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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

First Evidence of Microplastic Deposition in Snow from Turkey

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Abstract: Microplastic pollution in snow was investigated on top of the Amanos Mountain in Hatay region, southern Turkey. Snow samples were collected from four stations located in different heights and fronts of the mountain. Abundance of microplastic ranged from 10.5 to 16 MP per liter and a total of 519 microplastic particles (MPs) were identified in snow samples. The majority of identified microplastics were fiber (>99%), black and 0.5 – 2.5 mm (62%) size class and polyester (35%). This is the first study examining the microplastic pollution in snow from Turkey. Local wind and trajectory analyses revealed that MPs in the sampling region originated from closely located Amik Plain and/or were transported from remote areas with northwesterly and southerly airflows.

Keywords: Amanos mountain, atmospheric transport, snow, pollution, microplastic.

Türkiye'den Karda Mikroplastik Birikimine Dair Ilk Kanıt

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Öz: Bu çalışmada Türkiye'nin güneyinde Hatay il sınırları içerisinde bulunan Amonas Dağının zirvesinden alınan kar numunelerinde mikroplastik kirliliği araştırılmıştır. Dağın farklı yükseklik ve cephelerinde yer alan dört istasyondan kar örnekleri alınmıştır. Örneklerdeki mikroplastik bolluğu litrede 10,5 ile 16 mikroplastik (MP) arasında değişim göstermiş olup toplamda 519 adet MP tespit edilmiştir. Tespit edilen mikroplastiklerin büyük kısmı fiber (>%99), siyah renkli, 0,5-2,5 mm (%62) boyut aralığına sahiptir ve tespit edilen en yaygın polimer polyester (%35) olarak bulunmuştur. Bu, Türkiye'den kardaki mikroplastik kirliliğini inceleyen ilk çalışmadır. Yerel rüzgar ve yörünge analizleri, örnekleme bölesindeki MP'lerin yakın konumdaki Amik Ovası'ndan kaynaklandığını ve/veya kuzeybatı ve güney hava akımlarıyla uzak bölgelerden taşındığını ortaya koymuştur.

Anahtar kelimeler: Amanos dağı, atmosferik taşınım, kar, kirlilik, mikroplastik.

INTRODUCTION

Escalated number of studies have been reported the microplastic existence from different environments. Spread existence of microplastics in nature have become an emerging issue. Presence of microplastics was reported from extreme conditions or remote regions such as Polar Regions, Mariana Trench and Mount Everest (Jamieson et al., 2019; Napper et al., 2020). The presence or effects of microplastics (MPs) in terrestrial, freshwater and marine ecosystems and organisms have been extensively studied. MPs are found in almost all living things, from zooplankton to the top predator whale in the sea and from insects to mammals in terrestrial areas (Al-Jaibachi et al., 2019; Atamanalp et al., 2021; Betts, 2008; Boerger et al., 2010; Burton, 2003; Cole et al., 2013; Cowie, 2011; Davison & Asch, 2011; Enyoh et al., 2020; Eriksson & Ryan et al., 2009; Fossi et al., 2012; Horton et al., 2017; Mutlu et al., 2022; Murray et al., 2013; Wright et al., 2013; Yıldız et al., 2022).

According to the results of MPs studies in the literature, it is thought that there cannot be any uncontaminated place in the earth's surface due to the aerodynamic properties of MPs as fibers (Dris et al., 2016). MPs can travel very long distances inversely proportional to the particle size and its light-weight (Allen et al., 2019-2021; González-Pleiter et al., 2020). Microplastics can be transported thousands of kilometers by surface waters and currents, in addition to atmospheric events. MPs, which tend to fall by gravity, can be transferred by wind in different layers of atmosphere and fall by wet or dry deposition to the biosphere (Abbasi, 2021; Brahney et al., 2020; Dris et al., 2016; González-Pleiter et al., 2021).

