Potential Microplastic Threat: Environmental Assessment of The Face Mask Pollution

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Research Article

Keywords: covid-19, face masks, microplastic pollution, soil pollution, water pollution

Posted Date: February 23rd, 2021

DOI: https://doi.org/10.21203/rs.3.rs-216309/v1

Version of Record: A version of this preprint was published at Environmental Science and Pollution Research on April 24th, 2021. See the published version at https://doi.org/10.1007/s11356-021-14099-8.

Abstract

In recent studies, many reports on the environmental effects of microplastic pollution have been presented. Countries across the world have already started carrying out studies on the restrictions of the industrial use of microplastics based on these reports. Many non-governmental organizations try to clean the existing microplastics from the oceans using their resources. However, a new source of microplastics has started to be released into nature as a result of the single-use face masks that protect us against the spread of COVID-19 and are being thrown onto the streets and into seas and nature. Before the pandemic, it was reported that more than 300 million microplastics were discharged from the province of Mersin to the eastern Mediterranean. This number will inevitably increase if not managed correctly. A mass balance needs to be studied for the correct management of waste. This study aims to estimate the amount of face mask use during the COVID-19 pandemic in Turkey, thereby expressing our concerns about waste management and plastic pollution, and calling on appropriate solid waste management policies and governments to take the necessary measures to formulate their strategies at all levels.

Introduction

The coronavirus, which first emerged in Wuhan, China in December 2019, soon became a global pandemic. Life came to a standstill after the World Health Organization (WHO) declared that the disease could spread through the air (Velavan and Meyer 2020). The federals, states and governments have been mandated to use the face masks as a first measure to gradually ease restrictions. These masks, which are frequently used by individuals who are carrying on with their work/social life, are a means of protection from the virus (Chintalapudi et al. 2020). In March 2020, the early days of the pandemic, WHO announced that approximately 90 million masks were needed every month worldwide (WHO 2020). However, according to May 2020 data, 88% of the world's population live in countries that require the use of masks in public places. Therefore, it can be said that an average of 6.7 billion people needs to wear a mask to carry on with their daily/social life (Mask4all 2020).

Single-use face masks are produced from various polymers such as polyacrylonitrile, polyurethane, polypropylene, polycarbonate, polyethylene and polyester, which are also used in plastic production (Potluri and Needham 2005). The increase in the global production of single-use plastic has started to threaten wildlife. Once the face masks are thrown away, it breaks down as macroplastic or microplastic caused by exposure to environmental factors such as the sun's radiation or rain.

Plastics with a particle size of less than 5 mm are called microplastics (Zhang et al. 2017). There are two main sources of microplastics: 1) synthetically produced micro-sized plastics and 2) the breaking down of macroplastics into microplastics by environmental factors. Many studies have been conducted on the detection, quantification and identification of microplastics in the soil/aquatic ecosystem (Corradini et al. 2020; Gerolin et al. 2020).

Soil is the first environment to which plastics are transported. Approximately 32% of the existing plastic wastes are currently mixed with the soil (Kumar et al. 2020). WHO and various other authorities predict that the coronavirus pandemic will continue for at least another year. Accordingly, the use of face masks will also continue for some time, meaning that the possible threats of microplastics to the soil will increase. It has been reported that the presence of these microplastics significantly affects microorganisms, soil density, water holding capacity and evaporation rates (Huerta Lwanga et al. 2016; Scheurer and Bigalke 2018; Lu et al. 2019). In addition to all these effects on the soil biota, it is predicted that nano-sized (<1 mm) micro-pollutants can mix into groundwater through irrigation.

Face masks can be transported to the aquatic ecosystem. Research on microplastic pollution in the seas continues on a global scale, however, face masks will make it difficult to find solutions to the existing problems (Fadare and Okoffo 2020). Studies are still being conducted on a large scale regarding the effects of microplastics. One of the most current research topics is the effect of microplastics on the carbon sequestration of seas. Microplastics can adversely influence the growth and development of phytoplankton by affecting their metabolism (Sjollema et al. 2016). Furthermore, as the demand for fully synthetic occurring plastics increases day by day, the demand for raw materials is also increasing. Oil, gas and coal are the fossil-fuel building blocks of plastics. The extraction and transportation of these fossil fuels is a carbon-intensive activity that causes a high increase in carbon dioxide emission (IPCC 2014). Similar results are previously reported from surface stations along the coastline of Turkey. An average of 33 particles m^{-3}, which is mostly polyethylene, was observed on the southwestern coast of Istanbul, Turkey. In another study conducted on microplastic pollution in the Mediterranean coast of Turkey, the quantity of microplastic particles in surface water samples was up to 520 213 per km^2. It is expected that such a fraction of (micro-) plastic will continue increasing in the next few years due to the excessive use face masks to fight covid-19 pandemic. However, their effects cannot be predicted for now. Currently in many countries, including Turkey, there are no regulations regarding microplastic pollution management strategies.

