31: Microplastic concentrations (g/km^2) on the sea surface for samples in transect 14 in Italy.

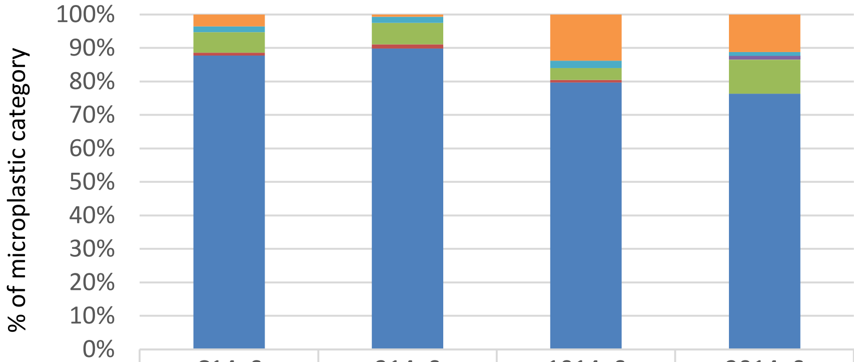
In all the sampling stations fragments were predominant in the microplastics composition, ranging between 50% and 90% (Figure 32, Figure 33). Transect 4 presented the highest amount of pellets (7.63-14.29%) and filaments (5.08-20%) (Figure 32), which were almost absent in transect 14 (Figure 33). Films were detected in different amounts (3.62-20.00%) in all the sampling stations, except in station 304_S and 1004_S. Foam showed also high variability depending on the site and sampling period, ranging between 0% and 14%. Foam were totally absent in station 1004_S (Figure 32).



	PG4_S	304_S	1004_S	2004_S
Other	0,00	0,00	25,00	5,08
Foam	3,33	14,29	0,00	9,32
Granules	0,00	0,00	0,00	0,85
Pellets	10,00	14,29	8,33	7,63
Films	20,00	0,00	0,00	5,08
Filaments	3,33	0,00	16,67	0,00
Fragments	63,33	71,43	50,00	72,03

Sampling transect

Figure 32: Microplastic categories for each sample of the transect 4 in Italy.



	C14_S	314_S	1014_S	2014_S
Other	0,00	0,00	0,00	0,00
Foam	3,51	0,63	13,77	11,24
Granules	1,75	1,90	2,17	1,12
Pellets	0,00	0,00	0,00	1,12
Films	6,14	6,33	3,62	10,11
Filaments	0,88	1,27	0,72	0,00
Fragments	87,72	89,87	79,71	76,40

Sampling transect

Figure 33: Microplastic categories for each sample of the transect 14 in Italy.

3.1.1.1.6 SLOVENIA

The amount of microplastic found in sea surface samples was in range from 23.6 x 10^4 to 33.4 x 10^4 particles per km^2 (items/km^2) with minimum abundance on sampling site S3 and maximum abundancy on sampling site S4 (Figure 34). In average there were 28.3 x 10^4 ± 5.5 x 10^4 particles per km^2.

Figure 34: Microplastic concentrations (items/km^2) on the sea surface for each transect in Slovenia.

The weight of the microplastic of the sea surface samples from August 2014 followed different trend as observed for the number of microplastic. The weight of microplastic in samples was in range from 0.5 to 12.1 g per km^2, with minimum weight at sampling site S4 and maximum weight at sampling site S2 (Figure 35). The data for the weight of categories “filaments” and “other” are excluded from this comparison, since the weight of the filaments wasn't established (due to the low weight of the filament particles and frequent contamination of filaments with non-plastic material).

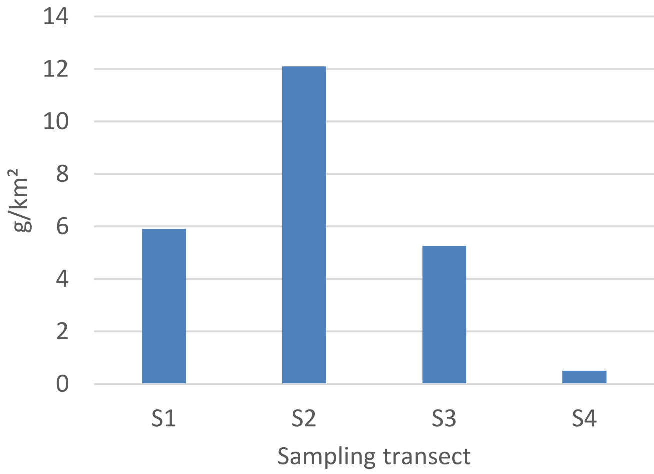
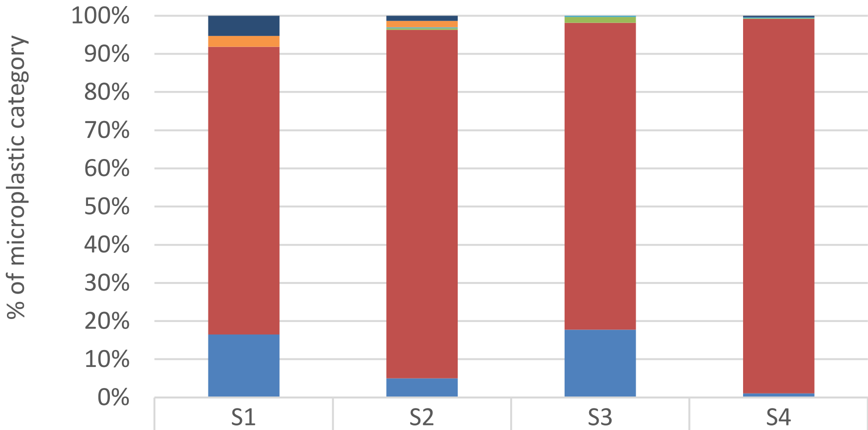


Figure 35: Microplastic concentrations (g/km^2) on the sea surface for each transect in Slovenia.

In all the sampling sites filaments were predominant type of the microplastic composition, ranging from 75% to 98% with minimum at sampling site S1 and maximum at sampling site S4 (Figure 36). The second most common type of microplastic composition were fragments ranging from 1.1% at sampling site S4 to 18% at sampling site S3. Films, granules and foams were absent at some sampling sites and were at least represented types of microplastic composition with maximum of 2.79% for foams at sampling site S1, and 1.53% for films and 0.31% for granules at sampling site S3. Pellets were absent from all sampling sites (Figure 36).



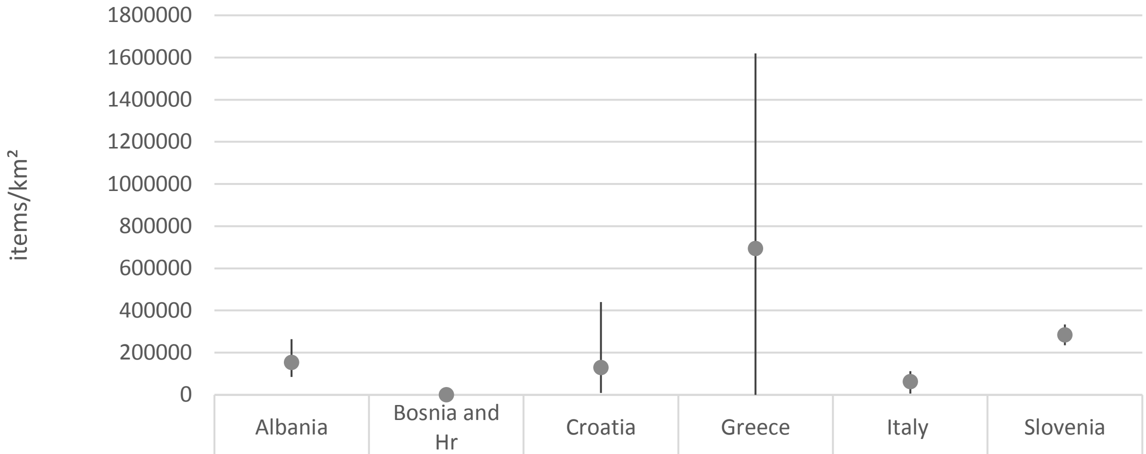
	S1	S2	S3	S4
Other	5,31%	1,31%	0,00%	0,43%
Foams	2,79%	1,75%	0,00%	0,00%
Granules	0,00%	0,22%	0,31%	0,22%
Pellets	0,00%	0,00%	0,00%	0,00%
Films	0,00%	0,44%	1,53%	0,22%
Filaments	75,42%	91,27%	80,43%	98,06%
Fragments	16,48%	5,02%	17,74%	1,08%

Sampling transect

Figure 36: Microplastic categories for each transect in Slovenia.

3.1.1.2 Regional level

On regional level the maximal and minimal average concentrations of microplastics were measured in Greece (0 - 1.6 x 10^6 items/km^2). The average number of microplastic pollution in the Adriatic Sea on the sea surface was measured as 23.4 x 10^4 ± 27.8 x 10^6 particles per km^2. Among measures there were a high diversity among samples, the highest in Greece and Croatia (Figure 37).



	Albania	Bosnia and Hr	Croatia	Greece	Italy	Slovenia
min (items/km2)	84236	75	8631	0	5747	235642
max (items/km2)	264501	250	439787	1619658	112057	333766
● average	153667	171	129236	694035	62046	283172

min (items/km2)   max (items/km2)   ● average

Figure 37: Comparison of average and range of microplastic concentrations among countries of the Adriatic region.

3.1.2 Size distribution

By image analysis software particles sizes were measured for Greece, Italian and Slovenian samples. Measures were done for categories: fragments, films, pellets, granules and other. The length of filaments were not measured, since this methodolically was not possible. In Greece microplastic particles were classified into three classes: <1 mm, 1-5 mm, >5 mm, among which class 1-5 mm was the most abundant (6985 particles), followed by class <1 mm (3820 particles) and at last class >5 mm (67 particles) (Appendix 3, Table A - 24).

In Italy and Slovenia, microplastic particles were measured by image analysis software very precisely and average size of microplastic particles were calculated and extremes determined. Average size of microplastic particles was 1.98 ± 1.26 for Italy and 1.42 ± 1.07 for Slovenia. In Italy and Slovenia particles were very variable in length, since their measurements were in range from 0.21 up to 13.6 mm in Slovenia and from 0.13 to 9.22 in Italy. According to the data of the image analysis there were some mezzoparticles included in the sample (maximum lengths over 5 mm), but average lengths from all categories were smaller than 5 mm, therefore they were in average microplastic. All results are presented in Appendix 3, Table A - 25, Table A - 26.

3.1.3 Identification of plastic type

Results of chemical identification of microplastic particles show that PE is the most abundant type of plastic founded on the sea surface in all countries of the Adriatic region, and the second is PP. Bellow are pie charts for each country separately.

3.1.3.1 Bosnia and Herzegovina

In Bosnia and Herzegovina predominant plastic type was polyethylene (PE), followed by polypropylene (PP). In these samples also natural material (wool) was detected (Figure 38).

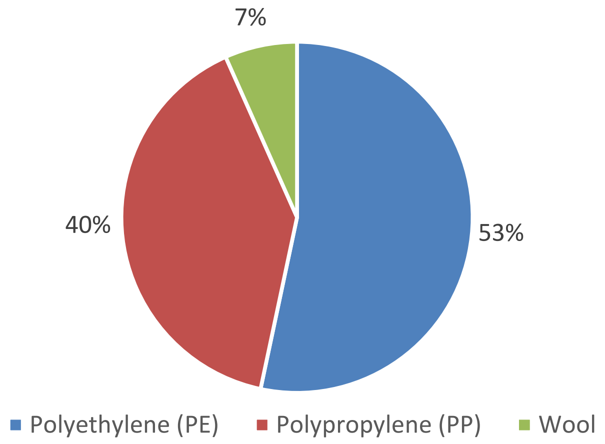


Figure 38: Chemical composition of microplastic for the sea surface samples in Bosnia and Hercegovina.

3.1.3.2 Croatia

In Croatia chemical characterization was done for all five samples. The most abundant material was polyethylene (PE) (32%), followed by polypropylene (PP) (16%), polystyrene (PES) (15.5%) and acrylic fibers (15%). In a few percent there were also present Nylon (1.5%), polyamide (PA) (3%), polystyrene (PS) (4.4%) and polyacrylonitrile (PAN) (9%). (Figure 39).

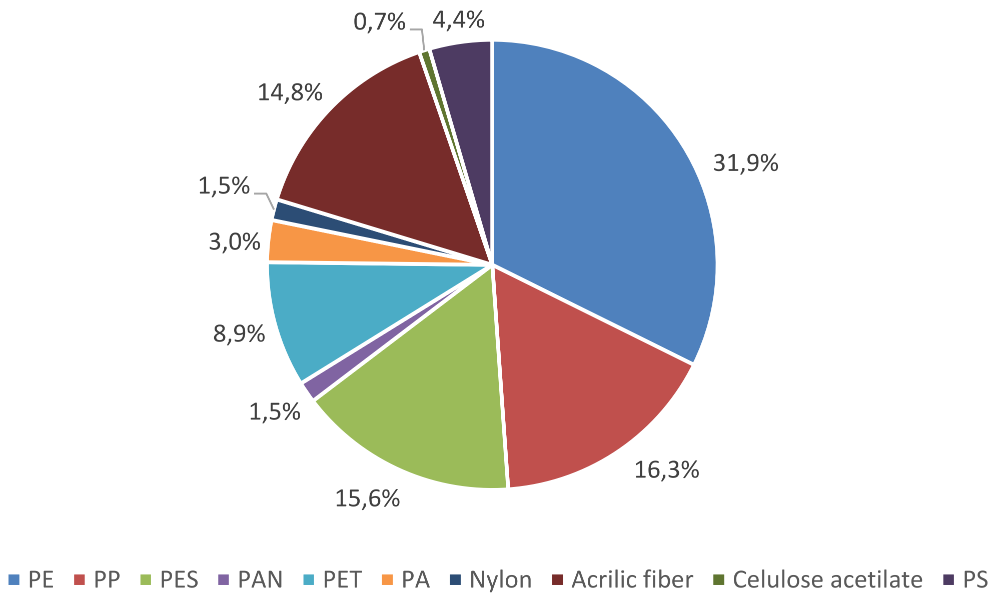


Figure 39: Chemical composition of microplastic for the sea surface samples in Croatia.

3.1.3.3 Greece

In Greece chemical identification was done separately for the particles <1 mm and 1-5 mm for one sea surface sample. For both size classes PE was the most abundant, followed by PP. Just in a few percent also PS was presented (Figure 40).

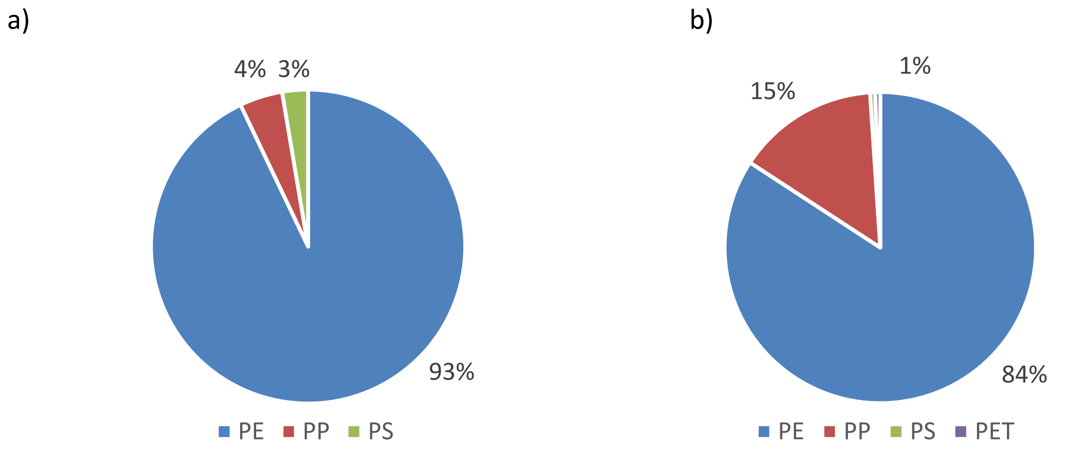


Figure 40: Chemical composition of microplastic for the sea surface sample 4-15M, for a) particles <1 mm and b) particles 1-5 mm, in Greece.

3.1.3.4 Italy

In the fall campaign polyethylene was most represented plastic type; 64% in the northern area (transect Porto Garibaldi) (Figure 41) and 66% in the central area (transect Cesenatico) (Figure 42). The second plastic category in both areas was found to be the polypropylene.

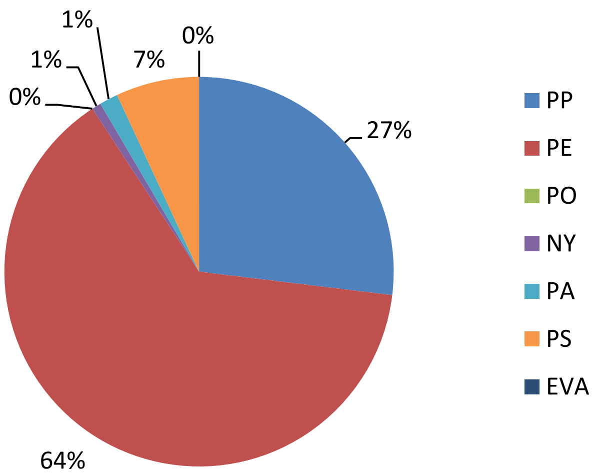


Figure 41: Chemical composition of microplastic for the sea surface samples of the transect 4 in Italy.

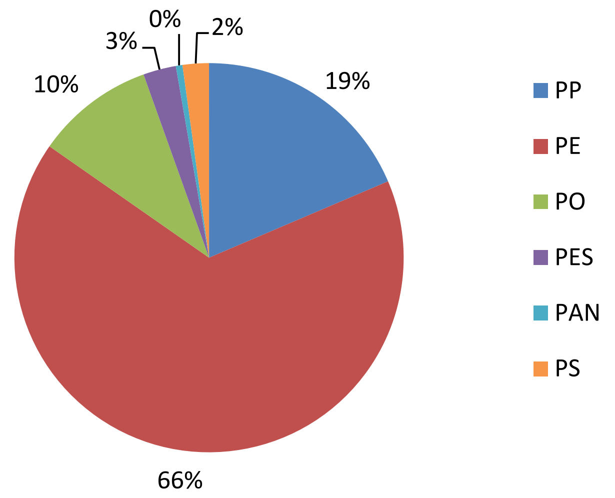


Figure 42: Chemical composition of microplastic for the sea surface samples for the transect 14 in Italy.

3.1.3.5 Slovenia

Chemical analysis of microplastic revealed that polyethylene (PE) and polypropylene (PP) were the far more common type of plastic in all the sea surface samples (S1-S4). In total there were 75% of PE and 17% of PP in the identified samples (Figure 43). Other types of plastic compound found were polyamide (PA), polystyrene (PS), polyethylene terephthalate (PET) and melamine urea formaldehyde resine (MUF).