There are many studies investigating the MP existence in atmospheric compartments, cryosphere and wet & dry deposition events from the different region of the world in the literature (Allen et al., 2021; Bergman et al., 2019; Evangeliou et al., 2020; Napper et al., 2020; Padha et al., 2022; Shao et al., 2022; Su et al., 2022). But, there is no data about the atmospheric deposition of MPs from Turkey. This study was aimed to investigate the MPs pollution in snow after heavy snowfall in Amanos Mountain in Turkey. Amanos Mountain is a special place; because, it divides the coastal region of Cilicia from Antioch and southwestern most Anatolia from the rest of Asia. Each side of the mountain is surrounded by different anthropogenic influences including urbanization, industrialization, and agriculture. Therefore, results of this study could be useful to relate the anthropogenic activities and microplastic deposition in snowfall by filling the information gap in the study area.

MATERIAL AND METHOD

Study area and sampling: Amanos Mountain is 175 km long and 20-30 km wide, with an average height of 1500-2000 m. The mountain range starts from Sır Dam Lake in Kahramanmaraş and extends to the Samandağ coast of Hatay province. It is mostly covered with moist forests and some tops without vegetation. Most of the mountain range is in the limits of Hatay province which is highly urbanized with 1.6 million populations. Also, it separates the Amik Plain, where intense agricultural activity carried out, from the Mediterranean Basin. While agricultural activities are concentrated in the east side, industrial activities are dominant in the west side of the Amanos Mountain. In the upper parts of the Amanos Mountains, snowfalls are observed in the period from January to March, and at the beginning of spring, the snow melts with the increase in temperature.

Heavy snowfall was observed in between the 1st of February and the 10th February in Amanos Mountain. Snow samples were collected from 4 stations located in the different sides of the mountain in 11 February 2022. Sampling was conducted in the areas where transportation is accessible by car and walking from the middle region of Amanos and stations were far away from residential areas (Figure 1 and Table 1). At the each sampling station, 1 m^2 (1x1 m) area was selected and a 5 cm thick snow sample was shoveled with metal spoons and transferred to metal buckets. To avoid possible contamination during the sampling, it was positioned against the wind direction. The lids of buckets were tightly closed and wrapped with tin foil and brought to the laboratory without melting. Transported samples were left for melting in the laboratory for 24 hours. Then, molten samples were filtered by 50 µm pore size filters. During laboratory, extensive precautions were taken to eliminate contamination. Only authorized personnel were allowed to enter the laboratory. Personnel always wore cotton aprons and nitrile gloves. Six blank filters (three filters in laboratory and three filters in microscope room) were placed in the laboratory. Only one fiber particle was detected in the blank samples which indicate that contamination is insignificant.

Identification of MPs: The filters were carefully examined under the Olympus SZX7 microscope with attached Olympus digital camera. Abundance, size, colors and type of MPs were recorded. Observed particles were exposed to a hot needle to validate plastic nature (Hanke et al. 2013).

To detect the origin of extracted microplastics, SHIMADZU QATR10 Fourier Transform Infrared Spectroscopy (FTIR) equipped with single reflection attenuated total reflectance (ATR) accessory was used in this study. The spectrum range arranged as 4000-400 cm^{-1} and a resolution of 4.0 cm^{-1} with 32 scans for each measurement. Identification of the polymer type was done by comparing absorbance spectra to reference libraries of SHIMADZU library.

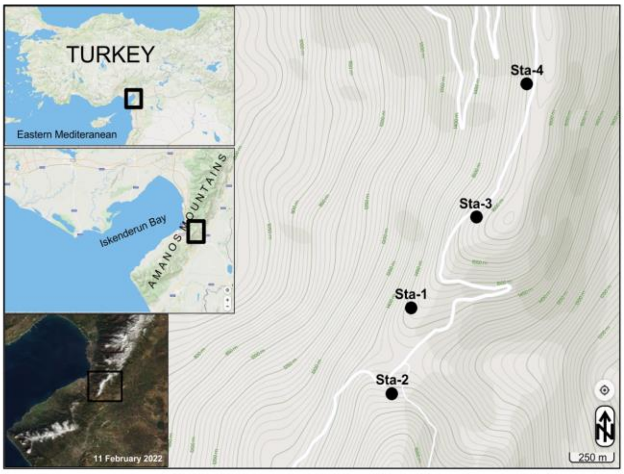

Figure 1. Sampling location and snow cover photos (in 11th of February 2022) in Amanos Mountains (from NASA Worldview and mapcarta.com).