People started to socialize again with the reduction of the first wave effect of the pandemic and disposable masks strewn around the streets, parks, beaches and oceans of many cities as reported by (Aragaw 2020). With the increase of similar studies, the regional distribution numbers and waste management methods of the single used masks became a subject of interest (Akber Abbasi et al. 2020). Researchers have started to report the number of used masks in their country and the number of regularly disposed ones (Aragaw 2020).

According to UN estimates, up to 75% of all coronavirus-related plastic could end up as waste in oceans and landfills (UNCTAD 2020). It has been estimated that as a result of the pandemic, 129 billion face masks and 65 billion gloves are used globally per month (Prata et al. 2020). Assuming each face mask weighs 4 grams and each glove weighs 5 grams (manufactured product), that's 841,000 metric tons of medical waste generated per month. It is also known that medical waste is included in the scope of non-recyclable waste according to the current legislation and regulations. Ultimately, most plastic waste around the globe ends up in the aquatic/soil ecosystem.

Moreover, reports have been published stating that disposable masks are not properly disposed of and that they are not sufficient in waste management (Sangkham 2020; Dharmaraj et al. 2021). As a result, one of the many problems that will inevitably arise is infectious waste and, if not properly managed, can be the root cause of serious illness and environmental problems. This study provides insight into the contribution of the significant change with COVİD-19 in the amount of plastic per unit area to plastic pollution and the environmental effects of this change.

In this study, we calculated the approximate number of face masks usage in Turkey and three cities in the country leading to a rough estimate on (micro-) plastic content in the environment. An FTIR spectral characteristics on single-use face masks were also examined to determine plastics polymer materials. Another objective was to estimate the face mask use of each city during the pandemic and compare the actual case values with the theoretical values. The results will enable a better understanding of the current situation and can be used to take action in terms of new policies and strategies regarding waste management.

Methods

The number of face masks used per day was estimated using an equation adapted from that of (Nzediegwu and Chang 2020) and is as follows:

$$D_{fm} = P \ x \ U_p \ x \ F_{mar} x \ F_{MGP} \qquad (1)$$

Where D_{fm} is daily face mask use (pieces), P is the population (persons), U_P is the urban population (percentage), F_{MAR} is face masks acceptance rate (this rate was accepted as 80% in this study) and F_{MGP} is the assumption that each person in the general population uses one face mask a day.

Disposable face masks that were in a 1 km^2 area on the central streets of the provinces of Adana, Mersin and Niğde, Turkey were also collected and examined. The deterioration of the chemical structures of the masks was determined with Fourier to transform infrared (FT-IR) and scanning electron microscope (SEM) analyses. Furthermore, the uncontrolled distribution of the masks per unit area was evaluated and the effect of the masks on the microplastic pollution for each city was determined according to Akber Abbasi et al. (2020)

Mersin and Adana are located in the southeast of Turkey and are very populous cities of the northeast Mediterranean. As the distance between these two cities (80 km) is quite short, they are socio-culturally similar. On the other hand, Niğde, which has only one-sixth of the population of Mersin and Adana, is located 200 km north of these cities (Figure 1.). Whether these factors are important or not was determined by comparing the cities.

The three cities represent 5% of Turkey, both in terms of population (approximately 4 million people) and surface area (40.000 km^2). Thus, the obtained results were considered sufficient to make a meaningful inference of the whole country. A common aspect of these cities is that the existence of the universities in this region causes the formation of a dense population and consumption dynamics. Millions of people use masks every day to protect against coronavirus. Since waste management is not fully established in this regard, most of these masks are not disposed of properly and have instead ended up dumped in the soil or the sea.

