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DEPARTMENT OF GEOLOGICAL ENGINEERING

MICROPLASTIC CONTENTS AND SEDIMENT CLASSIFICATION OF SELECTED SITES IN BODRUM AND GÜLLÜK BEACHES (MUĞLA, SW TURKEY)

MASTER OF SCIENCE

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APPROVAL OF THE THESIS

The thesis submitted by **AHMED MASUD** with the title of **"Microplastic Contents and Sediment Classification of Selected Sites in Bodrum and Güllük Beaches (Muğla, SW Turkey)"** has been unanimously accepted by the jury members on the 27th of June 2022 to fulfill the requirements for the degree of Master of Science in the Department of Bioinformatics.

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I hereby declare that all information in this document has been obtained and presented by academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Ahmed Masud
27/06/2022

ÖZET

BODRUM VE GÜLLÜK PLAJLARINDA (MUĞLA, SW TÜRKİYE) SEÇİLMİŞ YERLERİN MİKROPLASTİK İÇERİKLERİ VE SEDİMENT SINIFLANDIRILMASI

Ahmed MASUD

Yüksek Lisans Tezi

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Danışman: Prof. Dr. Murat GÜL

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Son 60 yılda plastiklerin kullanımı giderek artmıştır. Bu plastiklerin aşırı kullanımı, endüstriyel faaliyetlerden dolayı büyük çevre ve su kirliliğine neden olmuş, böylece amaçlarına bağlı olarak makro ve mikro boyutlu plastik üretmektedir. 2015'te kaydedilen plastik miktarı 322 milyon tondur. Araştırmacılara göre 5 ila 13 Mt plastik atık 2010 yılında okyanusa girmiştir. Büyük plastiğin daha küçük boyutlara kademeli olarak parçalanması mikroplastikleri oluşturur. Aslında 5 mm'den 1 mm'ye kadar olan plastikler mikroplastik (MP) olarak kabul edilir. Okyanuslar, denizler, göller, nehirleri ve çökeller dahil olmak üzere su kütlelerinde mikroplastiklerin anlık birikimi küresel bir sorun haline gelmiştir. Bunların gelecekte insan ve su hayvanları üzerindeki olumsuz etkiyi araştırmak ve ele almak için bilim adamlarının büyük ilgisini çekmiştir. Mikroplastikler üzerinde yapılan çalışmaların çoğu çoğunlukla okyanusa odaklanmıştır. Bu zamana kadar sedimanlardaki mikroplastikler üzerinde çok az çalışma yapılmıştır. Bu nedenle mikroplastikleri sedimandan ayırma konusu karmaşık kalmıştır. Bu çalışmanın temel amacı, mikroplastiklerin kıyı çökellerinde tanımlanması ve sistematik olarak ayrılmasına odaklanmaktır.

Bu amaçla kumsalın büyüklüğüne ve uzunluğuna bağlı olarak örnekleme yapılmıştır. Boğaziçi ve Güllük gibi daha geniş plajlar için, her noktada 50-100 m'lik bir şeritte hem kıyı şeridinde hem de arka kıyıda örnekler toplanmıştır. Tüm lokasyonlardan toplam 24 numune toplanmıştır. Yapılan elek analizleri sonucunda çökel çökellerinin çarpıklık, tasnif, basıklık ve ortalama tane boyutları tanımlanmıştır. Sedimentler Folk (1974) sediman sınıflandırmasına göre çakıl (G), kumlu çakıl (sG), hafif çakıllı kum (g)S ve çakıllı kum (gS) olarak sınıflandırılmıştır. Mikroplastikler, elle toplama, Damıtılmış su ile ayırma ve NaCl çözeltisi ile ayırma yöntemi gibi farklı metodolojiler kullanılarak ayrıştırıldı. Çalışma alanlarında toplam 7200g sediman kütlesinde toplam 1446 MP tespit edilmiştir. Polimerlerin türünü belirlemek için çeşitli MP'ler üzerinde Fourier Dönüşümlü Kızılötesi Spektroskopisi (FTIR) analizleri yapıldı. Sonuçlar, çeşitli çalışma alanlarında polietilen (PE), polivinil asetat (PVAC), Politetrafloroetilen (PTFE) ve Si–OH – bükme bandı ve SiOSi – çekme bandı içeren cam elyaflar dahil olmak üzere farklı polimerlerin net bir şekilde tanımlandığını gösterdi. Mikroplastiklerle ilgili morfoloji, mineralizasyon ve tortu özelliklerini belirlemek için Elektron mikroskobu (SEM), Enerji Dispersiv Spektrum (EDS) ve X-Işınları Difraktometresi (XRD) analizleri de yapılmıştır. Bulgularımız, hidrofilik minerallerin daha fazla mikroplastik tutma kapasitesinin yüksek olduğunu gösteriyor. İri taneli tortuların oranı arttıkça, bunlarda tutulan mikroplastik oranının nispeten düşük olduğunu da gözlemledik.

Bodrum Yarımadası'nda Güllük Formasyonu (Alt Triyas şist-kalşist), Pazardağı Formasyonu (Orta Triyas-Jura mermeri), Karadağ Formasyonu ve Kışladağ Formasyonu (Orta Jura-Kretase çörtlü kireçtaşları) ile Bodrum Formasyonu (Üst Kretase metakırıntılıları ve metakarbonatları) Miyosen klasikleri tarafından uyumsuz olarak üzerlenen Miyosen volkanikleri, Maden Tetkik ve Arama Enstitüsü (MTA) tarafından hazırlanan sayısallaştırılmış jeolojik harita kullanılarak Kuvaterner çökelleri ile haritalanmıştır.

Anahtar Kelimeler: Plastik, Mikroplastik, Kumsal sediman, Polietilen (PE), polivinil asetat (PVAC), Cam Elyaf, Hidrofilik mineraller, Bodrum Yarımadası

ABSTRACT

MICROPLASTIC CONTENTS AND SEDIMENT CLASSIFICATION OF SELECTED SITES IN BODRUM AND GÜLLÜK BEACHES (MUĞLA, SW TURKEY)

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The use of plastics has increased in the last 60 years. The excessive use of these plastics has caused great environmental and water pollution due to industrial activities, thus producing macro and micro-sized plastics depending on their purpose. The amount of plastic recorded in 2015 was 322 million tons. According to researchers, between 5 and 13 Mt of plastic waste entered the ocean in 2010. The gradual breakdown of large plastic into smaller sizes creates microplastics (MPs). Plastics from 5 mm to 1 mm are considered microplastics (MP). The instantaneous accumulation of microplastics in water bodies including oceans, seas, lakes, rivers, and sediments has become a global challenge. This has attracted great interest of scientists to study and address the negative impact on humans and aquatic animals in the future. Most of the studies on microplastics have focused mostly on the ocean. To date, very little work has been done on microplastics in the sediment. Therefore, the issue of understanding and separating microplastics from the sediment has remained complex. The main aim of this study is to focus on the identification and systematic separation of microplastics from coastal sediments.

For this purpose, sampling was carried out depending on the size and length of the beach. For wider beaches such as Boğaziçi and Güllük , the samples were collected on both shoreline and backshore at each 50-100m stretch at every point. A total number of 24 samples were collected from all locations. From the results of sieve analyses conducted, the skewness, sorting, kurtosis and average grain sizes of the sediment sediments were defined. The sediment was classified as gravel (G), sandy gravel (sG), slightly gravely sand (g)S and gravelly sand (gS) according to the Folk classification of sediment. Microplastics were separated using different methodologies such as hand picking, Distilled water separation, and NaCl solution separation method. A total number of 1446 MPs were determined in the overall mass of 7200g of sediments in the study areas. Fourier Transform Infrared Spectroscopy FTIR analyses were carried out on various MPs to identify the type of polymers. The results pointed out a clear identification of different polymers including polyethylene (PE), polyvinyl acetate (PVAC), Polytetrafluoroethylene (PTFE) and glass fibers containing Si-OH – bending band and SiOSi – tensile band in the various study areas. Scanning Electron

Microscope (SEM), Energy Dispersive Spectroscopy EDS and X-Ray Diffractometry (XRD) analyses were also carried out to identify the morphology, mineralization and sediment characteristics concerning microplastics. Our findings show that hydrophilic minerals have a high capacity to retain more microplastics. We also observed that as the proportion of coarse-grained sediments increases, the rate of microplastics retained in them is relatively low.

In Bodrum Peninsula, Güllük Formation (Lower Triassic schist-calcschist), Pazardağı Formation (Middle Triassic-Jurassic marble), Karadağ Formation, and Kışladağ Formation (Middle Jurassic-Cretaceous cherty limestones), as well as Bodrum Formation (Upper Cretaceous metaclastics and metacarbonates) which are unconformably overlain by Miocene classics, Miocene volcanic with Quaternary deposits, was mapped using the digitized geological map prepared by Mineral Research and Exploration Institute of Turkey (MTA).

Keywords: Plastic, Microplastic, Beach Sediment, Polyethylen (PE), polyvinil acetate (PVAC), Glass Fiber, Hidrophylic minerals, Bodrum Peninsula

TO MY FAMILY…

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Undertaking this MSc has been a wonderful step in my academic experience and it would not have been possibly achieved without the great support and guidance that I received from many people.

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1. INTRODUCTION

1.1. Microplastics Concept

Plastics as the subject has been indispensable to human life since the 1950s in many areas, including food packages, consumer products, medical devices, and the manufacturing industry, due to their low cost and lightweight (Galloway, 2015; SAM, 2019). By 2050, 33 billion tonnes of plastics are thought to be added to our world (Galloway, 2015). Preceding research has elicited that over 240 million tonnes of plastics are utilized annually (Brown et al. 2011). Commonly small pieces of plastic <5mm are evaluated as microplastic (Lusher, 2015; Thompson, 2015; Alomar et al., 2016; Barboza et al., 2018). In some studies, this limit has been taken as < 1mm (Galloway, 2015)(Figure 1.1.). Microplastics below 5 mm are estimated to account for 92% of plastic pollution in all oceans (Eriksen et al., 2014; Thompson, 2015; Suaria et al., 2016). But plastics below 100 nm are nano plastics, which are probably the least known and most dangerous (Koelmans et al., 2015). Microplastics can be found on the surface, in the water column, on the deep seafloor, and the coast of the seas (Hidalgo-Ruz et al., 2012; Lusher, 2015). Microplastic content in soil and freshwater is less studied (Galloway, 2015; Lusher, 2015).

Although the presence of plastic substances in seawater has been known since the 1970s, the presence of microplastics in sediment has only been noted in studies conducted after the 2000s (Alomar et al., 2016). Microplastics are formed by mechanical, photolytic-light, and/or chemical degradation of macroplastics (Browne, 2015; Alomar et al., 2016; Barboza et al., 2018). Microplastics; pre-production pellets-pellets, pieces of fishing line, package parts, pieces of plastic bottles, synthetic, textile parts, car rubber parts, paint chips (home and small boat used to paint plastics - polystyrene, acrylic, polyester, poly-allyl-diglycol-carbonate, urea-, melamine, and phenol-formaldehyde; 0.25–1.7 mm; DOD 1992), cosmetics, personal care products, spare parts, textile parts, electronic equipment parts, etc. (Browne, 2015; Barboza et al., 2018). Microplastics can be quite different in shape (angular-spherical-fibrous) and quite different in color (Thompson, 2015).

Industrial activities on land, urbanization activities, and transport in coastal areas are important sources of microplastics. Their transport, on the other hand, can be by rivers (or by air) (Barboza et al., 2018). In addition, activities such as oil and natural gas extraction and fish farms performed directly on the seas are other resources (Barboza et al., 2018). Microplastics can be included in the food chain, which extends from plankton to many marine vertebrates and invertebrates or even humans (Koelmans, 2015; Lusher, 2015; Guven et al., 2017; Rist et al., 2018). But because microplastics are made from complex polymers that are resistant to degradation, there is a risk of serious effects on human health (Galloway, 2015). Contact with microplastics can be through the mouth, skin, or breathing (Galloway, 2015).

In this project, the study of microplastic contents in the beach sands of four selected beaches on the Bodrum coast was conducted. Twenty-four samples were collected throughout the selected areas. To separate the microplastics from the beach sediments, the following analysis was performed; sieve analysis, visual identification, separation with different densities of solutions (distilled water and NaCl solution), To determine the type of microplastics and compare their relationship with the sediments in terms of the size variation and accumulation processes, FTIR analysis XRD, SEM analysis was carried out.

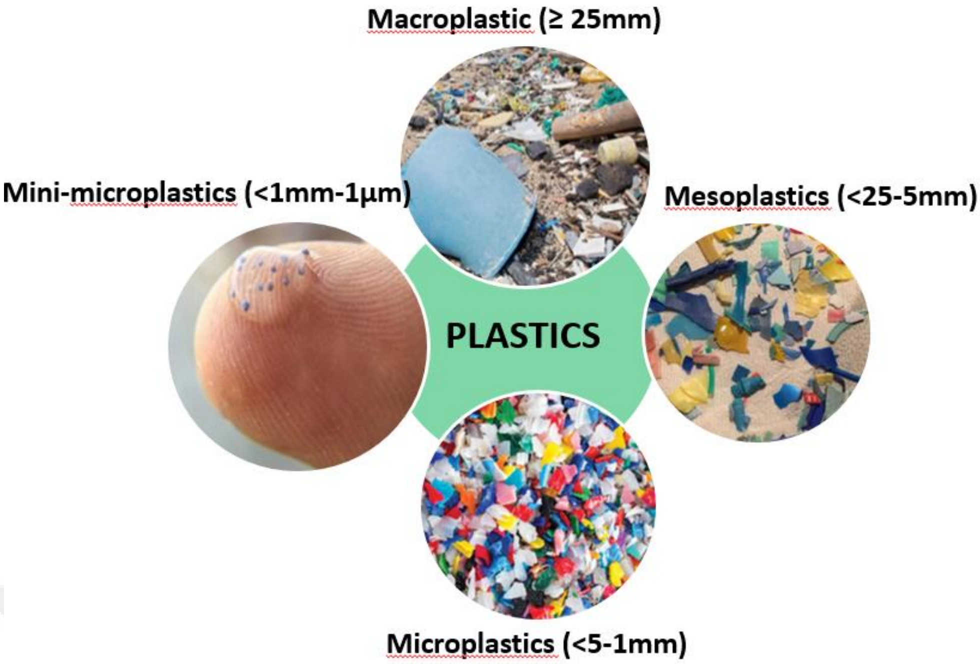


Figure 1.1. Categories of Plastics (Modified from Jeyasanta et al., 2020)

1.2. Purpose and Scope

Plastic waste has become one of the major global challenges. The accumulation of macro plastics, microplastics, and even nano plastics in seawater, seabed, and coastal sediments have spotlighted scientists to conduct numerous studies. Although many microplastic studies have been conducted in the world, there are very limited studies conducted in Turkey. Most of these studies are focused on microplastic content in seawater, microplastic content in seabed sediments, and microplastic content in the digestive systems of organisms such as fish mussels. However, the subject of understanding and separating microplastics from sediments has remained intricate.

The study of microplastics in beach sediment, their accumulation processes, and finding the ultimate procedure of separating them from sediments is a challenging topic, therefore, has not been studied yet in the selected study area. The area selected for this study is also favorable due to its high population and tourism. For a better estimation of microplastic contamination in the various selected areas, a standard sampling method will be applied. In the extraction and separating processes, all previously applied techniques such as handpicking method, distilled water separation method, NaCl separation method, Stereo microscope technique, FTIR analysis XRD analysis, etc. will be performed to come out with a unique step of identifying and separating microplastics from beach sediments.

The purpose of this study is (1) to identify and characterize beach sediments in Bodrum, Turgutreis, Güllük, and Boğaziçi in Bodrum Peninsula SW of Turkey, and (2) to determine microplastics content in the shoreline and backshore area of each selected beaches and (3) to discuss the microplastic distribution, microplastics-beach sediment size relation.

The research questions to be answered are formulated as follows:

- How many microplastics are gathered on Bodrum Peninsula coasts?
- Are there any differences in the microplastic content of the shoreline and back shores of the selected beach?
- Are sediment sizes having a relation with microplastic content?

1.3. Description of the Study Area

The selected areas for the study are located in Mugla, specifically the SW part of Turkey which is known as the Bodrum Peninsula (Figure 1.2.). The Bodrum Peninsula, which stretches west into the Aegean and borders the Mediterranean, is home to a dozen resort towns and villages along its shores, the most notable of which is Bodrum. Every island has its beach (https://turkeytravelplanner.com/). The population of these vicinities increases rapidly during this period. According to the mayor of Bodrum, the population which normally hovers around 180.000, jumped to 400.000 after the settlement of summer house vacationers (https://www.aa.com.tr/en/economy/turkish-tourism-hotspot-bodrum accessed 30.04.2021).

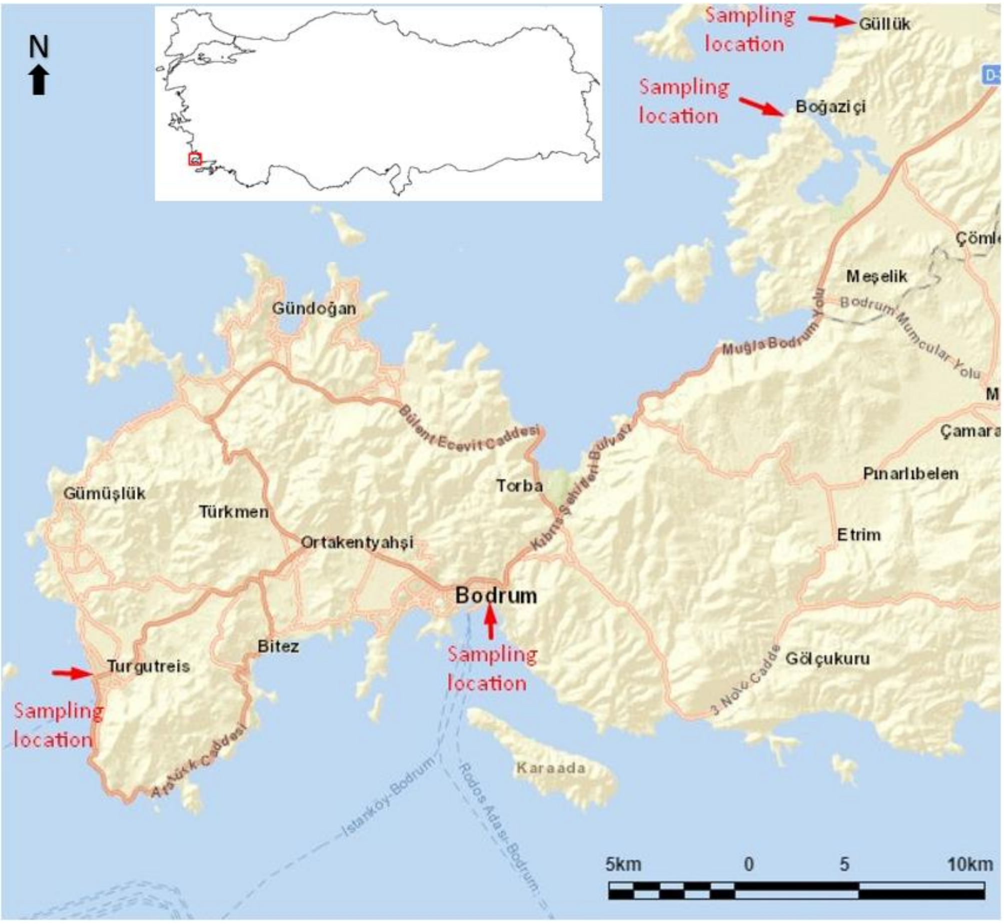


Figure 1.2. The map indicates the location of the study area

(http://yerbilimleri.mta.gov.tr/home.aspx accessed 01.04.2021)

2. LITERATURE REVIEW

2.1. Previous Studies on the Microplastic

2.1.1. Microplastic Determination Methods

Considering the range of studies that have been conducted previously, a lot of assumptions and random sampling methods were applied to determine microplastics. For example, Besley et al. (2017) used a random sampling method to investigate microplastics in beach sands. They emphasized the need to standardize the time and number of repeat extractions for comparison throughout the studies. Alomar et al. (2016) evaluated the deposition of microplastic in a given sediment grain fraction and realized that MPs were most abundant in marine protected regions. Alomar et al. (2016) pointed out that MPs intensity does not rise with lessening sediment grain size. Microplastic contamination of the ocean has a high impact not only on the ecological system but also on human health as a result of the food chain (Barboza et al. 2018)(Figure 2.1.). Understanding the procedures entailed in the absorption of microplastics into human tissues and their possible consequences on human health should be a top priority study, according to Barboza et al. (2018). Browne (2015) stated that numerous researchers have made an effort to examine the sources of microplastic, however, sources and pathways are poorly known due to the absence of a hypothesis-driven framework. As a geologist, this future study will also focus on examining and comparing the depositional processes of the sediments and classifying them to understand the source of microplastics and which group is highly concentrated.

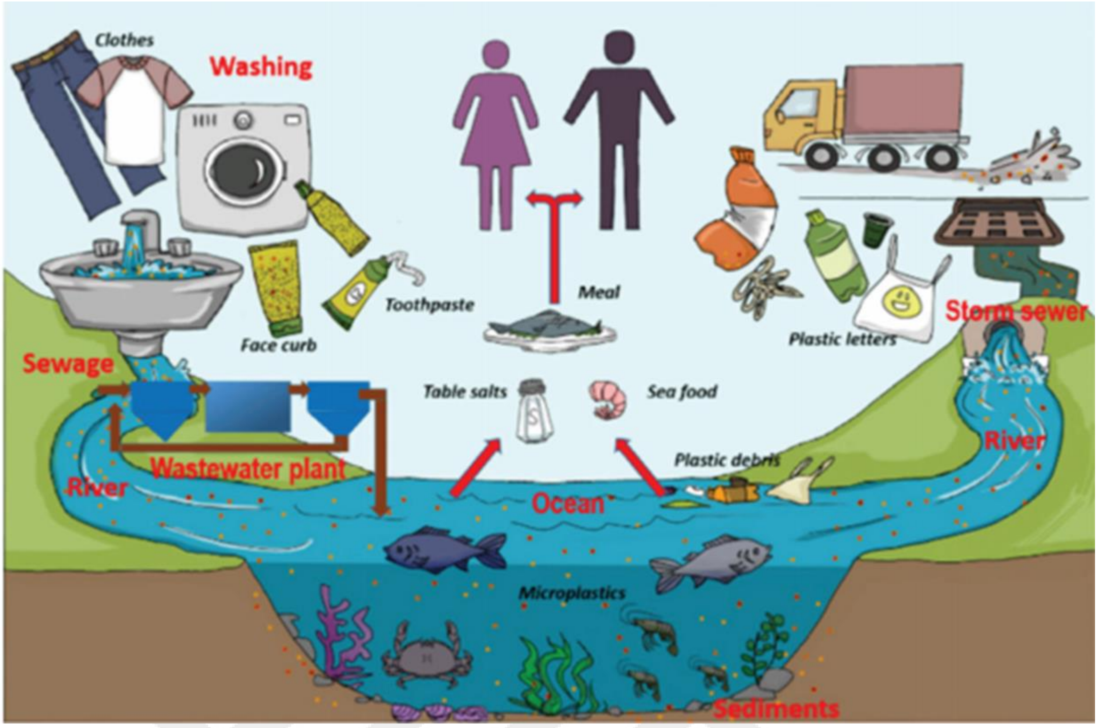


Figure 2.1. Microplastic pollution in the marine habitat and consequences on the food chain (Anderson et al., 2016)

2.1.1. Microplastic Content in Different Regions

(I) Global Perspective

Microplastic pollution of the marine environment has raised issues of public health and the environment on a global scale within the last decade (Perumal and Muthuramalingam, 2022). Microplastics-containing cosmetics are prohibited in many nations, including Canada and the United States due to their negative environmental consequences (Ballent et al., 2016). Microplastics in high amounts have been discovered in Arctic sea ice (Obbard et al., 2014). They can be included in the food chain, ranging from plankton-fed marine vertebrates to invertebrates and even humans (Koelmans, 2015; Lusher, 2015; Güven et al., 2017; Rist et al., 2018). But microplastics are produced from complex polymers resistant to degradation, there is a risk of serious effects on human health (Galloway, 2015). Contact with microplastics can be by mouth, skin, or respiratory (Galloway, 2015). Browne et al., (2011) examined the spatial distribution of microplastic along the coasts of six continents to see whether there are any correlations between sources and sinks (Figure 2.2.). They demonstrated the following hypotheses; more microplastic will be found in ecosystems that accumulate smaller sediment particles and in places with higher human population density. Sewage disposal is crucial in proving that microplastics were recovered from wastewater released by sewage treatment and serve as a source of microplastics for the marine environment. The result indicated that MPs fibers were predominantly obtained from sewage through washing clothes instead of fragmentation (Browne et al., 2011).

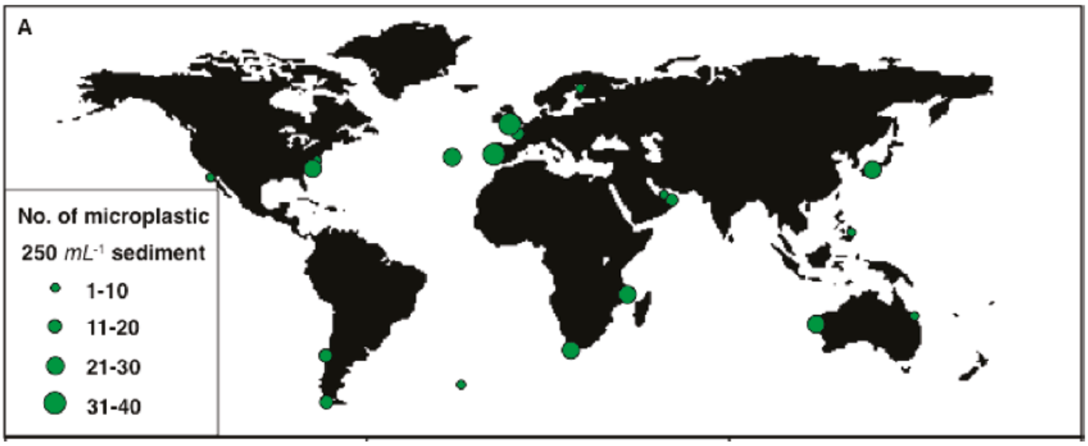


Figure 2.2. Microplastic in sediments from 18 sandy beaches throughout the world (from Brown et al., 2011)

(II) The Mediterranean

When it comes to marine debris, the Mediterranean Sea is among the most polluted place in the world. (Gündoğdu and Çevik, 2017; Cincinelli et al., 2019; Constantino et al., 2019). Even the term Mediterranean Plastic Soup is used in the literature because it has the densest amounts of garbage in the world (Constantino et al., 2019). The Mediterranean coast is home to more than 150 million people, the lack of a treatment system in some countries, the existence of busy travel areas, and summer tourism lead to an increase in marine pollution here (Cincinelli et al., 2019; Constantino et al., 2019).