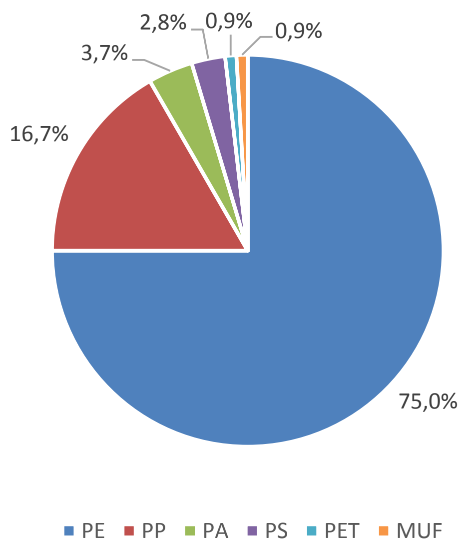


Figure 43: Chemical composition of microplastic for the sea surface samples in Slovenia.

3.2 Beach sediment

3.2.1 Quantity of microplastics according to the number and weight

3.2.1.1 Country level

3.2.1.1.1 CROATIA

On the beach in the vicinity of Neretva outflow, microplastic larger than 1 mm were significantly less represented then the particles smaller than 1 mm. Average number of microplastic <1 mm per kg of beach sediment were 155.07, while the number of particles >1 mm were 15.44 (Figure 44). Significantly predominant category in SMP and LMP samples were fragments with percentages of 91.02% and 91.76%, respectively. In both samples smaller amounts of filaments and films were found (Figure 45).

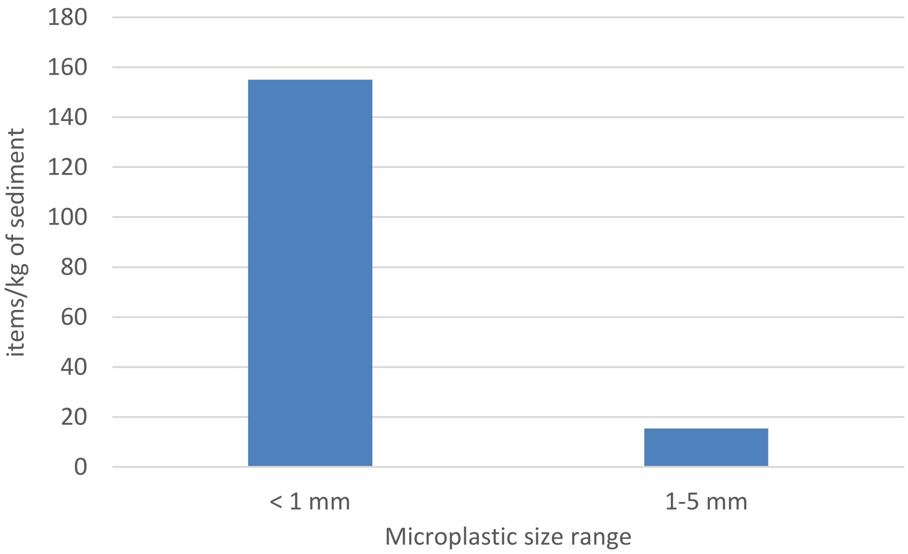
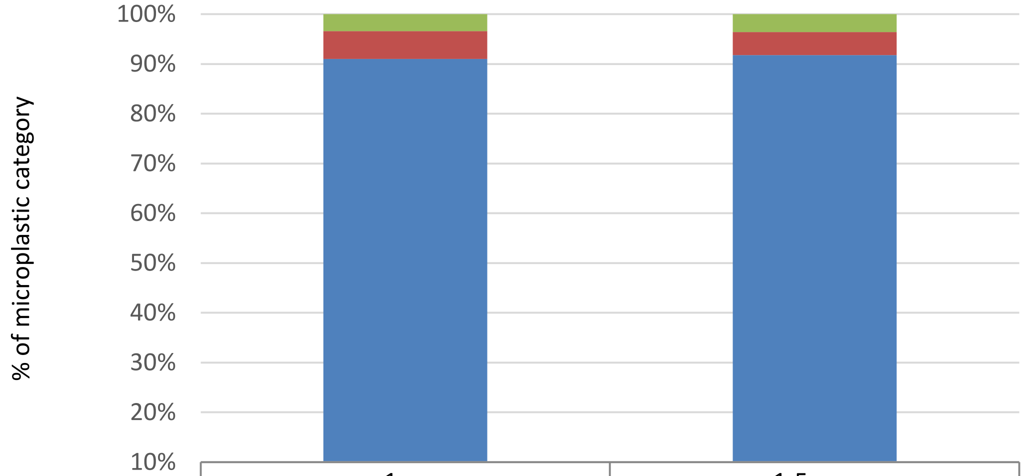


Figure 44: Microplastic concentrations (items/kg) in beach sediments of Neretva river outflow, Croatia.



	< 1 mm	1-5 mm
Other	0,00%	0,00%
Non-identifible	0,00%	0,00%
Foams	0,00%	0,00%
Granules	0,00%	0,00%
Pellets	0,00%	0,00%
Films	3,37%	3,59%
Filaments	5,61%	4,65%
Fragments	91,02%	91,76%

Microplastic size class

Figure 45: Microplastic categories in beach sediment samples on the Neretva river outflow, Croatia.

Samples taken from Bačvice beach showed considerably greater presence of smaller microplastic per kg of sediment in both seasons. The maximum number of particles <1 mm were noticed in the second season with value of 227.60 microplastic in kg of sediment. In the first season, SMP were presented with 110.88 particles per kg of sediment, while LMP were found in smaller number per kg in both seasons with values of 28.86 and 17.49, respectively (Figure 46). Different trends of microplastic distribution were found on Zaglav beach, where larger microplastic were predominant. The biggest amount of particles per kg of sediment were recorded in second season with value of 1242.19, while 198.96 particles were found in the first season. Particles smaller than 1 mm were found in higher concentration in second season (123.78 items/kg) in comparison with first one (26.73 items/kg) (Figure 47).

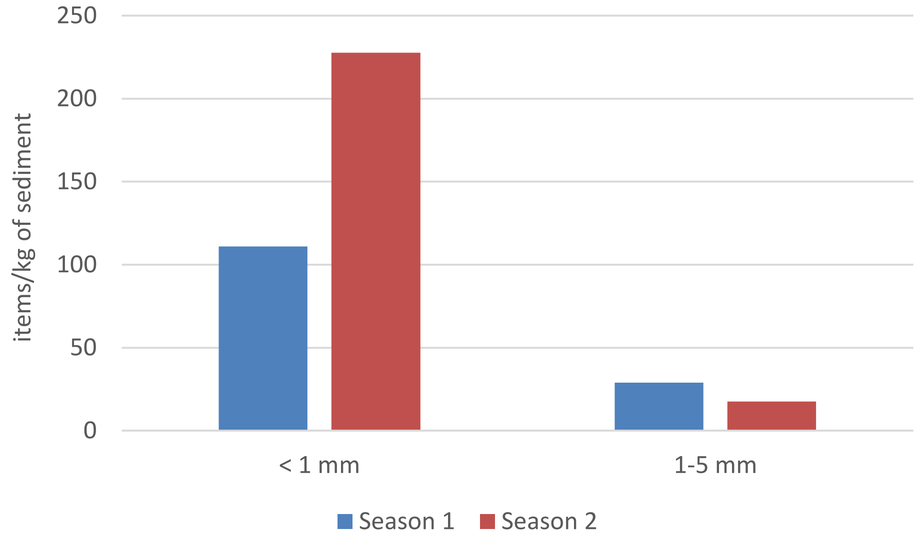


Figure 46: Microplastic concentrations (items/kg) in beach sediments of Bačvice, Croatia.

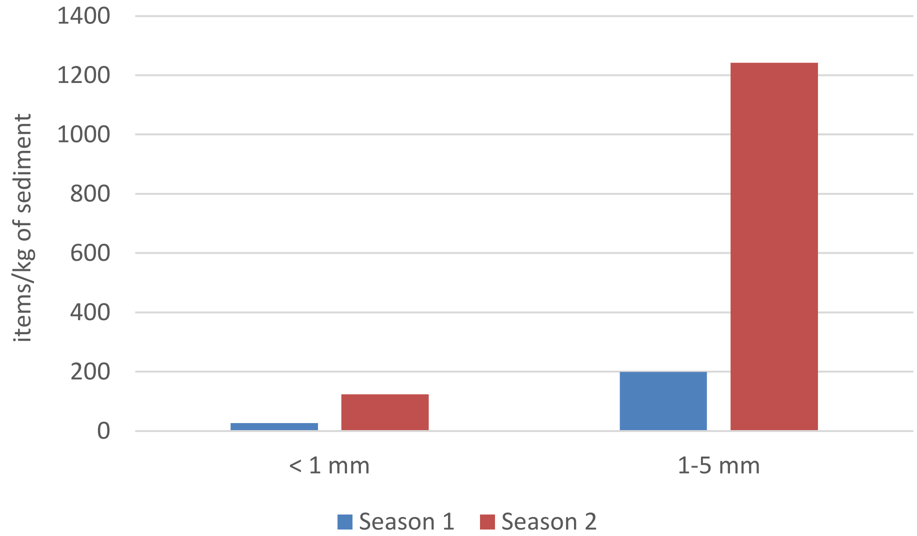
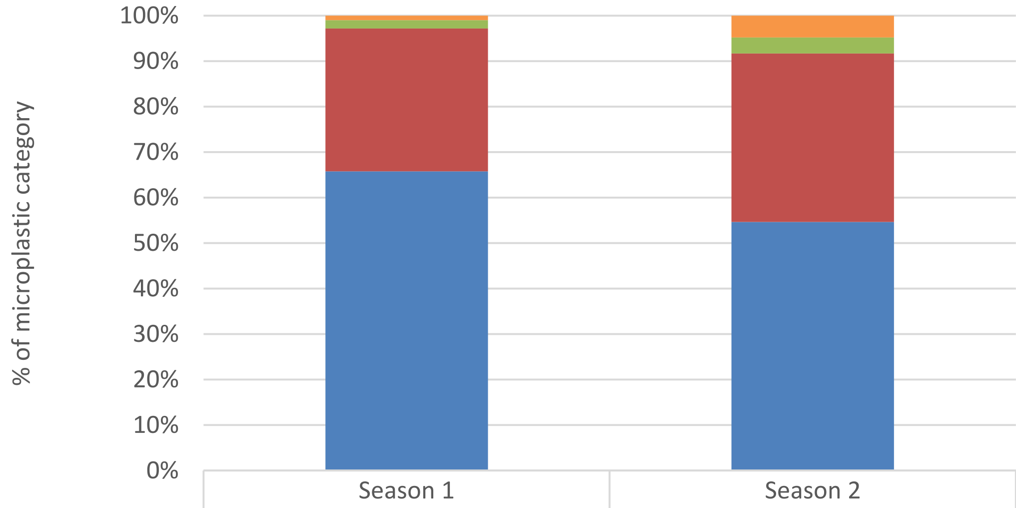


Figure 47: Microplastic concentrations (items/kg) in beach sediments of Zaglav, Croatia.

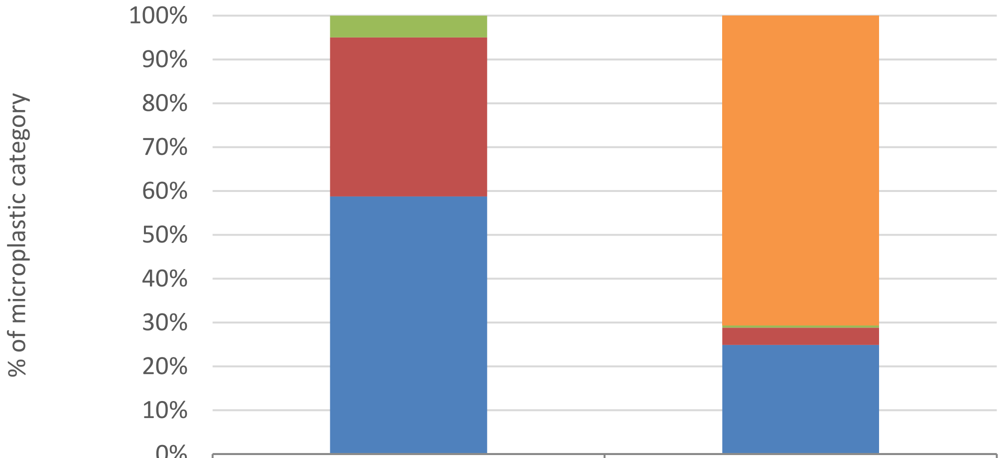
The composition of separated SMP from Bačvice beach showed the prevalence of plastic fragments in both seasons. In the season 2014, fragments represented 66.77%, followed by filaments with 31.40%. Smaller amount of film and foams were recorded in the first season, 1.87% and 0.97% respectively. Also in the second season films (3.49%) and foams (4.81%) were found in smaller amounts. In season 2015 fragments were present with 54.70% and filaments with 37.00% (Figure 48).



	Season 1	Season 2
Other	0,00%	0,00%
Non-identifible	0,00%	0,00%
Foams	0,97%	4,81%
Granules	0,00%	0,00%
Pellets	0,00%	0,00%
Films	1,87%	3,49%
Filaments	31,40%	37,00%
Fragments	65,77%	54,70%

Figure 48: Microplastic categories among SMP samples on Bačvice beach according the season, Croatia.

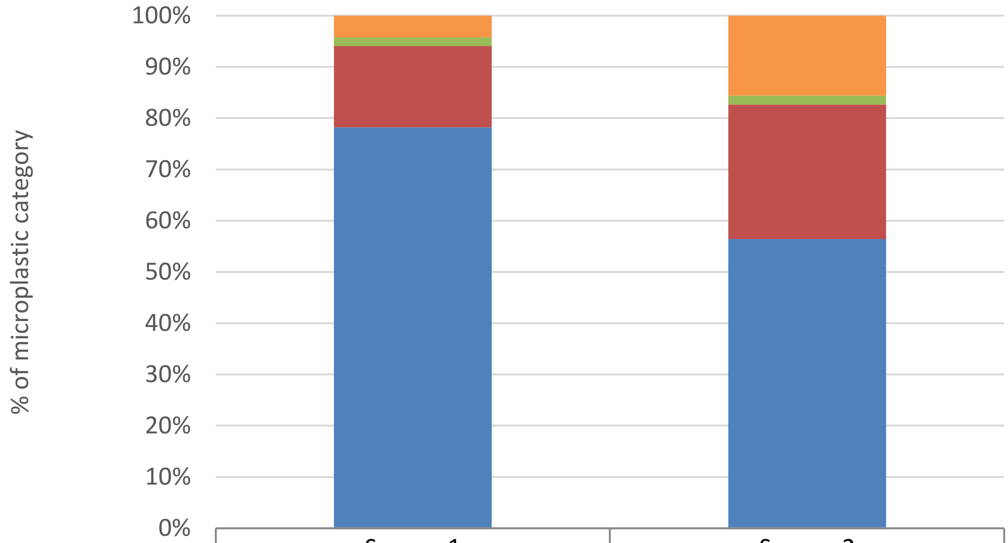
The composition of LMP from Zaglav beach were different regarding seasons. In the first season predominant category were fragments (58.79%), while in the second season were foams (70.60%), followed by fragments (24.91%). Filaments were second common category in first season with 36.26%, while in second season were presented in considerably less amount of 3.93%. Films were recorded in smaller amount, 4.95% in season 2014 and only 0.56% in the second season (Figure 49).



	Season 1	Season 2
Other	0,00%	0,00%
Non-identifible	0,00%	0,00%
Foams	0,00%	70,60%
Granules	0,00%	0,00%
Pellets	0,00%	0,00%
Films	4,95%	0,56%
Filaments	36,26%	3,93%
Fragments	58,79%	24,91%

Figure 49: Microplastic categories among SMP samples on Zaglav beach according the season, Croatia.

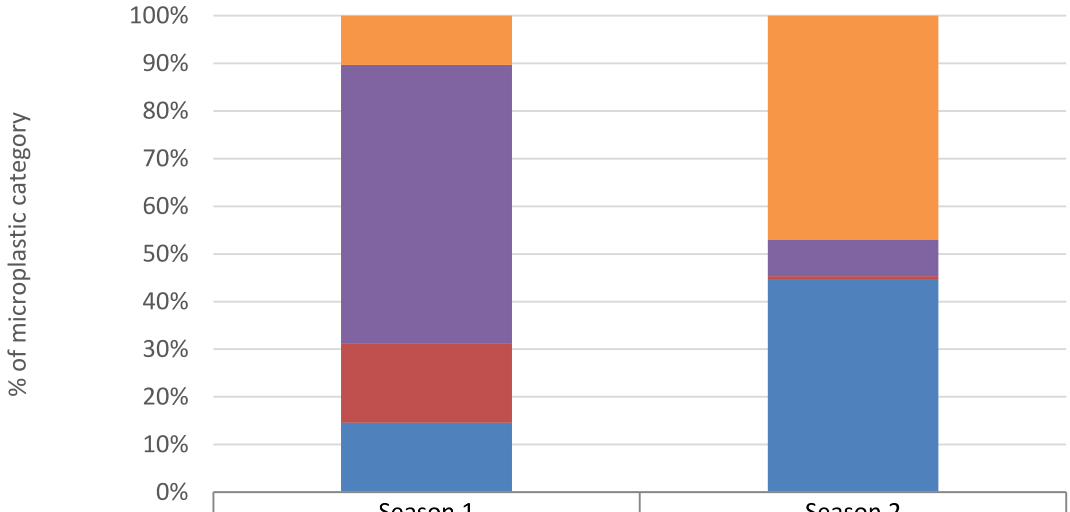
In sediment samples from Bačvice beach fragments were predominant category for SMP, as well as for LMP. In season 2014 fragments represented 78.22% and 56.41% in season 2015. In first season except the filaments (15.88%), films and foams were rather rare (1.65%, and 4.25%). Films were also recorded in smaller amounts in second season (1.75%), while filaments and foams were found in percentages of 26.21% and 15.63%, respectively (Figure 50).



	Season 1	Season 2
Other	0,00%	0,00%
Non-identifible	0,00%	0,00%
Foams	4,25%	15,63%
Granules	0,00%	0,00%
Pellets	0,00%	0,00%
Films	1,65%	1,75%
Filaments	15,88%	26,21%
Fragments	78,22%	56,41%

Figure 50: Microplastic categories among LMP samples on Bačvice beach according the season, Croatia.

Pellets were found only on Zaglav beach, where in the first season were presented as most common category with 57.55%. There were found on same beach in the second season but in smaller concentration (7.60%). Other LMP categories found on Zaglav beach in season 2014, were fragments (14.37%), filaments (16.45%) and foams (10.21%). The most common categories in the second season were foams with 57.06% and fragments with 44.77%, while filaments were presented only with 0.56% (Figure 51).