The Mediterranean, in which Mersin and Adana are located, is already susceptible to high levels of pollution due to its huge coastal population. Studies conducted in the eastern Mediterranean have reported that hundreds of millions of microplastics are discharged into the seas every day (Akarsu et al. 2020). Therefore, any work to be carried out on microplastics in this region is of vital importance for the sustainability of the aquatic ecosystem.

In this study, a perimeter of 1 km^2 in all three cities was determined by the geographical information system (GIS) and the masks found within these perimeters were collected. The locations of the collected masks are shown on the map given in Figure 2. Each mask was collected with metallic forceps and was placed in an individually sealed bag. Then, relevant information such as the coordinates of where the mask was found, was noted on the bag. The masks were kept away from UV light to examine their structural deterioration, disinfected with alcohol, analyzed via FTIR, SEM and weighing.

Disposable face masks can be manufactured from different polymeric materials. Polypropylene (PP), polyurethane (PUT), polyacrylonitrile (PAN), polystyrene (PS), polyethylene (PE) and polyester (PES) are the most common type of polymer materials used (Aragaw 2020). Therefore, some of the face masks were also analyzed using a Bruker-Vertex 70 FT-IR with a scanning range of 400–4000 cm^{-1} in the central laboratory of Niğde Ömer Halisdemir University to confirm the particles as plastic and identify their polymer type (Lenz et al. 2015). The level of fragmentation in the fibers was also important to show the seriousness of the issue. Hence, SEM images were recorded using a Zeiss/EVO 40. The samples were coated with gold before the measurements were carried out. In addition, weighing analyzes were carried out in order to determine the total microplastic potential of face masks. In this way, the weight of the plastic waste will be determined in the real amount.

Results And Discussion

3.1 Face mask density and distribution

The number of masks used in the three cities was calculated as given in Table 1. Face masks may help stop the spread of the coronavirus. However, according to these results, approximately 50 million contaminated facemasks were created each day in Turkey. This value also means 73 000 tons of contaminated waste per year. Akber Abbasi et al. (2020), also report that there is a significant increase of (micro-) plastic content in the Arabian Peninsula. Saudi Arabia, being the most populated country in the region may contribute up to 32–235 thousand tons of (micro-) plastic.

According to these results, the estimated number of masks per km^2 in the cities was calculated as 96.2 for Adana, 68.4 for Mersin and 29.9 for Niğde. However, the actual face mask data obtained in this real case study were as follows: 210 for Adana, 170 for Mersin and 166 for Niğde. The difference between the results indicated serious plastic pollution, especially in the city centers, as well as a lack of waste management. It was determined that the three cities used roughly 2.5 million face masks a day. Assuming that each face mask weighs 4 grams, 10 metric tons of face masks are generated as waste per day. Approximately 300 tons of plastic waste are produced per month, with most entering the soil/aquatic ecosystem and in turn threatening nature.

Table 2 shows the number of masks collected from the streets in the cities. Accordingly, the most masks were collected in Adana with 210 masks/km^2, which was followed by 170 masks/km^2 in Mersin and 166 masks/km^2 in Niğde. According to the data, the highest average mask weight was determined in Niğde with 3.0607 (±0.4340) g/mask, while it was 2.9914 (±0.4315) g/mask in Adana and 2.9554 (±0.5101) g/mask in Mersin as given in Figure 3. Taking into account the number of masks collected, the mask weight per km^2 was calculated as 628.194, 508.076 and 502.418 g/km^2 for Adana, Niğde and Mersin, respectively.

Most of the face masks were found around bus stops, hospitals, pharmacies and playgrounds. As protective equipment such as face masks and gloves are considered to be medical waste, the best disposal method for such equipment is incineration (Figure 4.). However, due to insufficient incineration facilities, medical waste is being buried, which is not an environmentally effective method of disposal. Single-use face masks contain large amounts of polypropylene, which release a lot of toxic substances including stabilizers and pigments (Hahladakis et al. 2018). The main problems in the world regarding this subject are the lack of medical waste bins for protective equipment and the lack of awareness. Most people consider masks to be similar to small clothes rather than a plastic product and therefore harmless to the environment. However small clothes also contain MPs (e.g., microfibres of nylon). Medical waste bins have been newly placed in various closed areas.