As stated by Cincinelli et al., (2019), plastic floating particles made up as much as 100% of the trash found in the central region of the basin, where detailed visual surveys were conducted, indicating that plastics are the most prevalent substance observed. Recent estimation showed that the Mediterranean Sea receives 100.000 tons of plastic annually, of which 50% is thought to come from land-based sources, 30% from riverine systems, and 20% from maritime navigation. The accumulation of plastics gradually degrades with time as a result of plastic fragmentation to obtain microplastics and nano plastics (Cincinelli et al, 2019). Cincinelli et al., (2019) also mentioned that plastic debris ingestion by aquatic animals has been well documented that marine creatures may mistake MPs for food or consume MPs indirectly through contaminated prey. Ingestion of MPs by marine biota has several implications, including decreased stomach storage capacity and a weakened sense of satiation, all of which influence eating behavior. Internal wounds in the gastrointestinal tract (e.g. perforated gut or gastric rupture) may result from ingestion, leading to death.

(III) Turkey

Sea surface water samples in the Black Sea in Turkish seas (Aytan et al., 2016), Marmara Sea surface water samples (Tunçer et al., 2018), the presence of microplastics in sea surface water samples, water column samples, seabed sediment samples, coastal sediment samples, and various marine organism species have been reported in the north-eastern Mediterranean (ÇŞB, 2017; Gündoğdu and Çevik, 2017; Güven et al., 2017; Kıdeyş, 2017; Gündoğdu et al., 2018). In the Aegean Sea coasts as part of the general European coasts, Lots et al. (2017), sampling from the coast of Dikili also revealed its microplastic content. Other than that, Yabanlı et al. (2019) revealed microplastic content in the south of Datça Peninsula which includes Aktur, Surf Camp, Ovabükü, and Kurucabük coastal sediments.

3. GENERAL GEOLOGY OF THE STUDY AREA

3.1. Regional Geology

Bodrum peninsula hosts Lycian nappes units and young sediments surrounding the south of the Menderes Massif (Figure 3.1.). The Lycian nappes outstretching up to Beydağları Autochthon of the Antalya-Muğla boundary in the south contain thrust slices (Triassic-Cretaceous - Paleocene) consisting of sedimentary rocks of different components which contain ophiolitic-ophiolitic mélange thrust slices (Late Cretaceous) that overlie them tectonically (Ersoy, 1990; Collins and Robertson, 1997, 1998, 1999, 2003; Robertson, 2000).

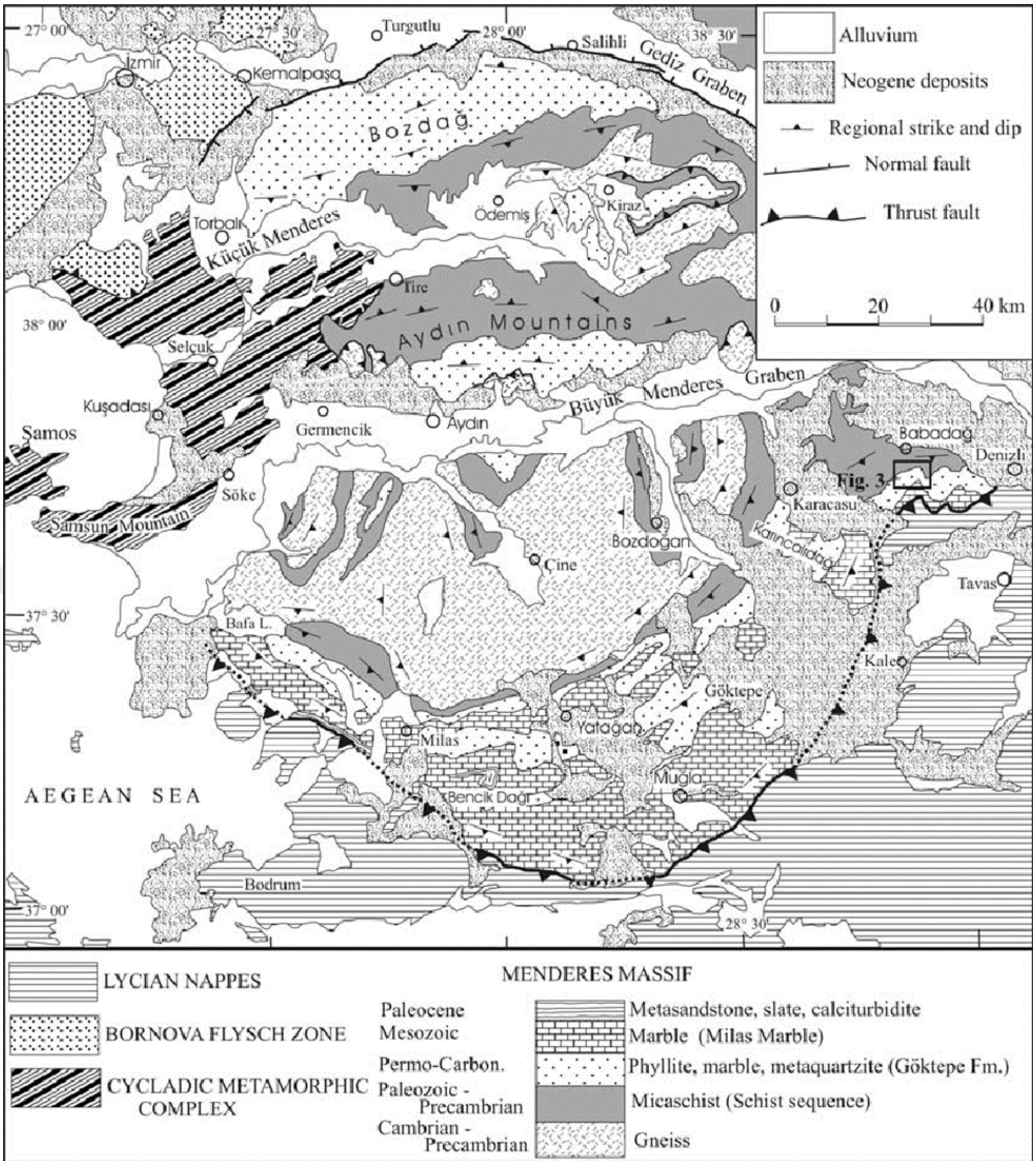


Figure 3.1. Geological map of the Menderes Massif and Cover units (Okay, 2007)

3.2. Local Geology

Considering the digitized geological map prepared by MTA, in Bodrum Peninsula, Güllük Formation (Lower Triassic schist-calcschist), Pazardağı Formation (Middle Triassic-Jurassic marble), Karadağ Formation, and Kışladağ Formation (Middle Jurassic-Cretaceous cherty limestones) as well as Bodrum Formation (Upper Cretaceous metaclastics and metacarbonates) which are unconformably overlain by Miocene classics, Miocene volcanic with Quaternary deposits have been mapped (Ercan et al., 1982; Akbaş et al., 2011).

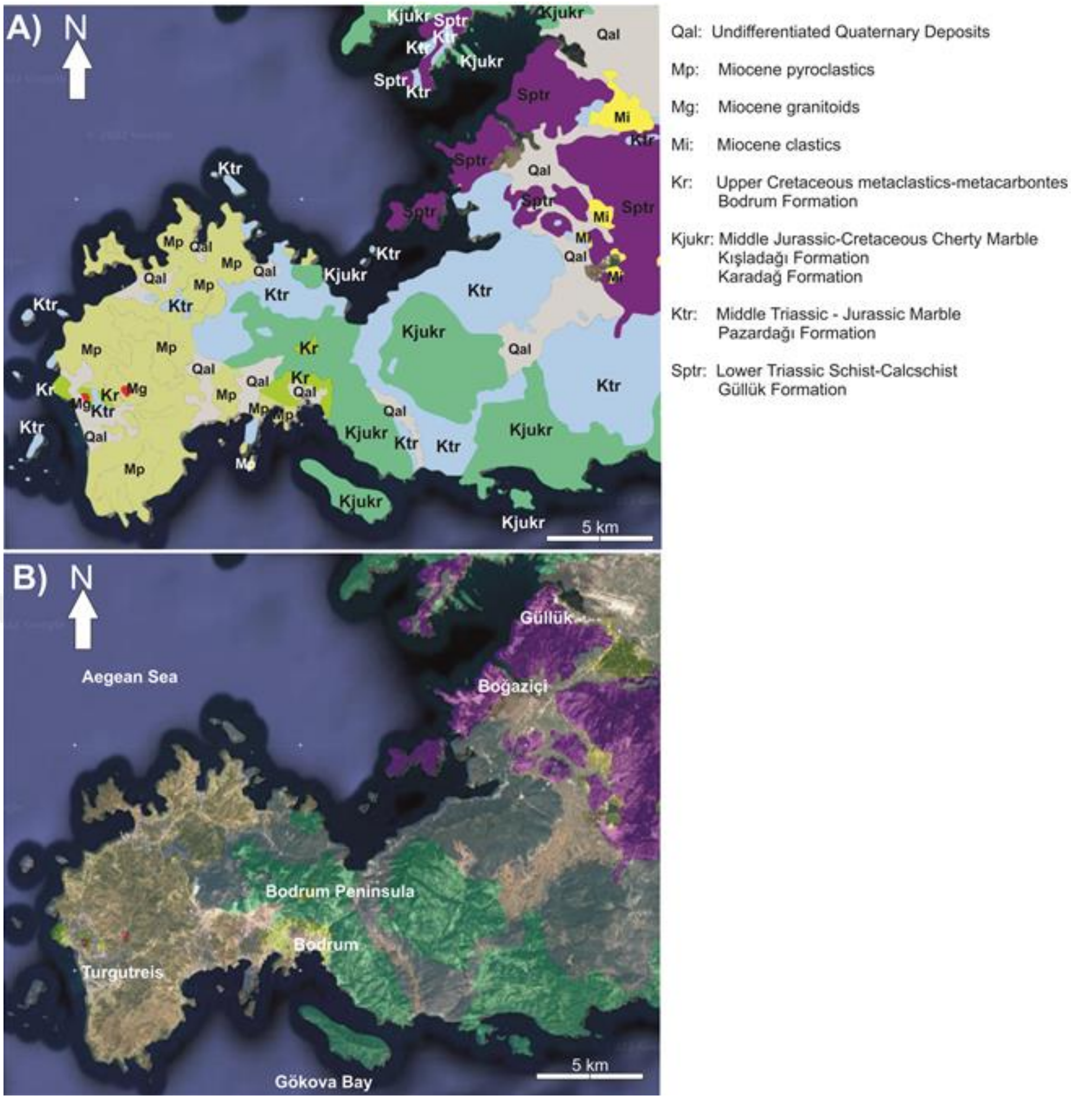


Figure 3.2. A) General geological map of Bodrum peninsula B) Relationship between the investigated beach areas and general geology (Ercan et al., 1982, 1984; http://yerbilimleri.mta.gov.tr/home.aspx accessed 29.04.2021; changed from Akbaş et al. 2011)

Since both lithology and age grouping was prepared by considering the units in Turkey during the digitization, the differences can be observed in the age data and lithology contents of the existing articles. Güllük Formation (Sptr), which is the oldest unit in the study area consists of units such as Upper Permian - Lower Triassic conglomerate-sandstone-shale and has undergone mild metamorphism (Ercan et al., 1982, 1984). The Güllük formation is conformably overlain by the unit consisting of Upper Triassic-

Upper Liassic aged mostly massive, locally thick layered, white-colored limestones, gray-colored dolomites with alternation units which were termed as the Pazardağı Formation (Ktr) (Ercan et al., 1982, 1984). The unit consisting of Upper Triassic-Lower Malm aged silty marl limestones concordant to the Pazardağı Formation was named the Karadağ Formation (Kjukr) (Ercan et al., 1982, 1984). This unit also includes chert bands. The Karadağ Formation which is conformably overlain by gray-colored, uniform thin-medium layered containing abundant shell particles, chert bands distributed in some places and contain nodules of Upper Jurassic-Lower Cretaceous pelagic limestones was defined as Kışladağ Formation (Kjukr) (Ercan et al., 1982, 1984). The unit called the Bodrum Formation (Kr), which consists of Campanian-Maastrichtian aged wild flysch deposits, contains alternations of conglomerate, sandstone and siltstone. In the lower levels, large blocks are located within the brecciated zones (Figure 3.2.; Ercan et al., 1982). The non-fossilized units, which consist of yellow-grey colored, thin, smooth sandstone marl-claystone layer alternations, reported in Cenozoic units, were distinguished as Koyunbaba Formation (?) (Ercan et al. 1982). Volcanic rocks (Mg, Mp) crop out in the west of the peninsula. Monzonitic, calc-alkaline andesite, trachyandesite, latite, and dacite lavas from the Middle Miocene, especially in the Bodrum peninsula, resulted in the latest olivine basalt type volcanic rock evolution (Ercan et al., 1982, 1984; Genç et al., 2001; Kurt and Arslan, 2001; Ulusoy et al., 2004; Karacık, 2006). All these aged units are unconformably overlain by the recent Quaternary aged (Qal) fluvial deposits and coastal sand dunes (Ercan et al., 1982; Figure 3.2.).

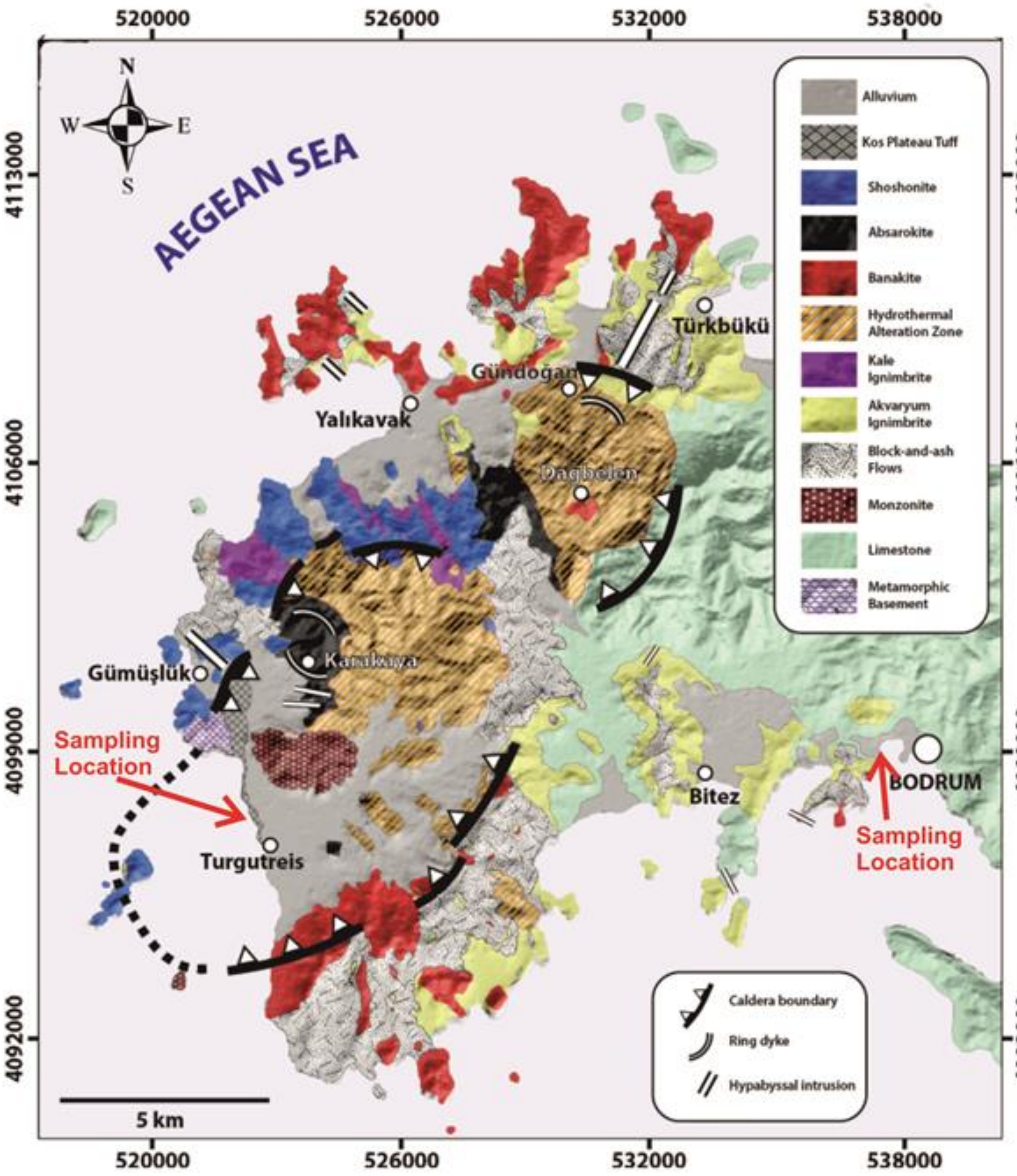


Figure 3.3. Geological map showing the distribution of volcanic units in the west of Bodrum Peninsula. (Modified from Ulusoy et al. 2004 andÇubukçu et al., 2019)

Considering Turgutreis beaches, it is understood that they are located at the edge of a deltaic area limited by different types of rocks (Figure 3.2B, Figure 3.3.). Limestones of the Pazardağı Formation and clastics of the Bodrum Formation provide sediment to the delta, albeit in limited quantities. Rocks such as the main component monzonite, alteration zone products, block and ash flows, ignimbrite, banakite, absarokite (Ulusoy et al., 2004; Çubukçu et al., 2019) first formed the source of the delta and then the coastal sediments (Figure 3.3.).

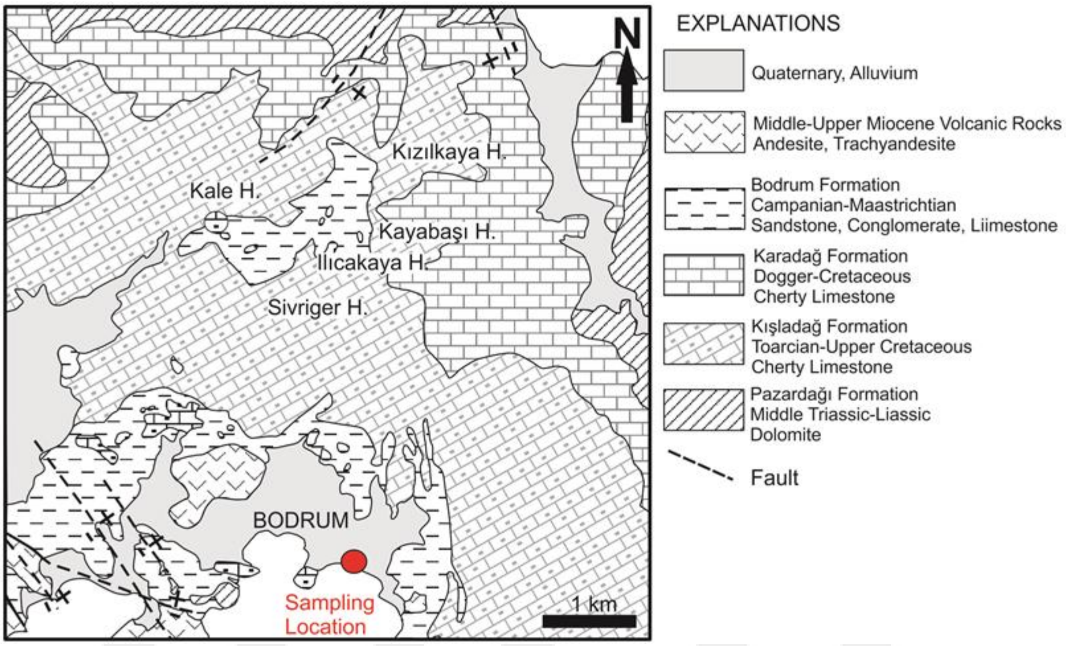


Figure 3.4. Geological map of Bodrum area (http://yerbilimleri.mta.gov.tr/home.aspx: accessed 29.04.2021; modified from Ercan et al., 1982, 1984; Akbaş et al. 2011)

Looking at Bodrum Beach, there are Pazardağı Formation marbles, Kışladağ and Karadağ Formation cherty marbles, Bodrum Formation clastic sediments, andesite-trachyandesitic volcanic rocks (Figure 3.4; Ercan et al., 1982, 1984) and rocks consisting of ignimbrite and block-ash flows (Figure 3.3.) in the source area (Figure 3.3.; Ulusoy et al., 2004; Çubukçu et al., 2019).

4. METHODOLOGY

4.1. Field Sampling

Samples were collected in 4 different locations (Figure 4.1.). The sampling strategy follows Besley et al., (2017) methodology. The samples were taken depending on the size and length of the beach. For wider beaches such as Boğaziçi and Güllük Güllük, the samples were collected on both shoreline and backshore at each 50-100 m stretches at every point. For Bodrum and Turgutreis, the samples were collected along the shoreline only. A sampling quadrant measuring 100 by 100 cm was put at each point to be sampled, and sampling was conducted. The top 5 cm of the sampling quadrant's four corners and its center were then used to collect samples (Figure 4.2.). The method was repeated at every point where samples were collected. However, for locations that have narrow beaches such as Bodrum and Turgutreis, the samples were collected on their specified shoreline. A total number of 24 samples, 1 kg each were gathered in these locations (Table 1.1.).

Table 1.1. The total number of samples gathered from the study area

Location	Sample No	Mass of Sample (Kg)	Sample code	Total Number of Samples
Bodrum	1	1	B1	24
	2	1	B2	
	3	1	B3	
	4	1	B4	
	5	1	B5	
	6	1	B6	
Turgutreis	7	1	T1	
	8	1	T2	
	9	1	T3	
	10	1	T4	
	11	1	T5	
	12	1	T6	
Güllük	13	1	G1	
	14	1	G2	
	15	1	G3	
	16	1	G4	
	17	1	G5	
	18	1	G6	
Boğaziçi	19	1	BO1	
	20	1	BO2	
	21	1	BO3	
	22	1	BO4	
	23	1	BO5	
	24	1	BO6	

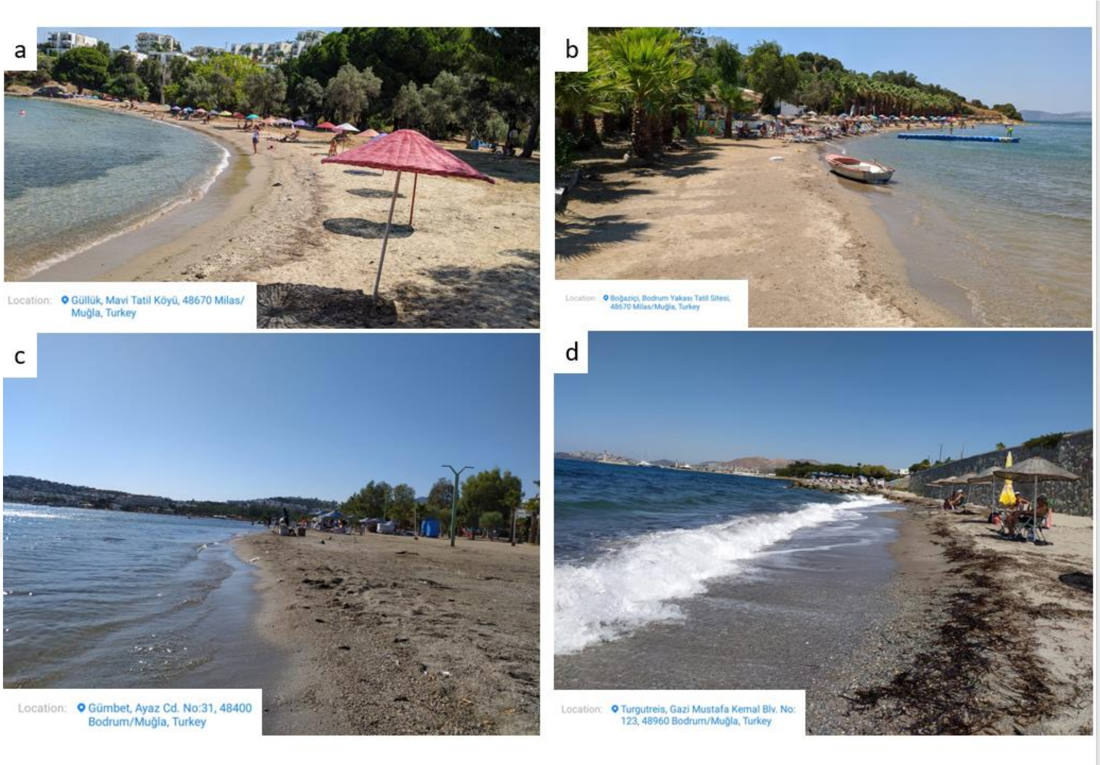


Figure 4.1. Location of the selected sampling areas, a) Güllük b) Boğaziçi c) Bodrum and d) Turgutreis

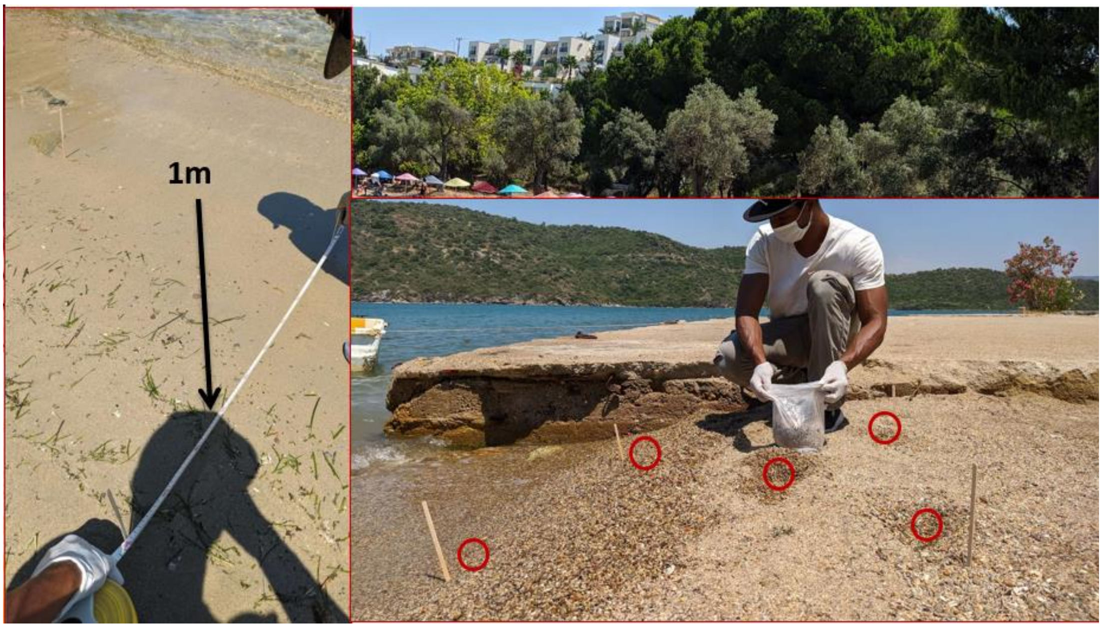


Figure 4.2. The field sampling technique applied in the selected sites (Besley et al., 2017)

4.2. Sieve analysis

To separate all 5 mm particle sizes from the bulk samples and also classify the sediment samples, sieve analysis was carried out through the entire samples using Retsch Test Sieves (Figure 4.3.). To commence the experiment, the sediment samples were initially dried completely at a normal room temperature for one week.