	Season 1	Season 2
Other	0,00%	0,00%
Non-identifible	0,00%	0,00%
Foams	10,21%	47,06%
Granules	0,00%	0,00%
Pellets	57,55%	7,60%
Films	0,00%	0,00%
Filaments	16,45%	0,56%
Fragments	14,37%	44,77%

Figure 51: Microplastic categories among LMP samples on Zaglav beach according the season, Croatia.

3.2.1.1.2 GREECE

The mean concentration (items/m^2) and the average weight (g/m^2) of LMPs in Halikounas beach were in all cases higher in July 2014 than July 2015 (Figure 52). Comparison of results of concentration of microplastic (items/m^2) among beaches show that Halikounas beach is the most polluted, followed by Issos and Acharavi. Trend was the same for particles >5 mm and particles between 1 and 5 mm large. Contrary the mass of microplastic 1-5 mm was the highest on Issos beach, followed by Halikounas and Acharavi (Figure 53).

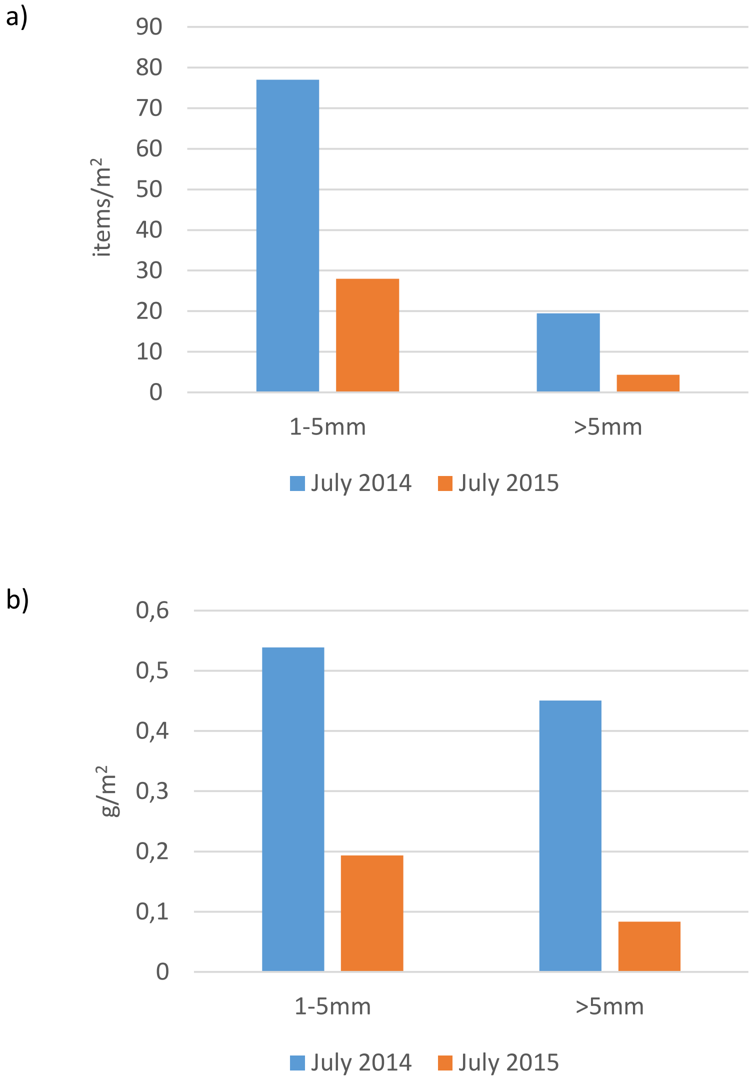


Figure 52: Microplastic concentrations by a) number (items/m^2) and b) weight (g/m^2) in beach sediments of Halikounas beach for LMP and mesoplastic, Greece.

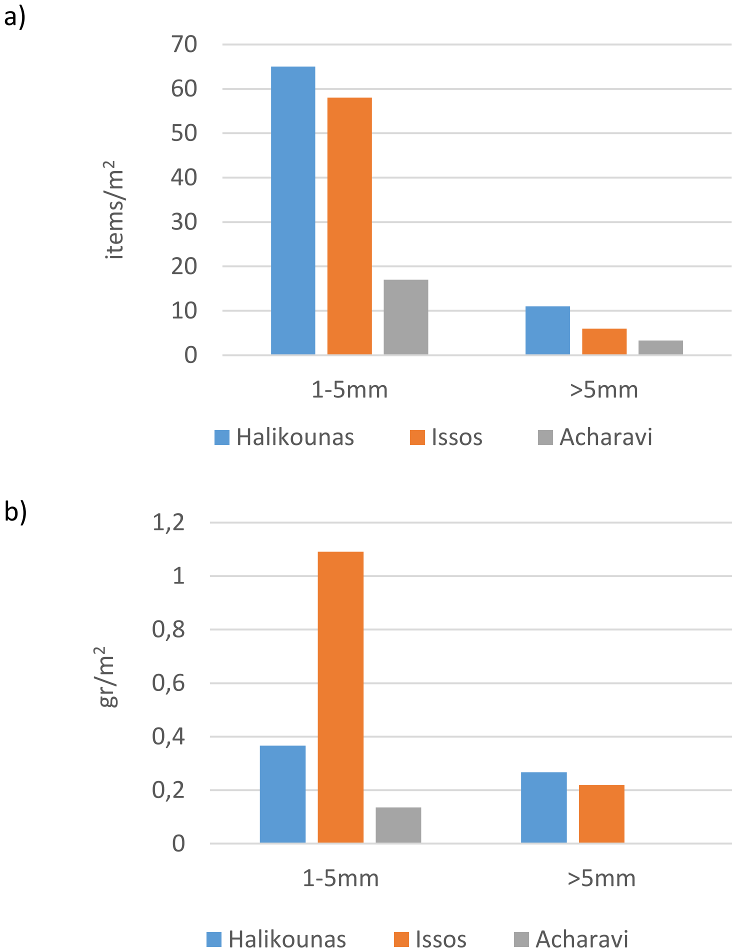


Figure 53: Microplastic concentrations by a) number (items/m^2) and b) weight (g/m^2) in beach sediments of Halikounas, Issos and Acharavi beach for LMP and mesoplastic, Greece.

Significant variability in the LMP distribution was observed between the different stations on the same beach as well as between the samples collected on the strandline and at the back of the beach. Based on this observation the results for Halikounas and Issos beach are presented in the following table (Table 4). In both beaches, the highest number of LMPs were found at the back of the beach.

Table 4: Comparison of total number of microplastic among back and strandline of the beach for the Halikounas and Issos beaches, Greece.

	LMP (total)			1-5 mm			5-25 mm		
	total	back	strandline	total	back	strandline	total	back	strandline
Halikounas	1349	764 (57%)	312 (24%)	1140	666 (58%)	251 (22%)	209	98 (45%)	61 (29%)
Issos	577	374 (65%)	24 (4%)	520	330 (63%)	24 (5%)	57	44 (77%)	0

The most abundant categories on Halikounas beaches among LMP were fragments and foam, while on Issos and Acharavi beach pellets were the most abundant (Figure 54).

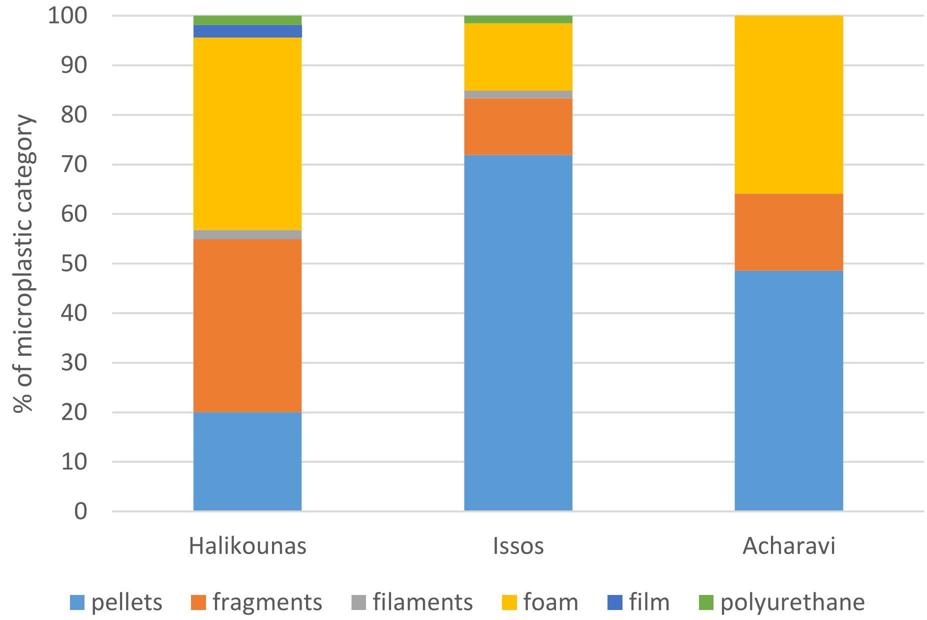


Figure 54: Microplastic categories among LMP samples on Halikounas, Issos and Acharavi beach, Greece.

The mean concentrations of particles <1 mm ranged from 120 items/L in Issos beach to 520 items/l in Acharavi beach. Filaments were the most abundant category of SMP, ranging from 100 items/l in Issos beach to 460 items/l in Acharavi beach (Figure 55).

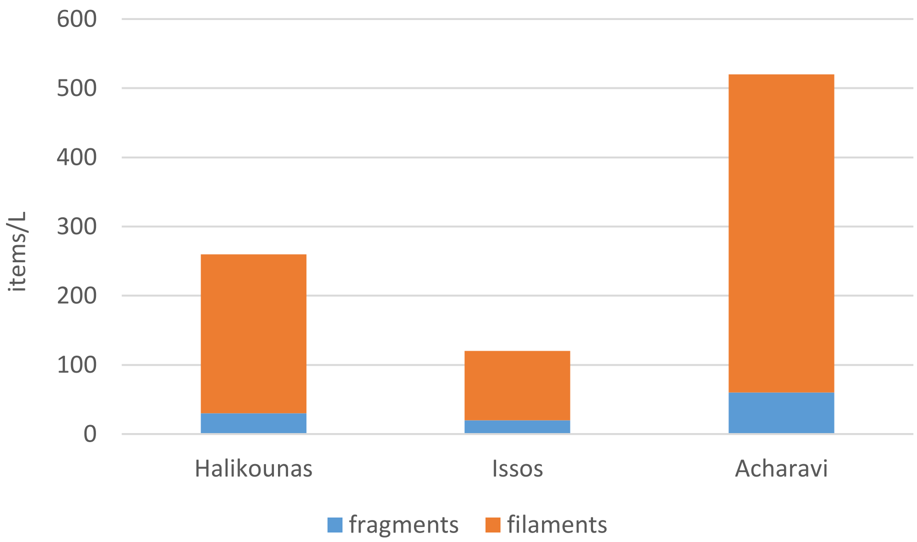


Figure 55: Microplastic categories among SMP samples on Halikounas, Issos and Acharavi beach, Greece.

3.2.1.1.3 ITALY

Cesenatico beach was characterized by a high amount of small microplastic particles (<1 mm) up to 2526.29 and 893.71 items/kg of sediment, respectively during August and November 2014 (Figure 56). Few amount (0.56-1.02 items/kg of sediment) of large particles (1-5 mm) were reported in both sampling periods (Figure 56).

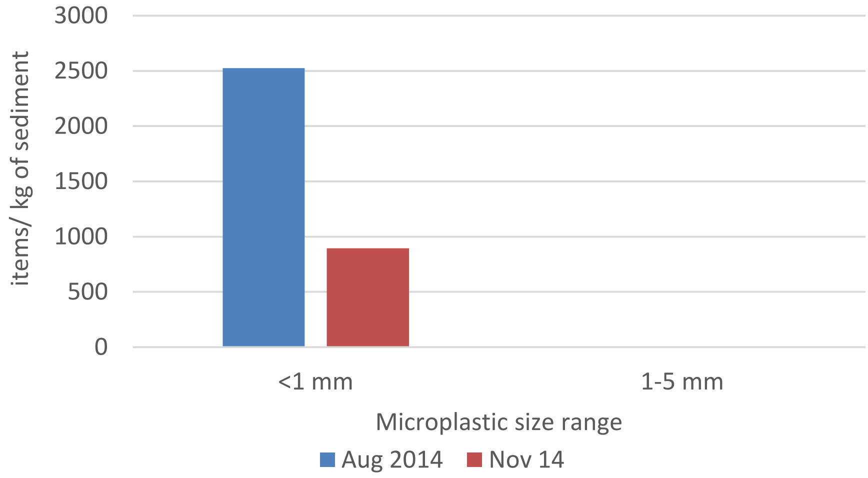


Figure 56: Microplastic concentrations (items/kg) in beach sediments of Cesenatico, Italy.

During August a higher quantity of both small and large microplastics was found compared to November. The average weight (g/Kg) of small microplastic were 2 times higher than the average weight of large microplastic in both sampling periods (Figure 57).

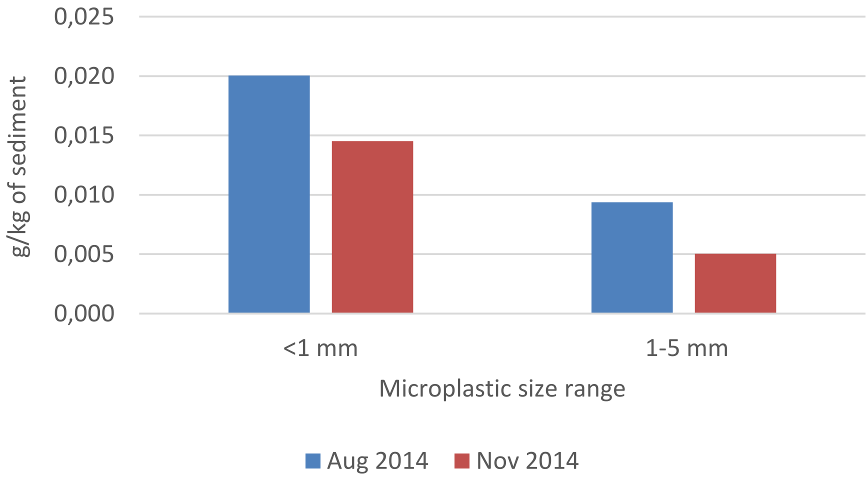


Figure 57: Microplastic concentrations (g/kg) in beach sediments of Cesenatico, Italy.

The small microplastic particles were mainly characterized by fragments (72.59% and 56.40% respectively during August and November) and filaments (26.44% and 43.08% respectively during August and November) (Figure 58). While the large microplastic particles had different amount of all categories (Figure 59). However, in both samplings, fragments resulted the most abundant category (44.68% and 45.31% respectively during August and November).

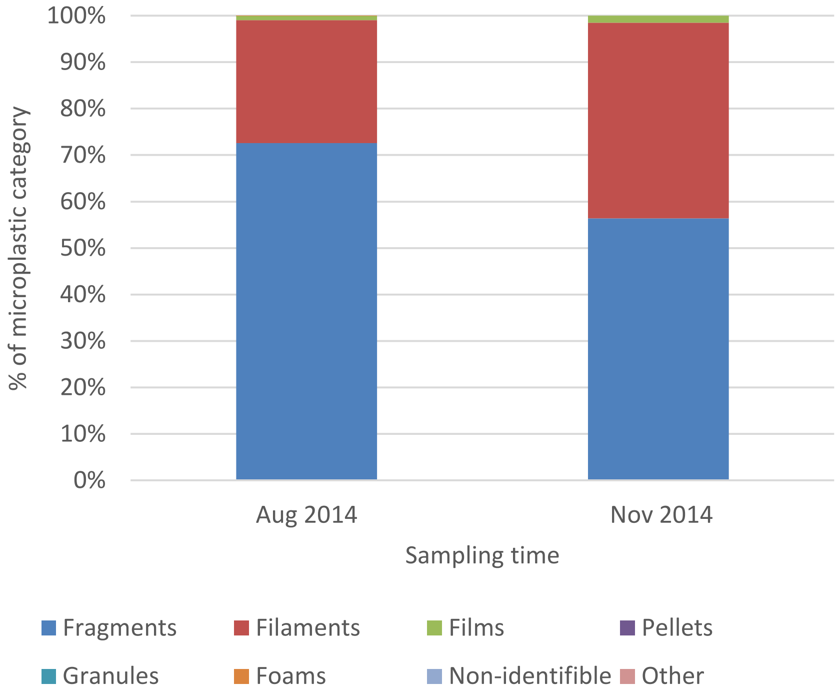


Figure 58: Microplastic categories in beach sediment SMP samples of Cesenatico beach, Italy.

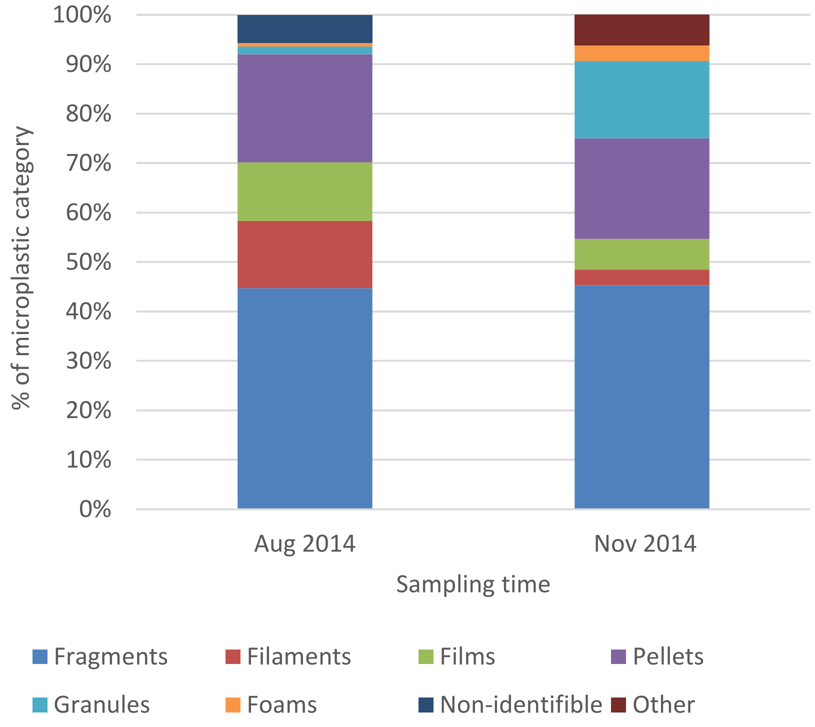


Figure 59: Microplastic categories in beach sediment LMP samples of Cesenatico beach, Italy.