Table 1. Estimated daily face mask use in the three cities

City	Population	Urban Population[a]	Face masks acceptance rate	Number of face masks used by each member of the general population each day	Total daily face mask use (pieces)	Average Face Mask Weight (Theoretical) (g)	Theoretical Face Mask Waste (tonnes/day)	Surface Area (km^2)	Face masks per km^2
Adana	2,237,940	74,4%	80%	1	1,332,022	4	5.3	13,844	96.2
Mersin	1,840,425	74,4%	80%	1	1,095,421	4	4.4	16,010	68.4
Niğde	362,861	74,4%	80%	1	215,975	4	0.9	7,234	29.9
Turkey	83,154,997	74,4%	80%	1	49,493,854	4	198	783,562	63.2

[a] Data source: retrieved on September 14, 2020 from: https://cevreselgostergeler.csb.gov.tr/

Table 2. The number and weight of the face masks found per km^2 in the three cities

City	Theoretical			Experimental		
	Face mask average weight (g)	Face masks per km^2	Weight of face masks per km^2 (g/km^2)	Face mask average weight (g)	Face masks per km^2	Weight of face masks per km^2 (g/km^2)
Mersin	4	96.2	384.8	2.955	170	502.418
Adana	4	68.4	273.6	2.991	210	628.194
Niğde	4	29.9	119.6	3.061	166	508.076

3.2 Experimental validation by chemical and physical structure analysis

Most studies carried out on plastic identification ignore the spectral change caused by plastic degradation when comparing plastic with the reference spectral library. Environmental exposure can cause polymer aging and mechanical and oxidative decomposition of the plastic surface (Xu et al. 2019). Some studies have also reported the changes in the infrared spectrum results due to weather conditions (Rajakumar et al. 2009; Brandon et al. 2016). It can also lead to underestimated results due to the use of polymers with different percentage content of the fibers because of the limited amount of reference polymers used.

The results showed that the surface of 83.3% of the face masks was polypropylene, while 16.7% of them were polyethylene (Fig. 5).

With the soil ecosystem being mostly the first contact point of face masks, which are widely used during the pandemic as protective equipment, it is important to evaluate microplastic pollution in the soil not only in terms of the disintegration of the mask but also in terms of the possibility of them mixing into the sewage sludge and being transported from the sewage systems to wastewater treatments. Treatment sludge containing microplastics used in soil activities threaten soil biota. Microplastics, which initially settle on the soil surface layer, can move to the lower layers over time and cause undesirable toxic effects on plants and organisms. Rodriguez-Seijo et al. (2017) reported that microplastics reached the lower layers of the soil through worms and affected their immune systems.

Chae and An (2018) emphasized the urgent need for studies in the field of plastic pollution regarding soil and stated that the PE and PA polymer types had a high potential to transport to the soil environment.

Due to their different surface areas and densities, some of the microplastics that reach the water ecosystem remain on the water surface, while others in fiber form reach the sediment. (Tsang et al. 2017) detected 0.4% fiber in the microplastic analysis of coastal waters in Hong Kong between June 2015 and June 2016 and microplastics with a fiber structure of 6.3% in the sedimentation. Besides, according to the results of their FT-IR analysis, 50.9% of the 240 different microplastics were PP polymer type.

Khoironi et al. (2020) investigated the degradation of PP in the sea at depths between 50 cm and 170 m and in the bottom sedimentation. They reported that the PP in the bottom sediment was mostly in the formation of microplastics as a result of plastic degradation.

When the results are examined in particular for Adana and Mersin, it is possible to associate them with the previous microplastic studies in the northeast Mediterranean. Akarsu et al. (2020) carried out an FTIR analysis on microplastic samples taken from the sea surface and sediment in Mersin Bay, which is located in the Northeast Mediterranean. When they examined fibers among the plastic samples taken from the treatment plant effluent, the most common type of plastic was polypropylene. Similar results were reported in the study of Gündoğdu et al. (2018) on the Levantine coast in the same region. They determined that 87.5% of the microplastic samples were either polyethylene or polypropylene. Both studies also found that the largest source of microplastics was fiber. According to the studies in the literature, the most common type of plastic is polyethylene (up to 51%), followed by polypropylene (up to 27%) (Sun et al. 2019). However, when it comes to fiber, there have been studies that were unable to detect polyethylene (Lares et al. 2018).