During sieving, the samples were subjected to vibratory sieving for 5 mins. The likelihood that a particle will pass through the sieve mesh is determined by the particle's size related to the mesh openings, its orientation, and the number of interactions it has with the apertures. (https://www.retsch.com, accessed 27.04.2022).

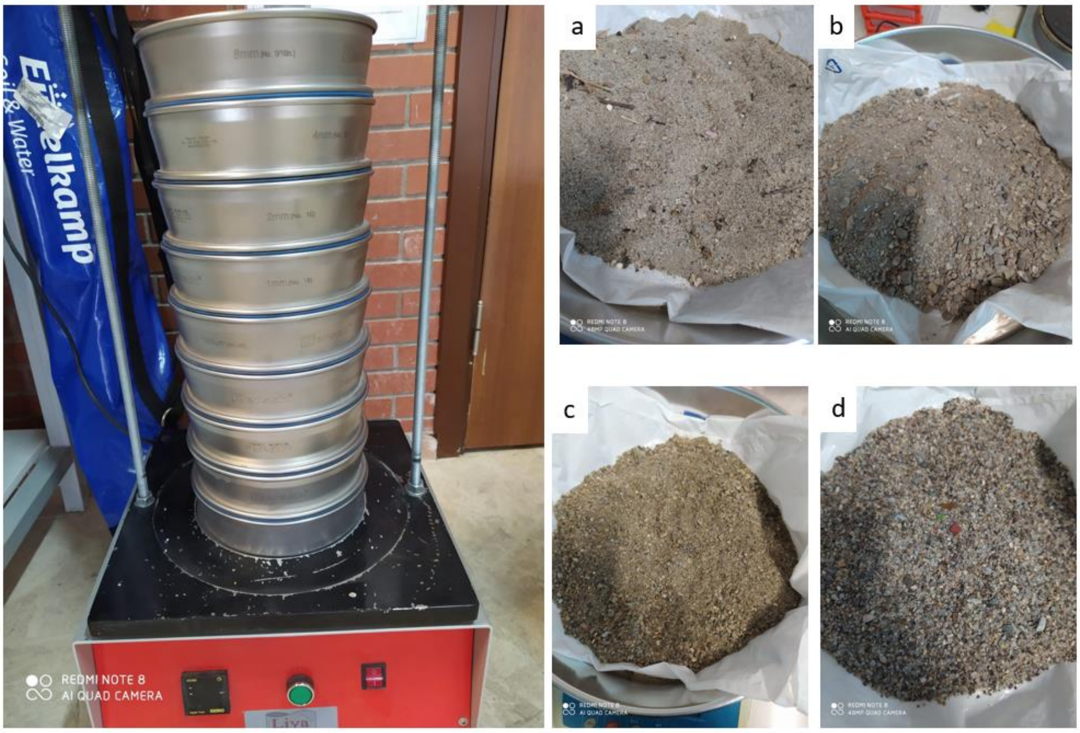


Figure 4.3. Sieve analysis conducted in the laboratory for grain size separation

The grain sizes of the samples were detailly evaluated and classified by following the Folk (1974) and Wentworth (1922) classification of sediments diagrams (Figure 4.4., Figure 4.5.).

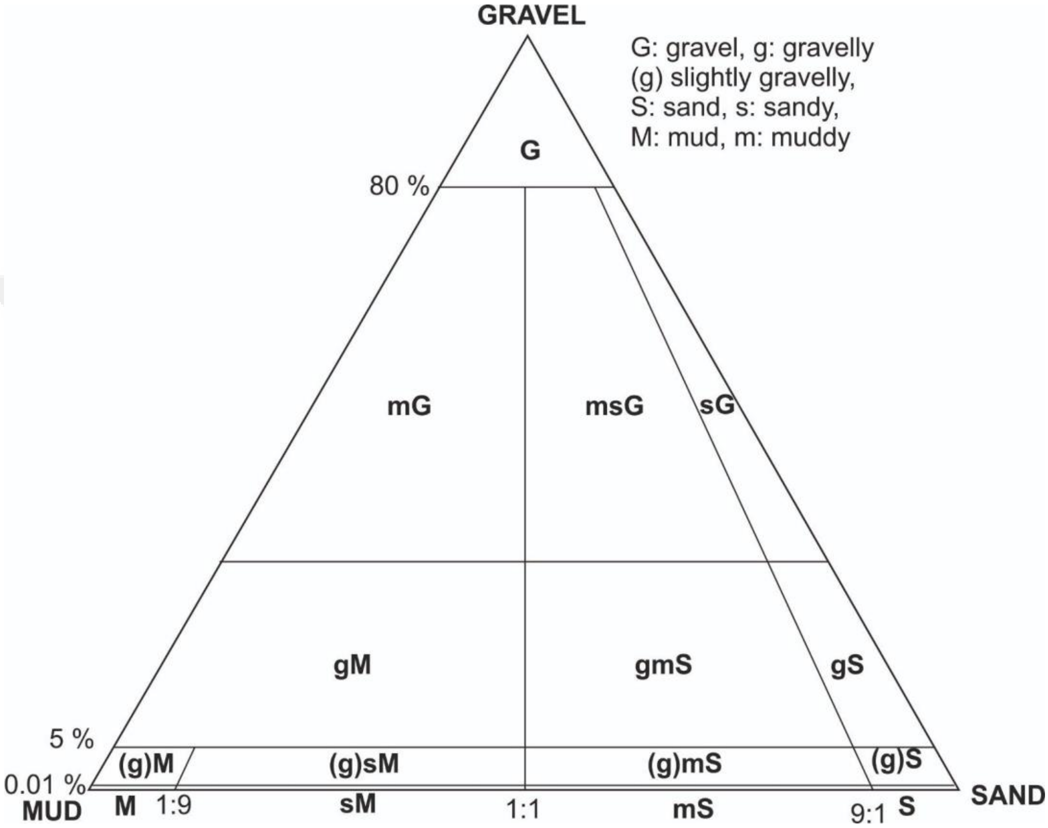


Figure 4.4. Classification of sediments (Folk, 1974)

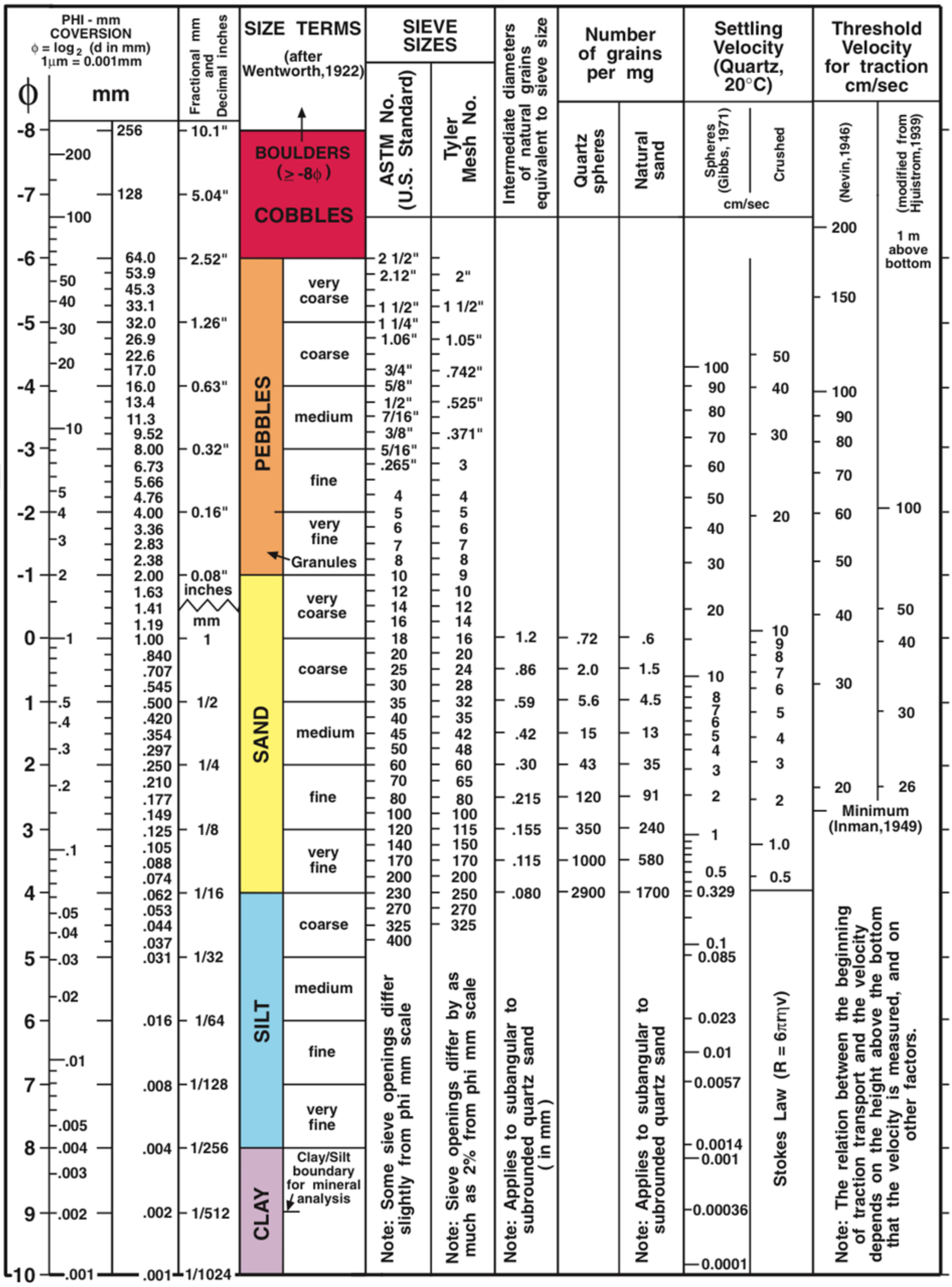


Figure 4.5. Wentworth (1922) grain size classification

4.3. Microplastic Separation Techniques

After separating sediments below 5mm from the bulk samples in each of the 24 samples, microplastics were separated/extracted from the sieved samples by hand-picking method and flocculation method. The flow chart below summarises microplastics extraction techniques (Figure 4.6.).

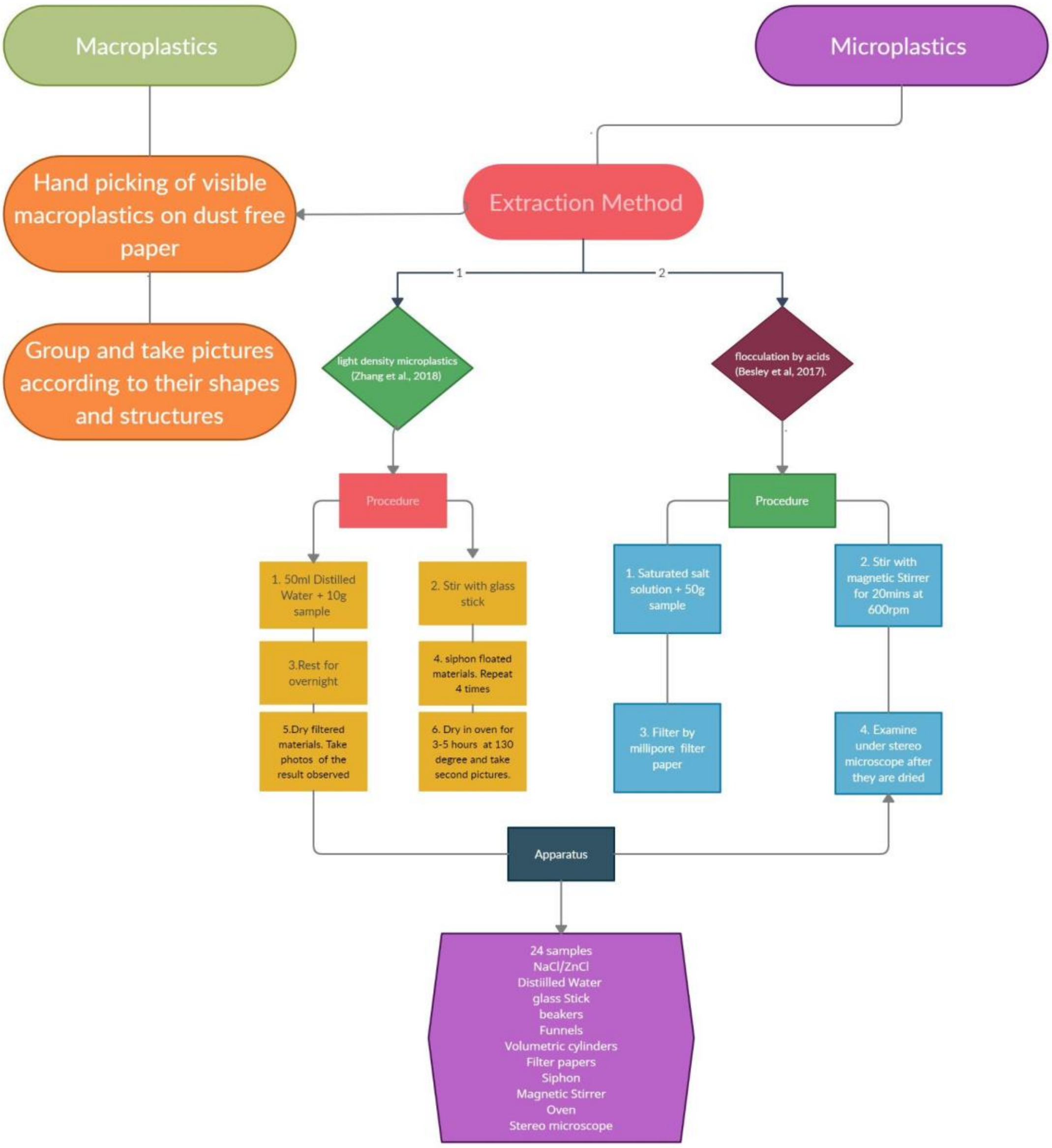


Figure 4.6. Flow chart for microplastic separation applying different methodologies depending on MP sizes and densities

4.3.1 Microplastics extraction by Handpicking method

100 g of sediments were separated from each sieved sample. The samples were then investigated visually to identify microplastics (MPs). The identified MPs were separated with small size tweezers and counted accordingly (Figure 4.7.).

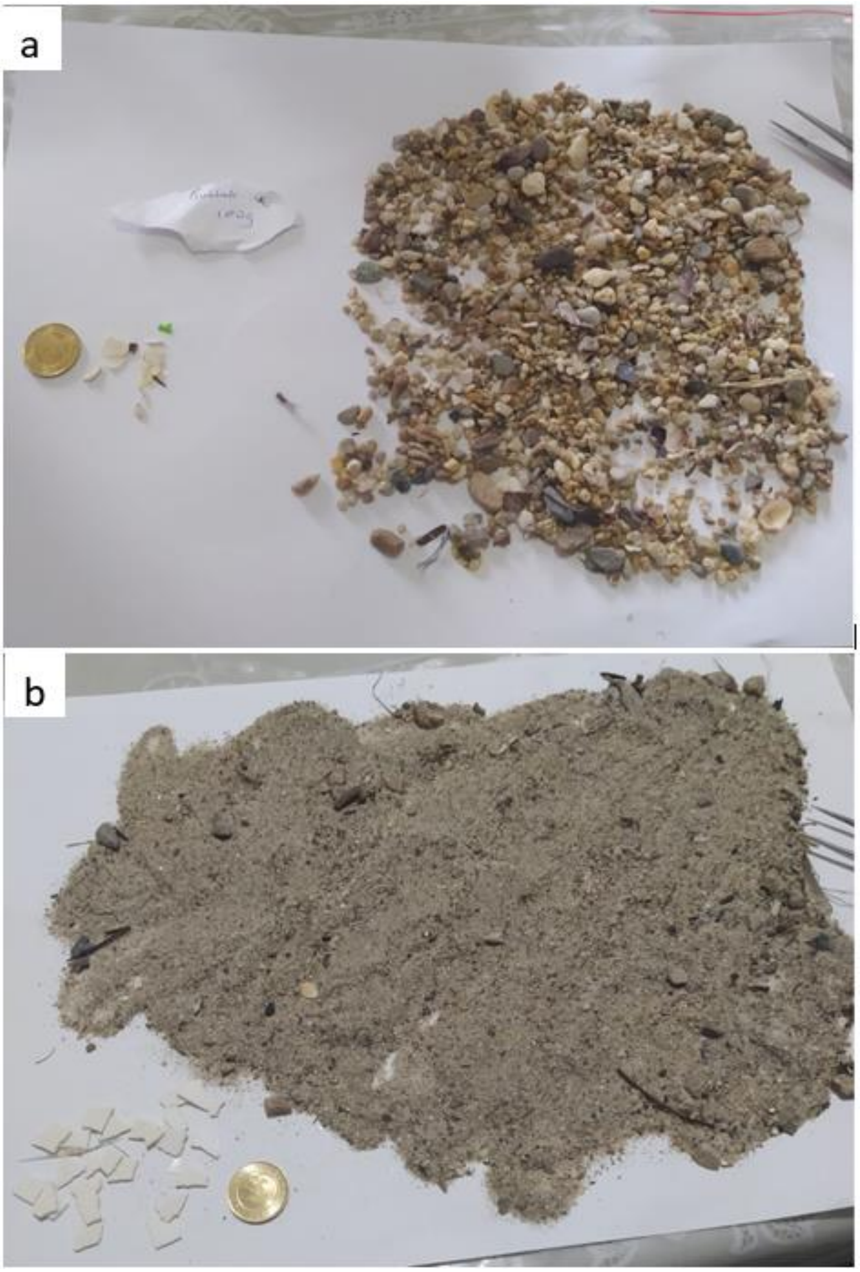


Figure 4.7. MP separation by handpicking method

4.3.2 Microplastics (MPs) extraction by flocculation (NaCl solution) method

358.9 g of NaCl were dissolved in 1 L of demineralized water, which has a density of 9043 kg/m3 at 20 °C, to provide a fully-saturated salt solution for each experiment. The mixture was agitated for 60 °C at 600 rpm until all of the salt was dissolved. After allowing the salt solution to cool, Millipore filter sheets were used to filter out any contaminants. The salt solution must be filtered because prior research revealed that table salt contains microplastic contamination (Yang et al., 2015). A mixture of dried sand and salt solution was prepared (ratio of 100 g dried sand in 400 mL of salt solution). A magnetic stirrer was used to stir the mixture for two minutes at a speed of 600 rpm. Carefully emptied into a filtration system, the supernatant was then run through Millipore filter sheets. The filter sheets were then scrutinized using stereo microscopes with a magnification of up to 40 times. The detected microplastics were methodically counted. This made it possible to measure the number of microplastics between 0.3-5 mm (NOAA, 2015). The MPs were classified as fiber-; film-; particle- and tubular morphologies with various colors. The experiment was repeated for all the selected samples (Figure 4.8.).

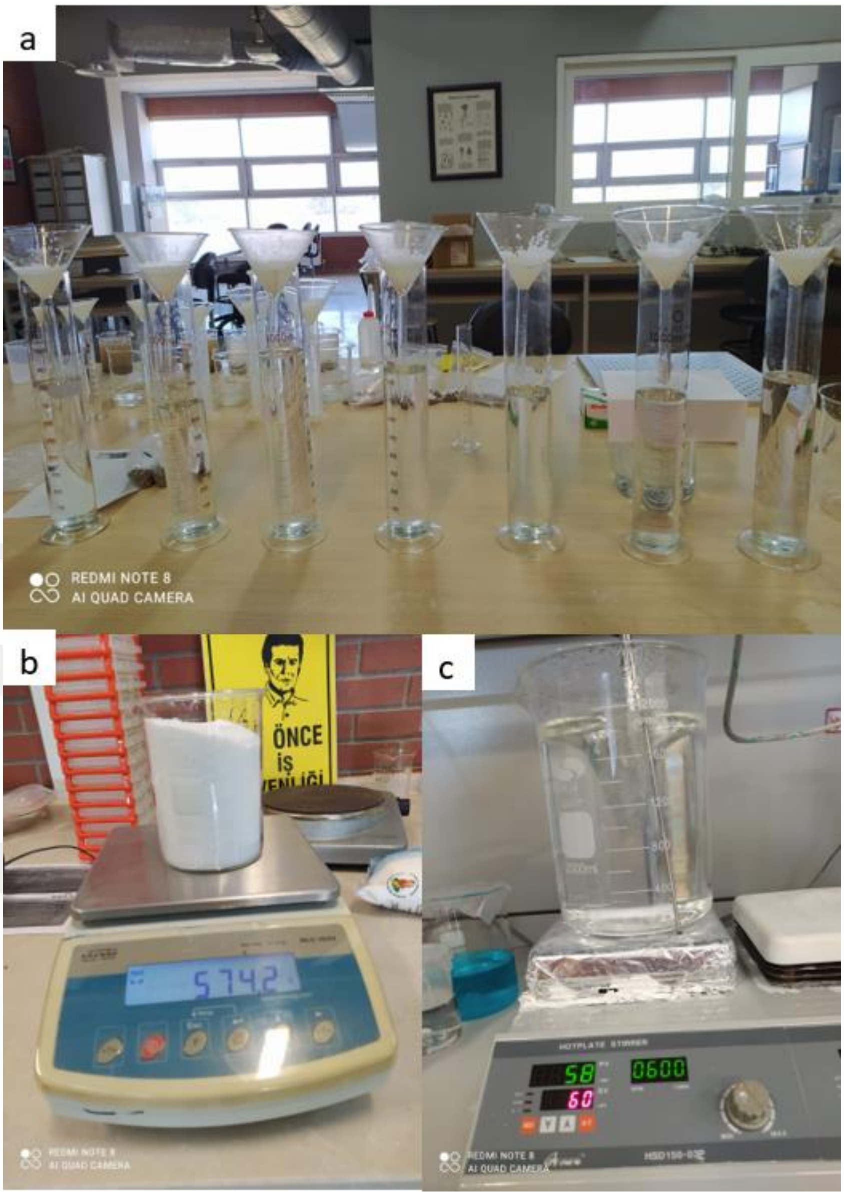


Figure 4.8. Set up for MPs extraction by flocculation method (NaCl solution)

4.3.3 Light Density Microplastic Extraction Method

Zhang et al. (2018), mentioned that distilled water is the most practical method for eliminating polyethylene (PE) and polypropylene (PP) light density microplastics. For this experiment, 500 ml of distilled water was mixed with 100 g of the sediment sample.

The mixture was stirred continuously with a glass stick to achieve homogeneous suspension. The mixture was allowed to rest overnight. The floating materials include MPs, sediments, and some organic matter. were then collected by siphoning. This procedure was repeated up to four times until all the suspensions remained clear. All the siphoned supernatants were filtered. The filtered materials were dried out at 60 °C. Pictures were taken under a microscope, then they were dried in the oven at 130 ºC for 3-5 hours and the second photos were taken to compare particle variations in shapes and sizes. The experiment was repeated for all the selected samples (Figure 4.9.).

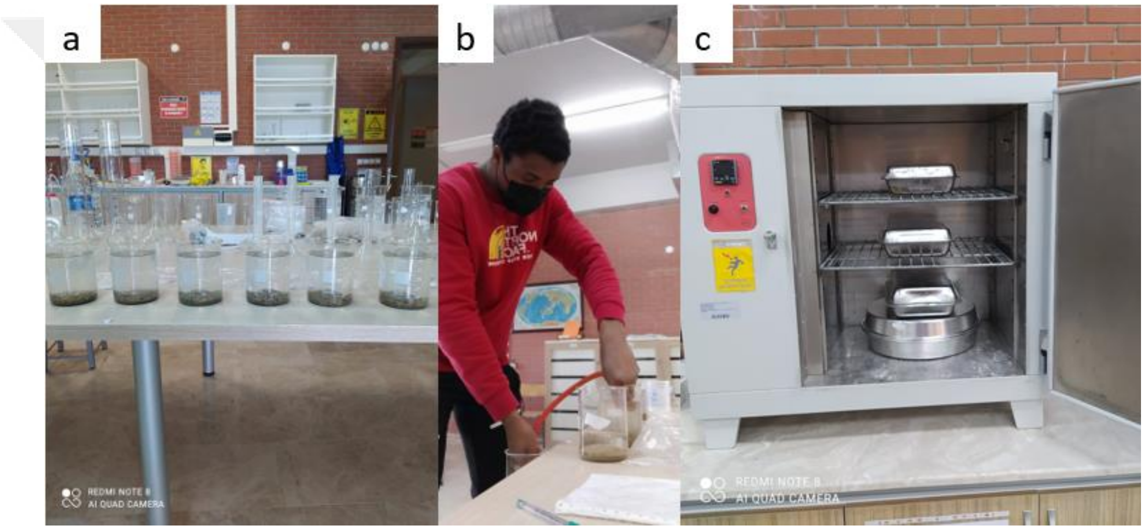


Figure 4.9. Set up for light density MPs extraction

4.3.4 Microscopic Identification of MPs

After flocculation and light density separation methods, all the dried filter papers on which the MPs are collected were closely examined under a stereomicroscope, to identify the microplastic types. In total 48 millipore filter papers containing MPs were investigated. Each filter paper was imaginarily divided into either two or four quadrants under the microscope depending on the dominance of the MPs. Photos of the MPs were taken in every quadrant (Figure 4.10.). According to their type, color, and shape, all the MPs that were identified were counted and categorized.