3.2.1.1.4 SLOVENIA

In Slovenia, the abundance of small microplastic particles (<1 mm) was higher than the abundance of large microplastic particles (1-5 mm). Mean density of SMP per kg of beach sediment were 615.5, while the mean density of LMP were 516. In winter the concentrations of SMP and LMP were smaller than in the summer season, 2.2 times for SMP and 1.9x for LMP (Figure 60). Similarly, the mean mass of both kind of particles was higher in September 2014 than in January 2015 sampling (10.6 times for SMP and 7 times for LMP). As expected the mass of SMP was smaller (Figure 61). The mean mass of LMP for both sampling dates was 4.6 mg per kg of sediment and for LMP was 65.8 mg per kg of sediment.

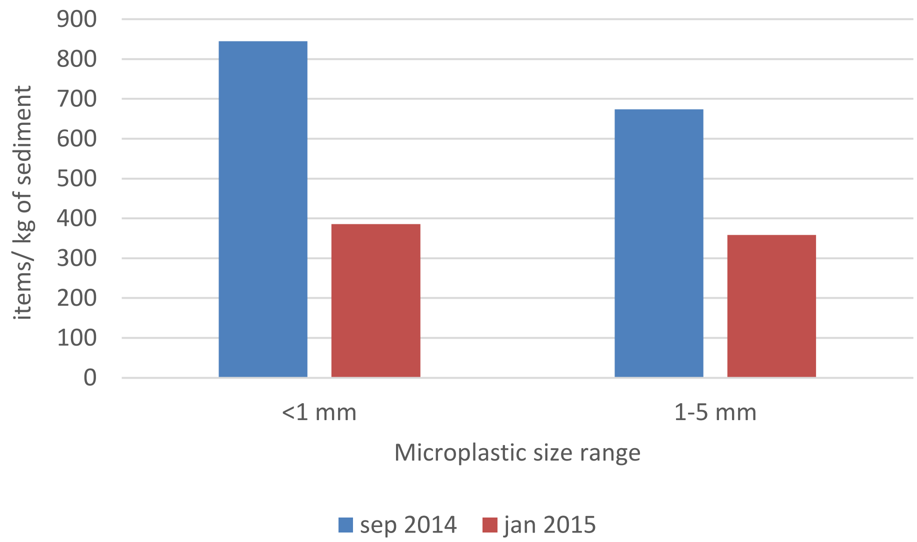


Figure 60: Microplastic concentrations (items/kg) in beach sediments, Slovenia.

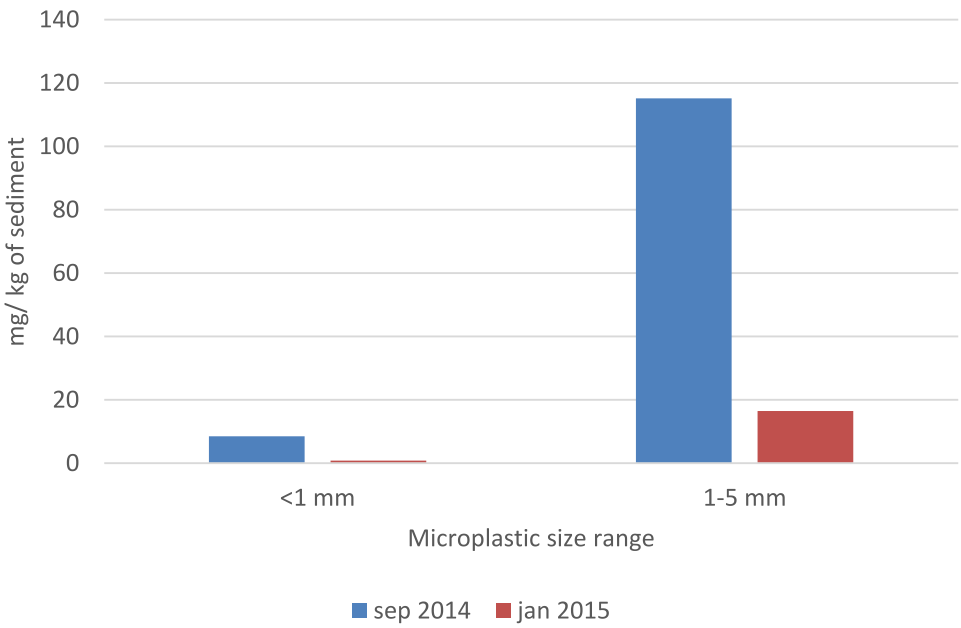


Figure 61: Microplastic concentrations (mg/kg) in beach sediments, Slovenia.

In SMP samples from both seasons, filaments were predominant type of the microplastic composition, with representation of 76% and 98% in September 2014 and January 2015, respectively. The second most common type of microplastic category were fragments and the third were films, with occurrence high as 9.5% in September 2014. Pellets and foams were absent in both seasons from SMP sample (Figure 62).

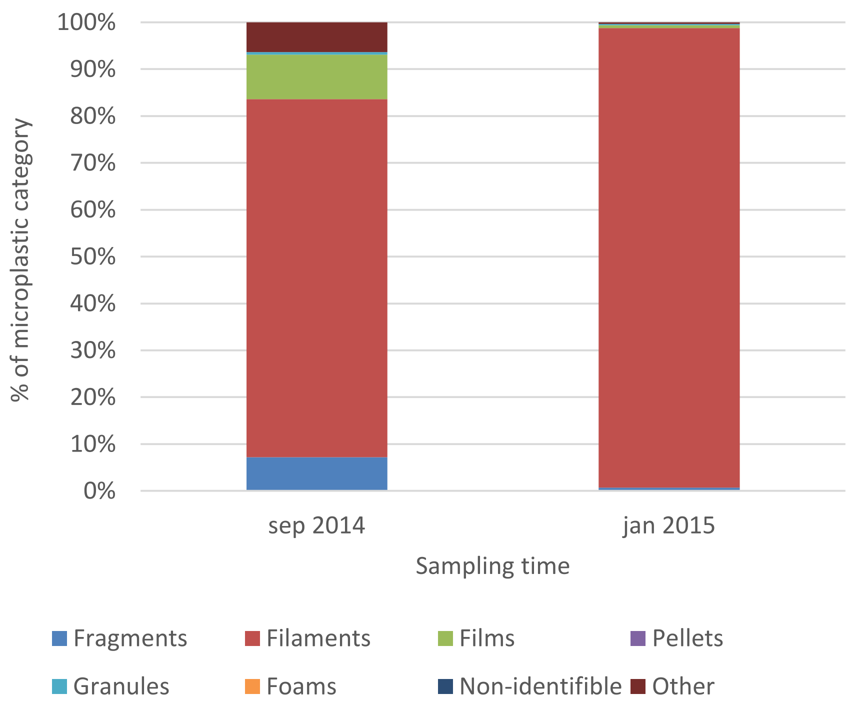


Figure 62: Microplastic categories in beach sediment SMP samples, Slovenia.

Again, in LMP samples from both season filaments were predominant type of the microplastic composition, but with lower representation of 11.9% and 10.4% in September 2014 and January 2015, respectively. The fraction of filament in LMP sample was much lower due to the particles in “other” category. There were only 3.12% of films in LMP sample from January and no fragments, pellets, granules and foams in both seasons (Figure 63).

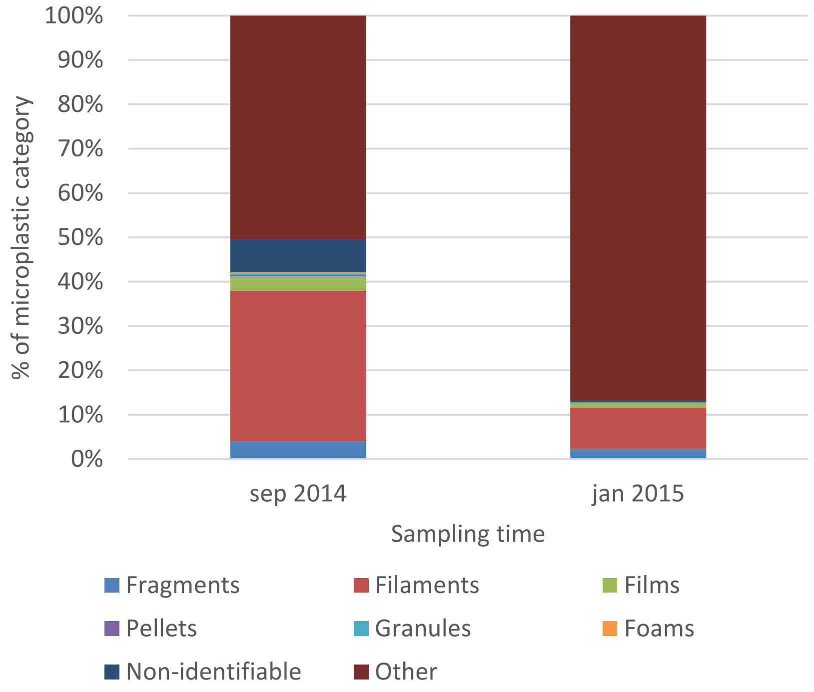
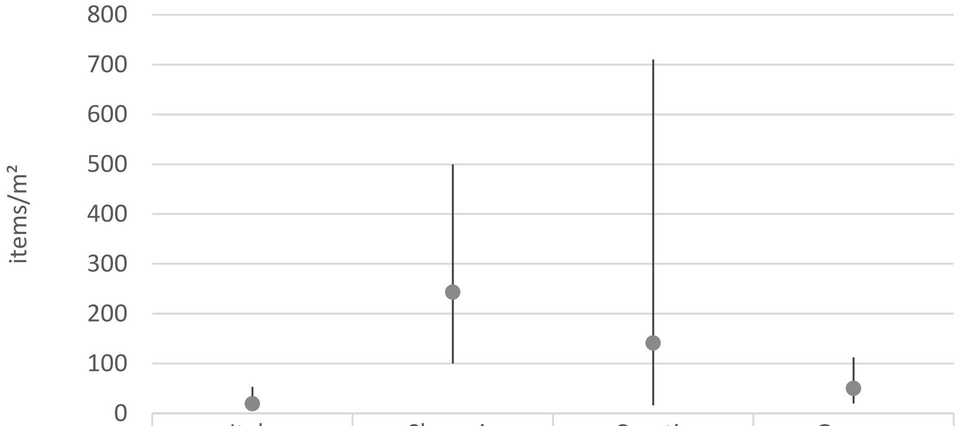


Figure 63: Microplastic categories in beach sediment LMP samples, Slovenia.

3.2.1.2 Regional level

On regional level the highest concentration of LMP were measured in Slovenia (243 items/m^2) and the lowest in Italy (19 items/m^2). In average the concentration of LMP in Adriatic region is 113 ± 101 particles per m^2. Among measures there were a high diversity among samples, especially in Croatia, where the range was from 16 to 710 particles per m^2, and Slovenia with the range from 100 – 500 particles per m^2 (Figure 64).

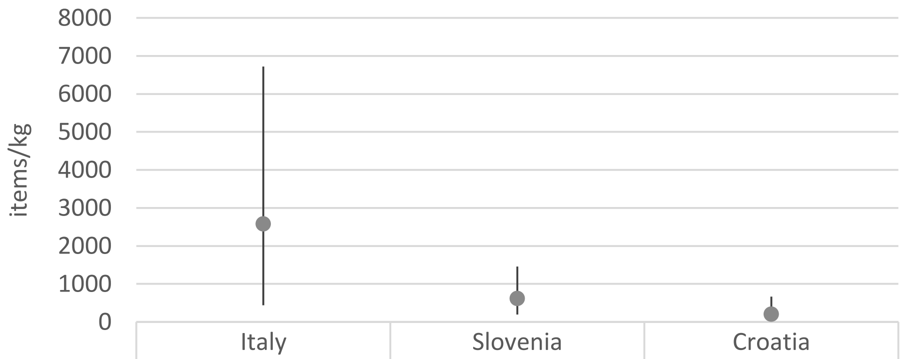


	Italy	Slovenia	Croatia	Greece
min	11	100	16	20
max	53	500	710	112
● average	19	243	141	50

min max ● average

Figure 64: Comparison of average and range of LMP concentration on beaches of countries of the Adriatic region.

On the contrary, the highest concentration of SMP were measured in Italy (2581 items/kg) and the lowest in Croatia (202 items/kg). In average the concentration of SMP in Adriatic region is 1133 ± 1271 particles per kg. Among measures there were a high diversity among samples, especially in Italy, where the range was from 440 to 6724 particles per kg (Figure 65).



	Italy	Slovenia	Croatia
min	440	196	70
max	6724	1460	670
● average	2581	616	202

min max ● average

Figure 65: Comparison of average and range of SMP concentration on beaches of countries of the Adriatic region.

3.2.2 Size distribution

By image analysis software particles sizes were measured for Croatian, Italian and Slovenian samples. Measures were done for categories: fragments, films, pellets, granules and other. The length of filaments were not measured, since this methodolically was not possible.

In Croatia only the length of LMP was measured, where the mean length was 3.44 mm. In Italy and Slovenia, microplastic particles were measured by image analysis software very precisely and average size of microplastic particles were calculated and extremes determined for SMP and LMP. Average size of LMP for Italy (Cesenatico beach) was 2.38 ± 1.46 and for Slovenia 3.2 ± 1.57. In Italy and Slovenia LMP were very variable in length, since their measurements were in range from 0.33 mm up to 14.89 mm in Slovenia and from 0.88 to 25.00 in Italy. Size range was very similar in Italy also for the SMP samples, where size range was from 0.01 mm to 25 mm. All results are presented in Appendix 4, Table A - 27, Table A - 28, Table A - 29, Table A - 30, Table A - 31, Table A - 32).

3.2.3 Identification of plastic type

Results of chemical identification of microplastic particles from the sediment samples are similar like for the sea surface samples, where PE is the most abundant type of plastic, followed by PP. Bellow are pie charts for each country separately.

3.2.3.1 Croatia

In Croatia chemical identification of microplastic was done for LMP for categories foams, pellets, fragments and filaments, while filaments and films were analysed among SMP particles. Beside the PE and PP in a few percent also PA, PET, PES, PS, PO, Nylon and Acrilic fibers were present among LMP, while among the SMP aldo viscose was present (Figure 66, Figure 67).

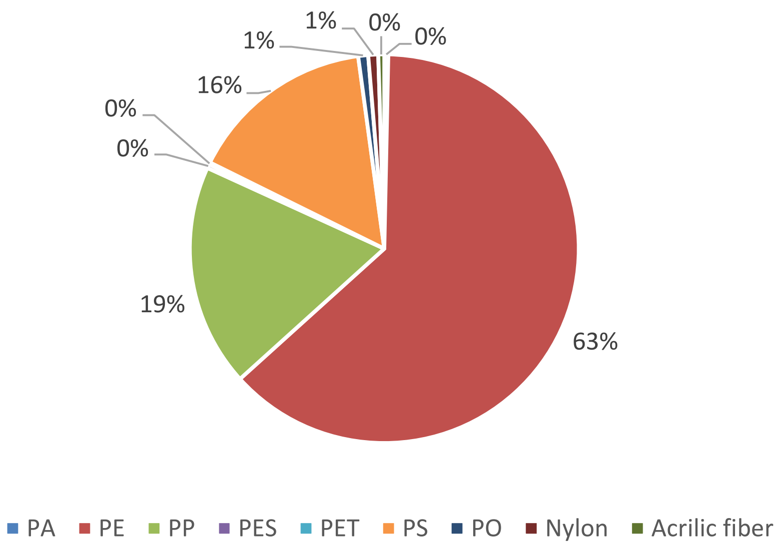


Figure 66: Chemical composition of LMP for Bačvice, zaglav and Neretva beach, Croatia.

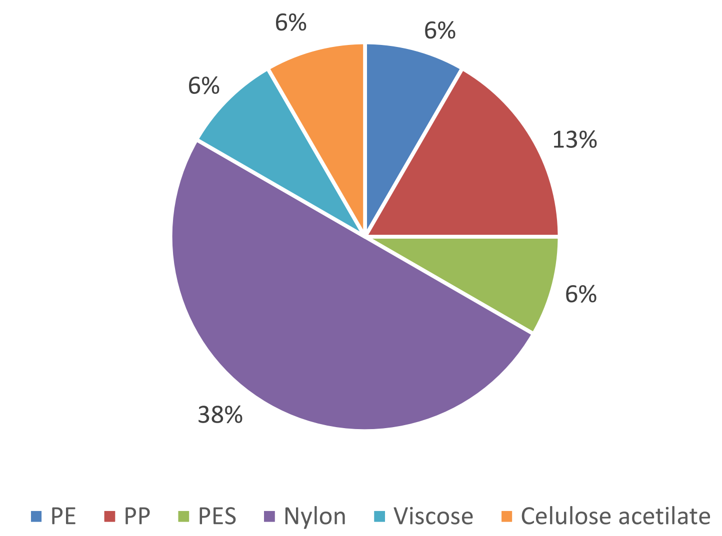


Figure 67: Chemical composition of SMP for Bačvice and Zaglav beach, Croatia.

3.2.3.2 Greece

In Greece chemical analysis of the two prevailing LMP categories, pellets and fragments, for Halikounas beach were done. For both PE, PP and tetrapack was identified (Figure 68). All the fragments from the SMP categories were tested with FTIR but only two were identified as PP.

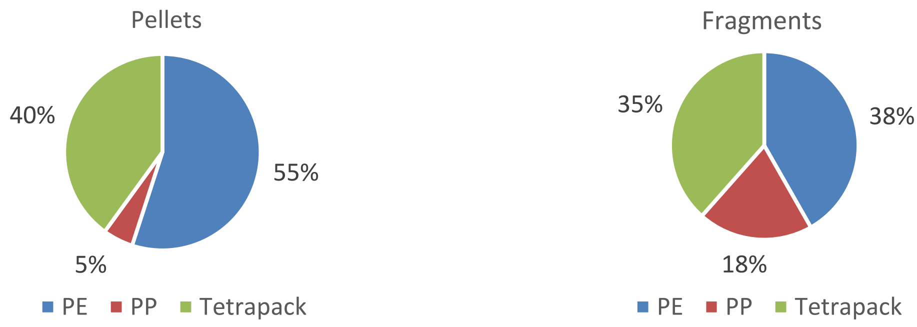


Figure 68: Chemical composition of LMP for Halikounas beach, Greece.

3.2.3.3 Italy

In Italy the chemical identification was done for LMP and SMP together. Like in other countries, PE was the most abundant material, followed by PP, PO, PES, PS and PAN (Figure 69).

