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Microplastics in snow of a high mountain national park: El Teide, Tenerife (Canary Islands, Spain)

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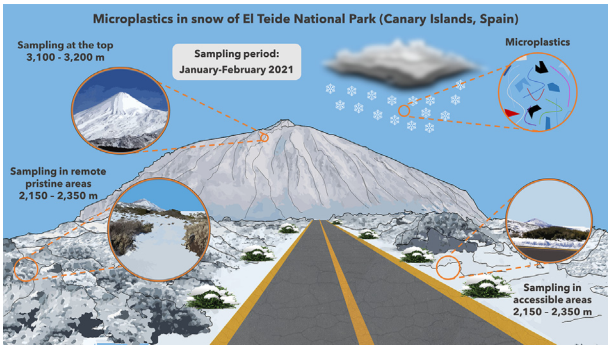
HIGHLIGHTS

- Microplastics have been detected in snow from a high mountain National Park.
- Similar morphology, colour, size and composition was observed after two storm events.
- Predominance of cellulosic, polyester and acrylic microfibers was observed.
- Human activities in isolated areas increased microplastics pollution.

GRAPHICAL ABSTRACT



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ABSTRACT

Human activities have introduced high amounts of microplastics (MPs) into the atmosphere that can be transported long distances and be later deposited in terrestrial and aquatic ecosystems with precipitation (rain or snow). In this work, it has been assessed the presence of MPs in the snow of El Teide National Park (Tenerife, Canary Islands, Spain, 2150–3200 m above sea level) after two storm episodes (January–February 2021). The data set (63 samples) was divided into three groups: *i)* samples from "accessible areas" (after the first storm episode and in places with a strong previous/recent anthropogenic activity); *ii)* "pristine areas" (after the second storm episode, in places with no previous anthropogenic activity), and *iii)* "climbing areas" (after the second storm episode, in places with a soft recent anthropogenic activity). Similar pattern profiles were observed among sampling sites in terms of morphology, colour and size (predominance of blue and black microfibers of 250–750 μm length), as well as in composition (predominance of cellulosic -either natural or semisynthetic-, with a 62.7 %, polyester, 20.9 %, and acrylic, 6.3 %, microfibers); however, significant differences in MPs concentrations were found between samples collected in pristine areas (average concentration of 51 ± 72 items/L) and those obtained in places with a previous anthropogenic activity (average concentration of 167 ± 104 and 188 ± 164 items/L in "accessible areas" and "climbing areas", respectively).

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This study shows, for the first time, the presence of MPs in snow samples from a high altitude protected area on an insular territory and suggests that the sources of these contaminants could be atmospheric transport and local human outdoor activities.

1. Introduction

Nowadays, it is well-known that microplastics (MPs) -plastic particles with a size between 1 μm and 5 mm in their largest dimension, as the most accepted definition- are present in all environmental compartments and also in biota (Pérez-Reverón et al., 2023; Priya et al., 2022; Shao et al., 2022). Up to now, most of the MPs monitoring studies have focused on their determination in marine and terrestrial environments. However, concerning air (which includes wet and dry deposition studies) the number of published manuscripts is relatively small. Several of such works have highlighted the role of the atmosphere as transporter and reservoir of plastics (Allen et al., 2019; Brahney et al., 2020), up to the point that MPs can be found at higher concentrations in urban areas and close environments as a result of the detachment of microfibers from textiles, tire wear and, in general, the degradation of plastics exposed to the air for a long period of time, in addition to other possible sources (Shao et al., 2022). Very recently, it has also been indicated that MPs, in sufficient quantities, could even act as cloud condensation nuclei or ice-nucleating particles (Aeschlimann et al., 2022). It has also been reported that MPs, mainly microfibers, can be transferred from the sea to the air through the marine spray (Allen et al., 2020) and transported long distances in short periods of time, reaching remote and pristine areas. As a result of that, airborne MPs can be inhaled by humans (Allen et al., 2019; Baeza-Martínez et al., 2022; Jenner et al., 2022); in fact, they have been detected in lung tissues (Jenner et al., 2022) and in the lower airway (Baeza-Martínez et al., 2022), though the fully degree of exposure and effects of airborne MPs on human health are not clearly understood yet.