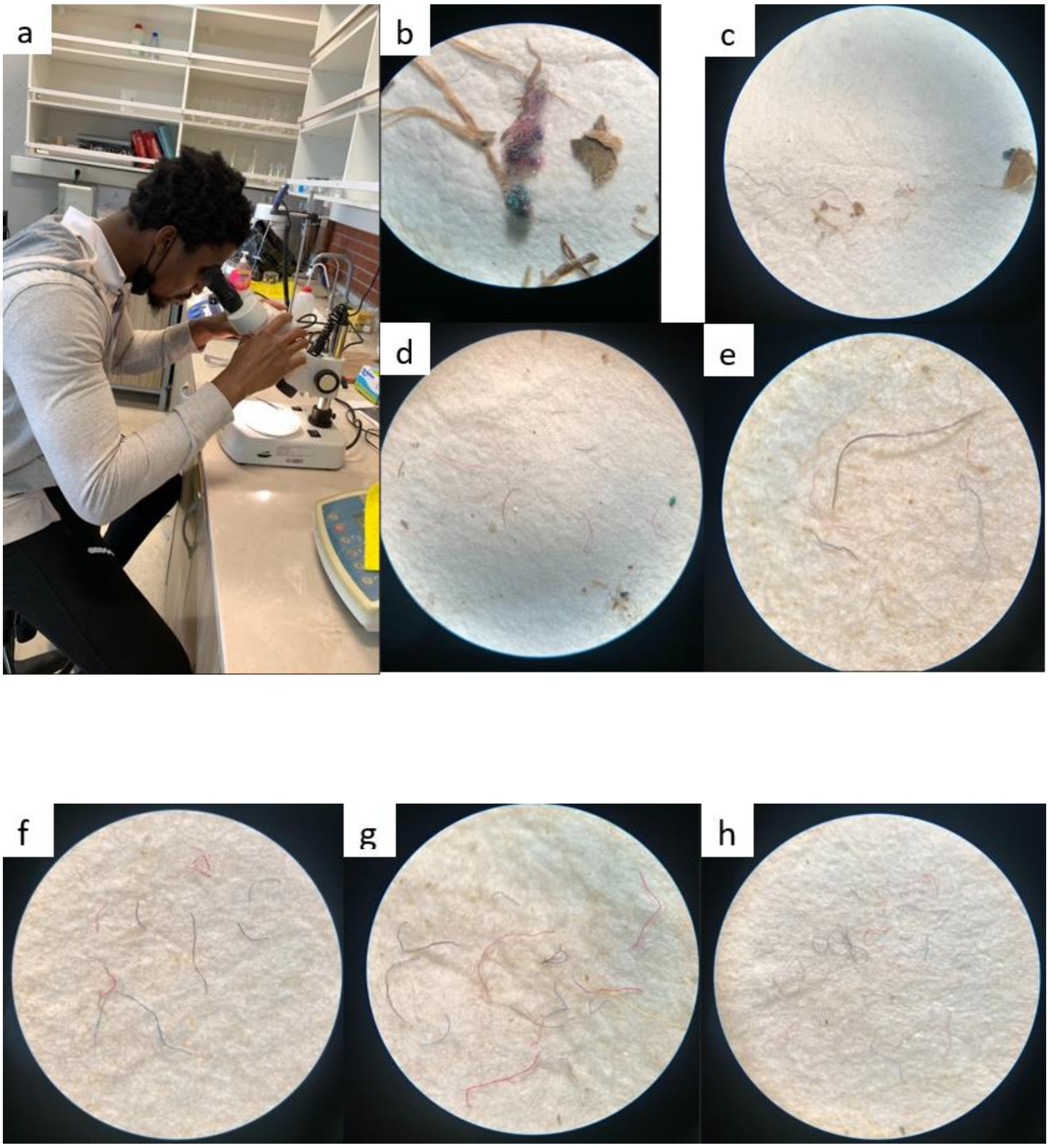


Figure 4.10. a) Microplastics observation under a stereo microscope. b-h) separated microplastics from other materials

4.3.5 Fourier Transform Infrared Spectroscopy Analysis (FTIR)

The non-plastic filter residue on filters where the microplastic fraction is concentrated is cleaned up and reduced using Fourier Transform Infrared Spectroscopy Analysis (FTIR) analysis. The analysis of the fibers was carried out together with the cellulose (A4 sheet) to obtain bands of both cellulose and fibers. The cellulose was separately analyzed. Both results were compared to evaluate bands of the Fibres. This technique was used to identify the indiscernible peaks. 30 samples of microplastics were subjected to FTIR analysis (Table 4.1.). MPs in fragment forms were ground to fine-grained size.

The experiment was conducted at Arel University at Polymer Technologies and Composite Application and Research Center (Figure 4.11.). By using a single bounce diamond attenuated total reflectance (ATR) module on a Fourier-transform infrared (FTIR) spectrometer (Nicolet Nexus 6700) equipped with a liquid nitrogen-cooled mercury-cadmium-telluride (MCT) detector, Tunçer et al. (2018) analyzed the presence of microplastics.

Table 4.1. Microplastics (MPs) selected for FTIR analysis

LOCATION	MP TYPE	MP COLOR	SAMPLE CODE	SAMPLE QUANTITY	TOTAL NUMBER OF SAMPLES
Bodrum	Fiber	Black	BFbB	1	30
		Red	BFbR	1	
		Blue+ Yellow	BFbBlY	1	
		Green+Brown	BFbGBr	1	
Turgutreis	Fiber	Black	TFbB	1	
		Red	TFbR	1	
		Blue+ Yellow	TFBlY	1	
		Green+Brown	TFbGBr	1	
	Fragment	Blue	TS1FgBl	1	
		Brown	TS2FgBr	1	
		Green	TS2FgG-TS3FgG	2	
		White	TS2FgW-TS3FgW	2	
		Rose	TS2FgRo	1	
Güllük	Fiber	Black	GFbB	1	
		Red	GFbR	1	
		Blue+ Yellow	GFBlY	1	
		Green+Brown	GFbGBr	1	
		Multicolor	GFbMc	1	
	Fragment	White	GS2FgW-GS4FgW	2	
		Pink	GS4FgP	1	
Boğaziçi	Fiber	Black	BoFbB	1	
		Red	BoFbR	1	
		Blue+ Yellow	BoFBlY	1	
		Green+Brown	BoFbGBr	1	
	Fragment	Light green	BoS1FgLG	1	
		White	BoS1FgW	1	
		Green	BoS5FgG	1	

Figure 4.11. FTIR analysis device set up for the experiment (https://potkam.arel.edu.tr/cihazlar/fouirer-transform-infrared-spektrofotometre-ftir, accessed 27.04.2022)

4.3.6 Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS)

Scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) were conducted at Arel University at Polymer Technologies and Composite Application and Research Center to analyze the surfaces of the selected microplastics and sediments of different locations. The details of all samples are illustrated in Table 3.

4.3.7 X-Ray Diffraction (XRD)

The X-Ray Diffraction (XRD) analysis was conducted in Afyon Kocatepe Üniversity Technology Application and Research Centre (TUAM) to understand the sediments' structural properties and their relation with microplastics retention. 10 grams of sediment were collected from a bulk sample in both plenty and a few observed MPs section of each location. The samples were then prepared by grinding to a powder form for the analysis to be carried out (Figure 18). A total number of 8 samples were prepared for the analysis (Table 4.2.).

Table 4.2. Samples prepared from bulk beach sediment for the XRD-SEM-EDS analysis

LOCATION	SAMPLE NAME	SAMPLE DEFINITION	SAMPLE CODE	APPROXIMATE MASS (g)	NUMBER	TOTAL NO: OF SAMPLES
Bodrum	B6	Bodrum Sample 6 High Quantity	BS6HQ	10,5	1	8
	B1	Bodrum Sample 1 Low Quantity	BS1LQ		1	
Turgutreis	T6	Treis Sample 6 High Quantity	TS6HQ		1	
	T3	Treis Sample 3 Low Quantity	TS3LQ		1	
Güllük	G1	Güllük Sample 1 High Quantity	GS1HQ		1	
	G4	Boğaziçi Sample 4 Low Quantity	GS4LQ		1	
Boğaziçi	BO5	Boğaiçi Sample 5 High Quantity	BOS5HQ		1	
	BO6	Boğaiçi Sample 6 Low Quantity	BOS6LQ		1	

The analyses were perfomed by using Shimadzu brand XRD-6000 model device with copper (Cu) X-ray tube and Copper Kα X-ray with a wavelength of 1.544 Å (Figure 4.12.). A minimum of 10 grams of sample was used for each analysis. Samples were ground gently to have fine powders of each. Minerals were identified qualitatively based on the method of Moore and Reynolds (1989).

Qualitative mineralogical or phase analyses and crystal structure definition of powder and smooth-surfaced solid samples are performed. Qualitative analyzes are performed by comparison with ICDD cards.

Figure 4.12. Shimadzu brand XRD-6000 model device used for the XRD analysis

5. RESULTS

5.1. Sedimentological analysis of beach sediments

The results of the sieve analyses divulge the classification of the sediment samples to their corresponding groups according to Folk (1974) (Table 5.1.).

Table 5.1. Results of the sieve analyses show the characteristics (sorting, skewness, kurtosis, etc.) of all the samples as well as sediment classification according to grain sizes.

Location	Bodrum						Turgutreis						Güllük						Boğaziçi					
Sample No	B1	B2	B3	B4	B5	B6	T1	T2	T3	T4	T5	T6	G1	G2	G3	G4	G5	G6	BO1	BO2	BO3	BO4	BO5	BO6
Average Grain Size (Ø)	-0.28	-0.17	0.07	0.27	0.23	-0.17	-0.78	-0.35	-0.24	-1.62	-1.41	-0.33	1.51	1.54	0.99	1.19	-1.58	-2.03	-1.93	-0.63	-1.77	0.05	0.24	-1.03
Average Grain Size (mm)	1.21	1.13	0.95	0.83	0.85	1.13	1.72	1.27	1.18	3.07	2.66	1.26	0.35	0.34	0.50	0.44	2.99	4.08	3.81	1.55	3.41	0.97	0.85	2.04
Average Grain Size (mm)	VCs	VCs	Cs	Cs	Cs	VCs	VCs	VCs	VCs	Gr	Gr	VCs	Ms	Ms	Cs	Ms	Gr	Pe	Gr	VCs	Gr	Cs	Cs	Gr
Sorting	1.37	1.75	1.41	1.79	1.70	1.32	0.58	0.86	0.86	0.60	1.07	0.65	0.45	0.89	1.28	1.42	0.52	1.23	1.75	1.27	1.86	1.49	1.73	0.76
	PS	PS	PS	PS	PS	PS	MWS	MS	MS	MWS	PS	MWS	WS	MS	PS	PS	MWS	PS	PS	PS	PS	PS	PS	MS
Skewness	0.15	0.32	-0.09	0.02	0.00	-0.21	-0.28	0.04	0.15	0.27	0.36	0.20	-0.01	-0.12	-0.29	-0.34	0.12	0.02	0.30	0.17	0.29	0.06	0.14	-0.06
	FS	VFS	NS	NS	NS	CS	CS	NS	FS	FS	VFS	FS	NS	CS	CS	VCS	FS	NS	FS	FS	FS	NS	FS	NS
Kurtosis	0.47	0.45	0.40	0.31	0.33	0.31	0.36	0.91	0.64	0.63	0.91	0.72	0.51	0.44	0.45	0.50	0.54	0.86	0.80	0.50	0.62	0.40	0.40	0.39
	VP	VP	VP	VP	VP	VP	VP	MK	VP	VP	MK	PK	VP	VP	VP	VP	VP	PK	PK	VP	VP	VP	VP	VP
Mode 1	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	0.00	0.00	0.00	-1.00	-1.00	0.00	2.00	2.00	2.00	2.00	-1.00	-3.00	-3.00	-3.00	-3.00	-1.00	-1.00	0.00
Mode 2	-	2.00	1.00	3.00	2.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-1.00	-2.00	-1.00	-2.00	2.00	2.00	-
Gravel	34.40	41.64	27.42	33.57	31.05	35.25	29.90	20.07	18.16	82.92	71.39	11.49	2.74	5.79	9.71	9.92	85.70	79.02	78.94	48.68	73.84	29.03	30.66	49.09
Sand	65.50	58.12	72.43	66.30	68.90	64.74	70.09	79.92	81.83	17.07	28.60	88.48	97.26	93.87	90.26	89.07	14.29	20.62	20.84	48.90	25.90	70.95	68.09	50.86
Mud	0.10	0.20	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	1.00	0.00	0.40	0.20	2.40	0.30	0.00	1.30	0.00
Classsification	sG	sG	gS	sG	sG	sG	gS	gS	gS	G	sG	gS	(g)S	gS	gS	gS	G	sG	sG	sG	sG	gS	sG	sG

Frequency ratios (Figure 5.1.), cumulative retained percentage (Figure 5.2.) and cumulative passing percentages (Figure 5.3) for all the locations were calculated and graphically presented based on the assumptions of Folk (1974). The mean, sorting, skewness, and kurtosis were also estimated and graphically illustrated (Figure 5.4. and Figure. 5.5.).

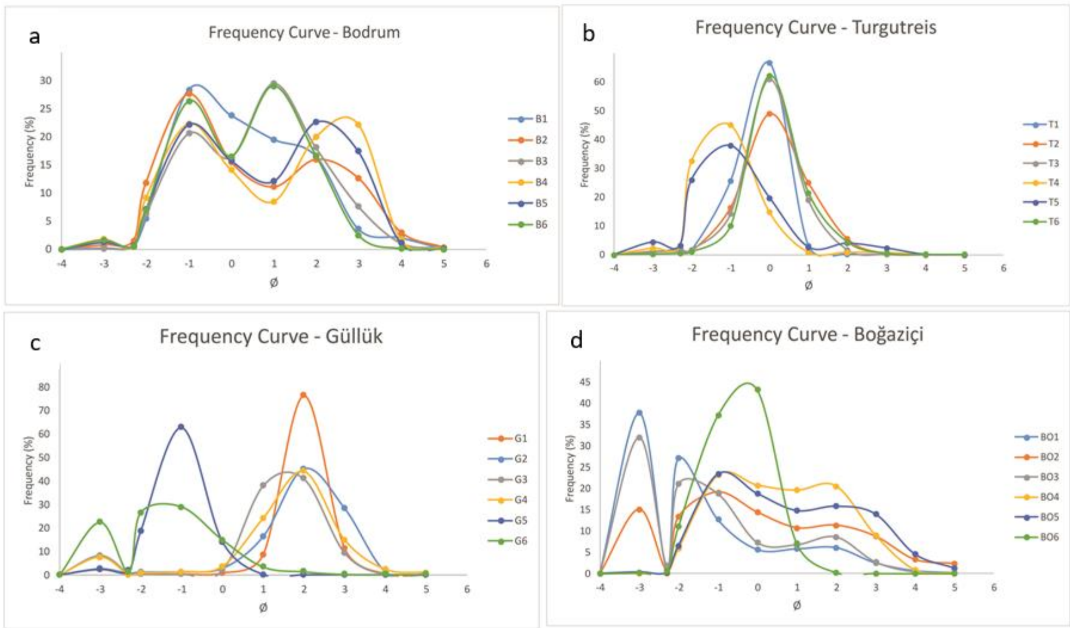


Figure 5.1. Graph indicating the frequency curve of sediment samples of all the locations. a) Bodrum b)Turgutreis c) Güllük and d) Boğaziçi

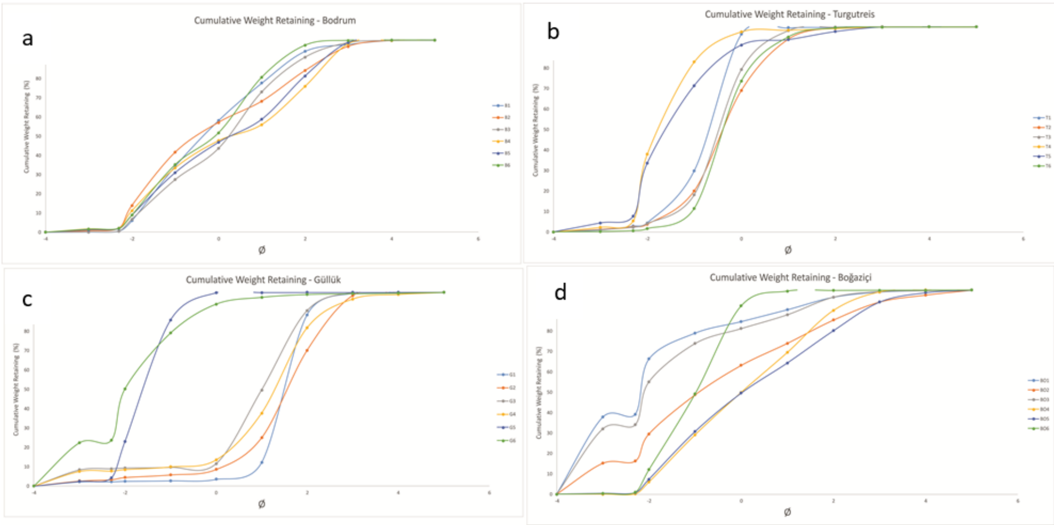


Figure 5.2. Graph indicating the cumulative retained percentages of sediment samples of all the locations. a) Bodrum b) Turgutreis c) Güllük and d) Boğaziçi

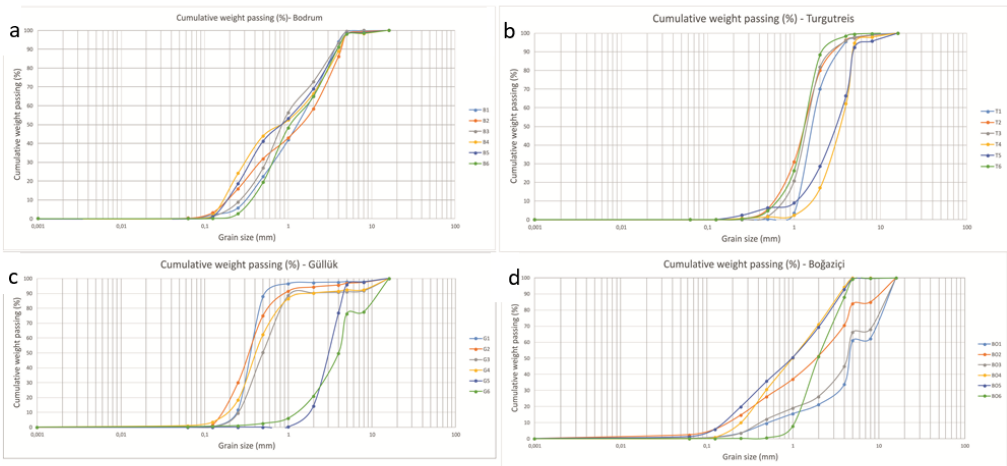


Figure 5.3. Graph indicating the cumulative passing percentages of sediment samples of all the locations. a) Bodrum b)Turgutreis c) Güllük and d) Boğaziçi.

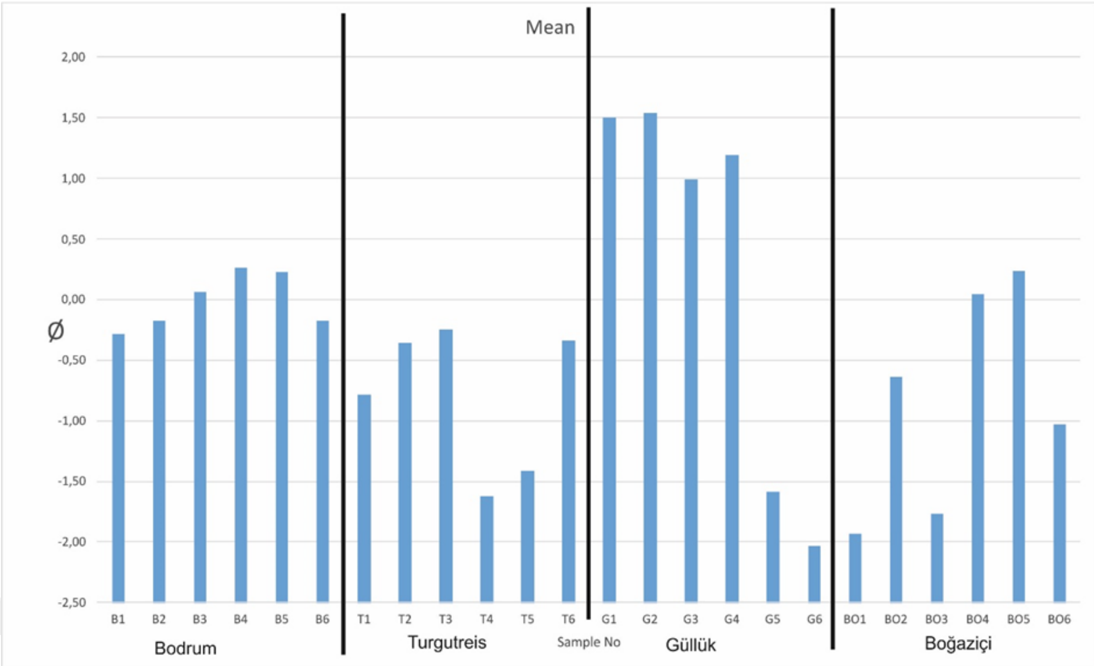


Figure 5.4. The histogram graph representing the mean variation of the sediments samples of the study area.

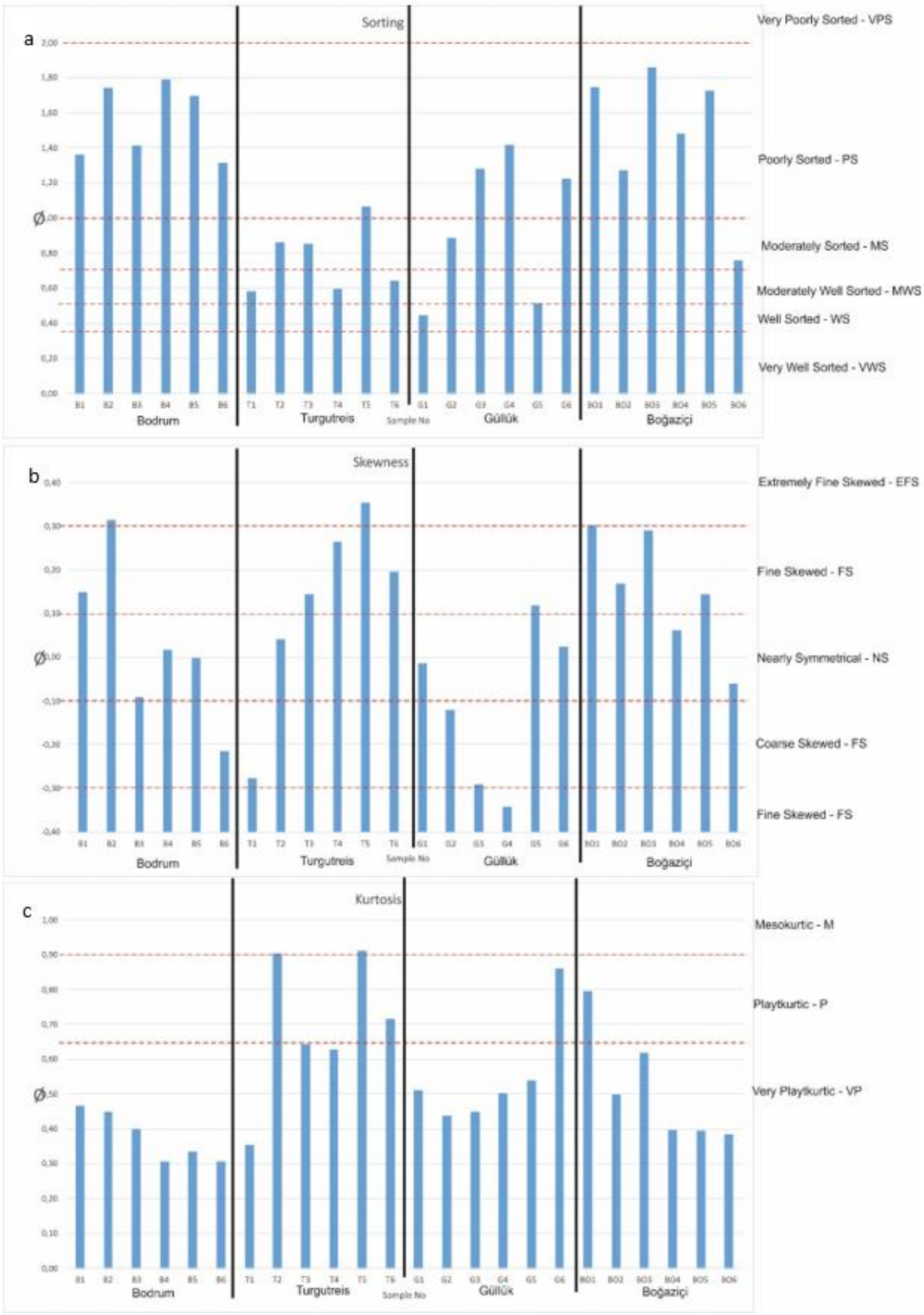


Figure 5.5. Sediment samples characterization of all locations. a) Sorting histogram of the study area, b) Skewness histogram of the study area c) Kurtosis histogram of the study area

All the evaluated results according to locations are explained below;

a) Bodrum

As a result of the sieve analysis performed on 6 samples (thus B1to B6) collected from Bodrum, the rate of gravel and sand determined varies between 27.42-41.64% and 58.12-72.43% respectively. According to these ratios, 5 of the sediments (B1, B2, B4, B5, B6) were classified as sandy Gravel (sG) and the last remaining sample (B3) as gravelly Sand (gS) using the (Folk, 1974) classification. Five of the samples (B2, B3, B4, B5, B6) are bimodal and one (B1) is unimodal. The most common mode value is -1Ø, which means that the 2mm gravel class is the most dominant grain size (Folk, 1974). The next dominant grain sizes are variable, which are 1 Ø, 2 Ø, 3 Ø and 0.5-0.25-0.125 mm respectively. The average grain sizes of the samples are coarse sand and very coarse sand grain size. All the samples are poorly sorted (PS). Considering the skewness values of the samples, while the middle parts are near-symmetrical, the edges are either fine skewed or coarse skewed. All Kurtosis values were determined as very platykurtic (Table 5.1. and Figure 5.5.).

b) Turgutreis

According to the result of the sieve analysis performed on 6 samples (thus T1-T6) collected from Turgutreis, the rate of gravel and sand determined varies between 11.41-82.92 % and 17.07-81.83 % respectively. According to these ratios, 4 of the sediments samples (T1, T2, T3, T6) were classified as Gravelly Sand (gS), the next sample (T4) as Gravel (G) and the last sample (T5) as sandy Gravel (sG) using the (Folk, 1974) classification. All the sample samples were determined as unimodal. The common-mode value is mostly 0 Ø, and -1 Ø, which means that the grain size is mostly 1 mm coarse sand and 2 mm gravel class respectively (Folk, 1974). Three of the samples (T1, T3, T6) are moderately well sorted (MWS), 2 samples (T2, T3) are moderately sorted (MS) and the last sample (T5) is poorly sorted (PS). The average grain sizes of the samples are very coarse sand and granule grain size. Considering the skewness values of the samples, sample 1 (T1) was determined as coarse-symmetrical (CS) followed by sample 2 (T2) as near-symmetrical (NS), samples 3, 4, and 6 (T3, T4, T6) as fine symmetrical (FS) while the last sample (T5) was identified as very fine symmetrical (VFS). All Kurtosis values of each sample were determined as follows; T1, T3, T4 as very platykurtic (VP), T2 and T5 as mesokurtic (MK), and T6 as Platykurtic (PK) (Table 5.1. and Figure 5.5.).

c) Güllük

In compliance with the result of the sieve analysis conducted on 6 samples collected from both shoreline and backshore (G1, G3, G5 and G2, G4, G6 respectively) of Güllük, the rate of gravel and sand of the foreshore samples determined varies between 2.74-85.70 % and 14.29-97.26 % respectively, while the rate of gravel and sand of the backshore samples determined varies between 5.79-79.02 % and 20.62-93.87 % respectively. According to the ratios of the sediments from the shoreline, sample G1 was classified as slightly gravelly sand (g)S, G3 as gravelly sand (gS) and G5 as gravel (G). Two of the backshore samples (G2, and G4) were classified as gravelly sand (gS), whereas the other sample (G6) was classified as sandy Gravel using the (Folk, 1974) classification. From the Eastern trend down to the Western part of the sampling area (G1-G4) includes unimodal samples, with a 2 Ø, which means that the most common sediment is 0.5 mm medium-grained sand. The average sediment grain sizes of those samples are medium-grained sand. However, the eastern sampling part contains unimodal (-1 Ø, dominant grain size 2 mm, average grain size in granule size) samples close to the shoreline, and bimodal samples in the backshore area (the most dominant grain size is -3 Ø - 8 mm, second dominant -1 Ø - 2 mm; average grain size in pebble size). The shoreline samples, G1, G3 and G5 were determined as well sorted (WS), Poorly sorted (PS) and Moderately well-sorted (MWS) accordingly. However, the backshore samples, G2, G4 and G6 vary from moderately sorted and poorly sorted from the western to the eastern part of the location. Considering the skewness of the samples, there are highly variable (near symmetrical, coarse skewed and fine skewed). All the samples except one (G6) were determined as very platykurtic (Table 5.1. and Figure 5.5.).

d) Boğaziçi

As a result of the sieve analysis performed on 6 samples collected from both shoreline and backshore (BO1, BO3, BO5 and BO2, BO4, BO6 respectively) of Boğaziçi, the rate of gravel and sand on the shoreline samples determined varies between 30.66-78.94% and 20.84-68.09 respectively, while the rate of gravel and sand of the backshore samples determined varies between 29.03-49.09% and 48.90-970.95% respectively. According to the ratios of the sediments from the coastline, all the 3 samples, BO1, BO3, and BO5 were classified as sandy gravel (sG). Two of the backshore samples (BO2, BO6) were also classified as sandy gravel (sG), whereas the other sample (BO4) was classified as gravelly sand (gS) using the (Folk, 1974) classification. Five samples of the region are bimodal. In the southeast part, the dominant grain size is -3 Ø - 8 mm, the second dominant -2 Ø - 4 mm close to the shoreline (BO1), while the dominant grain size is -3 Ø -8 mm, the second dominant -1 Ø - 2 mm in backshore (BO2). In the middle part, the dominant grain size is -3 Ø -8 mm, the second dominant -2 Ø - 4 mm close to the shoreline (BO3), while the dominant grain size is -1 Ø -2 mm, second dominant 2 Ø – 0,25 mm in backshore (BO5). In the northwest part, the most dominant grain size is -1 Ø -2 mm, the second dominant 2 Ø – 0,25 mm close to the shoreline (BO5), while the backshore sample is unimodal 0 Ø - 1 mm in backshore (BO6). The shoreline samples, BO1, BO3 and BO5 were determined as poorly sorted (PS). However, the edges of the backshore samples (BO2 and B06) were identified as sandy gravel (sG) while the middle portion (BO4) was identified as gravelly sand (gS). Considering the skewness of the samples, the shoreline samples were identified as fine skewed whereas backshore samples vary from fine skewed (FS) to near symmetrical

(NS). All the samples except one (BO1) were determined as very platykurtic (Table 5.1. and Figure 5.5.).