In general, prioritizing human health over environmental health due to the global state of emergency caused the postponement of policies to reduce the use of plastic (Patrício Silva et al. 2020). Polypropylene and polyethylene are the most common type of polymers and continue to be the most common type of plastic found in nature. As a result, the environmental footprint of plastics is increasing. In order to eliminate this problem, alternative studies, particularly those regarding the reusability of these polymer types, must be accelerated.

SEM is used to obtain information about the surface structure, characteristics and elemental composition of any material or particle. SEM is significant in determining the effect of environmental exposure on the surface texture (Wang et al. 2017). Characteristic cracks and deteriorations on the surface of microplastics can be revealed with SEM imaging. Grooves and gouges formed by mechanical aging processes can also be observed (Zbyszewski et al. 2014).

Within the scope of the SEM analysis, the randomly selected masks were examined. Polymer structures can differ in durability, solubility, fragmentation and rupture. As can be seen from Figure 6, there were polymer ruptures in their structure. These ruptured polymers can create microplastics and cause pollution in the soil and seas.

The face masks collected from bushes or soil surfaces appeared to have similar morphologies. The samples of these masks, which were made of polypropylene (magnified x100 to 1000 under SEM), did not appear to be resistant to disintegration, although they had not been in the area for a long period. Studies in the literature on polypropylene wastes have reported that polypropylene is not as durable as polyethylene and that changes such as breakage or deterioration occur in polypropylene (Ó Briain et al. 2020). This shows that face masks, which are classified as macroplastic, can turn into microplastic dimensions more easily.

Conclusion

Recently, microplastics originating from different personal care products have been gaining attention around the world. However, there are a few studies that have included face masks among these sources of microplastics. As a result of the coronavirus pandemic, the use of surgical face masks became more common and is increasing day by day.

In this study, more masks than expected were detected in all three cities. An average of 182 masks were found in each city. It was determined that the face mask pollution per unit area was 24.3% higher in Adana compared to the other two cities. However, it should be noted that a high number of masks, almost the same amount as in Mersin, were detected in Niğde, which has a smaller population compared to the other two cities and therefore lower consumption dynamics.

Analyzes conducted on the surface of the face masks revealed that all of them were made of plastic polymers. It was determined that the masks selected by the FT-IR analysis were generally made of polypropylene. Polypropylene is widely used in the production of surgical face masks and is known to easily break down in nature due to its fragile structure. The fracture between the bonds was determined by SEM images. As a result of the study, it was observed that due to the structure of polymers, face masks can easily mix in with and pollute the soil and water ecosystems.

It is almost impossible to determine the sources of face masks that have been thrown into the environment and it is also extremely difficult to take preventive measures. Therefore, for the environmentally successful execution of the pandemic that will last for many years, it is necessary to accurately manage the 300 tons of discarded face masks in these three cities and 60000 tons in Turkey for a month. New legislation and regulations on disposable face mask management should be introduced to minimize the effect of face masks that cause both visual and environmental pollution.

Another thing to do is to make the masks more eco-friendly. Nowadays, there are a numbered non-governmental organizations that run a project for recycling surgical face masks to keep them out of landfills. Although an academic report on this issue has not yet been presented, the initial results indicate that up to 60% of face masks can be recycled. However, it is not feasible to develop a separation system yet. Another alternative solution would be to use bio-based polymers. Hemp is primarily used to create a single-use face mask. However, there is not enough raw material to produce enough for the whole world or even a single country. Therefore, the importance of studies on reusable masks is increasing day by day.

Declarations

- **Ethics approval and consent to participate**

Not applicable.

- **Consent for publication**

Not applicable.

- **Availability of data and materials**

Data sharing does not apply to this article as no datasets were generated or analyzed during the current study.

- **Competing interests**

The authors declare that they have no competing interests

- **Funding**

The author(s) received no financial support for the research, authorship, and/or publication of this article.