Regarding the type of MPs found in air, current studies suggest that microfibres concentration is higher than any other morphotype. Furthermore, it has also been shown that the dry and wet deposition rates of MPs might vary regionally depending on different climatic factors and MPs quantity and mass in the atmosphere (Roblin et al., 2020; Tan et al., 2020). The determination of MPs in the air involves active or passive sampling methods. In the first case, pumping sampling systems are used, being necessary to control sampling time and volume. Passive sampling approaches, either dry and wet (rain or snow) deposition studies, represent simple, easy and economic alternatives in which standard laboratory equipment can be used (Shao et al., 2022). Up to now, a relatively low number of studies have focused on the determination of MPs in snow. This is the case of the manuscript of Parolini et al., who collected 12 snow samples in 4 sampling locations of the Western Italian Alps (above 2500 m above sea level -a.s.l.-) with 2 L glass jars by scraping the surface of the accumulated snow (Parolini et al., 2021). Only one of the sampling locations was reachable by car, and most of them were located away from neighbouring areas with no direct access to people. The mean concentration of MPs found was 2.32 ± 0.96 items/L, mainly fragments (61.0 %) and fibres (39.0 %), being the predominant colours white (50.0 %), blue (28.0 %), light blue (11.0 %), pink (5.5 %) and purple (5.5 %). However, in a study carried out in the Carnic Alps (one year later), at 1872 m a.s.l., Pastorino et al. only found one fragment of 220 μm (average concentration of 0.11 ± 0.19 items/L), after sampling at three different sites around a lakeside (4 replicates of 750 mL) (Pastorino et al., 2021). In northern Iran, Abbasi et al. studied 34 samples of fresh snow collected with 2 L glass jars at 29 locations in urban areas (including industrial zones, residential areas, transportation hubs and green spaces) and remote regions (Abbasi et al., 2022). Each location was easily accessed by vehicle and/or on foot. MPs concentration ranged from undetected to 86 items/L, being the most abundant shape microfibres (89.6 %). Napper et al., studied the stream water and snow (300 mL collected in stainless-steel containers) from multiple locations at Mount Everest, including the Balcony (8440 m a.s.l.) (Napper et al., 2020). The most common shapes were fibres (94.6 %) and fragments (5.4 %) probably linked to the detachment of fibres from the climbing clothes, climbing gears and the windblown transport. Aves et al. found a concentration of 29.4 ± 4.7 items/L in Antarctic snow (500 mL of snow were collected in stainless-steel bottles), being also fibres the most common morphotype (61 %) and polyethylene terephthalate (PET) the dominant polymer (41 %) (Aves et al., 2022). Other recent examples include the determination of MPs in snow from glaciers of the Tibetan Plateau (4260–5600 m a.s.l.) (Zhang et al., 2021) and the Ecuadorian Andes (Cabrera et al., 2020), among others (Ambrosini et al., 2019; Bergmann et al., 2022), which indicate potential long-range and high altitudes transportation regarding MPs as a ubiquitous airborne pollutant.

The Teide National Park, located in the centre of the island of Tenerife (Canary Islands, Spain), has an average altitude of 2000 m and a surface of 19 km^2. Due to its geographical position in the Atlantic Ocean (relatively isolated from the continent) and high altitude, it constitutes an excellent location to evaluate the arrival of MPs dragged by atmospheric phenomena, and that could reach the soil after dry (air, wind) and/or wet (rain, snow) deposition. Therefore, the aim of this work was to determine the presence of MPs in snow from the Teide National Park after two snow episodes in 2021. Our initial hypothesis was that MPs, particularly microfibres of different composition, could be deposited with snow as a result of short and long-distance transport, and additionally to that source, outdoor winter activities could increase the amount of MPs in the snow. Morphological characterization (size, shape and colour) and the determination of their composition by Fourier transform infrared microscopy (μFTIR) will help to infer potential sources. To the best of our knowledge, this work constitutes the first article dealing with the determination of MPs in snow samples of a Spanish territory, and also one of the very few articles in the literature dealing with the determination of MPs in high altitude areas of an oceanic island.