5.2. Microplastic Contents of beach sediments

Microplastics (MPs) separations were carried out on the overall mass of 7200 g samples by handpicking, light density separation and NaCl flocculation method for all locations. A total number of 1446 MPs were identified in the aforementioned mass of samples (Table 5.2.). The most abundant microplastic types found were fibers with a total number of 1137. The other Microplastics types identified were amorphous, platy and tubular fragments form. The handpicking method resulted in the accumulation of coarse-sized mesoplastics and microplastic, mainly glass, cable and plastic samples (Figure 5.6.).

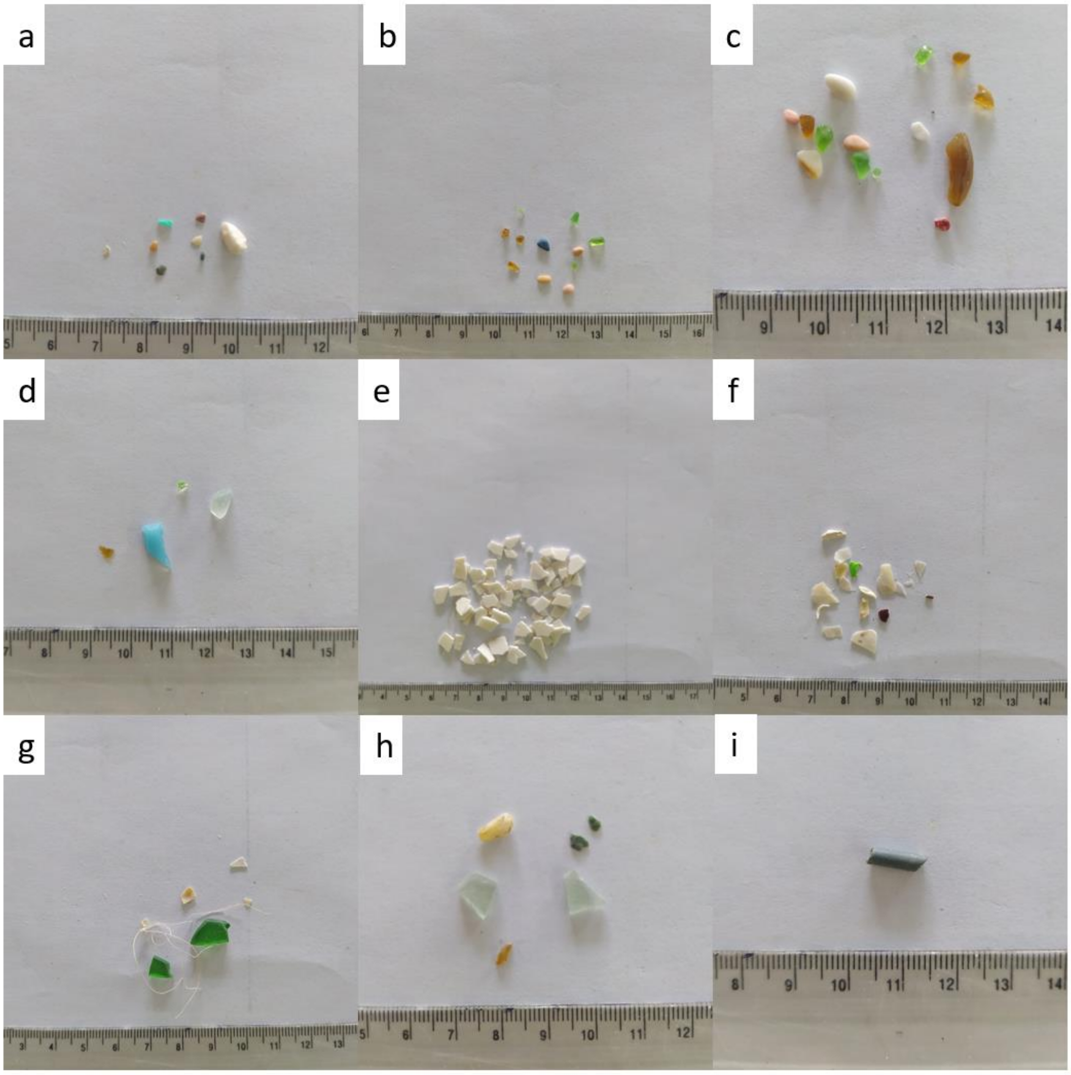


Figure 5.6. Hand-picked meso-microplastics separated from sampled sediments from all locations. a-Bodrum, b,c.d-Turgutreis, e,f,g-Güllük, h,i-Boğaziçi

Table 5.2. Total number of microplastics counted and classified

Location/1800 g	MP type	Total MPs (NaCl Method/ 600 g	Total MPs (Light Density Method)/600 g	Overall Count	Handpicking/600 g	Total
Bodrum	Fibre	221	207	445	38	500
	Amorphous	10	2	12		
	Plate	2	3	5		
	Tubular	0	0	0		
Turgutreis	Fibre	152	66	218	102	322
	Amorphous	0	2	2		
	Plate	0	0	0		
	Tubular	0	0	0		
Güllük	Fibre	124	157	281	108	396
	Amorphous	4	1	5		
	Plate	0	1	1		
	Tubular	1	0	1		
Boğaziçi	Fibre	93	100	193	35	228
	Amorphous	0	0	0		
	Plate	0	0	0		
	Tubular	0	0	0		

5.2.1 Microplastics Counting

All the evaluated results according to locations are explained below;

a) Bodrum

Upon the samples collected from the Bodrum, a total of 500 microplastics were separated in the examinations carried out on 1800 g samples. Only 38 of them are relatively coarse in size and were separated by handpicking (Table 5.2.). Most samples separated by NaCl and light density methods are fibers. Amorphous samples were further separated by the NaCl method.

b) Turgutreis

In the examinations conducted on 1800 g samples, a total of 322 microplastics were separated in the samples taken from Turgutreis. Only 102 of them are relatively coarse grains (mesoplastics and microplastics) and were collected by handpicking (Table 5.2.). Most samples separated by NaCl and the light density method are in fiber class.

c) Güllük

In the examinations carried out on 1800 g samples in the samples taken from Güllük, a total of 396 microplastics were separated. Only 108 of them are relatively coarse grains collected by handpicking (Table 5.2.). Most of the samples separated by both NaCl and light density method are in fiber type. Amorphous samples were further separated by the NaCl method.

d) Boğaziçi

A total of 228 microplastics were separated in the experiment conducted on 1800 g samples in the samples taken from Boğazici. Only 35 of them are relatively coarse grains (mesoplastics and microplastics) collected by handpicking separation (Table 5.2.). All of the samples separated by both the NaCl method and the light density method are in the fiber class.

5.3. Mineralogy

The results of the X-ray Diffraction, Scanning Electron Microscope and Energy Dispersive Spectroscopy provided insight into the mineralogical compositions and apparent morphological features of the study samples concerning their locations. The predominant minerals observed are quartz, plagioclase, K-feldspar, calcite and Mg-dolomite. The details of our findings are explained according to locations as follows.

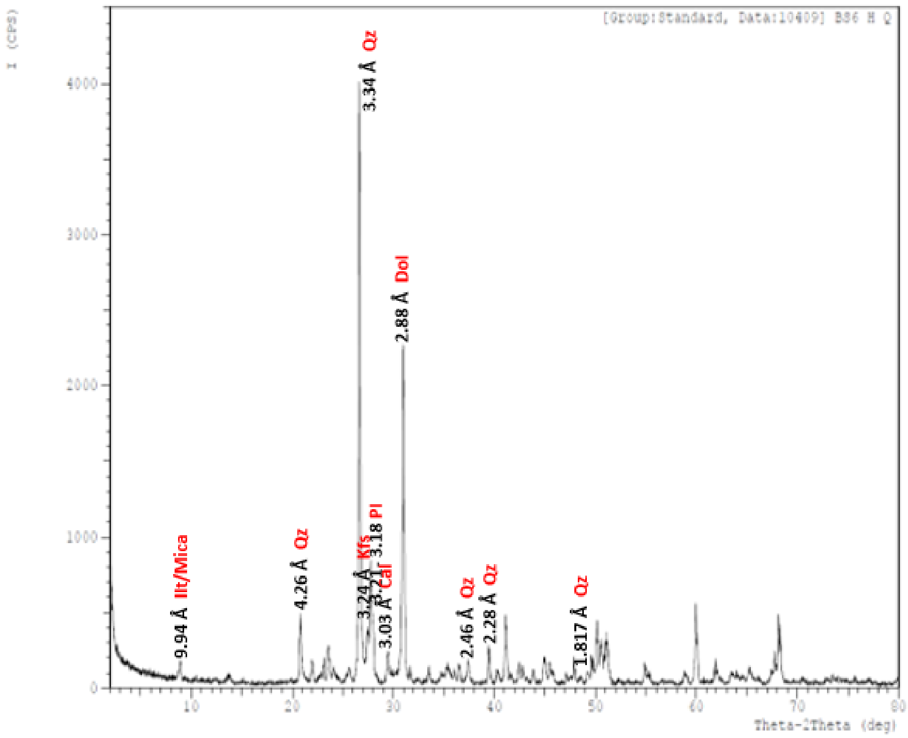
5.3.1 Results of X-Ray Diffraction

a) Bodrum

Varieties of minerals were obtained from the bulk composition sample taken from the Bodrum field. Quartz, K-feldspar, plagioclase, calcite, dolomite and mica minerals are observed with their relative reflections.

The XRD result of the bulk sample coded as BS6HQ exhibited dominance of quartz with related reflection peaks at 3.34 Å, 4.26 Å, 2.46Å, 2.28 Å and 1.817 Å. The existence of K-feldspar was observed with reflections of 3.24 Å. The presence of plagioclase was identified with twin reflections of 3.21-3.18 Å. The reflection of calcite at 3.03 Å was detected. Dolomite was also observed with a sharp and intense reflection peak of 2.88 Å. Illite/Mica was determined with a weak reflection of 9.94 Å and 3.35 Å (Figure 5.7.).

For the result of the bulk sample coded as BSLQ, quartz with a sharp and intense reflection of 3.34 Å, 4.26 Å, 2.46Å, 2.28 Å and 1.817 Å was observed. A twin reflection of plagioclase 3.21-3.18 Å was identified. The presence of K-feldspar was observed with reflections of 3.24 Å. A sharp peak of calcite was observed with a reflection of 3.03 Å. Dolomite was also observed with variable reflections of 2.99 Å, 3.77 Å and 2.46 Å. Illite/Mica was determined with a weak reflection of 9.94 Å and 3.35 Å (Figure 5.7.).



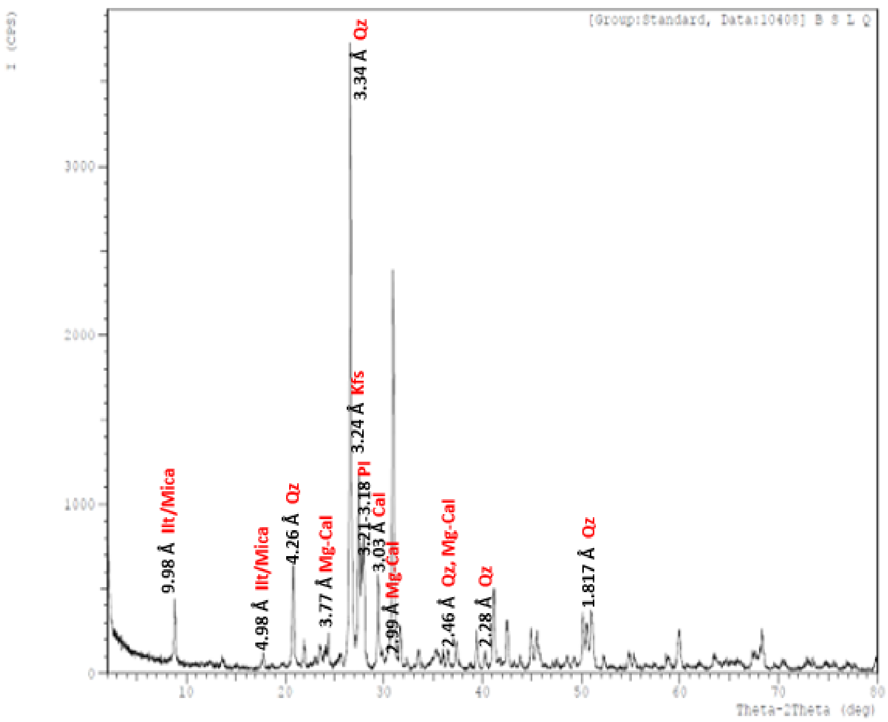


Figure 5.7. The X-ray diffractogram of the bulk composition sample from the Bodrum section (Ilt/Mica; Illite/Mica: Qz; Quartz: Mg-Cal; Magnesium Calcite: Kfs; K-feldspar: Pl; Plagioclase; Cal; Calcite)

b) Turgutreis

The result of the bulk samples coded as TS6HQ and TS3LQ portrayed the same attributes. Both samples show the presence of quartz with very sharp and intense reflection peaks of 3.34 Å, 4.26 Å, 2.46 Å, 2.28 Å and 1.817 Å. Another sharp and intense peak of plagioclase was observed with a reflection of 3.22 Å and 3.19 Å. K-feldspar was also observed with a reflection of 3.24 Å. The presence of Mg-calcite was identified with variable reflections of 2.99 Å, 3.77 Å, and 2.46 Å. A weak reflection of calcite at 3.03 Å was detected. Illite/Mica was also determined with a weak reflection of 9.99 Å. Serpentine was identified with different reflection peaks of 7.14 Å, 3.63 Å, 2.40 Å and 2.16 Å (Figure 5.8.).

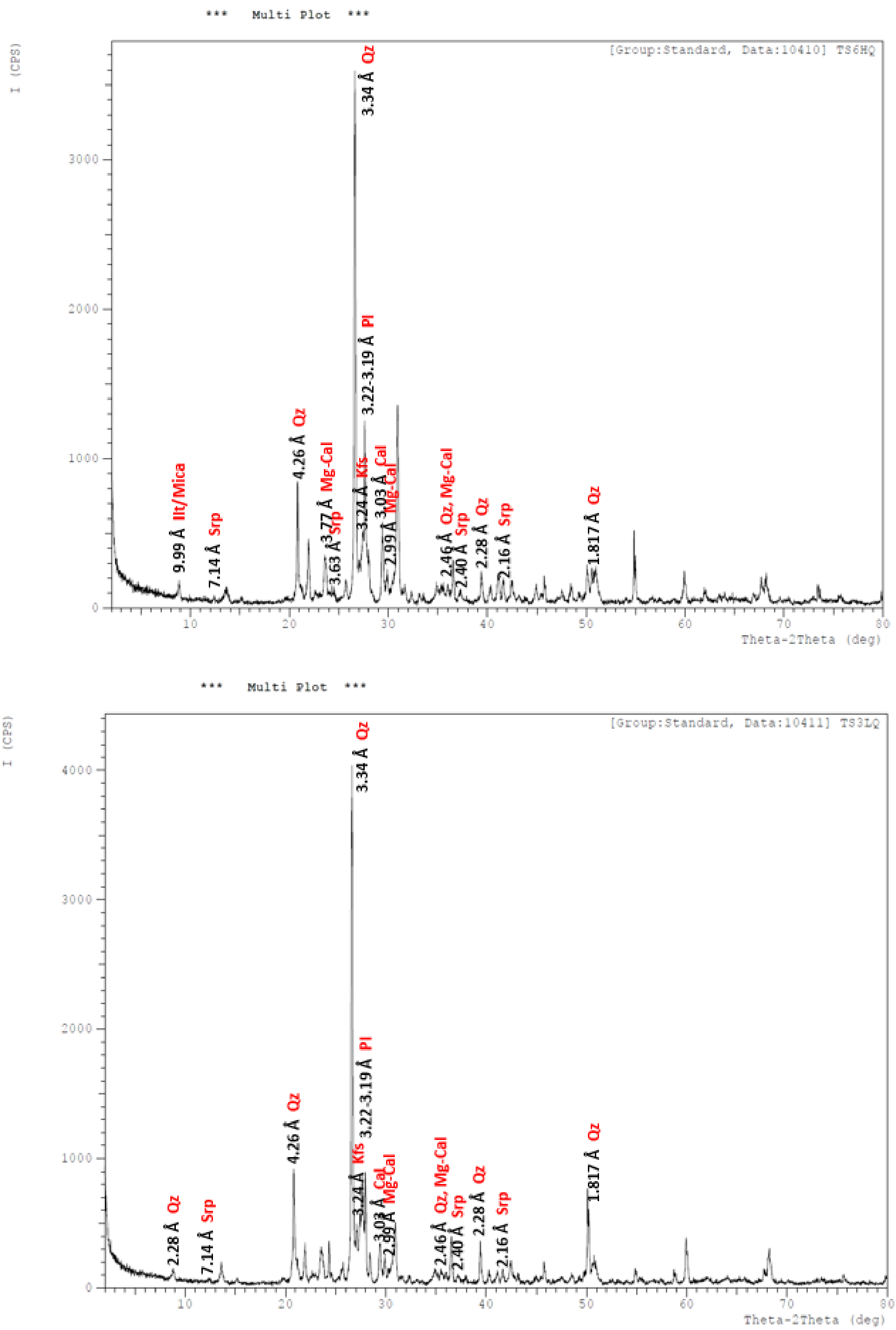


Figure 5.8. The X-ray diffractogram of the bulk composition sample from the Turgutreis section (Srp; Serpentine: Qz; Quartz: Mg-Cal; Magnesium Calcite: Kfs; K-feldspar: Pl; Plagioclase; Cal; Calcite)

c) Güllük

For the sample named GS1HQ, the recognition of quartz displayed distinct reflection of 3.34 Å, 4.26 Å, 2.46, 2.28 Å and 1.817 Å which is equivalent to the results obtained in Bodrum and Turgutreis. A reflection of plagioclase was observed with different peaks at 3.21 Å, 3.18 Å and 4.03 Å. The presence of calcite was obtained with a reflection of 3.03 Å. Mg-calcite was identified with variable reflections of 2.99 Å, 3.77 Å, and 2.46 Å. A weak reflection of dolomite at 2.90 Å. A sharp peak of 9.93 Å, 4.98 Å and 3.35 Å indicate illite/mica presence. Chlorite was observed with different peaks at 7.07 Å, 3.52 Å, and 2.82 Å (Figure 5.9.).

The bulk composition of the sample with a low quantity of microplastics identified as GS4LQ exhibited the same intense quartz reflection as that of GS1HQ. The reflection of Plagioclase and k-feldspar were observed with their corresponding peaks of 3.21 Å - 3.18 Å and 3.24 Å respectively. An intense reflection of calcite was observed at 3.03 Å followed by a weak reflection of dolomite at a peak of 2.90 Å. Illite/Mica was determined reflection of 10 Å, 4.99 Å and 3.35 Å. Serpentine was identified with different reflection peaks of 7.07 Å, 3.69 Å and 2.16 Å (Figure 5.9.).

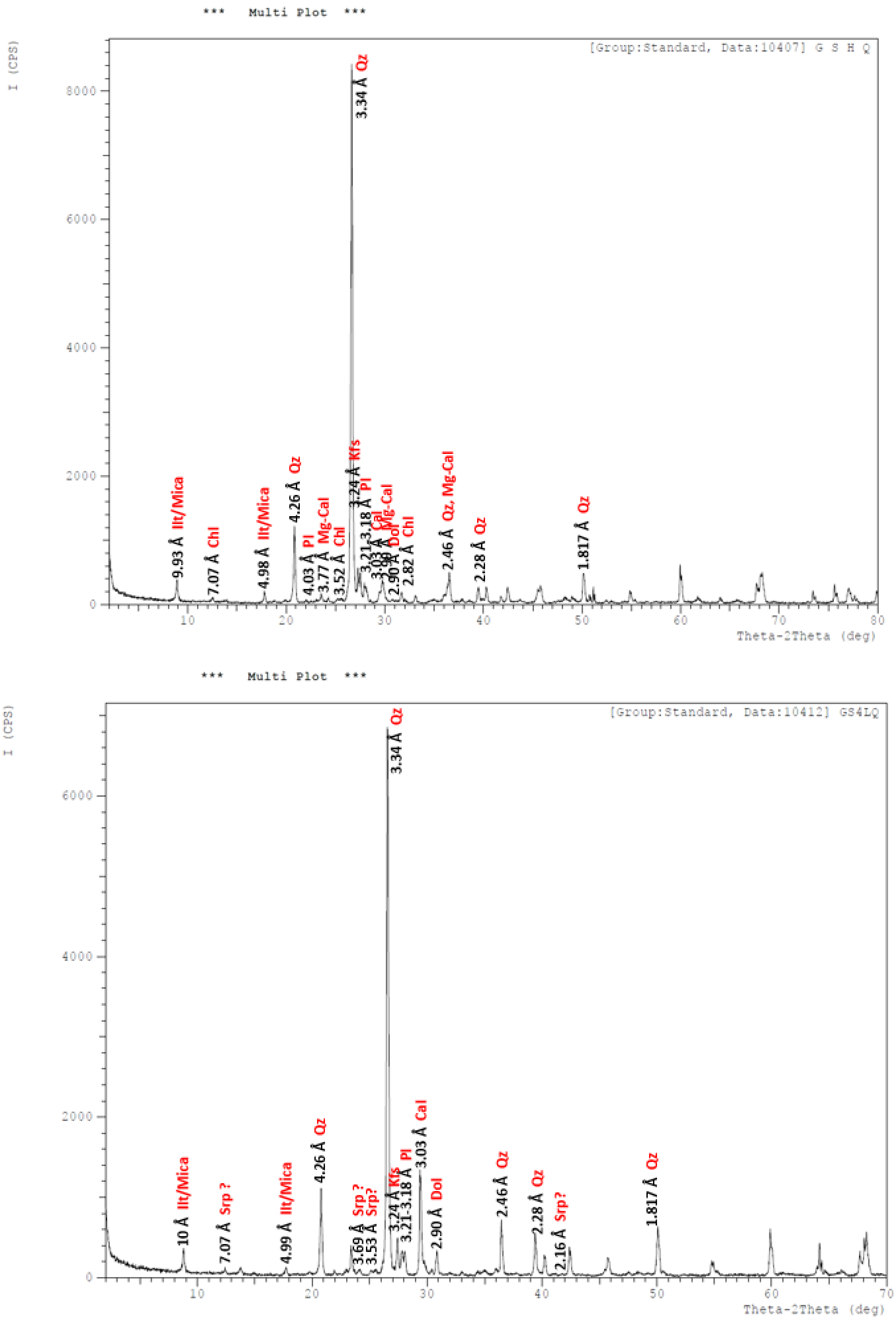


Figure 5.9. The X-ray diffractogram of the bulk composition sample from the Güllük section (Ilt/Mica; Illite/Mica: Srp; Serpentine: Chl; Chlorite: Qz; Quartz: Dol; Dolomite: Kfs; K-feldspar: Pl; Plagioclase; Cal; Calcite)

d) Boğaziçi

The main minerals observed were Quartz, K-feldspar, plagioclase, calcite, dolomite, Mg-calcite and mica minerals with their relative reflections. BOS5HQ and BOS6LQ display the same reflection of minerals except for the absence of Mg-calcite in BOS5HQ as no peak for the aforementioned mineral was observed.

The XRD result of the bulk composition of both high and low quantity observed microplastic samples, BOS5HQ and BOS6LQ exhibited the same reflection with predominantly quartz at the peaks of 3.34 Å, 4.26 Å, 2.46Å, 2.28 Å and 1.817 Å. The existence of K-feldspar in both samples was observed with reflections of 3.24 Å. The presence of plagioclase was identified with reflections of 3.21-3.15 Å. The reflection of calcite at 3.03 Å was detected with a sharp and intense peak for both samples. A reflection of dolomite was observed at a peak of 2.89 Å. A reflection of Mg-calcite was observed only in BOS6LQ at a peak of 2.99 Å, 3.77 Å, and 2.45 followed by Illite/Mica with a reflection of 9.97 Å and 3.35 Å ((Figure 5.10.).