- **Authors' contributions**

CA, EUD and ÖM contributed to the study conception and design. Material preparation and analysis were performed by ÖM and CA. EUD wrote the manuscript with support from CA, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Figures

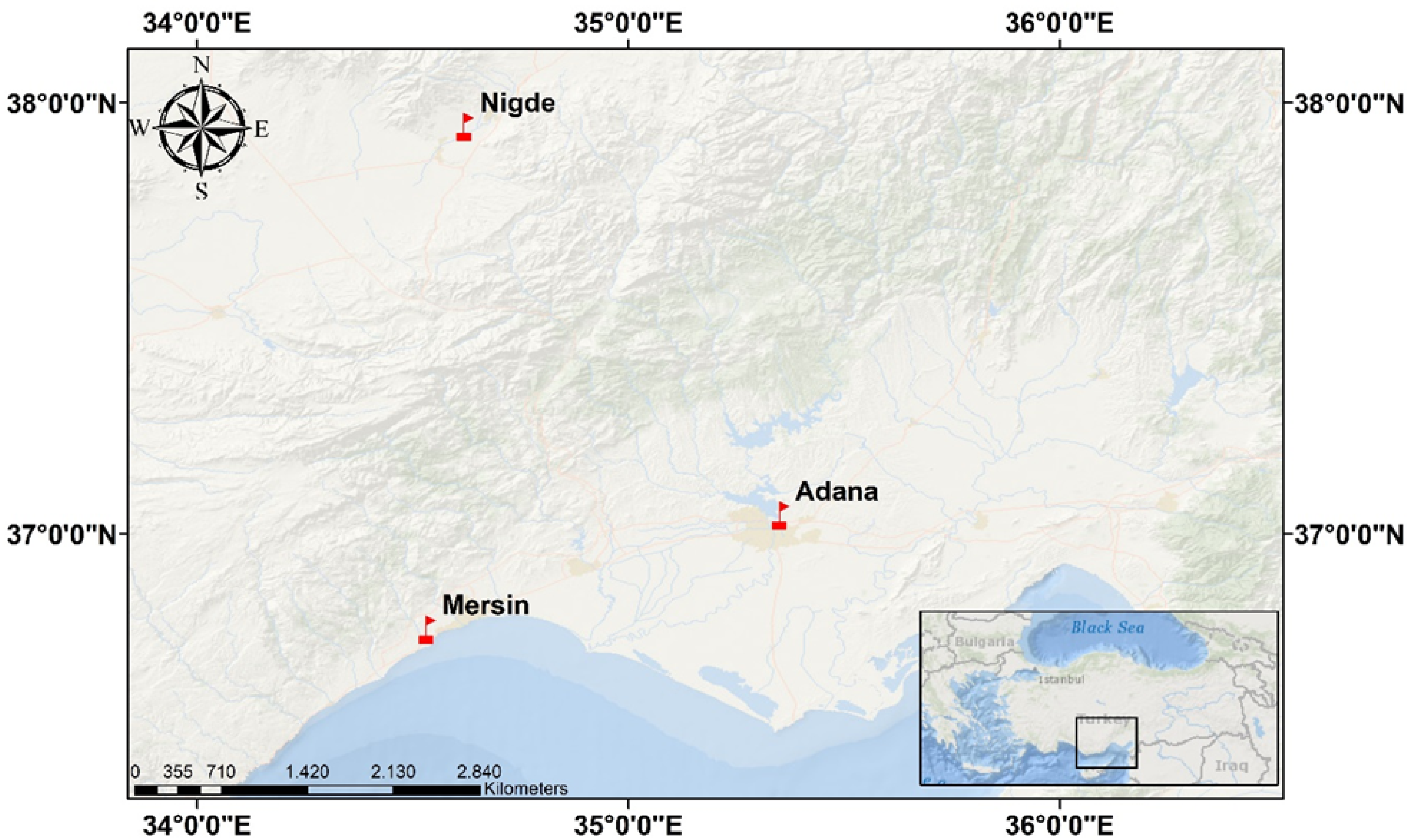
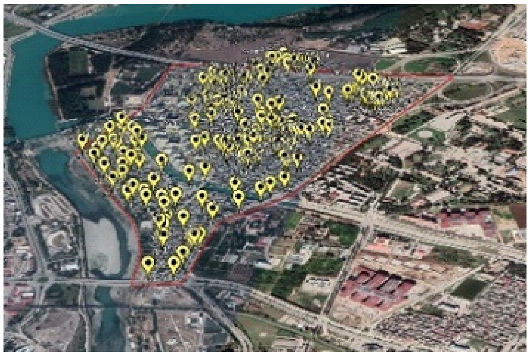


Figure 1

Locations of the three cities in southeastern Turkey Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