2. Materials and methods

2.1. Study area and sampling

Mount Teide's summit constitutes the highest point in Spain, with 3718 m a.s.l. In 2007, it was declared World Heritage Site by the UNESCO as a result of its unique environmental values, which include a high biodiversity. It currently receives >3 million visitors per year, being the most visited national park of Europe, being possible to reach the top by either cableway or trekking (Teide National Park, 2022). Occasionally, during wintertime several snowfalls can take place, though irregularly distributed throughout the park and with a relatively short persistence of snow (in some cases only days or weeks).

Snow samples were collected at the park (opportunistic samplings) after two storm episodes (GPS coordinates are given in Table S1 of the Supplementary Material). Meteorological information related to both of them was obtained from the Spanish Meteorological Agency (AEMET) and included in Tables S2 and S3 of the Supplementary Material. During a few days after each storm, the public access to the park was completely forbidden for security reasons.

The first snow event (named as Filomena storm) arrived at the Canary Islands on 7th January 2021, with strong winds and heavy rain all over the island of Tenerife, including the presence of snow above 2000 m a.s.l. According to the climatic data available at the Izaña meteorological observatory (altitude of 2371 m a.s.l.), there were 22.8 mm of precipitation (including snow), increasing to 46 mm on 8th January 2021. Average daily temperatures showed a gradual decrease from 7 °C to −3.8 °C from the 6th to 9th of January, which were maintained below zero until the sampling day when the average temperature increased to 1.6 °C. During the storm, access to the national park was forbidden, being reopened on 11th January (Monday).

The second storm episode took place on 4th February 2021. According to available meteorological data, that day there were 17.0 mm of precipitation (including snow) and 12.2 mm on 5th February 2021. Average daily temperatures ranged from 1 °C to 3.3 °C from 4th to 5th of February. During 5 days after this storm, the public access to the park was not permitted.

The first sampling was carried out on 15th January 2021 during the morning, 4 days after reopening public access to the park at altitudes between 2150 and 2350 m a.s.l., close to the road, where an important influx of people had previously stopped, walked, and played on the snow (trekking, sledding, among others). In fact, in some places, even macroplastic items (> 25 mm) could be clearly seen (plastic litter or pieces of plastics used for sledding). A total of 30 samples were collected. The location of the sampling points is indicated in Fig. 1. This sample batch was designated for the following discussion, graphs, and tables as “accessible areas” samples.

The second sampling was developed on 10th February 2021, also during the morning at altitudes between 2150 and 2350 m a.s.l., the same day public access to the park was allowed. Sampling sites showed no signs of anthropogenic activities (i.e. no footprints were observed). A total of 30 samples were collected. The location of the samples is also indicated in Fig. 1. This sample batch was designated for the following discussion, graphs, and tables as “pristine areas” samples.

A third sampling was carried out at higher altitudes on 12th February 2021 (between 3100 and 3200 m a.s.l.), during the morning, at places with a relatively low anthropogenic pressure during the previous two days, as a result of trekking and climbing activities (only those that visit the summit of 3718 m on foot from the peak base, 2350 m a.s.l.). Just 3 samples were collected due to the inaccessibility and need to transport the sampling bottles and to wear climbing equipment. The location of the samples is also indicated in Fig. 1. This sample batch was designated for the following discussion, graphs, and tables as “climbing areas” samples.

Snow was directly collected down to 5–10 cm depth using a metallic spatula and quickly introduced in 500 mL borosilicate glass laboratory flasks previously calcined at 550 °C for 4 h. To avoid/correct possible sampling contamination, distinctive clothes were worn, and samples were collected downwind. Besides, glass Petri dishes (previously calcined at 550 °C for 4 h) containing glass fibre filters of 0.45 μm from VWR International (PA, USA) were also opened next to the bottles as a contamination control while the snow was being collected. Particles found in those filters were classified and quantified to avoid an overestimation of the MPs concentration. Samples were transported to the laboratory and stored in a fridge at 4 °C until the following day for their ulterior processing once the snow melted.