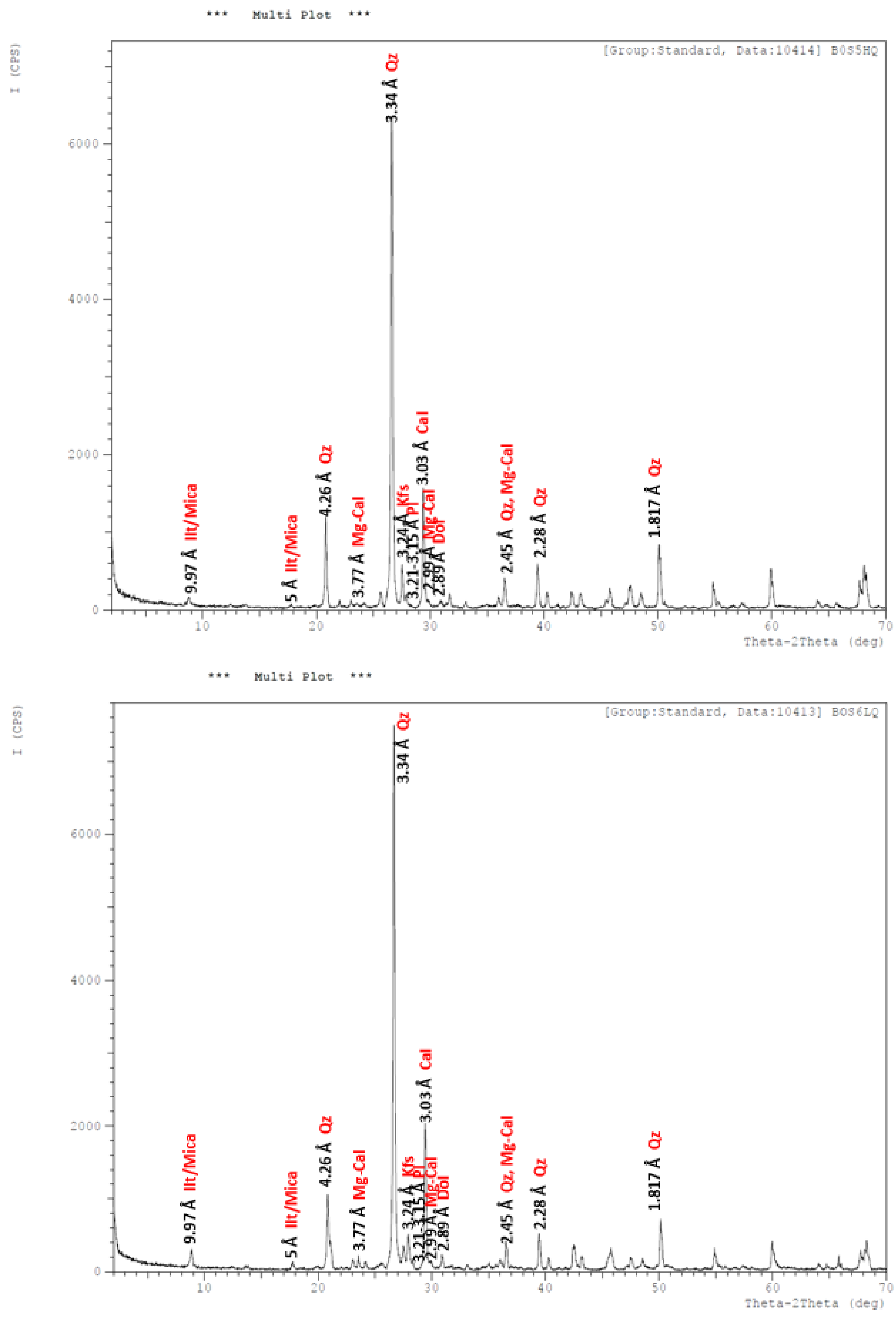


Figure 5.10. The X-ray diffractogram of the bulk composition sample from the Boğaziçi section (Ilt/Mica; Illite/Mica: Qz; Quartz: Dol; Dolomite: Kfs; K-feldspar: Pl; Plagioclase; Cal; Calcite)

5.3.3 Results of Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS)

Figure 5.11 represents the SEM results of bulk composition samples of both high and low quantity observed microplastics with their EDS spots of all locations. The EDS spectra indicate the element concentrations of the experimented samples.

From the general SEM images, the morphologies of the sediments vary according to locations. Our findings of SEM and EDS analysis of the studied samples are illustrated and interpreted according to locations in the following sections.

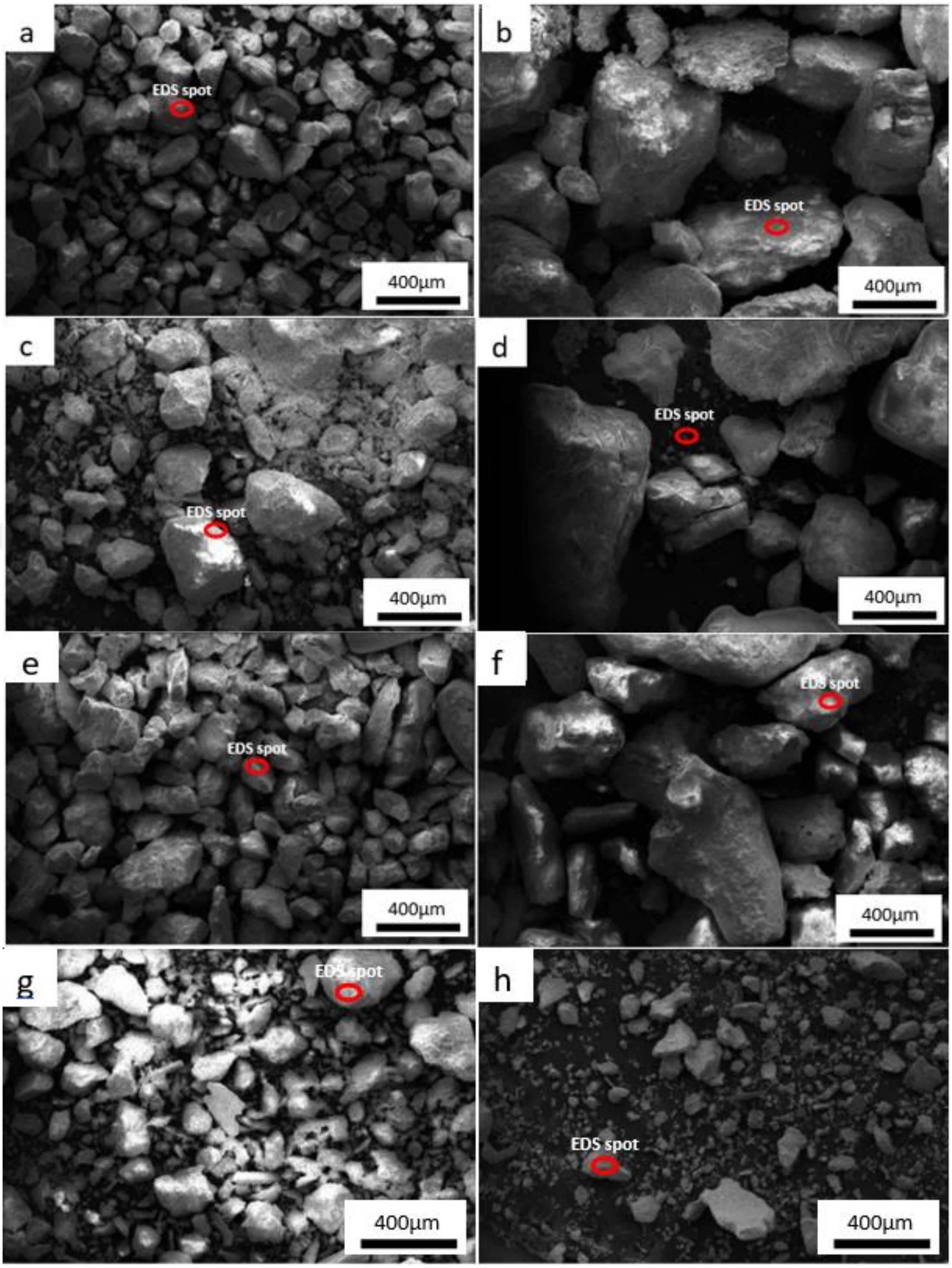


Figure 5.11. SEM images of sediments from the study area, a and b, are sediments from Bodrum with high and low MPs respectively, c and d are sediments from Turgutreis with high and low MPs respectively, e and f are sediments from Güllük with high and low MPs respectively, g and h are sediments from Boğaziçi with high and low MPs respectively

a) Bodrum

Figure 5.11 (a and b) represents the SEM images of BS6HQ (High quantity microplastics observed area) and BS1LQ (Low quantity microplastics observed area). Both samples show similar element distribution with different concentrations (Figures 5.12. a and b). For sample BS6HQ, O and Ca were most dominant with negligible ratios of Fe, Na, Si, Al, CI and K. Sample BS1LQ shows more elements with the dominance of O, Si, Al and low amount of K, Mg, Fe, Ca, Na, CI and S.

The SEM view of sample BS6HQ attributes similar grain size. The sample is characterized as a sub-angular sub-rounded. No shell fragments were identified. However, sample BS1LQ shows a high variation of grain sizes. It was characterized as sub-angular to angular. One flaky texture is observed with this sample while other grains attribute granular texture.

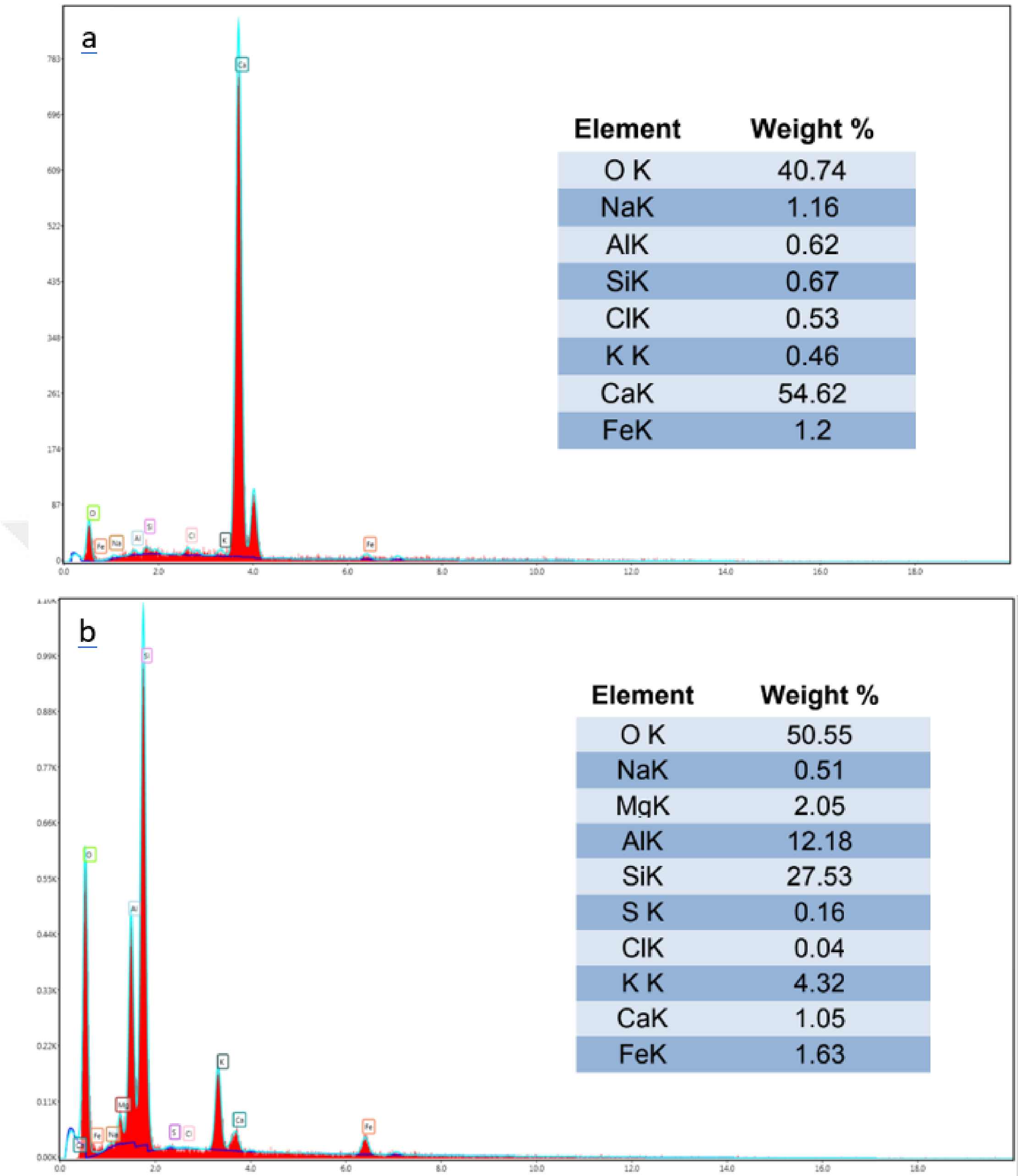


Figure 5.12. EDS spectrum of Bodrum sediment with high and low MPs respectively

b) Turgutreis

The SEM images of the bulk composition of Turgutreis namely TS6HQ (High quantity microplastics observed area) and TS3LQ (Low quantity microplastics observed area) are presented in figures 5.11 (c and d). The EDS analysis performed on both samples revealed similar elements with variable concentrations (Figure 5.13. a and b). TS6HQ indicates a significant concentration of O and Ca, whereas Mg, Si, Al, Fe and S were observed in minor ratios. Sample TS3LQ also indicates high concentrations of O and Si, followed by Al, Na, Ca, K and CI in lower concentrations respectively.

The SEM view of sample TS6HQ shows both fine and coarse grains. The roundness of the sample is high while sorting is low. TS3LQ on the other hand shows a sub-angular to angular grain size.

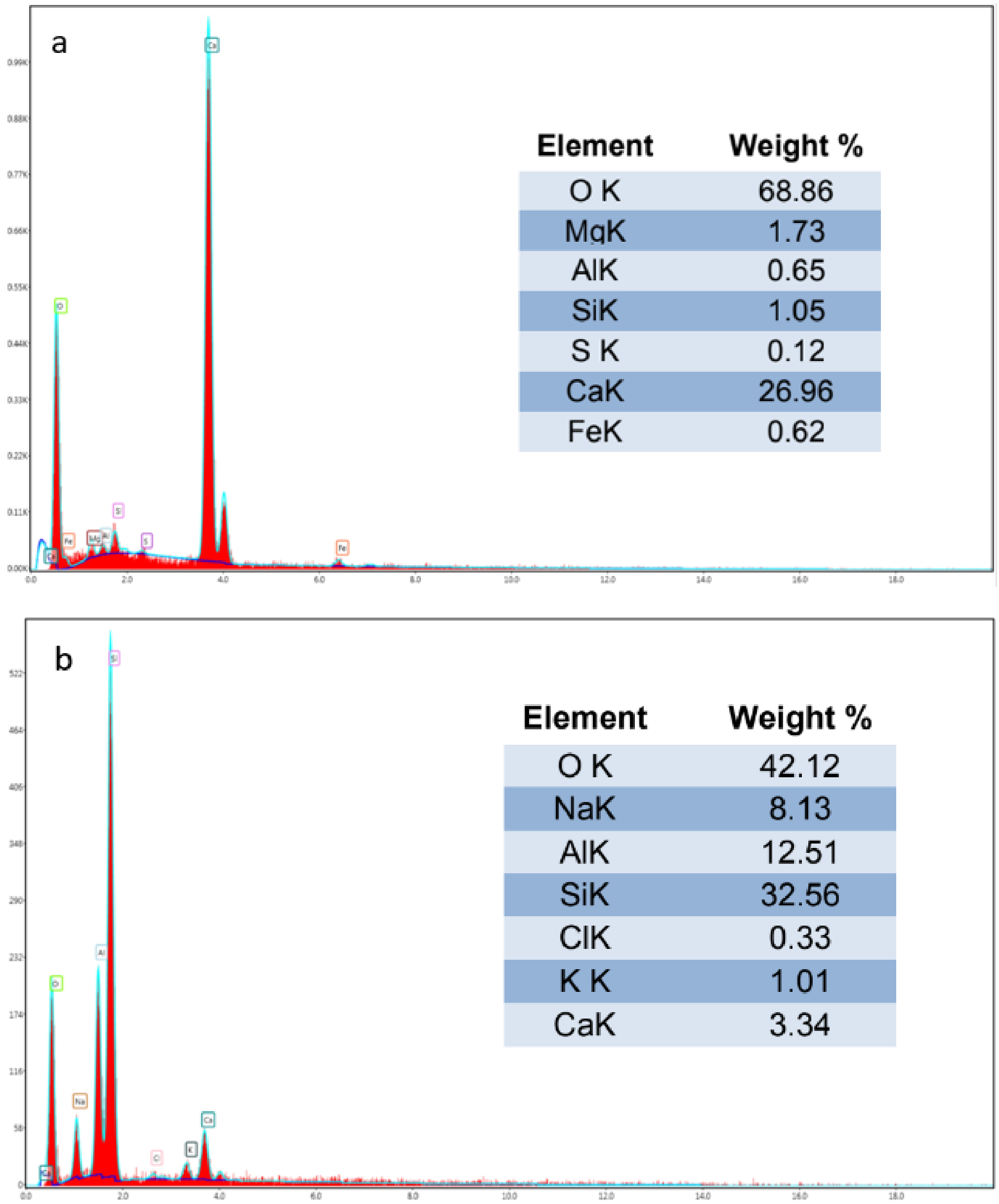


Figure 5.13. EDS spectrum of Turgut reis sediment with high and low MPs respectively

c) Güllük

The SEM results of the bulk composition of Güllük namely GS1HQ (High quantity microplastics observed area) and GS4LQ (Low quantity microplastics observed area) are shown in figures 5.11 (e and f). The EDS analysis performed on both samples revealed elements with their distinct concentrations (Figure 14. a and b). GS1HQ indicates high concentrations of O, Ca and Si whereas S, Na, As, Cl, Fe and Al were observed in low ratios. Sample TS3LQ, on the other hand, indicates high concentrations of Si and O whiles Al, Fe, K, As, Ca, Cl, Mg, Na and S are in lower concentrations respectively.

The SEM view of sample GS1HQ attributes similar grain size. The sample is characterized as sub-angular to angular grain sizes. However, sample GS4LQ shows a high variation of grain sizes. It was characterized as sub-rounded to rounded.

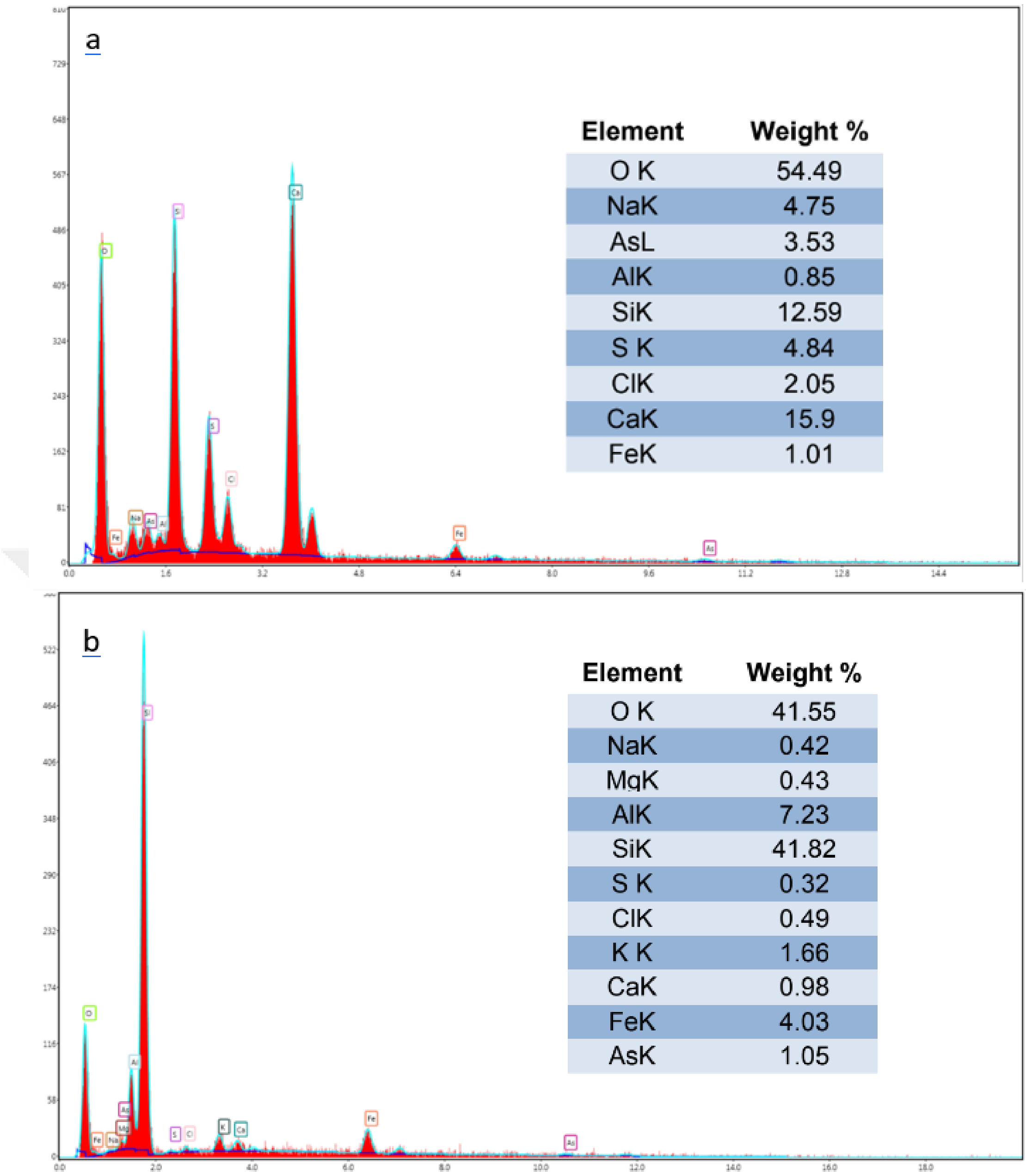


Figure 5.14. EDS spectrum of Güllük sediment with high and low MPs respectively

d) Boğaziçi

The SEM results of the bulk composition of Boğaiçi namely BOS5HQ (High quantity microplastics observed area) and BOS6LQ (Low quantity microplastics observed area) are shown in figure 5.11 (g and h). The EDS analysis performed on samples revealed elements with different concentrations (Figure 5.15. a and b). BOS5HQ shows high concentrations of O and Si whereas Al, Na, Ca, Mg, Fe, K, Cl and S were observed in low ratios. Sample BOS6LQ on the other hand indicates high concentrations of O and Ca whereas Al, Fe, K, Si, Na, Mg, and Cl are in lower ratios respectively.

The SEM view of sample BOS5HQ attributes highly weathered fragments. The sample is characterized as a sub-angular sub-rounded. BOS6LQ on the other hand shows as sub-angular grain sizes. A conchoidal structure of quartz is observed in this sample.

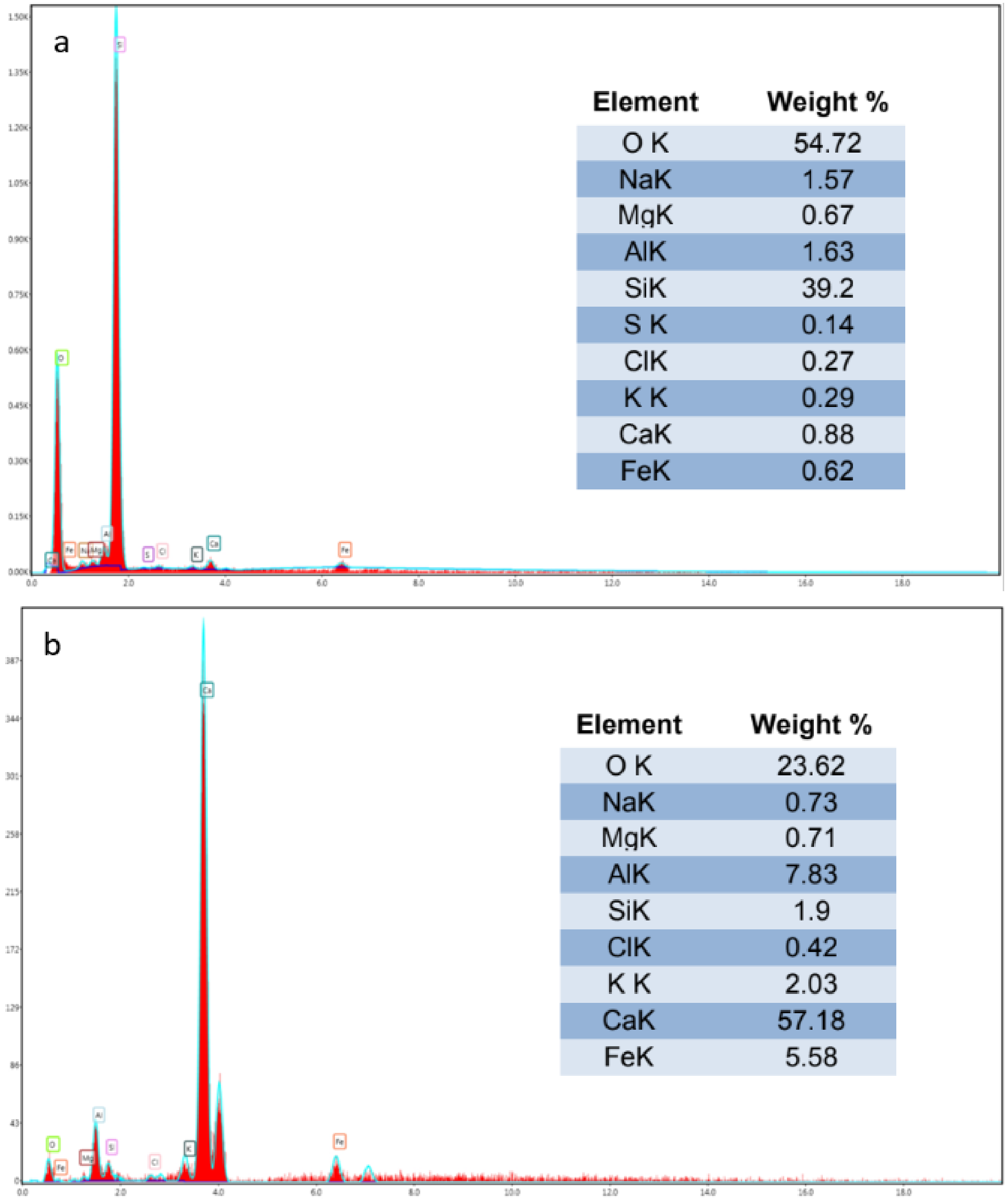


Figure 5.15. EDS spectrum of Boğaziçi sediment with high and low MPs respectively

5.3.4 Results of Fourier Transform Infrared Spectroscopy Analysis (FTIR)

The results of the FTIR were obtained to match the possible polymer types in our findings. The observations are interpreted in the following sections.

I. Cellulose

The characteristic peak values of the chemical groups in the cellulose molecule are observed in the wavelength range of 400-4000 cm-1. Hydroxyl groups (–OH) at 3200-3600 cm-1, aliphatic alkyl stretching vibrations (–CH2–) at 2850-2950 cm-1, C=O vibrations of aldehyde and ester groups at 1650-1750 cm-1 (with carboxyl groups (–COOH) adsorption band of –OH groups at 1600-1650 cm-1, –OH and –CH in-plane bending vibrations at 1400-1450 cm-1, ether bonds in pyranose rings at 1160 cm-1 stretching vibration (C–O–C) is observed (Arslan et al, 2021; Figure 5.16.).