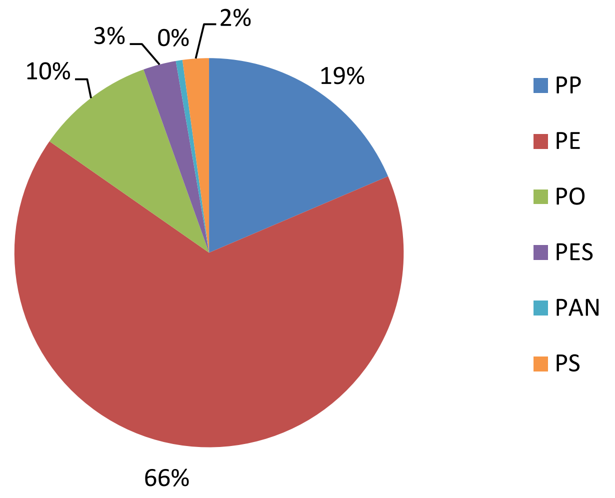


Figure 69: Chemical composition of SMP and LMP for Cesenatico beach, Italy.

3.2.3.4 Slovenia

In Slovenia chemical identification of particles was done for LMP particles. The most abundant was PE, followed by PP, PET and PVC (Figure 70).

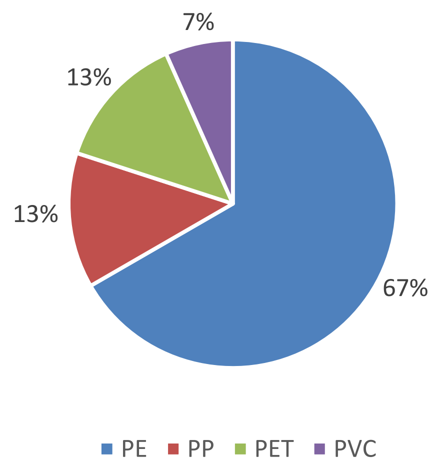


Figure 70: Chemical composition of LMP, Slovenia.

3.3 Organochlorine (OCl) and polychlorinated biphenyls (PCB) analysis

3.3.1 Level of OCPs adsorbed on plastic pellets

The level of organochlorine pesticides associated to plastic pellets are presented in this section.

Figures 71, 72 and 73 present the concentrations of each compound investigated per location. Each value takes into account all the surveys performed in each sampling site.

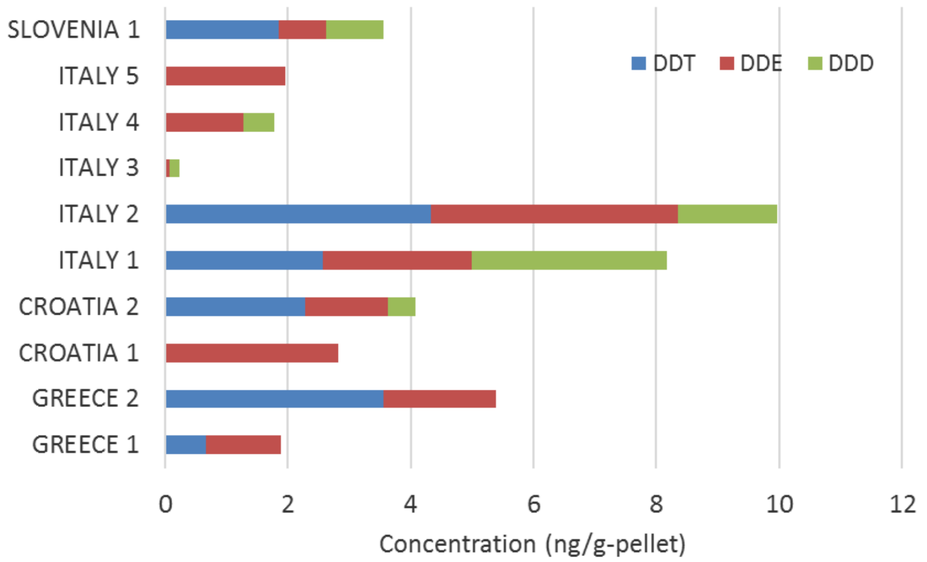


Figure 71: Median concentrations of DDT, DDE and DDD on plastic pellets at each sampling site.

DDTs are present in all sites (Figure 71). Mostly, DDE and DDD, as a sum, are predominant over the parent compound DDT, suggesting no current use of the insecticide in the region (Ogata et al., 2009).

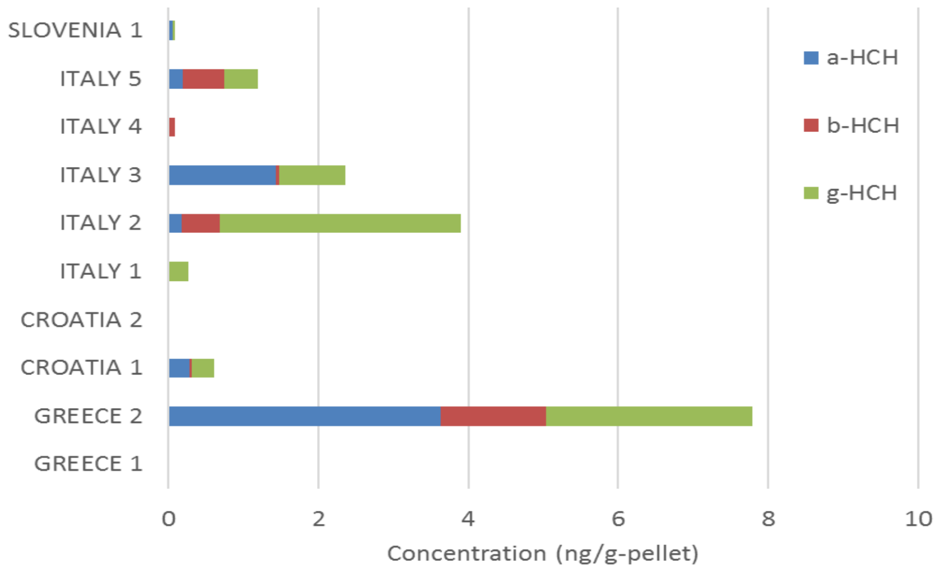


Figure 72: Median concentrations of α-HCH, β-HCH and γ-HCH on plastic pellets at each sampling site.

HCHs were found in all sites except in Croatia 2 and Greece 1 (Figure 72). Overall, the concentrations are relatively low (i.e. <2.5 ng g^{-1}) except on 2 sites (i.e. Italy 2 and Greece 2). In Italy 2, the isomer with the highest concentrations is γ-HCH, which is the active substance of the insecticide lindane, whereas in Greece 2, the predominant isomer is α-HCH from industrial origin (Ogata et al., 2009).

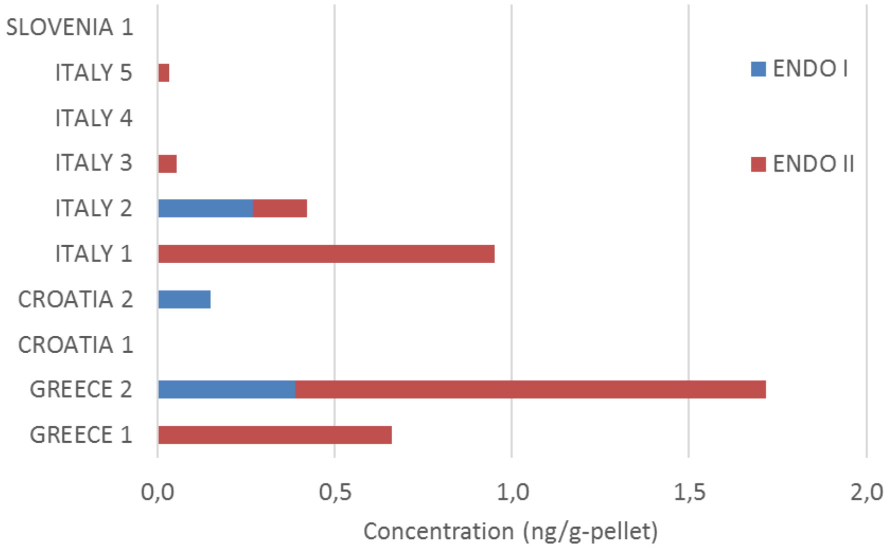


Figure 73: Median concentrations of Endosulfan I and II on plastic pellets at each sampling site.

ENDO I and II are present in all locations, except in Croatia 1, Italy 4 and Slovenia 1. The concentrations are relatively low (i.e. <2 ng g^{-1}) (Figure 73). The isomer ENDO II is predominant over ENDO I.

Table 5: Maximum concentrations of OCPs on plastic pellets and corresponding sampling sites. presents the maximum concentration obtained for each compound with the corresponding sampling location. It appears that Greece 2 is the most represented sampling site (i.e. 4 out of 8) with α-HCH, γ-HCH, ENDO I and II.

Table 5: Maximum concentrations of OCPs on plastic pellets and corresponding sampling sites.

Compound	α-HCH	β-HCH	γ-HCH	ENDO I	ENDO II	DDT	DDD	DDE
C (ng g^{-1})	2.63	0.55	4.75	0.39	1.33	4.33	3.18	4.03
Country	Greece 2	Italy 5	Greece 2	Greece 2	Greece 2	Italy 2	Italy 1	Italy 2

On Figure 74: Compositional patterns of OCPs on plastic pellets at each sampling site.it can be seen that DDTs compounds exhibit the highest concentrations in most of the sampling sites, followed by HCHs (i.e. Greece 2 and Italy 3). ENDOs are in minority compared to the over OCPs studied.

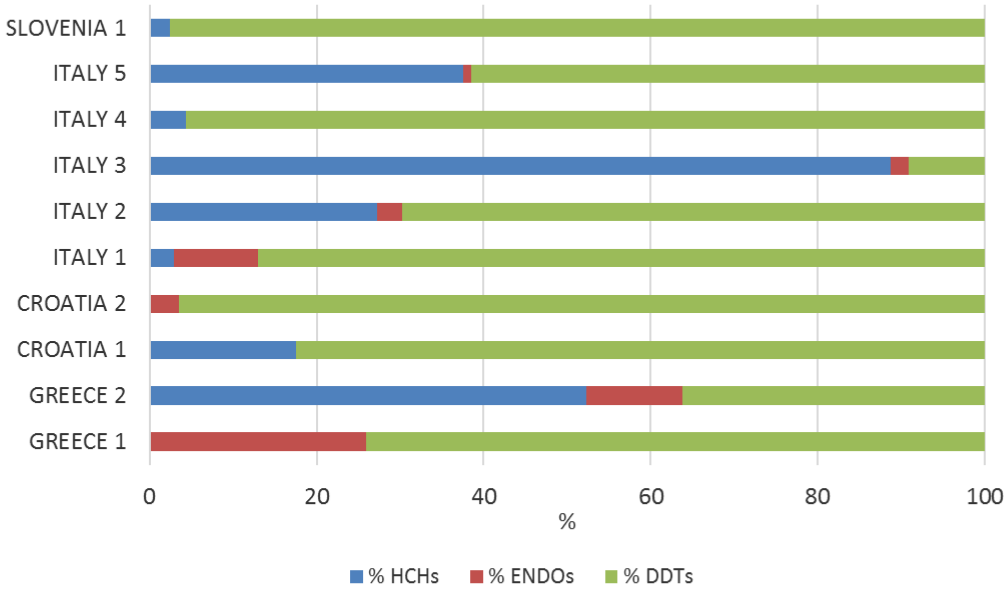


Figure 74: Compositional patterns of OCPs on plastic pellets at each sampling site.

All the investigated compounds were detected in at least 3 sampling site (i.e. ENDO I) and in 8 locations at the maximum (i.e. 44-DDE) (Figure 75).

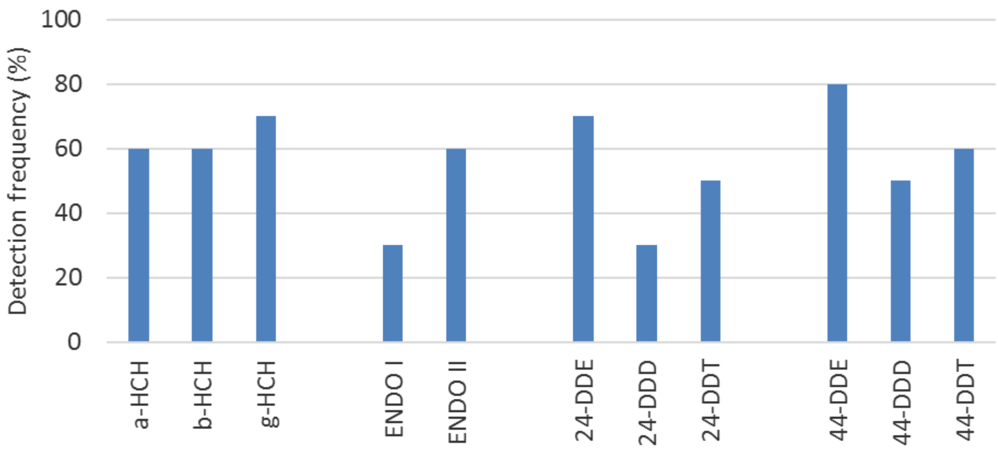


Figure 75: Detection frequencies of the studied OCPs on plastic pellets (over the 10 sampling sites).

3.3.2 Level of PCBs adsorbed on plastic pellets

The level of PCBs adsorbed on plastic pellets collected in the 10 selected sampling sites are presented in this section.

Figure 76 presents the PCBS composition for each location. Each value takes into account all the surveys performed in each sampling site.

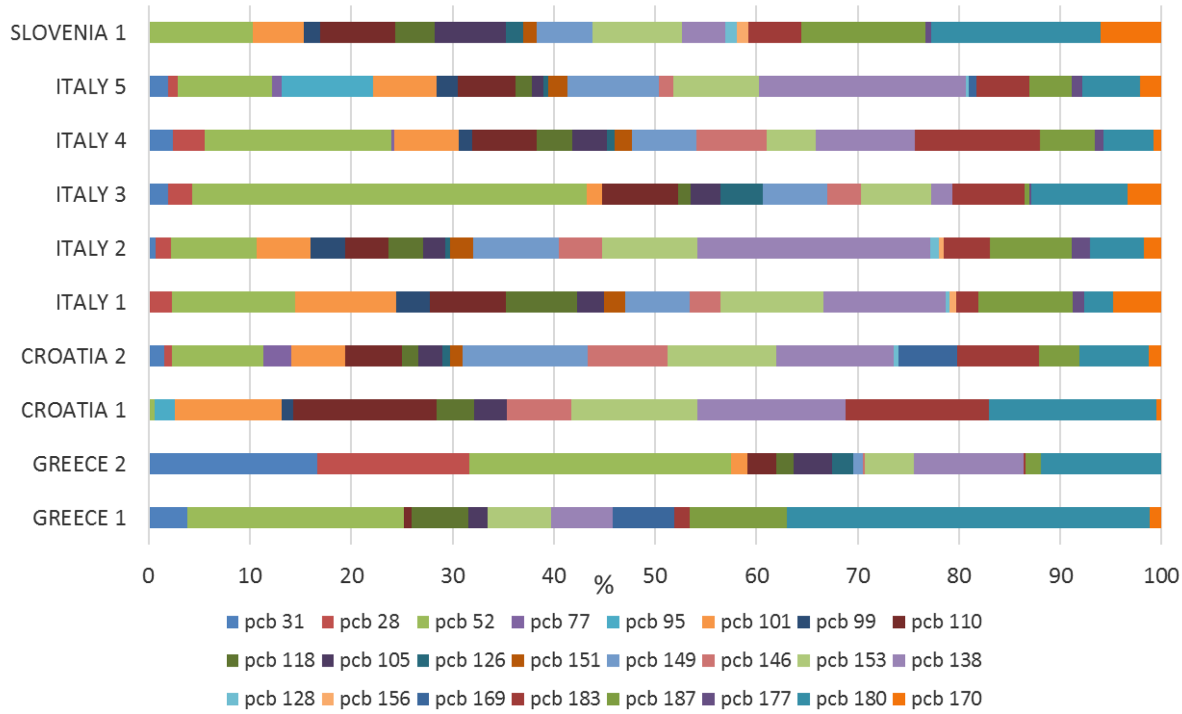


Figure 76: Compositional patterns of PCBs on plastic pellets at each sampling site.

On Figure 76 it can be observed that the composition in PCBs vary greatly from one location to another. However, some compounds are predominant compared to the others in concentration and frequency of detection. According to Table 6, the congeners PCB52, PCB138, PCB180 and PCB149 have the highest concentrations regarding sampling sites. The less abundant congener is PCB 95 and the most abundant ones (i.e. detected in all sites) are PCB52, PCB110, PCB118, PCB105, PCB153, PCB138, PCB183 and PCB180 (

Figure 77).

Table 6: Maximum concentrations of PCBs on plastic pellets at each sampling site.

Country	C (ng g^{-1})	Compound	Country	C (ng g^{-1})	Compound
Greece 1	4.7	**PCB180**	Italy 2	51.7	PCB138
Greece 2	13.9	**PCB52**	Italy 3	14.6	**PCB52**
Croatia 1	10.7	**PCB180**	Italy 4	13.8	**PCB52**
Croatia 2	26.4	PCB149	Italy 5	51.7	PCB138
Italy 1	12.4	**PCB52**	Slovenia 1	9.0	**PCB180**

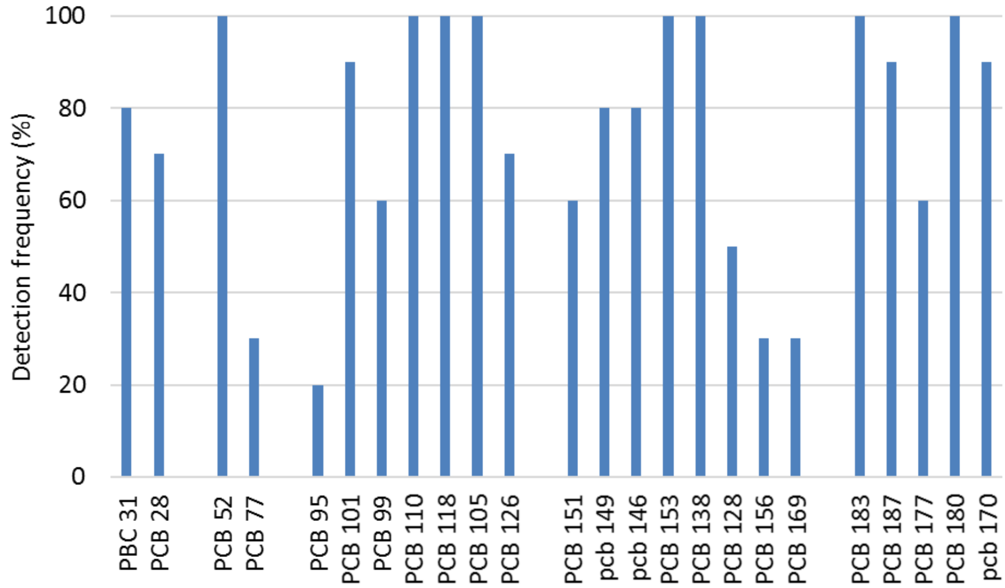


Figure 77: Detection frequencies of the studied PCBs on plastic pellets (over the 10 sampling sites).