Weather condition and back trajectory: To identify the potential source of MP pollution, local meteorological data such as hourly wind direction and speed were obtained from The Ministry of Environment, Urbanization and Climate Change of Turkey. In addition, three-day back trajectories of air masses were calculated using Hysplit Distribution Model (Hybrid Single Particle Lagrangian Integrated Trajectory) (Draxler & Hess, 1998; Stein et al., 2015). The air masses arriving to the sampling area at 1 km altitude for each day (06:00 UTC) were computed during the study period employing the meteorological data of the NCEP/NCAR Reanalysis Project.

Table 1. List of sampling stations.

Station	Latitude	Longitude	Altitude (m)	Sample amount (liter)
Sta-1	36°31'54.67"N	36°15'28.55"E	1457	≈ 10
Sta-2	36°31'39.61"N	36°15'28.89"E	1465	
Sta-3	36°32'13.48"N	36°15'49.17"E	1580	
Sta-4	36°32'35.23"N	36°15'55.73"E	1600	

A total of 519 particles were identified as MPs in snow samples in 11th of February 2022 (Figure 2). MPs were detected in all stations and abundance/type of MPs distribution is given in Table 2. Abundance of MPs was varied regionally from 10.5 to 16 MPs l^{-1} in stations. While the highest MPs abundance was observed in Sta-1 in low height (between two hills), the lowest abundance was detected in Sta-2 (on the eastern slope of hill) (Figure 1 and Table 1). It should be noted that MPs abundance in the Sta-4 (14.7 MPs l^{-1}) was closest to highest estimated value in Sta-1.

RESULTS

A total of 519 particles were identified as MPs in snow samples in 11th of February 2022 (Figure 2). MPs were detected in all stations and abundance/type of MPs distribution is given in Table 2. Abundance of MPs was varied regionally from 10.5 to 16 MPs l^{-1} in stations. While the highest MPs abundance was observed in Sta-1 in low height (between two hills), the lowest abundance was detected in Sta-2 (on the eastern slope of hill) (Figure 1 and Table 1). It should be noted that MPs abundance in the Sta-4 (14.7 MPs l^{-1}) was closest to highest estimated value in Sta-1.

Table 2. Microplastic abundance and type in the examined samples.

Station	MPs per m^2	MPs per liter	Fiber		Fragment	
			n	%	n	%
Sta-1	160	16.0	158	99	2	1
Sta-2	105	10.5	104	99	1	1
Sta-3	107	10.7	107	100	0	0
Sta-4	147	14.7	147	100	0	0

Only two types of MP (fiber and fragment) were found in the snow samples. Almost all of the MPs detected were fiber (higher than 99%). Three of 519 MP particles were fragment and observed in two stations (2 particles in Sta-1 and 1 particle in Sta-2). No fragment was observed in Sta-3 and Sta-4.

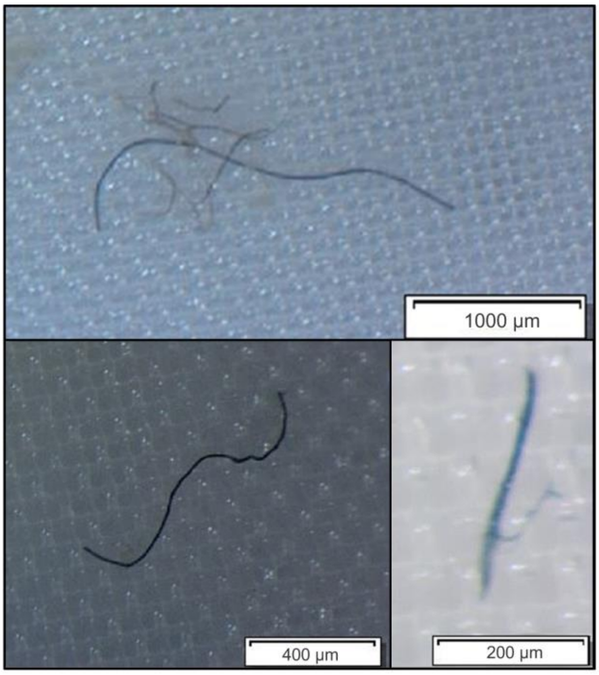

Figure 2. Some examples of isolated MPs from the snow samples.