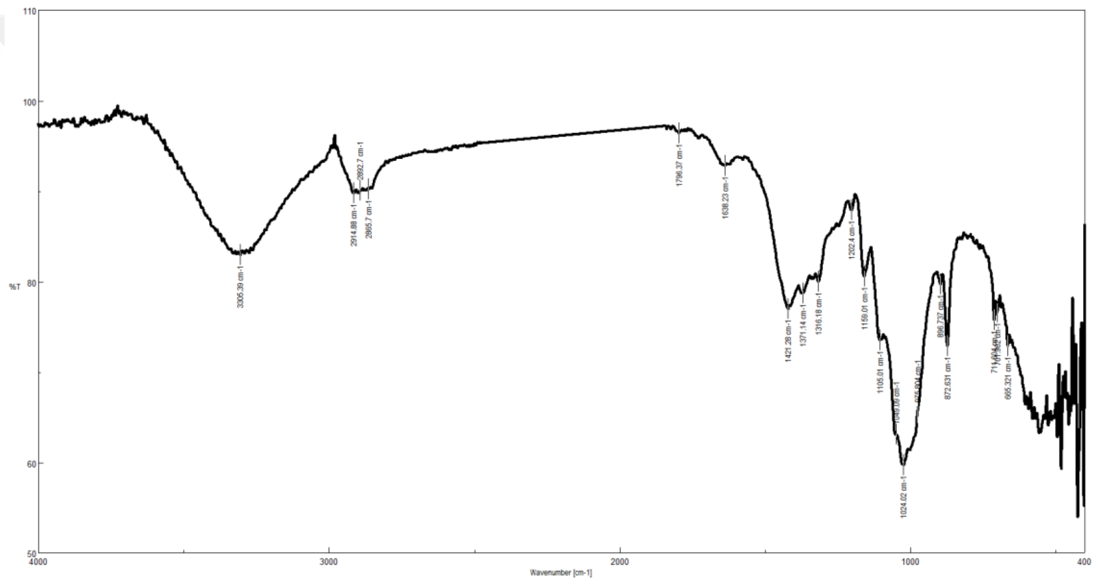


Figure 5.16. FTIR spectrum of cellulose

II. Boğaziçi Black Fibers (BoFbB)

Unlike the cellulose peaks, the intensity of the peaks at 871 cm-1, 1419-1316 cm-1 and 3338 cm-1 increased. The peak at 2896 cm-1 both increased in intensity and became more pronounced. (Arslan et al, 2021). When the presence of spectra is examined, characteristic polyethylene (PE) absorbance bands are found at 2896 cm-1, 2856 cm-1, 1419 cm-1 and 711 cm-1 (D'Amelia et al, 2016; Figure 5.17.).

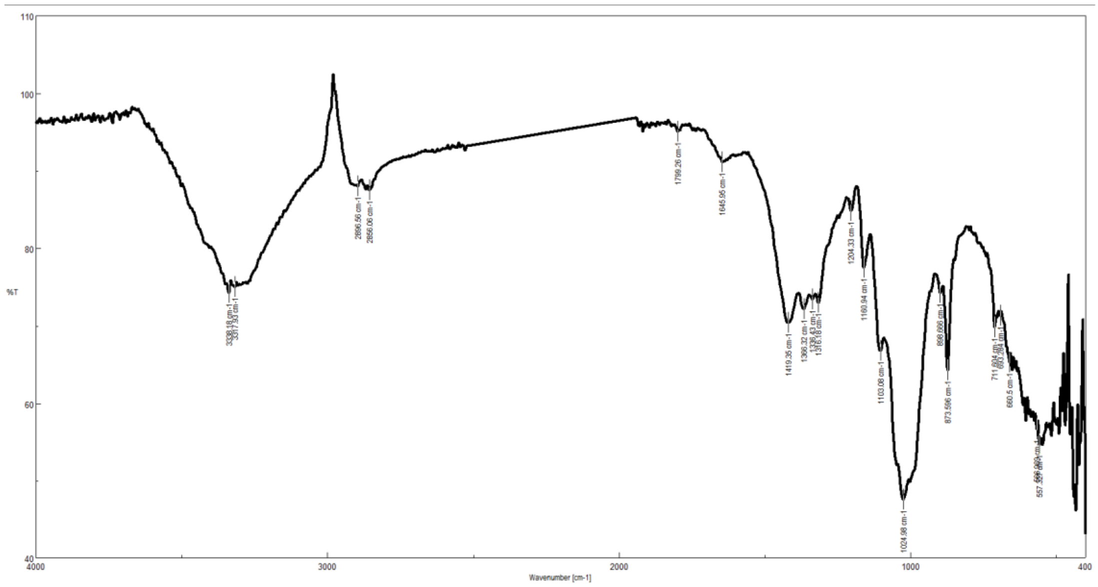


Figure 5.17. FTIR spectrum of BoFbB

III. Bodrum Black Fibers (BFbB)

Unlike the cellulose peaks, the intensity of the peaks at 871 cm-1, 1419-1316 cm-1 and 3338 cm-1 increased. The peak at 2896 cm-1 both increased in intensity and became more pronounced (Arslan et al, 2021). When the presence of spectra is examined, characteristic polyethylene (PE) absorbance bands are found at 2917 cm-1, 2851 cm-1, 1420 cm-1 and 711 cm-1 (D’Amelia et al, 2016). Compared to BoFbB, the peaks are more intense and slightly shifted (Figure 5.18.).

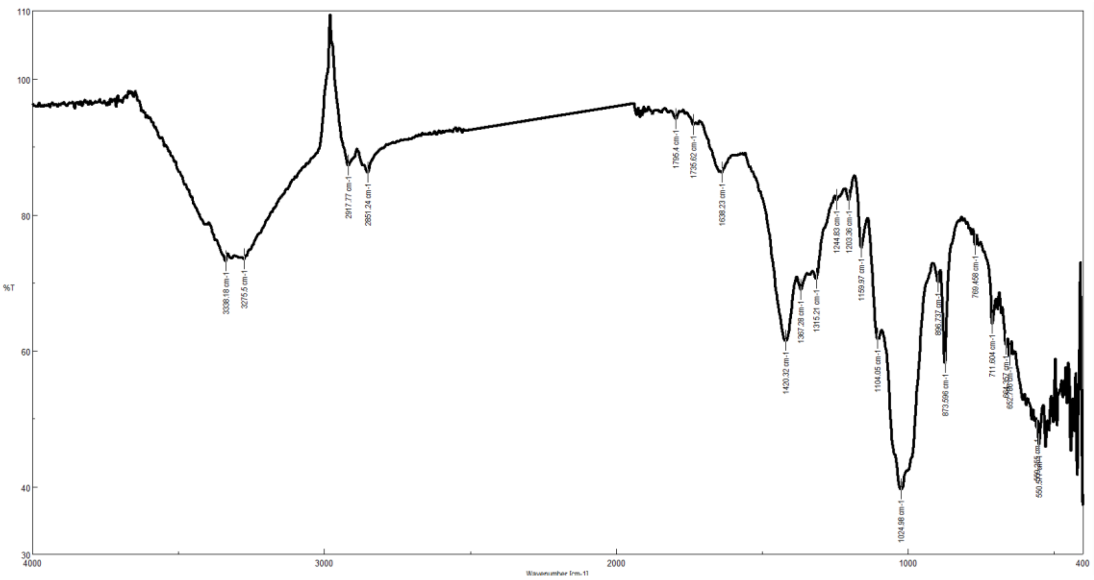


Figure 5.18. FTIR spectrum of BFbB

IV. Güllük Black Fibers (GFbB) and Other Experimented Fibers

Unlike the cellulose peaks, the intensity of the peaks at 871 cm-1, 1419-1316 cm-1 and 3338 cm-1 increased. The peak at 2896 cm-1 both increased in intensity and became more pronounced (Arslan et al, 2021). When the presence of spectra is examined, characteristic polyethylene (PE) absorbance bands are found at 2917 cm-1, 2851 cm-1, 1420 cm-1 and 711 cm-1 (D'Amelia et al, 2016). The peaks of the GFbB are less distinct (Figure 5.19.).

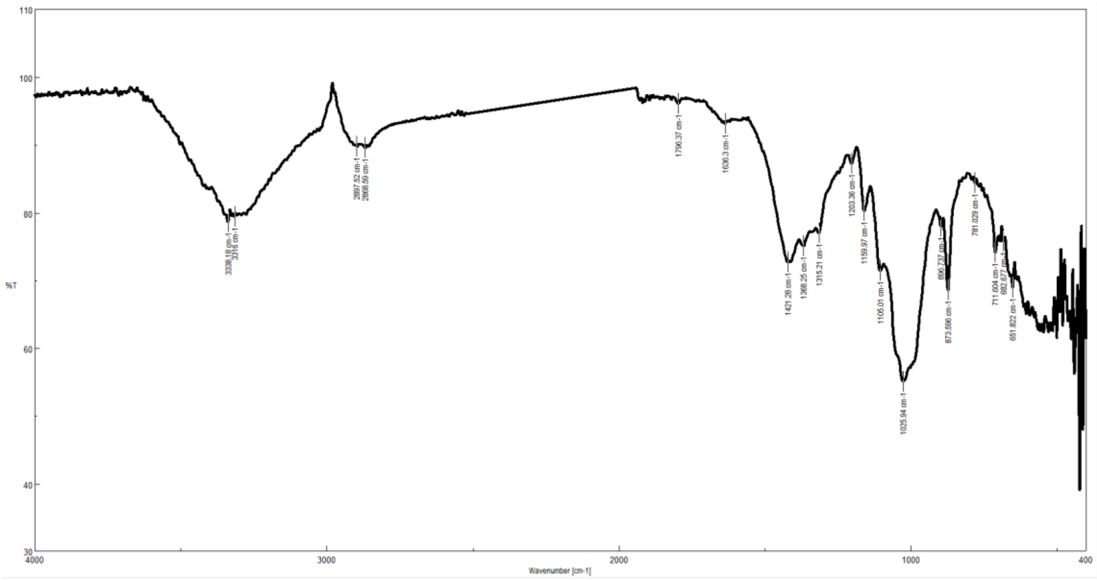


Figure 5.19. FTIR spectrum of GFbB

V. Turgutreis Black Fibers (TFbB)

Unlike the cellulose peaks, the intensity of the peaks at 871 cm-1, 1419-1316 cm-1 and 3338 cm-1 increased. The peak at 2896 cm-1 both increased in intensity and became more pronounced (Arslan et al, 2021). When the presence of spectra is examined, characteristic polyethylene (PE) absorbance bands are found at 2917 cm-1, 2851 cm-1, 1420 cm-1 and 711 cm-1 (D'Amelia et al, 2016). The peaks of the TFbB specimen are in a more severe form. In addition, there is another polymer, in short, a copolymer structure (Figure 5.20.).

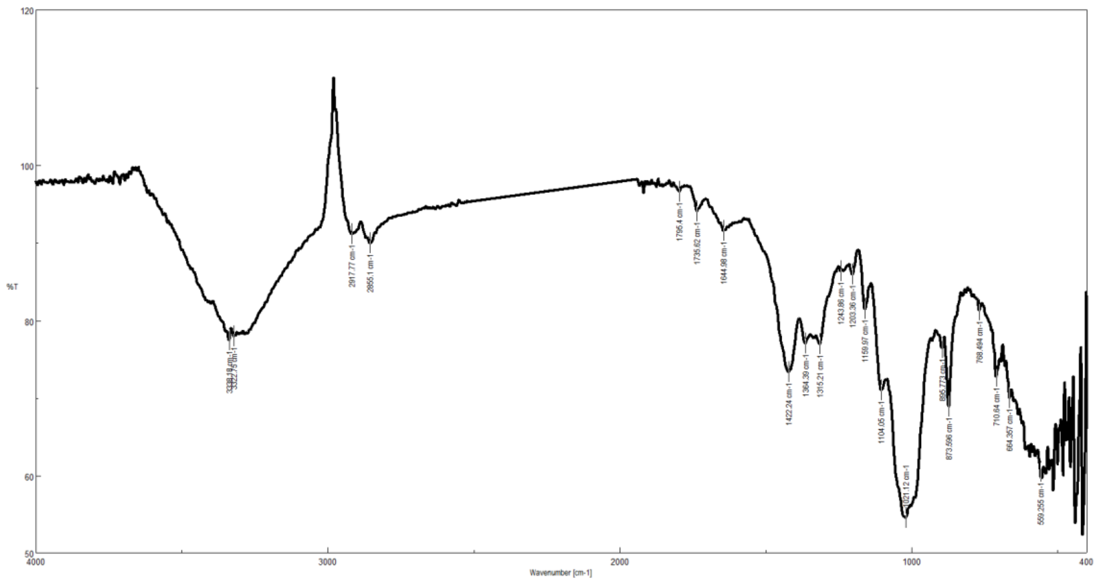


Figure 5.20. FTIR spectrum of TFbB

VI. Güllük Multicoloured Fibers (GFbMc).

GFbMc displayed different peaks compared to other samples observed. The intensity of the peaks at 871 cm-1, 1419-1316 cm-1 and 3338 cm-1 increased. The peak at 2896 cm-1 increased in both intensities and was more pronounced (Arslan et al, 2021; Figure 5.21.). It is a typical polyvinyl acetate (PVAC) sample, used as an adhesive and is water-based. Examining the strong acetate ester carbonyl bands were visible at 1728 cm-1 in the Polyvinyl Acetate (PVAC) FTIR spectrum. Other peaks: 1433 cm-1, 1370 cm-1, 1224 cm-1 and 1016 cm-1 are the specific peaks of the PVAC polymer (http://pubs.sciepub.com/wjce/4/2/1/figure/2, accessed 22.06.2022).

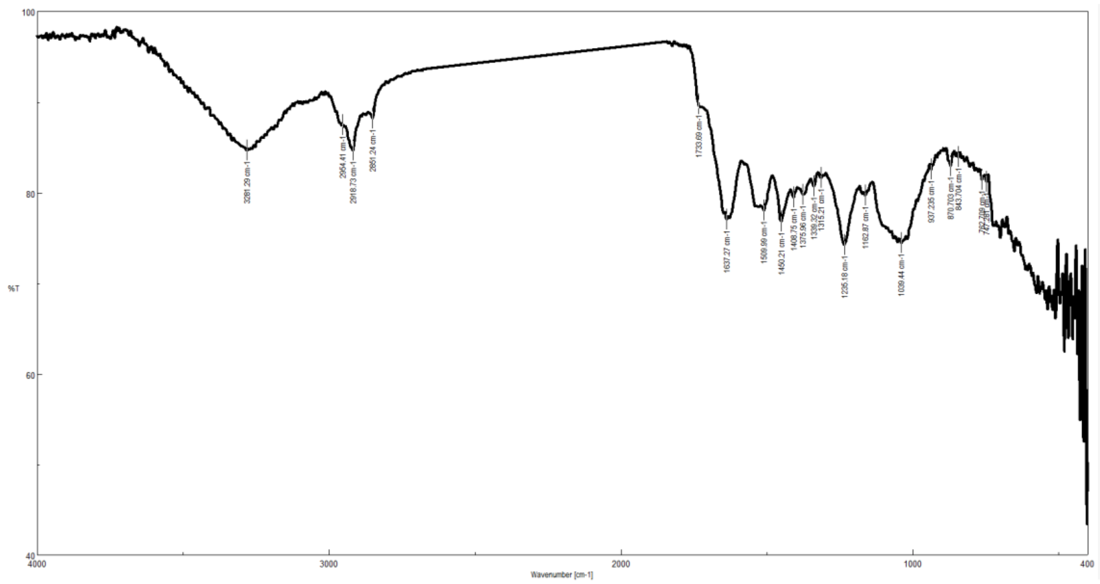


Figure 5.21. FTIR spectrum of GFbMc

VII. Güllük Blue and Yellow Fibers (GFBlY) and Other Experimented Fibers.

The intensity of the peaks at 871 cm-1, 1419-1316 cm-1 and 3338 cm-1 increased. The peak at 2896 cm-1 both increased in intensity and became more distinct (Arslan et al, 2021). When the presence of spectra is examined, characteristic polyethylene (PE) absorbance bands are found at 2917 cm-1, 2851 cm-1, 1420 cm-1 and 711 cm-1 (D’Amelia et al, 2016). The peaks of the GFBlY are less intense in some sections and more intense in other sections. The results of the other fibers from various sampled locations exhibited similar peaks as discussed above (Figure 5.22.).

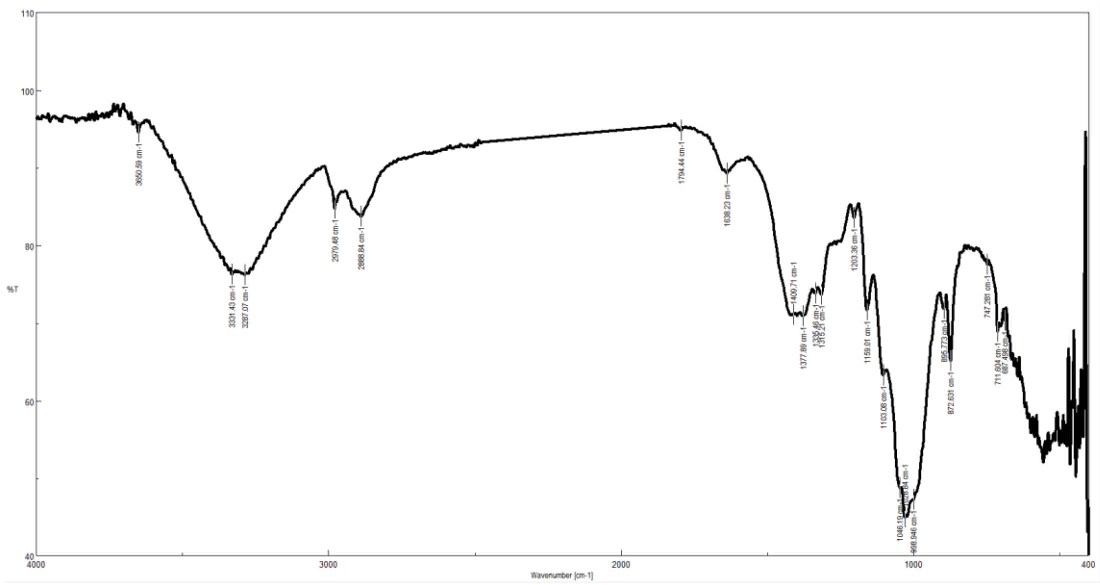


Figure 5.22. FTIR spectrum of GFBlY

VIII. Boğaziçi Green Glass (BoS5FgG)

Banon et al, (2016) determined the composite's glass fiber content and the polymeric elements' chemical composition. As they also noted the wavenumbers of the diglycidyl ether bisphenol A resin and glass fiber, our results resemble their FTIR result. BoS5FgG sample contained Si-OH – bending band at 823 cm-1 and SiOSi – tensile band at 1000 cm-1 (Figure 5.23.).

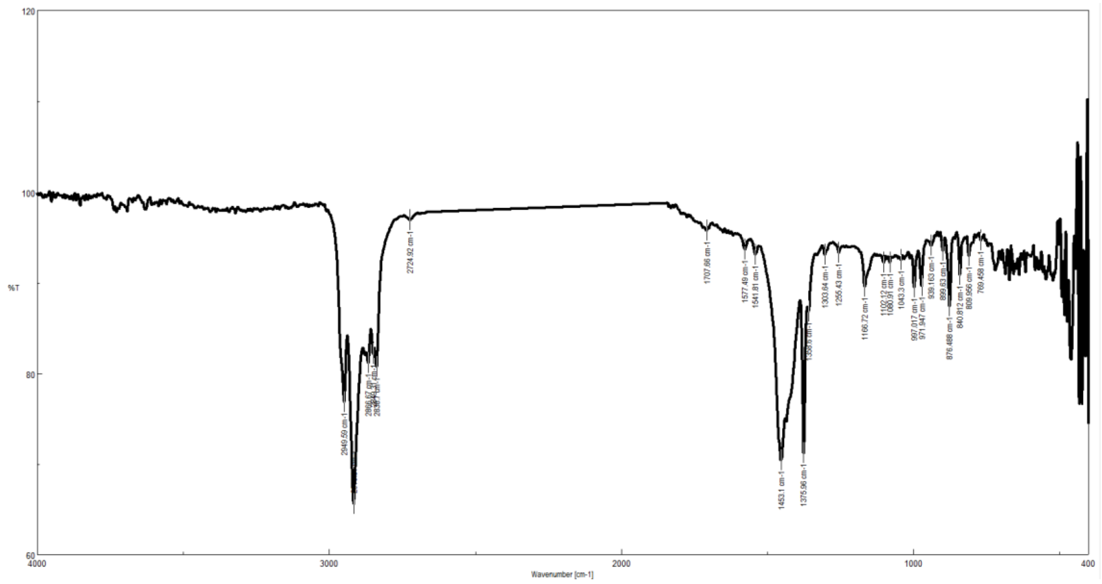


Figure 5.23. FTIR spectrum of BoS5FgG

IX. Güllük White Fragment (GS2FgW-GS4FgW)

Güllük white fragment sample is observed as Polytetrafluoroethylene (PTFE). It was demonstrated that the ratio of the intensities of the asymmetric and symmetrical tensile bands was reversed when the primary absorption bands (CF2 -) of PTFE were taken into account and the absorption maxima underwent higher wave numbers at 1230 and 1155 cm-1. (1230 and 1155 cm-1) (Piwowarczyk et al, 2019; Figure 5.24.).

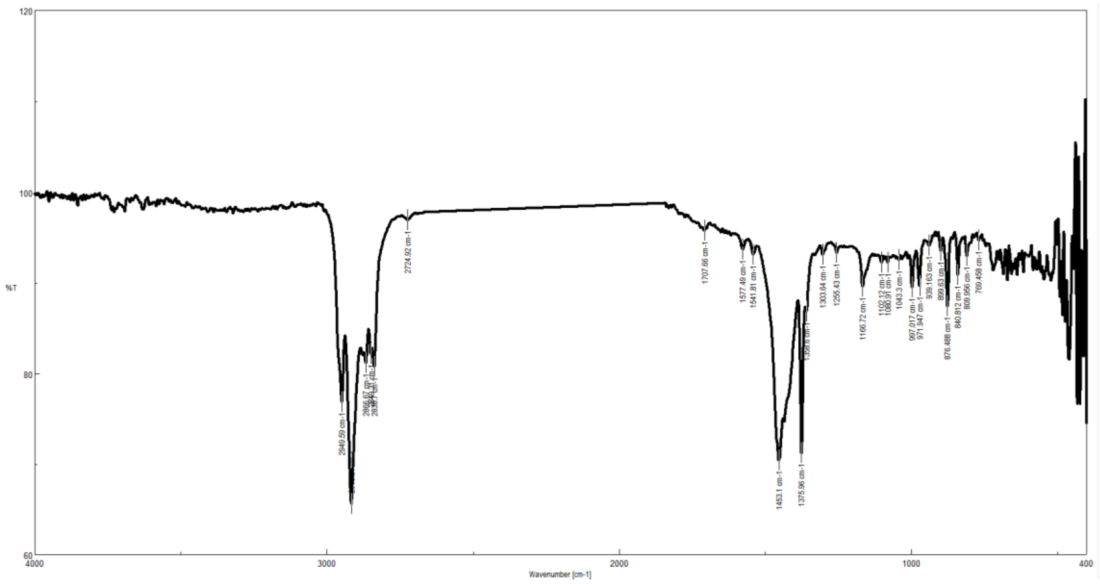


Figure 5.24. FTIR spectrum of GS2FgW-GS4FgW

X. Turgutreis Fragments

Turgutreis green glass sample (TS2FgG-TS3FgG) composed of Si–OH – bending at 780 cm-1 and SiOSi – tensile band at 1003 cm-1(Figure 5.25). The blue (TS1FgBl), green (TS2FgG-TS3FgG), rose (TS2FgRo) and white (TS2FgW-TS3FgW) fragments were identified as Polytetrafluoroethylene (PTFE). It was demonstrated that the ratio of the intensities of the asymmetric and symmetrical tensile bands was reversed when the primary absorption bands (i.e., -CF2 -) of PTFE were taken into account and the absorption maxima underwent higher wave numbers at 1230 and 1155 cm-1(Figures 5.26, 5.27, 5.28, 5.29).