Figure 78 present the concentration of PCBs for each sampling site as the sum of all the congeners studied in this project (Sum PCBs) and as the sum of the congeners as specified in IWP program (Sum IWP – PCB206 is missing). The general trend is similar whatever sum is considered. The locations Croatia 2, Italy 2 and Italy 5 present the highest concentration of PCBs. Similar observation is done from Table 7 where the maximum concentration of each congener is given with the corresponding sampling site. PCB138 has the highest concentration compared to all other congeners, followed by PCB149 and PCB153.

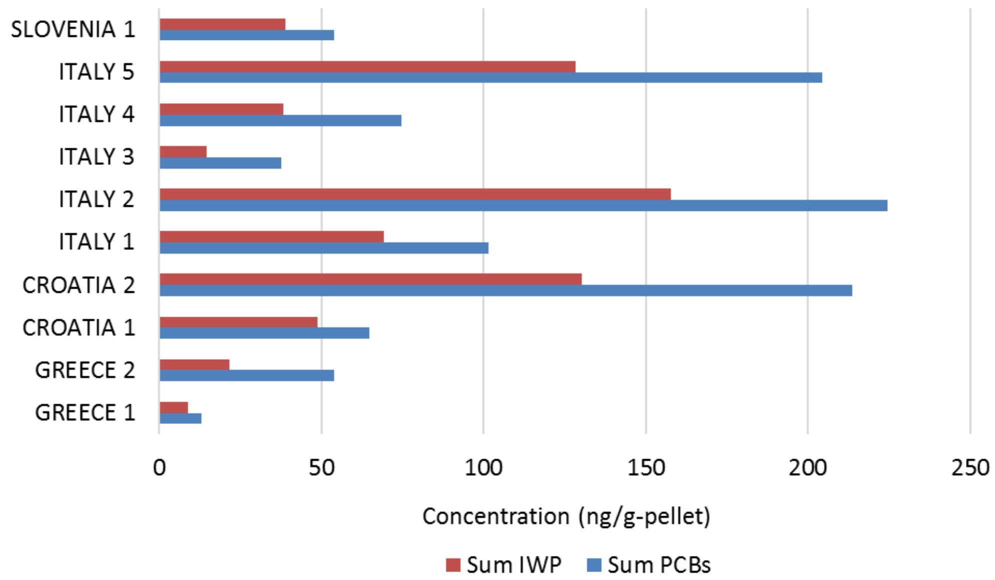


Figure 78: Median concentrations of PCBS on plastic pellets as the sum of all congeners studied and as the sum of the congeners as studied in IWP monitoring (except PCB206).

Table 7: Maximum concentrations of PCBs on plastic pellets and corresponding sampling sites

Compound	C (ng g^{-1})	Country	Compound	C (ng g^{-1})	Country
PCB28	8.1	Greece 2	**PCB138**	**51.7**	**Italy 2**
PCB31	9.0	Greece 2	PCB146	16.7	Croatia 2
PCB52	19.1	Italy 5	**PCB149**	**26.4**	**Croatia 2**
PCB77	6.0	Croatia 2	PCB151	5.1	Italy 2
PCB95	18.4	Italy 5	**PCB153**	**23.0**	**Croatia 2**
PCB99	7.6	Italy 2	PCB156	1.0	Italy 2
PCB101	12.8	Italy 5	PCB169	12.4	Croatia 2
PCB105	5.0	Croatia 2	PCB170	4.9	Italy 1
PCB110	11.9	Croatia 2	PCB177	4.0	Italy 2
PCB118	7.5	Italy 2	PCB180	14.6	Croatia 2
PCB126	1.6	Croatia 2	PCB183	17.2	Croatia 2
PCB128	1.8	Italy 2	PCB187	18.1	Italy 2

3.3.3 Level of POPs adsorbed on plastic pellets

Figure 79 present the cumulative concentrations of OCPs and PCBs for each sampling location. It can be clearly seen that the levels of OCPs (i.e. from 1.9 to 16.2 ng g^{-1}) are 1 to 2 orders of magnitude lower than PCBs levels (i.e. from 13.1 to 224.3 ng g^{-1}). Overall, the obtained values are within the range of concentrations determined in the Mediterranean region by IWP (Table 1 and 2).

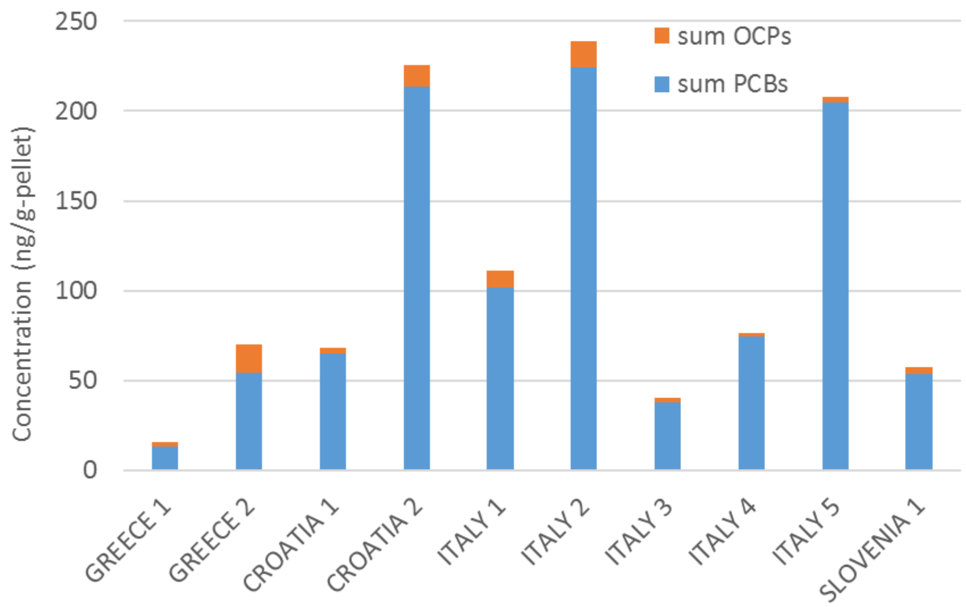


Figure 79: Total median concentrations of OCPs and PCBs on plastic pellets at each sampling site.

According to the obtained results, the plastic pellets sampled during the campaigns in Croatia 2, Italy 2 and Italy 5 are the most contaminated with POPs with total concentrations above 200 ng g^{-1}. The pellets collected on the sites Greece 1 and Italy 3 present the lower levels of POPs, which are below 50 ng g^{-1}. Finally, intermediate levels of POPs adsorbed on pellets (i.e. 50-150 ng g^{-1}) were found for the remaining sampling sites (i.e. Greece 2, Croatia 1, Italy 1, Italy 4 and Slovenia 1).

4 Discussion

4.1 Interpretation of analytical results of the sea surface samples

The distribution of microplastics is influenced by many factors, including coastal population density (recreational and urban areas), as well as activity connected with tourism, fishery and maritime transport (Suaria and Aliani, 2014; Galgani, 2014). Beside a litter from mainland, riverine inputs and sewage discharges are one of most important sources of marine litter. Oceanographic features (currents and waves) are responsible for different accumulation rates of microplastic in marine environment (Galgani, 2014; Andrady, 2011; Browne et al., 2011). The coast of Adriatic sea is highly populated, with about 4 million inhabitants and 18 million tourists during summer season, resulting high amounts of land-based waste consequently ends up in the sea (Guerzoni et al., 1984; Marchetti et al., 1989; Picer, 2000). As Adriatic Sea is small, shallow and semi enclosed basin it represents one of the hot-spots regarding pollution (Halpern et al., 2008). Third of the annual mean of river discharge in Mediterranean inflows in the Adriatic (Suaria and Aliani, 2014). Adriatic Sea is one of the most important fishing area in the Mediterranean, with the fishing fleet about 10,000 operating fishing vessels (Mannini et al., 2004). In the Adriatic, the maritime transport is also significant, with 19 seaports handling with more than million tons per year. Beside mentioned factors, in this area, Western Adriatic Current directly influence a litter distribution. Significant surface cyclonic gyres noticed in the central and southern Adriatic, as consequence of water circulations, entering through Otranto Strait along the Albanian coast and exiting on opposite side of Strait (Artegiani et al., 1997; Poulain and Zambianchi, 2007). All of multiple, interacting factors can be a precondition for accumulation of higher density of debris in the Adriatic Sea.

Results of the sea surface samples analysis offer a view on microplastics (300 µm - 5 mm) in six areas of the Adriatic region. The first observation from these results is that all researched areas are polluted by microplastic particles in average concentration ~230000 items/km^2. The highest microplastic concentrations were measured in Greece (~700,000 items/km^2), followed by Slovenia (~280,000 items/km^2), Albania (~150,000 items/km^2), Croatia (~130,000 items/km^2), Italy (~60,000 items/km^2) and Bosnia and Herzegovina (~175 items/km^2). In comparison with other Mediteranean regions, where concentration of microplastic in Nortwest Mediterranean was measured as 1,330,000 items/km^2 (Collignon et al., 2012) and in the bay of Calvi on Corsica Island as 62,000 items/km^2, measured concentrations in Adriatic region are in the middle. Although previous surveys recorded a maximum floating litter in the Adriatic Sea (>52 items/kg) in whole Mediterranean Sea (Suaria and Aliani, 2014). In comparison with Pacific ocean (NP Subtropical gyre 20,000 – 450,000 items/km^2 (Goldstein et al., 2013); NP central gyre 85,184 items/km^2 (Carson et al., 2013); NP central gyre 334,271 items/km^2 (Moore et al., 2001) and Atlantic ocean (North Atlantic gyre 20,328 items/km^2 (Law et al., 2010); Northwest Atlantic 490 items/km^2 (Wilber, 1987); Caribbean 1,414 items/km^2 (Law et al., 2010) concentration range is more or less the same. Differences on larger scale, between different parts of Mediterranean are affected by regional oceanographic conditions (Collignon et al., 2012; Ribić et al., 2012), while the spatial heterogency of microplastic distribution on smaller scale can be linked with wind forcing (Browne et al., 2011). In global, distribution of microplastics is affected by hydrodynamics, geomorphology and human factors (Barnes et al., 2009).

Almost each study represent a high concentration range and standard errors higher that average value of microplastic on the sea surface (Lusher, 2015). The estimations of microplastic pollution in distinct area is hard to determine, while there are several factors with impact on final estimation of microplastic pollution. Factors that influence on the process of sampling are: 1) weather conditions (wind speed and direction, direction of sea currents and direction of boat flying) – if boat fly in opposite direction than sea currents, more microplastic should be caught; 2) the quantity of seston, in which microplastic paricles collide and accumulate; 3) specific conditions related to sampling microlocation (near the city, river outflow, outflow of waste water treatment plant, harbour…). In the process of separation of microplastic particles from the samples factors as 1) the quantity of seston, which make separation difficult 2) the quality of stereomicroscope, where polarization light could help to distinguish among plastic and non plastic particles, 3) the experience and precision of working person and 4) the laboratorium room, which need to be clean and closed, due to contamination of samples with air born filaments, can strongly influence on final results.

Among microplastic categories, fragments and filaments were the most abundant in all countries, except Bosnia and Herzegovina, where category other was the most abundant. In Slovenia, Albania and Croatia, filaments were first common category with 34% - 100% and fragments were the second with 0% – 44%. While in Italy and Greece the relation was oposite where fragments was the first common category (50 – 90%), followed by filaments (0% – 17%). There are few reasons that influence on density of which microplastic category is the most common. Filaments are mainly derived from textiles either during industrial production/use or in domestic use (Browne et al., 2011) and are most likely emitted through wastewater treatment and domestic outflows, where seawage system is missing. Filaments are also the category of microplastic where is the most easily to confuse the synthetic with natural filaments, for this reason the mistake in results could be the highest. The sources of fragments are not the same like for filaments, since they origin from fragmentation of large plastic litter. As the both categories have different specific weight, their transport on the sea surface is different and thus the areas of concentration. Most likely the fragments are concentrated on the same areas as large plastic litter, where sea currents make gyres, while filaments are concentrated near the cities and other areas influenced by humans.

Among other microplastic categories pellets were found only in Italy on transect 4, which is located near the Porto Garibaldi in front off the Burana river. The most probably pellets in this part of the sea origin from plastic industry from the Po basin. In Croatia each transect contained filaments in prevailing percentages, except transect taken in vicinity of island Vis, where filaments were presented with 33.93%, followed by foamed plastics with 30.36%. The source of styrofoam particles, found only in this transect, can be linked with fishery activities in this area (Mannini et al., 2004).

Chemical analysis of particles were for all samples similar, with polyethylene as the most abundant material, followed by polypropylene. This result could be expected. Polyethylene is the most commonly used plastic polymer in the world because it is strong, light, tough, resistant to acids, alkalis and other organic solvents and resistant to higher temperatures. It is an essential material for power transmission, food packaging, consumer goods, electronics, household goods, industrial storage, and transportation industries. The second reason for this result is the fact that polyethylene and polypropylene have very low densities and will thus float on water and be highly mobile. We believe that the combination of large quantities and the mobility due to floating leads to the observed situation.

4.2 Interpretation of analytical results of the beach sediment samples

Results of beach sediment samples offer a view on microplastic pollution of 8 beaches, distributed in the north, middle and south of the Adriatic Sea. Microplastic was analysed separately for particles 1 –

5 mm length (LMP) and particles <1 mm (SMP). The average concentration of LMP for all beaches was 113 items/m^2 and of SMP 1133 items/kg of sediment. Because sampling methods for LMP and SMP differ, the normalization to a common denominator was not possible. From the literature both kind of normalizations are used, but most common the normalization per kg of sediments. When comparison of DFG results was done among studies around the Europe, the DFG concentrations were higher than concentration measured in Germany (Dubaish and Liebezeit, 2013; Dekiff et al., 2014) or Belgium (Claessens et al., 2011) and more or less the similar with two studies from Adriatic Sea (Vianello et al., 2013; Laglbauer et al., 2014).

The microplastic concentrations on the beach is strongly influenced by local factors, which could be constant or seasonaly dependant. Constant factors that can influence on microplastic pollution are the nearby city, WWTP, harbour, industry, the population density, fisheries (Suaria and Aliani, 2014) and the seasonaly dependant factors are weather conditions (sea currents, wind direction and speed) (Andrady, 2011; Costa et al., 2011) and tourism. From DFG results we can see that some beaches are more contaminated by pellets and foams, some by fragments and some by filaments. On Slovenian beach, filaments were in both season the most common microplastic category. As filaments origin mostly from the WWTP and domestic outflows from washing mashines and this beach is not very touristic, the high concentration of them on this beach could be expected. On the beach of Cesenatico (Italy) and Bačvice (Croatia) that both of them are city beaches, the fragments were the most common microplastic category. As fragments origin from the fragmentation of large plastic litter, that are usualy most common on city beaches. On the beach of Zaglav (Croatia) and Acharavi and Issos (Corfu Island), pellets and foams were the most common categories. Foams origin mostly from fishing activities (Galgani et al., 2000) and pellets from the sea transport of industrial pellets. The amount of pellets can be connected with position of the beach and its exposure to winds. Nearby there was no possible source of pellets, but finding them stranded, can be explained with direct influence of open sea currents. These concentrations showed accidentally occurrence in comparison with pellets found on beaches of island Malta (1000 pellets/m^2) (Galgani, 2014). The appearance of foamed plastic in smaller size can be due to fragmentation of larger parts caused by mechanical forces (waves and winds) (Barnes et al., 2009).

In Greece, microplastic pollution among sediment samples from the back of the beach and from the strandline was compared, where the highest number of LMPs were found at the back of the beach. At the back of the beach is accumulation zone where particles are influenced just in extreme conditions (high waves), while on strandline particles are under tide pressure.

The findings of chemical analysis are the same like for the sea surface, where PE is the most abundant material found on the beach.

Through the process of microplastic analysis on the beaches, a few gaps were identified. In addition the improvement of methodology for SMP and LMP is recommended in way that results of both categories should be normalized to a common denominator.

4.3 Interpretation of analytical results of the POPs quantity

Plastics debris released to the environment can act as a carrier of organic contaminants to wildlife. Hazards due to the ingestion of chemicals associated to plastic fragments remain mostly unknown. However, there are increasing evidences suggesting that these compounds, once released from their support, may bioaccumulate into tissues of organisms, which ingested small plastic pieces.

Numerous studies worldwide have shown that resin pellets tend to adsorb organic pollutants from their surrounding environment (e.g. seawater, sediments, atmosphere) such as POPs. However, little was known about the concentrations of organic contaminants adsorbed on plastic pellets found in the Adriatic and Ionian regions. So far, only data from three sites were available, all located in the East part of the Adriatic coast (i.e. Albania, Croatia and Greece). Thus, this study aimed to assess the levels of POPs (i.e. PCBs and OCPs) adsorbed on plastic resin pellets collected along the Adriatic and Ionian coasts, applying an identical protocol.

A number of conclusions can be drawn from this investigation:

- PCBs and OCPs were detected in all samples from all sampling locations;
- Total concentrations of the studied OCPs range from 1.9 to 14.9 ng g^{-1}, the sites Greece 2 and Italy 2 showing the highest concentrations (>14 ng g^{-1});
- Concentrations of DDTs range from 0.2 to 10.0 ng g^{-1}. The predominance of the degradation products DDE and DDD over DDT reflects a background pollution from past treatments rather than a recent use of the insecticide;
- Concentrations of HCHs are relatively low (<2.5 ng g^{-1}) except on 2 sites (i.e. Italy 2 and Greece 2). Overall, there is no clear predominance of the isomer γ-HCH that would suggest a recent application of the pesticide, except eventually for the site Italy 2;
- ENDOs were measured in 70% of the sampling site in concentration lower than 2.0 ng g^{-1} suggesting a background level of this insecticide from past use;
- Total concentrations of the studied PCBs range from 13.1 to 224.3 ng g^{-1}, the sites Croatia 2, Italy 2 and 5 presenting the highest concentrations (>200 ng g^{-1});
- The PCBs congeners exhibiting the highest concentrations are PCB138, PCB153 and PCB149, PCB138 being the highest (about 50 ng g^{-1});
- The less abundant PCBs congener is PCB 95 (i.e. detected in 2 sites) and the most abundant ones are PCB52, PCB110, PCB118, PCB105, PCB153, PCB138, PCB183 and PCB180 (i.e. detected in all sites);
- Overall, the concentrations of OCPs and PCBs are consistent with the data obtained by the IPW monitoring programme in similar (i.e. Adriatic and Ionian areas) and surrounding regions (i.e. Mediterranean and Aegean areas);
- The sites Croatia 2, Italy 2 and Italy 5 are the most contaminated with POPs (total concentration >200 ng g^{-1}), whereas the sites Greece 1 and Italy 3 present the lowest levels of POPs (total concentration <50 ng g^{-1}).