Figure 3 shows the percentage of MPs color distribution in snow samples from Amanos Mountain. Depending on color, MPs were identified as black, red, blue, yellow, brown, green and white. Majority of the identified MPs were black (47.6%) and it is followed by blue (28.1%) and red (18.3%) in all samples. Color distribution of identified MPs varied depending on stations. Black particles varied in the range of 36.2 – 59.2 %, blue and red were 19-33.3 % and 15-25.7%, respectively.

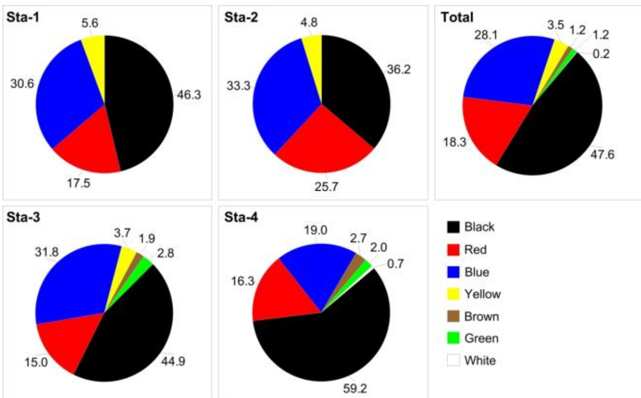

Figure 3. Percentage of detected microplastics categorized by color.

Size distribution of detected MPs was given in Figure 4 in snow samples. Most of the fiber shaped MPs was comprised in the 0.5-1 mm (152 particles - 29.4%) and 1-2.5 mm (168 particles – 32.5%) size class. The dimensions of identified three fragment particles were between 130-380 µm.

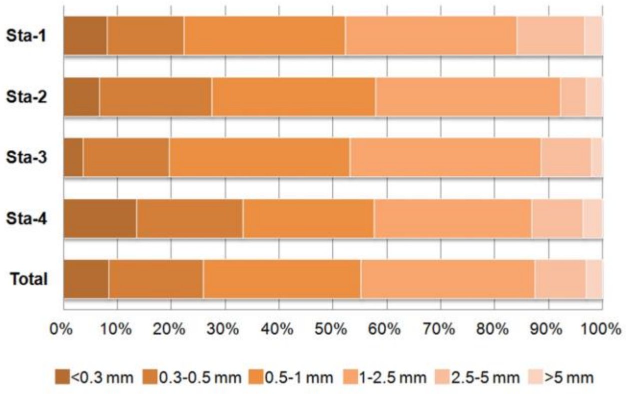

Figure 4. Size range of detected microplastics.

Ten percent of extracted MPs were analyzed by FTIR analysis. Polyester (PES) (35%), polypropylene (PP) (25%), polyethylene (PE) (10%) and polyamide (PA) (10%) were the most abundantly identified polymers in the FTIR analysis. Among identified particles, only polymers representing more than 70% similarity were considered in the results.

DISCUSSION

In general, microplastic studies in different habitats continue to increase, especially in marine and aquatic ecosystems (Kılıç and Yücel, 2022; Kılıç et al., 2022). And, the presence of microplastics has been reported in almost all habitats and organisms, even in areas far from the mainland or in remote/extreme areas (Jamieson et al., 2019; Napper et al., 2020). Studies on the atmospheric transport of microplastics in recent years showed that microplastics could be transported thousands of kilometers not only by surface waters, currents and local winds, but also by events in different layers of the atmosphere and spread by different precipitation types such as rain, snow, hail etc. and dry deposition (Abbasi, 2021; Allen et al., 2019; Allen et al., 2021; Brahney et al., 2020; Dris et al., 2016; González-Pleiter et al., 2021). This study is the first report investigating the MPs pollution in snow after heavy snowfall from Turkey.