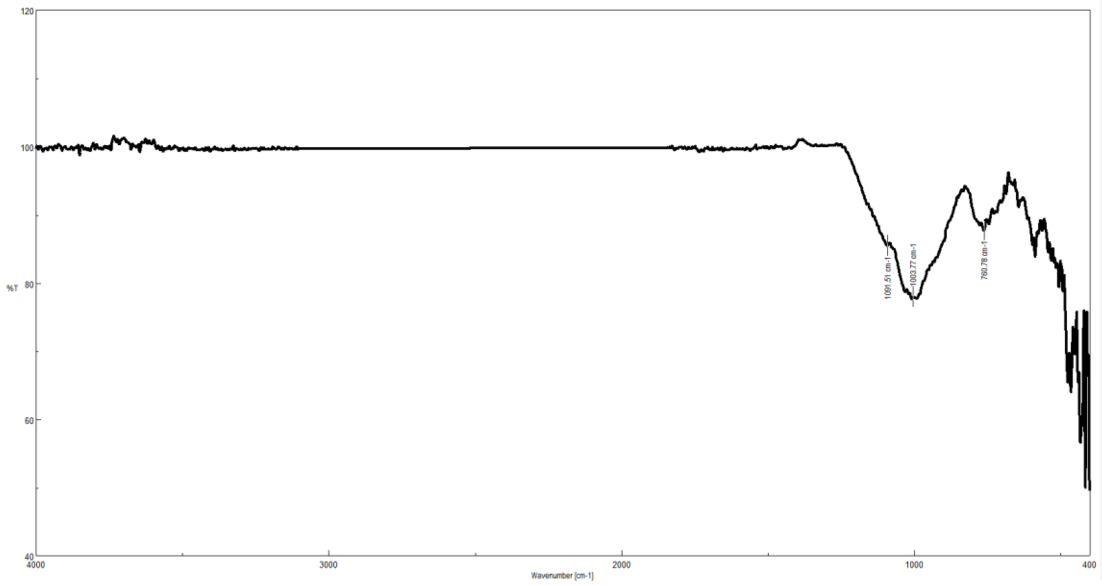


Figure 5.25. FTIR spectrum of TS2FgG-TS3FgG

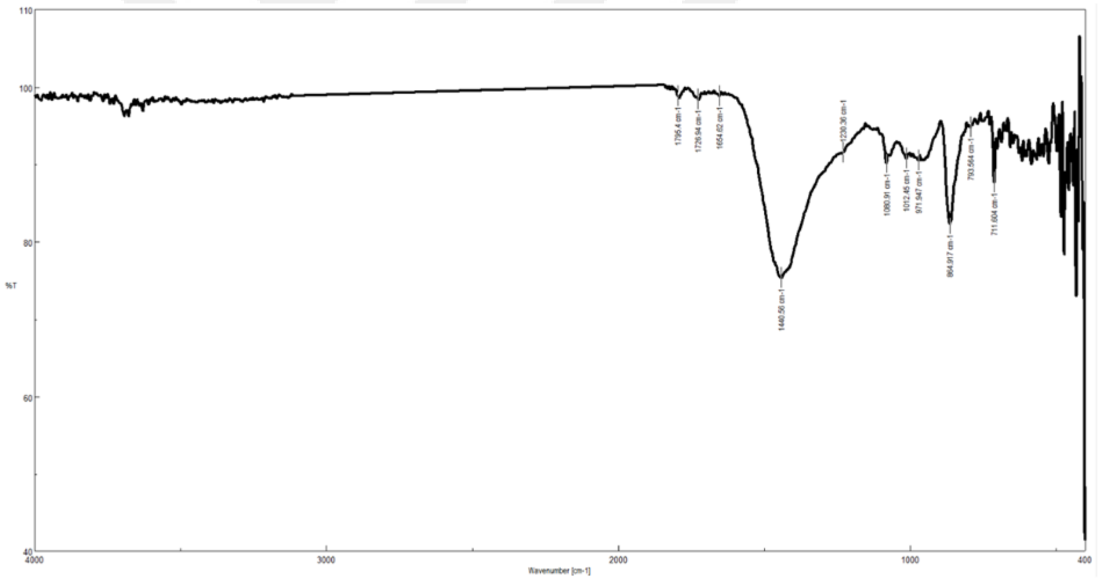


Figure 5.26. FTIR spectrum of TS1FgBl

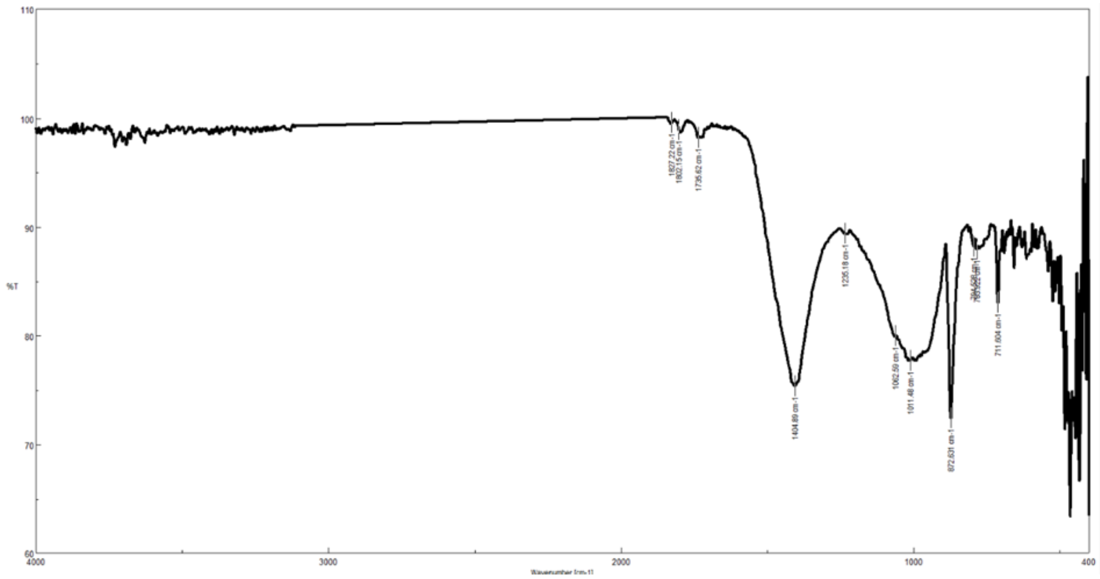


Figure 5.27. FTIR spectrum of TS2FgG-TS3FgG

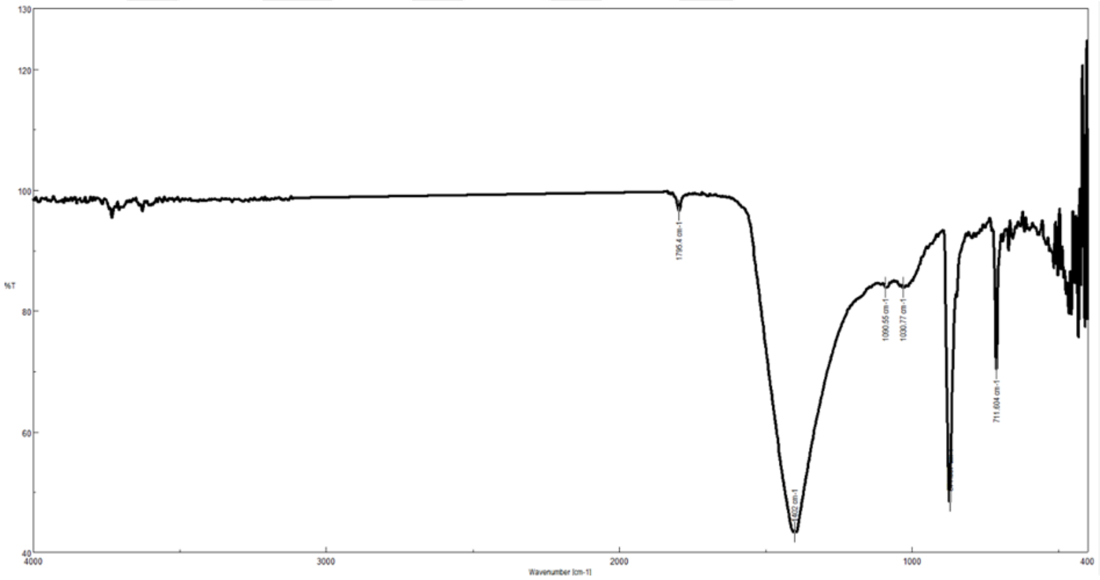


Figure 5.28. FTIR spectrum of TS2FgRo

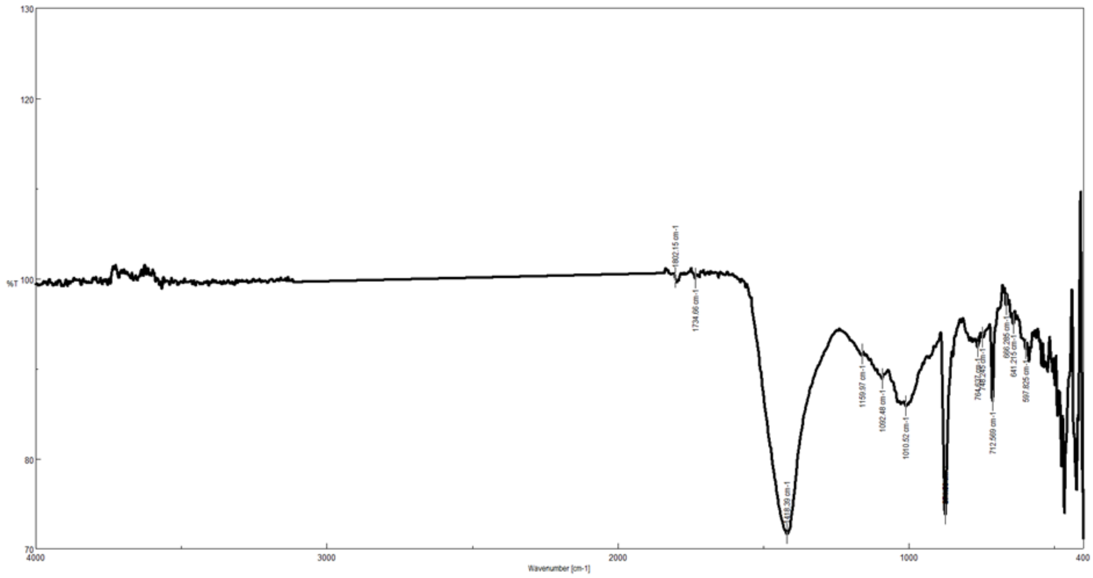


Figure 5.29. FTIR spectrum of TS2FgW-TS3FgW

6. DISCUSSION

6.1. Microplastics Distribution Factors

The presence of microplastics confirmed that MP pollution on Bodrum Peninsula (study areas) is intense by applying standardized sampling and extraction methodologies. The MPs discovered in this particular study contained a high amount of fibrous MPs. Several studies also achieved similar results (Thompson, 2004; Claessens et al., 2011; Dekiff et al., 2014; Alomar et al., 2016; Graca et al., 2017; Zobkov and Esiukova, 2017; Lots et al.,2017). The physical characteristics such as colors, sizes and chemical contents are different from each other. No obvious trend was detected according to the findings in the study area. The case study of Besley (2017) revealed that the location of the sampling on the beach might not have an impact on how the results turn out in the end. Our findings follow several previous studies as no specific distribution pattern of the microplastics was indicated (Hidalgo-Ruz and Thiel, 2013; Mathalon and Hill, 2014; Besley, 2017). However, population density and anthropogenic activities have been noted as one of the major microplastic distribution factors. Previous studies have revealed that given that the population is expected to treble in the next 40 years and continue to concentrate in big coastal areas, which will release more sewage into marine environments, microplastic contamination is projected to rise (Browne et al., 2011). Gündodu and Evik (2017) came to a similar result in their research study, which focused on the fact that the Seyhan River and the urban layout of the Mersin province are to blame for Mersin Bay's considerably higher microplastic concentration. According to Lots et al, (2017), the most contaminated region is the Mediterranean zone, particularly the eastern subzone, which exhibits the highest average abundance of MPs. They underlined that this might be caused by MPs being partially geographically trapped, together with dense coastal populations and waste intake.

Bodrum is the town with the largest population among the other locations that recorded the highest number of microplastics. The most intense tourism activity is experienced in this region. The second highest rate was found in Güllük. In terms of population, although Turgutreis is denser than this region, its microplastic content is less. The reason for this can be attributed to the size of the drainage area responsible for sediment deposition in and around Güllük, the existence of an airport, the intensity of various port-customs operations, and the presence of industrial areas. Bogazici, which is the least intense area both in terms of summer tourism density and industry, has been determined as the area with the lowest microplastic content. One of the recent studies our work was compared is Yabanlı et al. (2019). Their study reported one of the few studies done on Turkish beaches, and it provided the earliest findings on microplastic content from Southern Aegean beaches. Table 6.1 summarizes the MP concentrations found in beach sands from different parts of the world in comparison to the results of our current investigation. A significant amount of MPs was recorded in our study as compared to previous studies illustrating that, in addition to the high intensity of tourism activities, other MPs accumulation factors can be geographical as Yabanlı et al. (2019) mentioned that the Aegean Sea's irregular shoreline and variety of islands add to the area's distinctive and particular weather characteristics.

Table 6.1. Comparing microplastics disclosed in beach sediments from diferent areas globally to our study (modified from Yabanlı et al., 2019)

Location	Sample type	Abundance	References
Geoje Island, South Korea	Sand	27.606[a]	Lee et al., 2013
Kea Island, Greek	Beach sediment	977[a]	Kaberi et al., 2013
Gulf of Trieste, Slovenia	Beach sediment	133.3	Laglbauer et al., 2014
Mediterranean Sea	Beach sediment	291 ± 62	Lots et al., 2017
Aegean Sea (Dikili, İzmir, Turkey)	Beach sediment	248 ± 47	Lots et al., 2017
Southern Baltic Sea, Poland	Beach sediment	39 ± 10	Graca et al., 2017
Northern Crete Island, Greece	Sand	1197.5[a]	Karkanorachaki et al., 2018

Baja California Peninsula, Mexico	Sand	135 ± 92	Piñon-Colin et al., 2018
Isle of Rügen, Baltic Sea	Beach sediment	88.10	Hengstmann et al., 2018
Caribbean Beaches	Sand	261 ± 6	Bosker et al., 2018
Qinzhou Bay, China	Beach sand	3266.0 ± 6390.8	Li et al., 2018
Portuguese Coast	Beach sediment	454 ± 1908[a]	Antunes et al., 2018
Hiroshima Bay, Japan	Beach sediment	5 to 1245	Sagawa et al., 2018
Lambra, Canary Islands	Sand	1656[a]	Herrera et al., 2018a
Datça Peninsula, Aegean Sea	Beach sediment	1154.4 ± 700.3 (4617.6 ± 2801.2)[a]	Yabanlı et al., 2019
Bodrum Peninsula, Aegean Sea	Beach sediment	1446	Current study

In addition, it is important to conduct subsequent annual analyses to be able to track microplastic intensity variation of the Bodrum Peninsula. 2015 and 2016 estimated baseline average values of microplastics on the sea surface by UNEP/MAP in 3 stations of Mesin Bay range between 200000-500000 pieces. (ÇŞB, 2017). ÇŞB (2017) evaluated report indicated a significant decrement in microplastic from 2014 to 2016 from both sea column, sea surface and sediment.

6.2. Climate Impacts on Beach Sediment Deposition and MPs Distribution

For the first time, Tuncer et al. (2018) investigated the occurrence of microplastic in the Sea of Marmara. They observed that, particularly on current- and wind-dominated water masses in the research area, surface currents constitute the primary force permitting the distribution of low-density MPs. It is hypothesized that several circumstances such as seasonal fluctuations in upwelling or downwelling, vertical stratification, and weather interference affect the Sea of Marmara's surface current's capacity to transfer microplastic from the source to other places (Tuncer et al., 2018). The massive amount of light density MPs identified in our study is in line with this research work. The sea level variation and current direction data of our study area were also evaluated to understand their contribution to sediment formation and MPs distribution.

There is a station on the Bodrum Peninsula where sea-level changes are observed (Figure 6.1.). In this station, which is located close to the town center of Bodrum, it has been determined that the measurements cover the years 1986-2010, monthly averages due to tides and seasonal changes, the sea level changes between a maximum of 7.2 m and a minimum of 6.75 m, therefore a total change of 45 cm is observed (https://www.psmsl.org/data/obtaining/rlr.monthly.plots/1680_high.png; Access date: 27/06/2022).

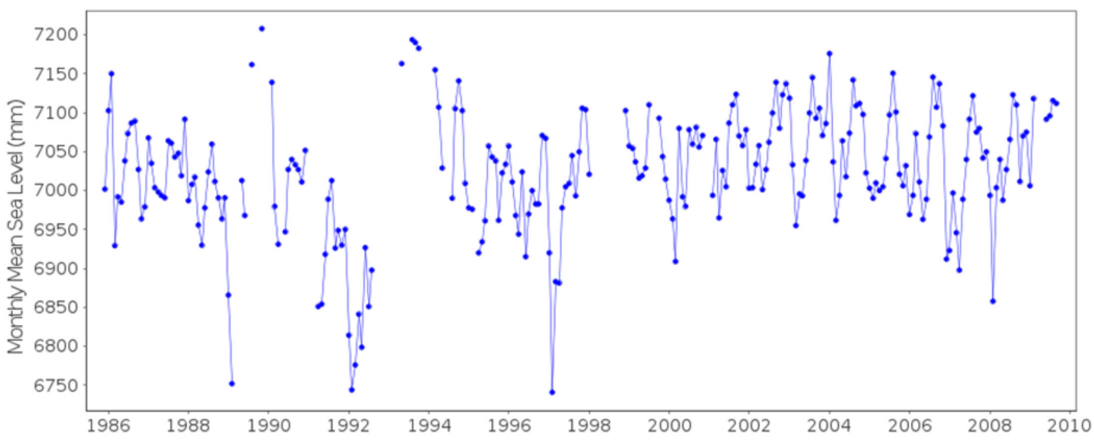


Figure 3.1. The sea level variation of the Bodrum Peninsula (https://www.psmsl.org/data/obtaining/rlr.monthly.plots/1680_high.png; Access date: 27/06/2022)

In Bodrum town center, the average temperature in summer months is 32-34 °C, the average temperature in winter is 10 °C, the annual average is 20 °C, the humidity is considered low, and the precipitation is thought to be around 700 mm, similar to Turgutreis. Wind direction is variable throughout the year; In the spring-South; In summer - 1st dominant direction is North-Northwest, 2nd dominant direction is Southwest; in autumn - 1st dominant direction is North-Northwest, 2nd dominant direction is Southwest; In winter - The dominant direction is South (https://www.coastguidetr.com/tr/korfez/1003/bodrum-yarimadasi-guney-yakasi;

Access date: 28/06/2022). These directions cause the variation of both wave direction and longitudinal currents. In addition, it is suggested that the breakwater, island formations and coastal morphology observed in both field studies and satellite Google-Earth images prevent sediment arrival from long distances. Sediment analysis results also indicate that beach sediment formation is principally fed from land.

Turgutreis area is an area where the wind is strong (3.1 m/s), wavy, the average temperature in summer months is 32 °C, the average temperature in winter months is 7 °C, and the annual average is 20 °C. Humidity rate is evaluated as 64%, precipitation is thought to be around 743 mm. Wind direction the prevailing wind direction throughout the year is Southeast, and the strongest wind direction predicted to be in winter is Northeast (https://www.coastguidetr.com/tr/korfez/1002/bodrum-yarimadasi-bati-yakasi: Access date: 28/06/2022). Since the coastal morphology is limited to the hilly-rocky areas from both the north and the south, only the sediments in the delta area are reprocessed by the longitudinal currents. However, this process has been interrupted by the breakers built in recent years.

In Güllük, the average temperature in the summer months is 27.3 °C, the annual average is 18.4 °C, the humidity is 62.9% and the precipitation is thought to be around 578.1 mm per year. Wind direction is variable throughout the year; In spring - 1st dominant direction is East, 2nd dominant direction is West-Northwest; In summer - 1st dominant direction is Northwest, 2nd the dominant direction is East; in autumn - The dominant direction is Southwest; In winter - dominant direction is South (https://www.coastguidetr.com/tr/korfez/1001/Güllük -korfezi; Access date: 28/06/2022).

It is suggested that there are similar aspects in the Boğaziçi area. In both areas, some rivers are thought to be the main feeding area in the eastern parts. It is predicted that the sediments obtained from here are transported to the sampling site by westerly wind-wave and longitudinal currents. The results of the chemical analysis and the macro observations made in the sieve analyses also confirm this.

6.3. Sediment Grain Size Relationship with Microplastics

Alomar et al., (2016) mentioned that as is the case for organic material and other pollutants, MPs concentrations do not rise with decreasing sediment grain size (Bergamaschi et al., 1997; Chakraborty et al., 2015). Browne et al. (2010) asserted that other mechanisms, such as aggregation with organic material, may play a significant role in the mobility of MPs. However, upon our findings, considering the relationship between average grain size and microplastic quantity, it is observed that as the proportion of coarse-grained sediments increases, the rate of microplastics retained in them is relatively low (Figure 6.2). Bodrum samples with the smallest grain size have relatively the highest microplastic content. This shows that microplastic quantification might not directly relate to geological processes of the beach sediments, the grain size of the sediments play important role in MPs retention. Meanwhile, it is important to further test this situation in areas where common conditions prevail. The result also prevails a significant variation in MP quantity in terms of shoreline and backshore of the study area specifically in Güllük and Boğaziçi. From the graph, it is obvious that the number of MPs detected from the shorelines (thus G1, G3, G5 for Güllük and BO1, BO3, BO5) was higher than that of the back shores (thus G2, G4, G6 for Güllük and BO2, BO4, BO6). The reason is suggested to be the accumulated MPs in the seafloor carried to the surface by sea tides.

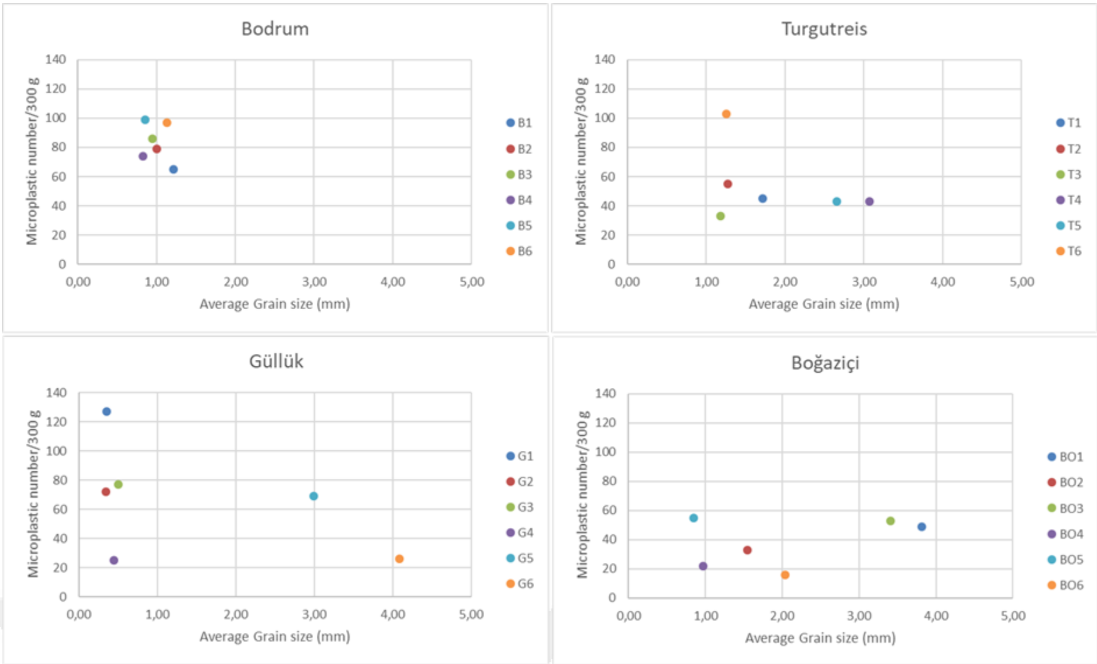


Figure 6.2. Grain sizes relationship with microplastics was observed in all locations

6.4. Microplastics Control Challenges

Due to the rapid growth of industrialization, the prevention of microplastic dispersal in the coastal areas is a challenging topic to touch. Westphalen and Abdelrasoul (2018), mentioned that the prevention of microplastic pollution in thewater bodies is challenging due to the lack of technology that actively retains these materials at wastewater facilities. Browne et al., (2011) suggested that architects of clothing and washing machines should consider the need to minimize the release of fibers into wastewater and research is required to improve techniques for removing microplastic from sewage.

6.5. XRD SEM AND EDS, FTIR Evaluation

The XRD results uncovered the variation in the mineral distribution of the sampled locations. The major minerals dominant in all locations are quartz, plagioclase, K-feldspar, calcite, dolomite and micas. The identification of minerals is based on EDS analysis yielding the major elements Si, O, Al, Ca, Na, Fe, Mg and K are typical EDS spectra for silicate minerals (Welton, 1984). Silica minerals were dominant in all sampled locations peculiarly in Bodrum and Turgutreis. Microplastic content was highly intense within these locations. Most of the inorganic soil components have hydrophilic surfaces made of oxides and silicates including quartz, feldspar, and silicate clays (Boyd and Jaynes, 1994). The XRD findings of our study indicated the dominance of hydrophilic minerals such as calcium carbonate, dolomite, quartz and mica in various studied locations suggesting that these minerals play a major role in microplastic retention.

The FTIR results displayed 3 different polymers including polyethylene (PE), polyvinyl acetate (PVAC), Polytetrafluoroethylene (PTFE) and glass fibers containing Si-OH – bending band and SiOSi – tensile band in the various study areas. The results obtained are comparable with several related studies. Lots et al stated that three different types of polymers—polyethylene (PE), polypropylene (PP), and polyester—were separated by the percentage of fibers that they could detect using Raman spectroscopy (PEST). Research conducted in in 6 European countries found PE and PP as the most common polymer types (Martins and Sobral, 2011; Kaberi et al., 2013; Vianello et al., 2013; Faure et al., 2015; Bonon et al., 2016; D’Amelia et al., 2016 Frère et al., 2017; Lots et al., 2017).

CONCLUSION

This thesis was carried out to identify and classify beach sediments and determine microplastic contents along select coastal areas in Bodrum Peninsula, SW of Turkey. The samples were gathered from Bodrum, Turgutreis, Güllük and Boğaziçi and subjected to sieve analysis. To identify microplastics, handpicking, flocculation method, FTIR, SEM-EDS and XRD analyses were carried out. Depending on the findings of the research, the following conclusions can be drawn;

- Population density and anthropogenic activities have been noted as one of the major microplastic distribution factors.
- Our findings unveil the relationship between average grain size and microplastic quantity as it is observed that when the proportion of coarse-grained sediments increases, the rate of microplastics retained in them decreases. Bodrum samples containing the smallest grain size showed the highest microplastic content. This means that microplastic distribution might not directly relate to sediment depositional processes, the grain size of the sediments plays a major role in MPs retention.
- Another important goal of our study was to determine the differences in the microplastic content of the shoreline and back shores of the selected beach. In our findings, it is clear that the number of MPs obtained from the shorelines (thus G1, G3, G5 for Güllük and BO1, BO3, BO5) was higher than that of the back shores (thus G2, G4, G6 for Güllük and BO2, BO4, BO6). It is suggested that the accumulation of MPs on the seafloor could be a key factor in the shoreline distribution of MPs as well.
- The identification of minerals according to EDS analysis disclosed the major elements Si, O, Al, Ca, Na, Fe, Mg and K which are typical EDS spectra for silicate minerals (Welton, 1984). Silica minerals were dominant in all the sampled locations, especially in Bodrum and Türgürtreis. Microplastic contents were highly intense within these locations.

- The XRD findings of our study indicated the dominance of hydrophilic minerals such as calcium carbonate, dolomite, quartz and mica in various studied locations propounding that these minerals play a major role in microplastics retention.
- A total number of 1446 MPs were identified in 7200g of samples. The most abundant microplastic types found were fibers with a total number of 1137.
- The FTIR results pointed out a clear identification of different polymers including polyethylene (PE), polyvinyl acetate (PVAC), Polytetrafluoroethylene (PTFE) and glass fibers containing Si-OH – bending band and SiOSi – tensile band in the various study areas.
- The prevention of microplastic dispersal in the coastal areas is a challenging topic to touch. Westphalen and Abdelrasoul (2018), mentioned that the prevention of microplastic pollution in water bodies is challenging due to the lack of technology that actively retains these materials at wastewater facilities.

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2016-2017 **Erasmus Program (1 year)** Vsb- Technical University of Ostrava, Ostrava, CZECH REPUBLIC

Experiences

Summer Intern **June 2018-Sep 2018**

Eczacıbaşı Esan Kurşun-Çinko İşletmesi,Balya/Balıkesir

- **Underground Exploration Activities**
  - Gallery face mapping, underground drilling and underground protection techniques
- **Surface Exploration Activities**
  - Lithological and geotechnical logging, drilling, sampling, optical mineralogy, chemical analysis and field works

Projects

Engineering Design Project: Rockfall potential and slope stability

Course Projects:

Mineral Deposits: Poster about Major Porphyry Cu Deposits of Eastern Turkey

Remote Sensing: 3D modeling using Pix4d program, Band combination, Supervise and Unsupervised Classification using Snap program

Computer Applications of Geological Engineering: Interpolation (IDW and Kriging) using bathymetry data and 3D
modeling using ArcGIS.

Field Geological Mapping: Drawing geological, stratigraphical and cross-sectional maps.

Skills

Computer Programmes ArcGIS, Adobe Illustrator, Corel Draw, Microsoft Office

Languages English(Native)
Turkish(Advanced)

Czech(Basic)

Relevant Courses

- Mineral Deposits
- Computer Application in Geological Engineering
- Remote Sensing
- Drilling
- Surveying

Publication

Gül, M., Küçükuysal, C., Çetin, E., Ataytür, Ö., & Masud, A. (2020). Coastal Erosion Threat on the Kızkumu Spit Geotourism Site (SW Turkey): Natural and Anthropogenic Factors. Geoheritage, 12(3), 1-14.

Hobbies

Football

Athletics

Table Tenis