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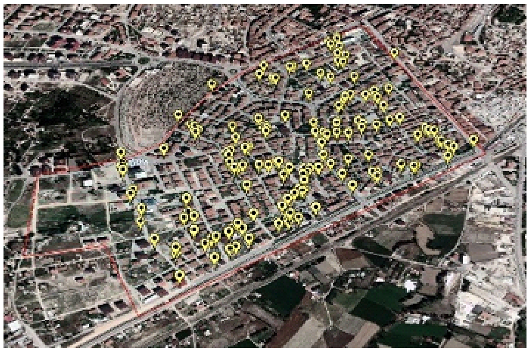

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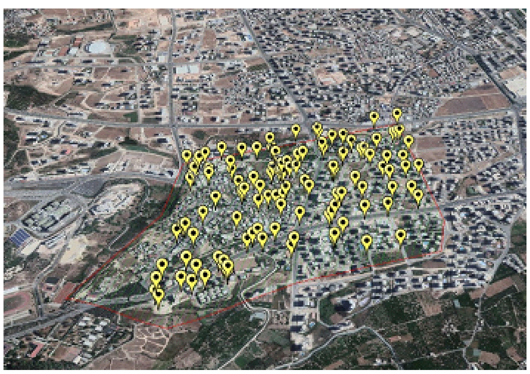
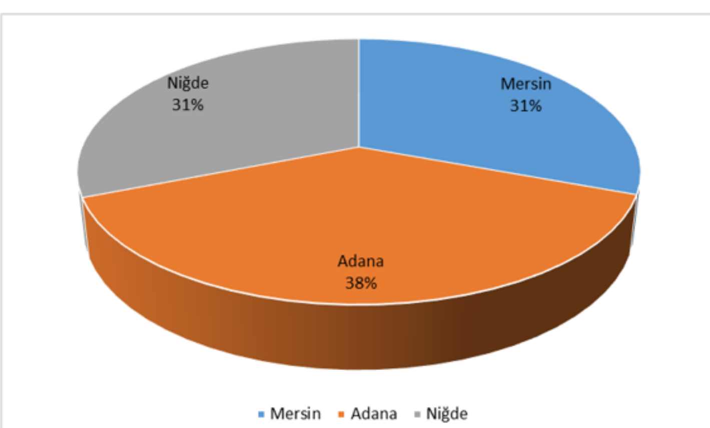


Mersin

Figure 2

Coordinates and locations of the study area on the map Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



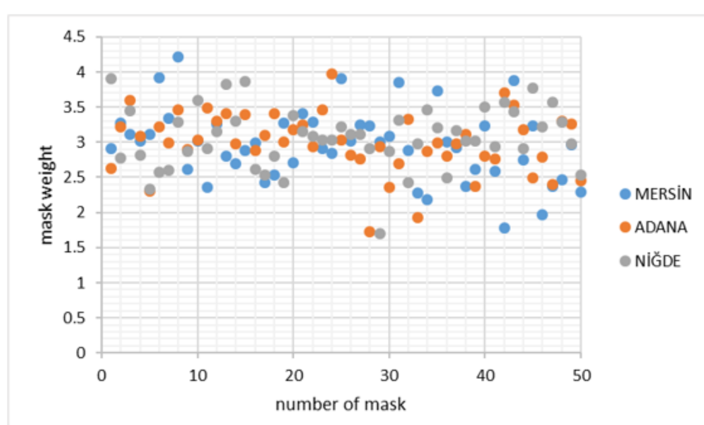


Figure 3

Weight and percentage distribution of the 50 masks randomly selected for each city

Figure 4

Examples of the different colors and types of masks collected from the streets of the three cities