Small microplastic particles are transferred in atmosphere by wind depending on wind direction and speed and they fall with wet or/and dry deposition to the somewhere (Brahney et al., 2020; González-Pleiter et al., 2021). Suspended microplastics are also washed away by precipitation and snow, and they can scavenge larger particles more efficiently than rain (Abbasi, 2021; Jylhä, 2000; Zhao et al., 2015). But, scavenging amount for particles depends on duration of precipitation, size and velocity of snowflake or raindrop, and size of particles (Jylhä, 2000; Zhao et al., 2015). In addition, the snow on the surface acts like a wet sponge and the disposed particles stick and accumulate in snow.

Amanos Mountain is surrounded by different anthropogenic influences. Although not close to the sampling area, there is city of Iskenderun, with a population of two hundred and fifty one thousand people and surrounded by heavy metal and different industrial activities, on the west side, and the wide Amik Plain with rural settlements and agricultural activities on the eastern side. Therefore, characteristics of deposited particles were altered depending on the direction of wind.

The wind direction in the sampling area was generally southeast and east during the snowfall (Figure 5). Higher MPs abundance was observed in Sta-1 and Sta-4. Sta-1 was the closest station to sea level, located between two hills and was more open to the winds blowing from Amik Plain. Sta-4 which was on top of the Amanos Mountain and can be affected by winds blowing from all directions. Both stations show open front features and are exposed to wind coming from several directions. On the contrary, Sta-2 and Sta-3 is located at the hillside of the mountain and receive the wind from one direction which is probably the cause of lower MPs detection.

According to air masses back trajectories, the sampling area was generally affected by the air masses coming from the south (70% of all air trajectories) and northwest (30 % of all air trajectories) directions during snowfall (Figure 6). These findings are consistent with local wind directions obtained from wind roses results (Figure 5). Therefore, the microplastic pollution in the sampling region is dominantly resulting from the Amik Plain and long range transport rather than the city.

In average, 13 fiber shaped MP l^{-1} were detected in the sampling area. Bergman et al. (2019) reported significantly higher microplastic abundance in the snow samples collected from Arctic and European environments (varying from 20 to 154000 MP l^{-1}). Abbasi et al. (2022) reported the MPs abundance in fresh snow after 12-15 hours of precipitation from Iran. MPs abundance was varied from 0 MP l^{-1} to 86 MP l^{-1} with a mean of 12 MP l^{-1}. Even though, mean MPs abundance reported from Abbasi et al. (2022) was comparable with the results of this study, higher MPs was also possible at some sampling stations. Higher abundance values reported from other studies could be related with the methodological constraints. First of all, Bergman et al. (2019) employed 11 µm mesh size and Abbasi et al. (2022) employed 2 µm mesh size in their study which may result with higher MPs abundance. Secondly, snow samples were collected after the snowfall event which last for 10 days in Amanos Mountain. Atmospheric events like wind could wash away the MPs in the upper layer until the sampling period which causes less microplastic occurrence in the upper layer.

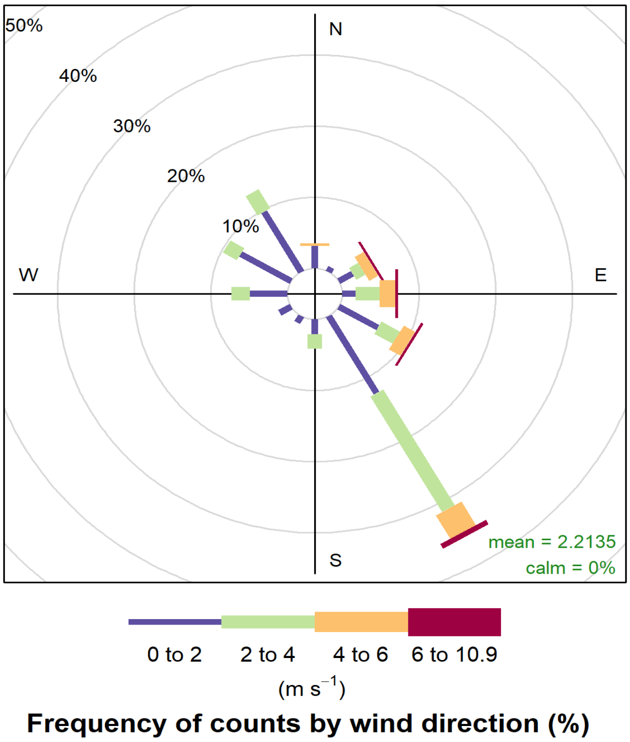

Figure 5. Wind frequency and direction (from 1 to 11 February 2022) in sampling area.