Taking into account the outcomes of this study, the following recommendations can be formulated:

- Further monitoring should be carried out in order to better assess the concentrations of adsorbed contaminants on small plastic fragments and their trend over time;
- Sampling sites should be selected not only on the base of the beach characteristics, but also according to their surroundings (i.e. industrial, touristic, remote, agricultural areas), which impact the composition of the contaminants present in the environment;
- The selection of the sampling locations should also take into account the sea currents and the presence of river outflows;
- Besides POPs, the monitoring should include the assessment of emerging contaminants (e.g. new class of pesticides or antibiotics), plastic additives (e.g. flame retardants or plasticizers) and metals;
- The monitoring should include the analysis of plastic fragments and microplastics other than resin pellets that could be sampled both on beaches and on sea surface.

Finally, it must be underlined that organic contaminants such as POPs are ubiquitous in the environment. Thus, organisms can be exposed to these chemicals through other routes than the ingestion of plastic debris. It is therefore crucial to understand whether the compounds released from plastic fragments induce a significant effect on the organism compared to the load of contaminants already present in its tissues.

5 Conclusions

On the basis of this study the following conclusions are presented:

- Adriatic Sea is contaminated by microplastic in all studied regions including all countries of Adriatic region. The mean concentration is ~230000 items/km^2.
- All studied beaches of Adriatic Sea are also contaminated by microplastic of both size class (LMP and SMP), where is the mean concentration of LMP 113 ± 101 items/m^2 and for SMP 1133 ± 1271 items/kg of dry sediments.
- The most abundant plastic material among microplastic particles is polyethylene in sea surface and beach sediment samples.
- Results of microplastic concentrations on the sea surface and beach sediment show a high variability among samples, while several factors in the process of sampling and sample analysis influence on final results.
- PCBs and OCPs were detected in all samples from all sampling locations, where total concentrations of the studied OCPs range from 1.9 to 14.9 ng g^{-1}, and total concentrations of the studied PCBs range from 13.1 to 224.3 ng g^{-1}.
- Overall, the concentrations of OCPs and PCBs are consistent with the data obtained by the IPW monitoring programme in similar (i.e. Adriatic and Ionian areas) and surrounding regions (i.e. Mediterranean and Aegean areas);
- The sites Croatia 2, Italy 2 and Italy 5 are the most contaminated with POPs (total concentration >200 ng g^{-1}), whereas the sites Greece 1 and Italy 3 present the lowest levels of POPs (total concentration <50 ng g^{-1}).

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Appendices

Appendix 1: Sampling data – sea surface

Albania

Table A - 1: Sampling data of sea surface survey on 25th of January 2016, Albania.

Sample ID		**S1**	**S2**	**S3**	**S4**	**S5**
Sampling date (d/m/y)		25/1/2015	25/1/2015	25/1/2015	25/1/2015	25/1/2015
Start point	Time	10:30	11:10	12:00	12:35	13:20
	Lat (Y)	41.28047	41.27024	41.27192	41.25058	41.26019
	Lon (X)	19.45008	19.42067	19.36139	19.36758	19.37624
Stop point	Time	11:00	11:39	12:28	13:14	13:48
	Lat (Y)	41.26512	41.23242	41.25174	41.26987	41.28166
	Lon (X)	19.44717	19.40809	19.35419	19.36982	19.37727
Average speed (kn)		2.1	2.2	2.1	2.4	2.1
Transect length (nmi)		1.438	1.563	1.750	1.750	1.438

Bosnia and Herzegovina

Table A - 2: Sampling data of sea surface survey on 11th and 12th of December 2014 in Neum bay, Bosnia and Hercegovina.

Sample ID		**2 AB**	**2 CD**
Sampling date (d/m/y)		11/12/2014	12/12/2014
Start point	Time	9:10	9:55
	Lat (Y)	42°43`17.24``	42°55`31.34``
	Lon (X)	17°36`22.41``	17°36`1.01``
Stop point	Time	9:42	10:28
	Lat (Y)	42°55`31.34``	42°55`45.68``
	Lon (X)	17°36`1.01``	17°35`43.22``
Average speed (kn)		2.4	2.8
Transect length (km)		2.33	2.45

Table A - 3: Sampling data of sea surface survey on 8th and 9th of December 2015 in Neum bay, Bosnia and Hercegovina.

Sample ID		**2 AB**	**2 CD**
Sampling date (d/m/y)		8/12/2015	9/12/2015
Start point	Time	9:30	9:30
	Lat (Y)	42° 55.977'N	42° 55.039'N
	Lon (X)	17° 34.583'E	17° 36.268'E
Stop point	Time	10:00	10:00
	Lat (Y)	42° 55.594'N	42° 55.513'N
	Lon (X)	17° 35.666'E	17° 36.495'E
Average speed (kn)		2.4	2.8
Transect length (km)		2.33	2.50

Croatia

Table A - 4: Sampling data of sea surface survey on 24th of October 2014 near Split, Croatia.

Sample ID		SD6	SD7	SD8	SD9	SD10
Sampling date (d/m/y)		24/10/2014	24/10/2014	24/10/2014	24/10/2014	24/10/2014
Start point	Time	10:00	10:55	11:50	12:45	13:40
	Lat (Y)	43°20'37.02"	43°20'31.52"	43°18'45.75"	43°12'25.11"	43°11'5.06"
	Lon (X)	16°24'8.59"	16°17'18.54"	16° 7'28.54"	16° 6'18.00"	16°14'46.47"
Stop point	Time	10:30	11:25	12:20	13:15	14:10
	Lat (Y)	43°18'11.04"	43°21'47.54"	43°15'47.55"	43°10'4.58"	43°12'1.36"
	Lon (X)	16°24'3.73"	16°13'34.46"	16° 6'21.48"	16° 9'33.62"	16°17'53.79"
Average speed (kn)		2.2	2.5	2.6	3	2.4
Transect length (nmi)		2.47	3	2.87	3.22	2.31
Sea state (0 - 9 B)		1	1	1	1	1
Wind velocity (1 - 12 B)		1	1	2	2	1
Wind direction (°)		N	N	N	N	N

Table A - 5: Sampling data of sea surface survey on 19th of December 2014 near Split, Croatia.

Sample ID		SD1	SD2	SD3	SD4	SD5
Sampling date (d/m/y)		19/12/2014	19/12/2014	19/12/2014	19/12/2014	19/12/2014
Start point	Time	9:48	10:45	11:25	12:02	15:00
	Lat (Y)	43°30'4.00"	43°27'51.70"	43°29'57.95"	43°29'12.77"	43° 2'23.04"
	Lon (X)	16°21'55.63"	16°21'51.37"	16°24'30.42"	16°28'22.69"	16° 4'39.42"
Stop point	Time	10:20	11:10	11:50	12:30	15:30
	Lat (Y)	43°31'56.04"	43°24'38.07"	43°29'37.47"	43°27'45.46"	42°59'33.65"
	Lon (X)	16°19'57.29"	16°22'8.70"	16°27'33.24"	16°30'56.57"	16° 1'26.47"
Average speed (kn)		2.2	2.5	2.3	2.7	3
Transect length (nmi)		2.39	3.34	2.25	2.45	3.79
Sea state (0 - 9 B)		0	0	0	0	1
Wind velocity (1 - 12 B)		0	0	0	0	1
Wind direction (°)		/	/	/	/	N

Greece

Table A - 6: Sampling data of sea surface survey on 9th of October 2014 near Corfu Island, Greece.

Sample ID		10-1M	10-2M	10-3M	10-4M
Sampling date (d/m/y)		9/10/2014	9/10/2014	9/10/2014	9/10/2014
Start point	Time	11:13	12:22	13:28	15:08
	Lat (Y)	39.9003	39.9279	39.8995	39.9254
	Lon (X)	19.2225	19.2018	19.1251	19.2824
Stop point	Time	11:45	12:50	13:59	15:39
	Lat (Y)	39.9037	39.9414	39.8906	39.9148
	Lon (X)	19.2146	19.1906	19.1070	19.2643
Average speed (kn)		2.1	2.0	1.9	2.0
Transect length (km)		0.78	1.79	1.84	1.95

Table A - 7: Sampling data of sea surface survey on 11th of October 2014 near Corfu Island, Greece.

Sample ID		10-5M	10-6M	10-7M	10-8M	10-9M
Sampling date (d/m/y)		11/10/2014	11/10/2014	11/10/2014	11/10/2014	11/10/2014
Start point	Time	13:02	14:06	15:18	16:35	17:52
	Lat (Y)	39.4193	39.4018	39.3931	39.3892	39.4004
	Lon (X)	19.6187	19.6766	19.7414	19.8192	19.8981
Stop point	Time	13:32	14:36	15:48	17:05	18:22
	Lat (Y)	39.4045	39.3866	39.3785	39.3687	39.3840
	Lon (X)	19.6139	19.6643	19.7278	19.8134	19.9039
Average speed (kn)		1.9	2.1	2.1	2.0	2.1
Transect length (km)		1.71	2.00	1.99	2.33	1.88

Table A - 8: Sampling data of sea surface survey on 13th of October 2014 near Corfu Island, Greece.

Sample ID		**10-10M**	**10-11M**	**10-12M**
Sampling date (d/m/y)		13/10/2014	13/10/2014	13/10/2014
Start point	Time	13:34	14:31	15:29
	Lat (Y)	39.4731	39.4970	39.4944
	Lon (X)	20.0934	20.1258	20.1659
Stop point	Time	14:04	15:01	15:59
	Lat (Y)	39.4886	39.5042	39.4767
	Lon (X)	20.0892	20.1222	20.1684
Average speed (kn)		1.9	2.0	2.0
Transect length (km)		1.76	1.83	1.98

Table A - 9: Sampling data of sea surface survey on 14th of October 2014 near Corfu Island, Greece.

Sample ID		**10-13M**	**10-14M**	**10-15M**
Sampling date (d/m/y)		14/10/2014	14/10/2014	14/10/2014
Start point	Time	11:15	12:17	13:15
	Lat (Y)	39.6477	39.6546	39.6677
	Lon (X)	19.9437	19.9818	20.0193
Stop point	Time	11:45	12:47	13:48
	Lat (Y)	39.6338	39.6394	39.6579
	Lon (X)	19.9534	19.9869	20.0400
Average speed (kn)		1.9	2.0	2.0
Transect length (km)		1.76	1.74	2.09

Italy

Table A - 10: Sampling data of sea surface survey on 16th of October 2014 near Cesenatico, Italy.

Sample ID		**14**	**314**	**1014**	**2014**
Sampling date (d/m/y)		16/10/2014	16/10/2014	16/10/2014	16/10/2014
Start point	Time	8:05	8:36	09:15	10:00
	Lat (Y)	44°12.773	44°13.292	44°14.849	44°16.969
	Lon (X)	12°24.418	12°25.967	12°30.613	12°37.467
Stop point	Time	08:25	08:56	09:35	10:20
	Lat (Y)	44°13.192	44°13.966	44°14.868	44°15.559
	Lon (X)	12°26.000	12°27.425	12°32.303	12°37.441
Average speed (kn)					
Transect length (nmi)		1.21	1.27	1.2	1.45
Sea state (0 - 9 D)		2	2	3	3
Wind velocity (1 - 12 B)		2	1	0	2
Wind direction (°)		N-NW	NW	/	SW

Table A - 11: Sampling data of sea surface survey on 17th of October 2014 near Porto Garibaldi, Italy.

Sample ID		**4**	**304**	**1004**	**2004**
Sampling date (d/m/y)		17/10/2014	17/10/2014	17/10/2014	17/10/2014
Start point	Time	11:19	10:45	10:00	09:15
	Lat (Y)	44°39.755	44°39.379	44°38.983	44°37.954
	Lon (X)	12°15.561	12°17.563	12°22.756	12°29.914
Stop point	Time	11:49	11:05	10:25	09:40
	Lat (Y)	44°38.088	44°39.284	44°38.207	44°37.030
	Lon (X)	12°16.513	12°16.012	12°21.598	12°29.515
Average speed (kn)					
Transect length (nmi)		1.8	1.1	1.12	0.96
Sea state (0 - 9 D)		2	2	3	3
Wind velocity (1 - 12 B)		2	2	2	2
Wind direction (°)		SW	SW	SW	SW

Slovenia

Table A - 12: Sampling data of sea surface survey on 25th and 26th of August 2014, Slovenia.

Sample ID		**S1**	**S2**	**S3**	**S4**
Sampling date (d/m/y)		25/8/2014	26/8/2014	26/8/2014	26/8/2014
Start point	Time	7:50	9:02	10:10	10:42
	Lat (Y)	45°32`59.3``	45°33`35.2``	45°33`46.3``	45°29`88.7``
	Lon (X)	13°33`28.6``	13°36`84.9``	13°40`45.6``	13°33`58.6``
Stop point	Time	8:20	9:32	10:40	11:12
	Lat (Y)	45°32`95.5``	45°33`42.2``	45°33`51.9``	45°30`74.6``
	Lon (X)	13°34`97.2``	13°38`62.3``	13°42`22.8``	13°32`22.7``
Average speed (kn)		2,5	2.5	2.5	2.5
Transect length (nmi)		1,295	1.242	1.249	1.246

Appendix 2: Sampling data – beach sediments
Albania

Table A - 13: Sampling data for LMP and SMP from beach sediment survey on 8th of June 2015, Albania.

Large microplarticles sampling (LMP)		1st quadrant	2nd quadrant	3rd quadrant	4th quadrant	5th quadrant
Sample name		Velipoja 1	Velipoja 2	Velipoja 3	Velipoja 4	Velipoja 5
GPS coordinates	Lat (X)	41°51'45.4"N	41°51'45.4"N	41°51'45.5"N	41°51'45.5"N	41°51'45.5"N
	Lon (Y)	19°24'53"E	19°24'53.1"E	19°24'53.3"E	19°24'53.5"E	19°24'53.6"E
Volume of sediment sampled (l)		5	5.2	5.3	5	5.1

Small microplarticles sampling (SMP)		1st replicate	2nd replicate	3th replicate	3rd replicate	4th replicate
Sample name		Velipoja 1	Velipoja 2	Velipoja 3	Velipoja 4	Velipoja 5
GPS coordinates	Lat (X)	41°51'45.4"N	41°51'45.4"N	41°51'45.5"N	41°51'45.5"N	41°51'45.5"N
	Lon (Y)	19°24'53"E	19°24'53.1"	19°24'53.3"E	19°24'53.3"E	19°24'53.6"

Croatia

Table A - 14: Sampling data for LMP and SMP from beach sediment survey on 25th of September 2014 on Bačvice beach, Croatia.

LMP		1st quadrant	2nd quadrant	3th quadrant	4th quadrant	5th quadrant
Sample name		S01-LMP	S02-LMP	S03-LMP	S04-LMP	S05-LMP
GPS coordinates	Lat (X)	43°30'7.99"N	43°30'8.21"N	43°30'8.21"N	43°30'8.30"N	43°30'8.41"N
	Lon (Y)	16°26'47.82"E	16°26'48.34"E	16°26'48.71"E	16°26'49.22"E	16°26'49.59"E
Volume of sediment sampled		1100	950	950	1200	1000

SMP		1st quadrant	2nd quadrant	3th quadrant	4th quadrant	5th quadrant
Sample name		S01-SMP	S02-SMP	S03-SMP	S04-SMP	S05-SMP
GPS coordinates	Lat (X)	43°30'7.99"N	43°30'8.21"N	43°30'8.21"N	43°30'8.30"N	43°30'8.41"N
	Lon (Y)	16°26'47.82"E	16°26'48.34"E	16°26'48.71"E	16°26'49.22"E	16°26'49.59"E

Table A - 15: Sampling data for LMP and SMP from beach sediment survey on 23th of December 2014 on Bačvice beach, Croatia.

LMP		1st quadrant	2nd quadrant	3th quadrant	4th quadrant	5th quadrant
Sample name		S06-LMP	S07-LMP	S08-LMP	S09-LMP	S10-LMP
GPS coordinates	Lat (X)	43°30'8.21"N	43°30'8.27"N	43°30'8.40"N	43°30'8.49"N	43°30'8.61"N
	Lon (Y)	16°26'47.79"E	16°26'48.15"E	16°26'48.55"E	16°26'48.95"E	16°26'49.43"E
Volume of sediment sampled		850	950	1100	1000	1000

SMP		1st replicate	2nd replicate	3th replicate	4th replicate	5th replicate
Sample name		S06-SMP	S07-SMP	S08-SMP	S09-SMP	S10-SMP
GPS coordinates	Lat (X)	43°30'8.21"N	43°30'8.27"N	43°30'8.40"N	43°30'8.49"N	43°30'8.61"N
	Lon (Y)	16°26'47.79"E	16°26'48.15"E	16°26'48.55"E	16°26'48.95"E	16°26'49.43"E

Table A - 16: Sampling data for LMP and SMP from beach sediment survey on 31th of July 2014 on Zaglav beach, Croatia.

LMP		1st quadrant	2nd quadrant	3th quadrant	4th quadrant	5th quadrant
Sample name		Z01-LMP	Z02-LMP	Z03-LMP	Z04-LMP	Z05-LMP
GPS coordinates	Lat (X)	43°1'59.09"N	43°1'58.84"N	43°1'58.51"N	43°1'58.06"N	43°1'57.58"N
	Lon (Y)	16°13'42.25"E	16°13'42.20"E	16°13'42.21"E	16°13'42.32"E	16°13'42.32"E
Volume of sediment sampled		850	900	750	1000	900

SMP		1st replicate	2nd replicate	3th replicate	4th replicate	5th replicate
Sample name		Z01-SMP	Z02-SMP	Z03-SMP	Z04-SMP	Z05-SMP
GPS coordinates	Lat (X)	43°1'59.09"N	43°1'58.84"N	43°1'58.51"N	43°1'58.06"N	43°1'57.58"N
	Lon (Y)	16°13'42.25"E	16°13'42.20"E	16°13'42.21"E	16°13'42.32"E	16°13'42.32"E

Table A - 17: Sampling data for LMP and SMP from beach sediment survey on 31th of October 2014 on Zaglav beach, Croatia.