2.2. Melted snow filtration and stereomicroscope visualization

Once the snow was thawed, the water volume was measured using a graduated cylinder of 500 mL (± 2.5 mL at 20 °C). Afterwards, it was directly filtered under vacuum through glass microfibre filters of 0.45 μm (VWR International) inside a glove box. The filtrates were immediately introduced in glass Petri dishes and visualized under a trinocular light stereomicroscope with magnifications ×0.65 – ×5.5 (Euromex Nexius Zoom EVO, Arnhem, The Netherlands) and with an image analysis system (Levenhuk M1400 PLUS-14Mpx digital camera with the Levenhuk Lite software version x64, 4.10.17659.20200906) which was used to identify, classify, and measure MPs dimensions. The lower length limit of the particles studied was ~75 μm and the viewing time per filter was between 1 and 2 h. To visually establish if a particle is made of plastic, the criteria of Hidalgo-Ruz et al. was met (Hidalgo-Ruz et al., 2012), even though, a subset of samples was confirmed by μFTIR, as it will be later indicated (Marine & Environmental Research Institute, 2017).

2.3. Precautions to avoid sample contamination

During MPs determination, special care was taken to minimize airborne laboratory contamination. All laboratory material used was plastic-free. Glassware material was washed with Milli-Q water (obtained from a Milli-Q Gradient A10 system from Millipore) (Burlington, MA, USA). Additionally, non-volumetric glassware was heated up to 550 °C for 4 h in a muffle Carbolite CWF 11/13 instrument (Sheffield, United Kingdom), while volumetric glassware was cleaned using a Nochromix® solution from