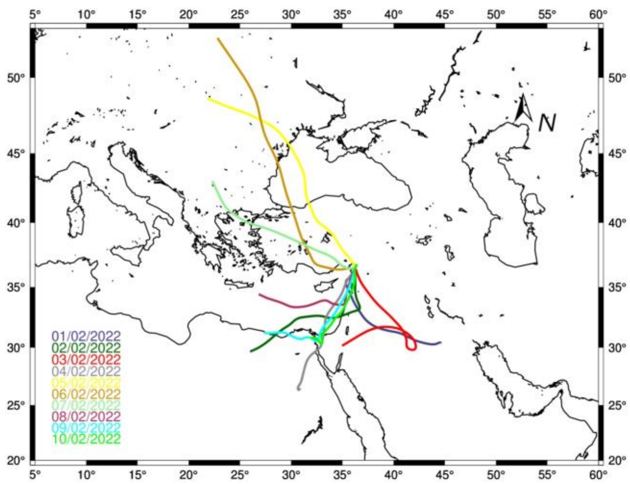

Figure 6. Wind back trajectories in 1000 m (from 1st to 10th of February 2022).

Majority of the identified MPs were fiber which is consisted with previous studies (Abbasi et al. 2022; Bergman et al. 2019; Dris et al., 2016). It is very difficult to determine the source of the fiber particles which can be released from clothes, plastic production or some processes of manufactures or distinguished with natural silk or wool etc. (González-Pleiter et al. 2021). Also, their aerodynamic structures, lightness and size make it easier to be transported far away by atmospheric events compared to other types of microplastic (fragment, foam, pellet etc.). However, the dominance of fiber shaped particle may suggest the importance of anthropogenic influences.

Locally released microplastics become a global pollutant over time. They may be tending to increase the ambient temperature, albeit a little, by absorbing solar radiation in the atmosphere. In addition, due to their dark color, they can absorb more radiation and may accelerate the snow melting which might end it up with speed of warming of the world. In this study, more than 90% of the samples was consist of dark colors (47.6% black, 28.1% blue, 18.3% red) compared to snow. Therefore, by absorbing more solar radiation than snow, they might heat up and accelerate the melting of the snow around them (Abbasi et al., 2022; Ming & Wang, 2021).

Microplastics stored in the snow melt, they will be transferred to the streams to be transported by the surface waters or cause point pollution in the soil where MPs could be found as a pollutant for organisms in different habitats (Abbasi et al., 2022; Chen et al., 2018; Rehm et al., 2021; Zhu et al., 2012).

Major polymer types identified in the FTIR analysis were polyester, polypropylene, polyethylene and polyamide. Presence of these polymers in snow was reported before (Abbasi et al., 2022; Bergman et al., 2019; Napper et al., 2020; Parolini et al., 2021). Presence of these polymers were also reported in glaciers and remote areas where major source of MP was considered as atmospheric deposition (Padha et al., 2022). Major source of polyester, polypropylene and polyamide were identified as textile industry and it could be transferred from cities or populated areas (Dris et al., 2016; González-Pleiter et al. 2021; Padha et al., 2022). Polyethylene is commonly used in production of single-use plastic products.

CONCLUSION

Here we report for the first time that microplastic pollution was detected in snow on top of Amanos Mountain after heavy snowfall in the first ten days of February 2022. Study area is surrounded by urbanized, industrialized and agricultural regions which influence the wet and dry deposition characteristics during snowfall. In this study, the highest microplastic abundance was estimated in the stations where particles were transported from agricultural area, Amik Plain, by dominant winds. Majority of the identified particles were fiber which is suggesting the dominance of anthropogenic influences. In addition, HYSPLIT modelling showed that MPs originated from remote areas may be transported into the sampling area with northwesterly and southerly airflows. More studies are essential to better understand the importance of snowfall in deposition of MPs from the atmosphere to earth’s surface.

Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Statements and Declarations

The authors did not receive support from any organization for the submitted work. The authors have no relevant financial or non-financial interests to disclose.

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