LMP		1st quadrant	2nd quadrant	3th quadrant	4th quadrant	5th quadrant
Sample name		Z06-LMP	Z07-LMP	Z08-LMP	Z09-LMP	Z10-LMP
GPS coordinates	Lat (X)	43° 1'58.90"N	43° 1'58.49"N	43° 1'57.88"N	43° 1'57.33"N	43° 1'56.66"N
	Lon (Y)	16°13'42.38"E	16°13'42.43"E	16°13'42.65"E	16°13'42.95"E	16°13'43.38"E
Volume of sediment sampled		750	1100	950	1000	1000

SMP		1st replicate	2nd replicate	3th replicate	4th replicate	5th replicate
Sample name		Z06-SMP	Z07-SMP	Z08-SMP	Z09-SMP	Z10-SMP
GPS coordinates	Lat (X)	43° 1'58.90"N	43° 1'58.49"N	43° 1'57.88"N	43° 1'57.33"N	43° 1'56.66"N
	Lon (Y)	16°13'42.38"E	16°13'42.43"E	16°13'42.65"E	16°13'42.95"E	16°13'43.38"E

Table A - 18: Sampling data for LMP and SMP from beach sediment survey on 25th of October 2014 on Neretva outflow, Croatia.

LMP		1st quadrant	2nd quadrant	3th quadrant	4th quadrant	5th quadrant
Sample name		NR1-LMP	NR2-LMP	NR3-LMP	NR4-LMP	NR5-LMP
GPS coordinates	Lat (X)	43° 1'8.36"	43° 1'8.18"	43° 1'8.05"	43° 1'8.09"	43° 1'8.10"
	Lon (Y)	17°26'43.89"	17°26'44.08"	17°26'44.48"	17°26'44.92"	17°26'45.43"
Volume of sediment sampled		2000	1400	1200	1650	1000

SMP		1st replicate	2nd replicate	3th replicate	4th replicate	5th replicate
Sample name		NR1-SMP	NR2-SMP	NR3-SMP	NR4-SMP	NR5-SMP
GPS coordinates	Lat (X)	43° 1'8.36"	43° 1'8.18"	43° 1'8.05"	43° 1'8.09"	43° 1'8.10"
	Lon (Y)	17°26'43.89"	17°26'44.08"	17°26'44.48"	17°26'44.92"	17°26'45.43"

Greece

Table A - 19: Sampling data for LMP and SMP from beach sediment survey on July 2014 and 2015 on Halikounas beach, Greece.

Sample ID		HALIKOUNAS 1	
LMP + SMP		1st quadrant	2nd quadrant
Sample name		HAL1-1	HAL1-2
GPS coordinates	Lat (X)	39° 27.179'N	39° 27.167'N
	Lon (Y)	19° 52.487'E	19° 52.502'E
Volume of sediment sampled		8,4 L	7,6 L

Sample ID		HALIKOUNAS 2				
LMP + SMP		1st quadrant	2nd quadrant	3th quadrant	4th quadrant	5th quadrant
Sample name		HAL2-1	HAL2-2	HAL2-3	HAL2-4	HAL2-5
GPS coordinates	Lat (X)	39° 26.994'N	39° 27.000'N	39° 26.999'N	39° 27.005'N	
	Lon (Y)	19° 52.791'E	19° 52.790'E	19° 52.794'E	19° 52.790'E	
Volume of sediment sampled		6 L	6,1 L	8L	8 L	

Sample ID		HALIKOUNAS 3				
LMP + SMP		1st quadrant	2nd quadrant	3th quadrant	4th quadrant	5th quadrant
Sample name		HAL3-1	HAL3-2	HAL3-3	HAL3-4	HAL3-5
GPS coordinates	Lat (X)	39° 26.669'N	39° 26.666'N	39° 26.665'N	39° 26.666'N	
	Lon (Y)	19° 53.687'E	19° 53.687'E	19° 53.686'E	19° 53.678'E	
Volume of sediment sampled		8 L	7,2 L	7,2 L	8 L	9 L

Table A - 20: Sampling data for LMP and SMP from beach sediment survey on September 2015 and 2015 on Acharavi beach, Greece.

Sample ID		**Acharavi 9**		
LMP + SMP		1st quadrant	2nd quadrant	3th quadrant
Sample name		Ach9-1	Ach9-2	Ach9-3
GPS coordinates	Lat (X)	39° 47.930'N	39° 47.932'N	39° 47.933'N
	Lon (Y)	19° 49.063'E	19° 49.062'E	19° 49.059'E
Volume of sediment sampled		6 L	6 L	6 L

Table A - 21: Sampling data for LMP and SMP from beach sediment survey on June 2015 on Issos beach, Greece.

Sample ID		**Issos 1**		
LMP + SMP		1st quadrant	2nd quadrant	3th quadrant
Sample name		issos1-1	issos1-2	issos1-3
GPS coordinates	Lat (X)	39° 25.888'N	39° 25.885'N	39° 25.882'N
	Lon (Y)	19° 55.058'E	19° 55.058'E	19° 55.058'E
Volume of sediment sampled		7,6 L	7,6 L	7,6 L

Sample ID		**Issos 2**		
LMP + SMP		1st quadrant	2nd quadrant	3th quadrant
Sample name		issos2-1	issos2-2	issos2-3
GPS coordinates	Lat (X)	39° 25.933'N	39° 25.929'N	39° 25.926'N
	Lon (Y)	19° 55.728'E	19° 55.728'E	19° 55.729'E
Volume of sediment sampled		7 L	7 L	7 L

Sample ID		**Issos 3**		
LMP + SMP		1st quadrant	2nd quadrant	3th quadrant
Sample name		issos3-1	issos3-2	issos3-3
GPS coordinates	Lat (X)	39° 25.882'N	39° 25.879'N	39° 25.876'N
	Lon (Y)	19° 56.082'E	19° 56.080'E	19° 56.079'E
Volume of sediment sampled		7 L	7 L	7 L

Italy

Table A - 22: Sampling data for LMP and SMP from beach sediment survey on Cesenatico beach, Italy.

SMP + LMP		1st replicate	2nd replicate	3th replicate	4th replicate	5th replicate
Sample name		CES_A	CES_B	CES_C	CES_D	CES_E
GPS coordinates	Lat (X)	44.12386	44.1239	44.1239	44.12385	44.12387
	Lon (Y)	12.24019	12.24018	12.24024	12.24028	12.24011

Slovenia

Table A - 23: Sampling data for LMP and SMP from beach sediment survey on September 2014 and January 2015 on Lazaret beach, Slovenia.

Large microplarticles sampling (LMP)		1st quadrant	2nd quadrant	3rd quadrant
Sample name		D. Rtič 1	D. Rtič 2	D. Rtič 3
GPS coordinates	Lat (X)	45°35´26.5˝	45°35´26.5˝	45°35´26.5˝
	Lon (Y)	13°43´10.1˝	13°43´10.1˝	13°43´10.1˝
Volume of sediment sampled		5	5.2	5.3

Small microplastic sampling (SMP)		1st quadrant	2nd quadrant	3rd quadrant
Sample name		D. Rtič 1	D. Rtič 2	D. Rtič 3
GPS coordinates	Lat (X)	45°35´26.5˝	45°35´26.5˝	45°35´26.5˝
	Lon (Y)	13°43´10.1˝	13°43´10.1˝	13°43´10.1˝

Appendix 3: Size distribution – sea surface

Greece

Table A - 24: Number of microplastic particles according to its length, Greece.

Sample name	Category	Nr of particles <1 mm	Nr of particles 1 – 5 mm	Nr of particles >5 mm
10-1M	fragments	464	284	12
	filaments		10	
10-2M	fragments			
	filaments		2	
10-3M	fragments	120	136	13
	filaments		3	
10-4M	fragments	72	16	4
	filaments		1	
10-5M	fragments	360	175	6
	filaments	13		
10-6M	fragments	80	71	
	filaments	1	6	
10-7M	fragments	296	752	
	filaments		8	
10-8M	fragments	244	864	3
	filaments		5	
10-9M	fragments	140	117	3
	filaments	3	17	
10-10M	fragments	384	1056	5
	filaments		6	
10-11M	fragments	524	840	3
	filaments		2	
10-12M	fragments	172	76	2
	filaments		11	
10-13M	fragments	360	1224	10
	filaments		3	
10-14M	fragments	124	159	4
	filaments	2	5	
10-15M	fragments	460	1136	2
	filaments	1		

Italy

Table A - 25: Results of image analyses: average, maximum and minimum length of the different microplastic categories collected in the sea surface sampling transects for the year 2014, Italy.

Data	Sample name	Category	Nr of particles 5-0.3 mm	Average lengh ± SD (mm)	Max length (mm)	Min length (mm)
2014-10-17	PG4_S	fragments	19	1.11 ± 0.79	2.77	0.13
2014-10-17	PG4_S	filaments	1	-	-	-
2014-10-17	PG4_S	films	6	3.11 ± 2.53	6.76	1.01
2014-10-17	PG4_S	pellets	3	1.31 ± 1.04	2.51	0.7
2014-10-17	PG4_S	foam	1	-	-	-
2014-10-17	304_S	fragments	5	2.55 ± 1.66	5.06	0.7
2014-10-17	304_S	pellets	1	-	-	-
2014-10-17	304_S	foam	1	-	-	-
2014-10-17	1004_S	fragments	6	1.83 ± 0.93	3.63	1.07
2014-10-17	1004_S	filaments	2	-	-	-
2014-10-17	1004_S	pellets	1	-	-	-
2014-10-17	1004_S	other	3	1.13 ± 0.54	1.47	0.51
2014-10-17	2004_S	fragments	85	2.09 ± 1.53	8.25	0.23
2014-10-17	2004_S	films	6	5.07 ± 2.37	9.22	2.97
2014-10-17	2004_S	pellets	9	1.21 ± 1.39	4.8	0.54
2014-10-17	2004_S	granules	1	-	-	-
2014-10-17	2004_S	foam	11	1.83 ± 1.05	4.06	0.6
2014-10-17	2004_S	N.C. plast. pieces	6	2.35 ± 1.17	3.93	0.84
2014-10-16	C14_S	fragments	100	1.38 ± 0.97	5.84	0.22
2014-10-16	C14_S	filaments	1	-	-	-
2014-10-16	C14_S	films	7	3.27 ± 1.99	6.19	1.29
2014-10-16	C14_S	granules	2	0.63	0.63	0.63
2014-10-16	C14_S	foam	4	1.98 ± 0.78	2.43	0.82
2014-10-16	314_S	fragments	142	1.36 ± 0.94	4.48	0.34
2014-10-16	314_S	filaments	2	-	-	-
2014-10-16	314_S	films	10	3.21 ± 2.44	8.81	0.36
2014-10-16	314_S	granules	3	0.47 ± 0.09	0.55	0.38
2014-10-16	314_S	foam	1	-	-	-
2014-10-16	1014_S	fragments	110	1.80 ± 1.27	8.43	0.44
2014-10-16	1014_S	filaments	1	-	-	-
2014-10-16	1014_S	films	5	2.74 ± 0.93	3.99	1.54
2014-10-16	1014_S	granules	3	0.59 ± 0.07	0.65	0.51
2014-10-16	1014_S	foam	19	2.08 ± 1.62	7.62	0.47
2014-10-16	2014_S	fragments	68	1.42 ± 1.14	6.22	0.27
2014-10-16	2014_S	films	9	2.21 ± 1.26	4.93	0.79
2014-10-16	2014_S	pellets	1	-	-	-
2014-10-16	2014_S	granules	1	-	-	-
2014-10-16	2014_S	foam	10	2.67 ± 1.80	5.83	0.56

Slovenia

Table A - 26: results of image analyses: Number of particles in each category, average length with standard deviation, maximum and minimum length of particles [mm] in sea surface samples from August 2014, Slovenia.

Sample name	Category	Nr of particles	Average length (mm)	Max length (mm)	Min length (mm)
S1	fragments	59	1,60 ± 1,38	6,21	0,21
	foam	10	1,43 ± 0,8	2,66	0,43
	other	19	1,34 ± 1,28	5,30	0,26
S2	fragments	23	2,09 ± 2,74	13,59	0,28
	films	2	2,06 ± 0,51	2,42	1,70
	foam	8	2,22 ± 0,73	3,02	1,11
	granules	1	0,60	-	-
	other	6	1,22 ± 1,18	-	-
S3	fragments	58	1,30 ± 1,10	5,84	0,29
	films	5	2,20 ± 1,30	4,19	0,81
	granules	1	0,58	-	-
S4	fragments	5	1,57 ± 0,68	2,40	0,52
	films	1	1,19	-	-
	granules	1	0,88	-	-
	other	2	1,07 ± 0,04	1,10	1,04

Appenidx 4: Size distribution – beach sediments

Croatia

Table A - 27: Average length for LMP for categories fragments, foam and pellets, Croatia.

Sample name	Category	Average length (mm)
Neretva	fragments	4.23 ± 0.918
Bačvice	fragments	2.58 ± 0.758
	foam	2.88 ± 0.94
Zaglav	fragments	3.40 ± 1.174
	foam	3.65 ± 0.271
	pellets	3.89 ± 0.264

Italy

Table A - 28: Results of image analyses reported as average, maximum and minimum length of small (<1 mm) microplastic categories collected in Cesenatico beach on 13th of August 2014, Italy.

Data	Sample name	Category	Nr of particles <1 mm	average lengh ± SD (mm)	Max length (mm)	Min length (mm)
2014-08-13	CES	fragments	76	4.00 ± 1.94	14.88	1.09
2014-08-13	CES	filaments	9	-	-	-
2014-08-13	CES	films	24	2.89 ± 1.60	7.01	0.64
2014-08-13	CES	pellets	62	4.00 ± 0.75	6.01	1.58
2014-08-13	CES	granules	3	2.10 ± 1.59	3.94	1.13
2014-08-13	CES	foam	2	4.16 ± 2.58	6.00	2.30
2014-08-13	CES	N.C. plastic pieces	3	1.74 ± 0.83	2.69	1.25

Table A - 29: Results of image analyses reported as average, maximum and minimum length of small (<1 mm) microplastic categories collected in Cesenatico beach on 24th of November 2014, Italy.

Data	Sample name	Category	Nr of particles <1 mm	Average lengh ± SD (mm)	Max length (mm)	Min length (mm)
2014-11-24	CES	fragments	1332	0.25 ± 0.13	1.18	0.01
2014-11-24	CES	filaments	677	-	-	-
2014-11-24	CES	films	25	0.59 ± 0.59	2.19	0.06
2014-11-24	CES	pellets	-	-	-	-
2014-11-24	CES	granules	-	-	-	-
2014-11-24	CES	foam	-	-	-	-
2014-11-24	CES	N.C. plastic pieces	5	19.52 ± 4.85	25.00	12.80

Table A - 30: Results of image analyses reported as average, maximum and minimum length of large (1-5 mm) microplastic categories collected in Cesenatico beach on 13th of August 2014, Italy.

Data	Sample name	Category	Nr of particles 1-5 mm	Average lengh ± SD (mm)	Max length (mm)	Min length (mm)
2014-08-13	CES	fragments	23	8.47 ± 2.79	13.32	2.34
2014-08-13	CES	filaments	9	-	-	-
2014-08-13	CES	films	2	8.44 ± 3.68	11.04	5.84
2014-08-13	CES	pellets	-	-	-	-
2014-08-13	CES	granules	-	-	-	-
2014-08-13	CES	foam	-	-	-	-
2014-08-13	CES	N.C. plastic pieces	5	19.52 ± 4.85	25.00	12.80

Table A - 31: Results of image analyses reported as average, maximum and minimum length of large (1-5 mm) microplastic categories collected in Cesenatico beach on 24th of november 2014, Italy.

Data	Sample name	Category	Nr of particles 1-5 mm	Average lengh ± SD (mm)	Max length (mm)	Min length (mm)
2014-11-24	CES	fragments	24	3.97 ± 1.82	7.15	1.00
2014-11-24	CES	filaments	2	-	-	-
2014-11-24	CES	films	4	3.13 ± 2.02	5.73	0.88
2014-11-24	CES	pellets	5	4.13 ± 1.27	5.89	2.86
2014-11-24	CES	granules	6	1.81 ± 0.99	3.63	1.05
2014-11-24	CES	foam	1	4.77	-	-
2014-11-24	CES	n.c. plastic pieces	6	4.55 ± 0.66	5.10	3.68

Slovenia

Table A - 32: Results of image analyses: average length, maximum and minimum length of particles [mm] from SMP and LMP beach samples from September 2014 and January 2015, Slovenia.

Small microplastic particles	Category	Average length (mm)	Max length (mm)	Min length (mm)
Lazaret, Debeli rtič September 2014	fragments	1.02	3.25	0.32
	films	1.43	4.14	0.37
	granules	0.28	0.28	0.28
Lazaret, Debeli rtič January 2015	fragments	0.40	0.50	0.30
	films	0.45	0.53	0.37
	granules	0.52		

Large microplastic particles	Category	Average length (mm)	Max length (mm)	Min length (mm)
Lazaret, Debeli rtič September 2014	fragments	3.58	10.72	1.78
	films	5.73	14.89	2.95
	foam	3.01	4.43	0.33
	pellets	4.47		
	granules	0.93		
Lazaret, Debeli rtič January 2015	granules	1.47	1.75	1.2
	fragments	2.50	4.52	0.76
	films	3.92	6.64	2.41

Appendix 5: List of studied PCBs and OCPs compounds and their CAS numbers

Compound	CAS number	Compound	CAS number
		PCBs	
PCB28 (3Cl)[a]	7012-37-5	PCB138 (6Cl)[d]	35065-28-2
PCB31 (3Cl)[a]	16606-02-3	PCB146 (6Cl)[d]	51908-16-8
PCB52 (4Cl)[b]	35693-99-3	PCB149 (6Cl)[d]	38380-04-0
PCB77 (4Cl)[b]	32598-13-3	PCB151 (6Cl)[d]	52663-63-5
PCB95 (5Cl)[c]	38379-99-6	PCB153 (6Cl)[d]	35065-27-1
PCB99 (5Cl)[c]	38380-01-7	PCB156 (6Cl)[d]	38380-08-4
PCB101 (5Cl)[c]	37680-73-2	PCB169 (6Cl)[d]	32774-16-6
PCB105 (5Cl)[c]	32598-14-4	PCB170 (7Cl)[e]	35065-30-6
PCB110 (5Cl)[c]	38380-03-9	PCB177 (7Cl)[e]	52663-70-4
PCB118 (5Cl)[c]	31508-00-6	PCB180 (7Cl)[e]	35065-29-3
PCB126 (5Cl)[c]	57465-28-8	PCB183 (7Cl)[e]	52663-69-1
PCB128 (6Cl)[d]	38380-07-3	PCB187 (7Cl)[e]	52663-68-0
		OCPs	
2,4’-DDT	789-02-6	Endosulfan I	959-98-8
4,4’-DDT	50-29-3	Endosulfan II	33213-65-9
2,4’-DDE	3424-82-6	α-HCH	319-84-6
4,4’-DDE	72-55-9	β-HCH	319-85-7
2,4’-DDD	53-19-0	γ-HCH	58-89-9
4,4’-DDD	72-54-8		

[a] Congeners having a total of 3 chlorine substituents
[b] Congeners having a total of 4 chlorine substituents
[c] Congeners having a total of 5 chlorine substituents
[d] Congeners having a total of 6 chlorine substituents
[e] Congeners having a total of 7 chlorine substituents