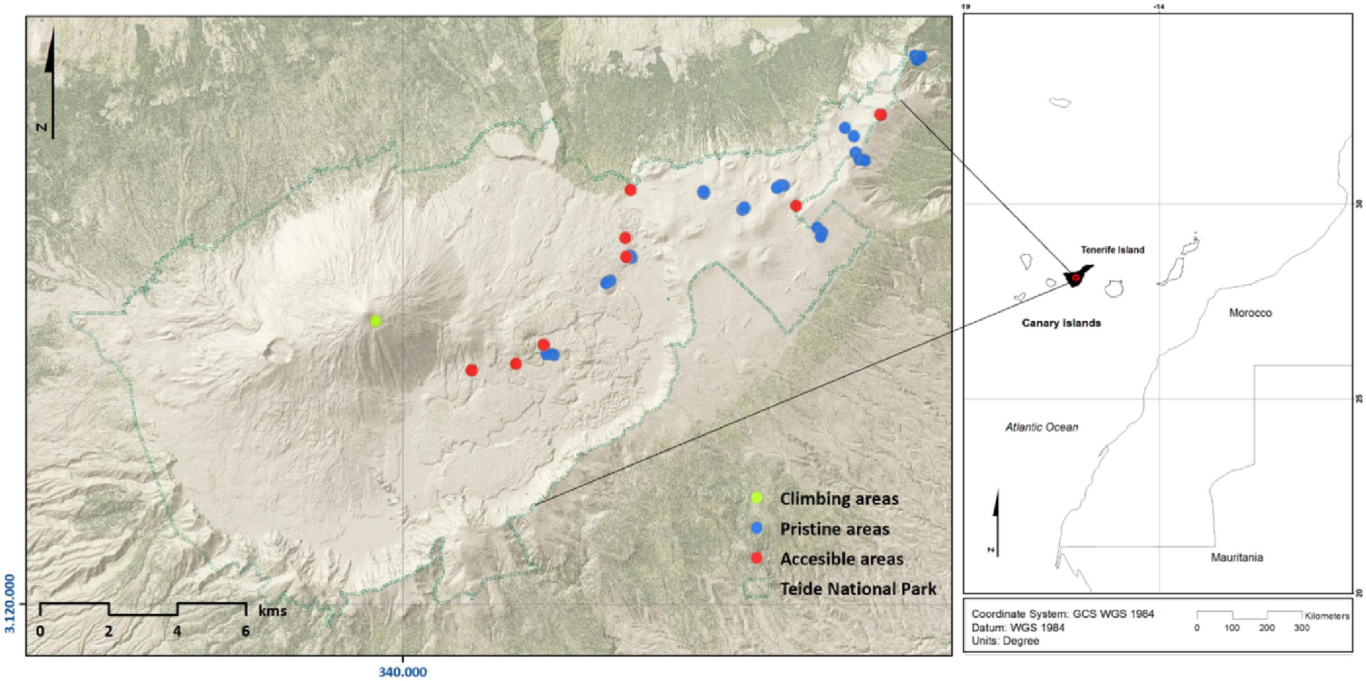

Fig. 1. Location of the snow sampling areas at the Teide National Park (Tenerife, Canary Islands, Spain) after the two snowfalls that took place in 2021. Snow samples were only collected at the places of the park that had snow, which were only the indicated zones. Some of the points in the figure include several sampling points.

Table 1
Results of the analysis of the snow collected at the Teide National Park (Canary Islands, Spain) after two different snowfalls.

Sampling date	Sampling height (m a.s.l.)	Total number of particles found	Average items/L ± SD	Items/L range	Average fibres length ± SD	Fibres length range	Shape classification and percentage (%)
01/15/2021 Accessible areas (n = 30)	2150–2350 m	1274[a]	167 ± 104 162 ± 103*	19–502 19–502*	1393 ± 1698 μm 1188 ± 929 μm *	96–26,741 μm 96–4980 μm *	Fibres (99.5 %, n = 1268) Fragments (0.2 %, n = 3) Tangled messes (0.2 %, n = 2) Films (0.1 %, n = 1)
02/10/2021 Pristine areas (n = 30)	2150–2350 m	446[b]	51 ± 72 49 ± 71 *	6–392 6–392 *	949 ± 920 μm 892 ± 766 μm *	80–6194 μm 80–4037 μm *	Fibres (99.3 %, n = 443) Fragments (0.2 %, n = 1) Tangled messes (0.5 %, n = 2)
02/12/2021 Climbing areas (n = 3)	3100–3200 m	64[c]	188 ± 164	50–358	743 ± 634 μm	92–2824 μm	Fibres (100 %, n = 64)

a.s.l.: above sea level.
[a] 37 particles had a length > 5 mm.
[b] 5 particles had a length > 5 mm.
[c] All particles had a size < 5 mm.
* Data not considering particles with a length > 5 mm.

Godax Laboratories (MD, USA) in sulfuric acid (95 % w/w, VWR International) for 24 h. The laboratory air was filtered with an air purifier (Mi Air Purifier 2H, Model:AC-M9-AA, Beijing Smartmi Electronic Technology Co., Ltd., Beijing, China) equipped with an HEPA (High Efficiency Particulate Air) filter (99.97 % removal efficiency of particles with size ≥0.3 μm). All sample processing was carried out inside a glove box. Contamination controls were established during sample processing by exposing filters to the air of the laboratory. Besides, orange laboratory coats were worn to quickly detect possible contamination.

2.4. MicroFTIR analysis

A randomly distributed subsample of microparticles (n = 364, 20.3 % of the total) that included fibres of each filter with sizes above 75 μm (the stereomicroscopy visualization limit), was analysed by μFTIR using a Perkin-Elmer Spotlight™ 200 Spectrum Two instrument with a mercury cadmium telluride detector. Microparticles were placed on KBr, which was used as a slide, and their spectra were recorded in micro-transmission mode using the following parameters: spot 50 μm, 32 scans, and spectral range 550–4000 cm^{-1}. All spectra were compared with Omnic 9.1.26 database (ThermoFisher Scientific Inc., MA, USA) and with spectra from our own database. Microparticles were considered plastics when the match confidence was at least 70 %. Natural (cotton and linen) and semi-synthetic fibres (rayon/viscose/cellophane, lyocell/Tencel) as well as cotton and linen with non-natural colours that consist of cellulose, were classified as cellulosic since their spectra are practically identical and they are difficult to differentiate, especially in the case of the microparticles found in the environment due to weathering processes. Polyethylene terephthalate (PET) was classified as “polyester” (PES) since it is a thermoplastic polymer resin of PES.