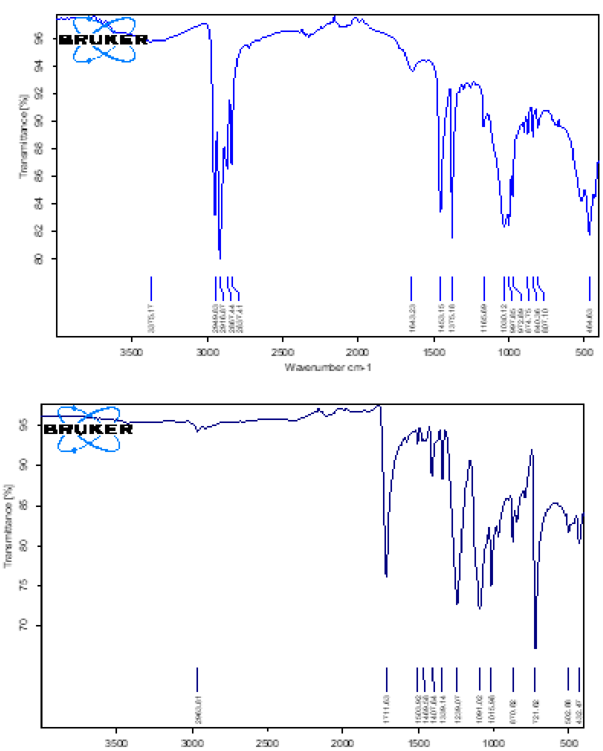


Figure 5

FT-IR spectra of the dominant microplastics including polyethylene and polypropylene

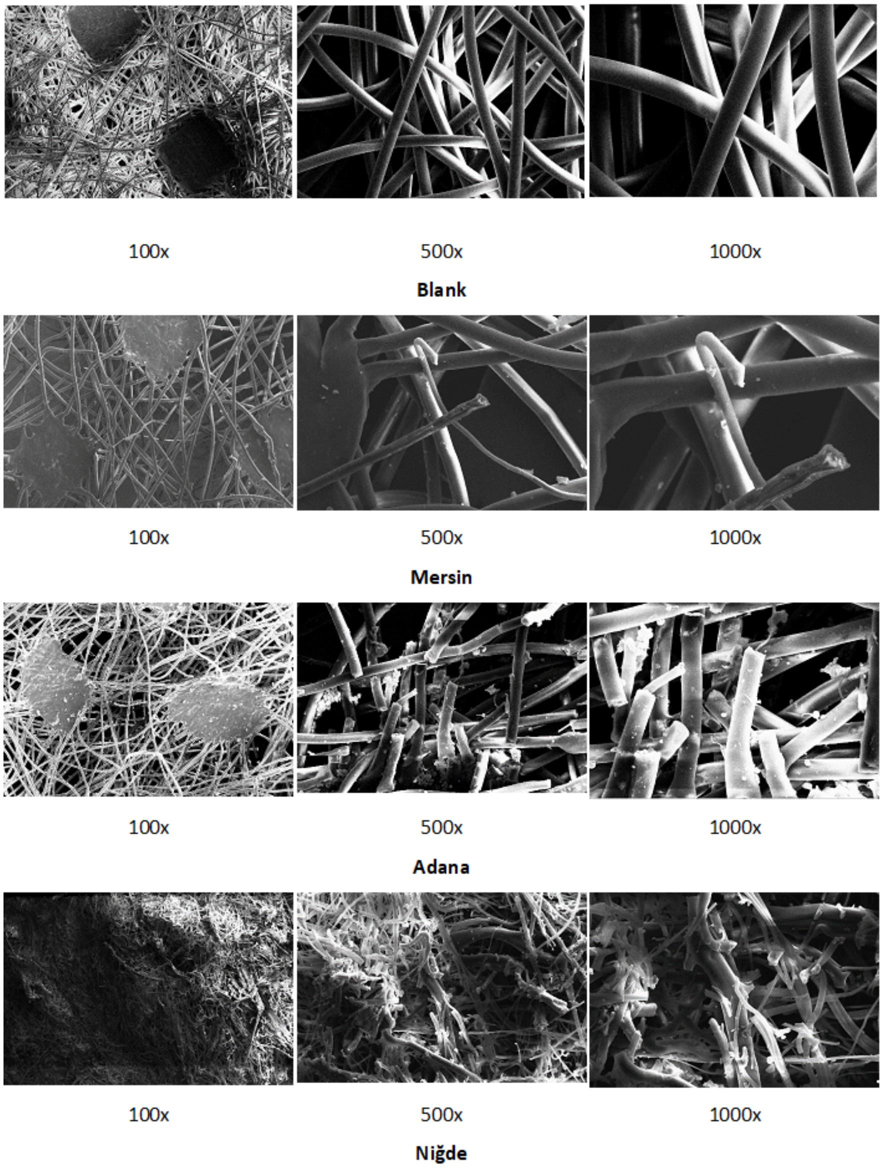


Figure 6

SEM images of the face masks