2.5. Statistical analysis

Statistical methods were implemented using Statistical Package for the Social Sciences (IBM SPSS Statistics, Version 26.0). The level of significance for all test was set to $p < 0.05$. Assumptions of normality (Kolmogorov-Smirnov test) and homogeneity of variance (Levene test) were met for each analysis. To detect differences in particles abundances (items per litre of snow) between sampling locations an ANOVA and post hoc Tukey's test were used.

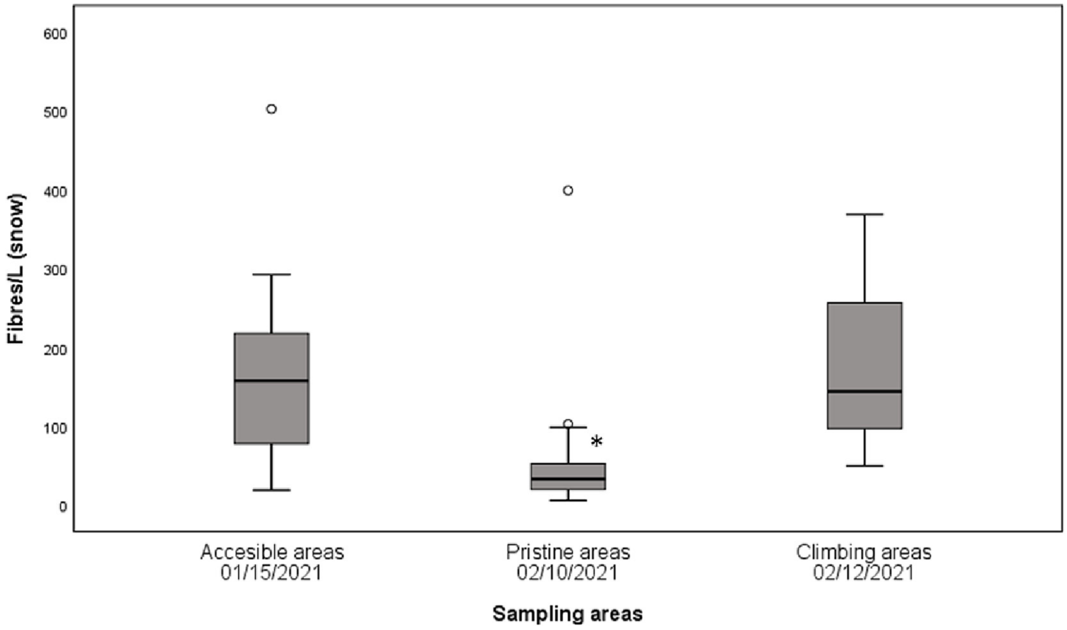

Fig. 2. Box and whisker plot of the fibres per litre of snow from the three sampling areas at the Teide National Park. *Significative differences between sampling location were observed (F value = 12,903, $p = 0.00$).

3. Results and discussion

3.1. Microplastics morphology, size and colour

Table 1 shows the results of the analysis of the snow samples collected at the different sampling periods. Since particles of a size higher than 5 mm (largest dimension) were also detected, the table includes information concerning <5 mm particles and higher. A total of 1784 particles were identified under the trinocular light stereomicroscope among the 63 snow samples, after their thawing and filtration through a glass microfibre filters of 0.45 μm. Forty two of them had a size higher than 5 mm. Concerning the snow samples collected at "accessible areas" (01/15/2021) an average concentration of 167 ± 104 items/L was found (162 ± 103 items/L if particles >5 mm are not considered, n = 37), most of which (99.5 %) were fibres with an average length of 1393 ± 1698 μm (1188 ± 929 μm if particles >5 mm are not considered, n = 37). Regarding samples collected after the second snowfall in "pristine areas" (02/10/2021) a much lower average concentration of 51 ± 72 items/L was observed (49 ± 71 items/L if particles >5 mm are not considered, n = 5), being also fibres the most abundant shapes (99.3 %) with an average length of 949 ± 920 μm (892 ± 766 μm if

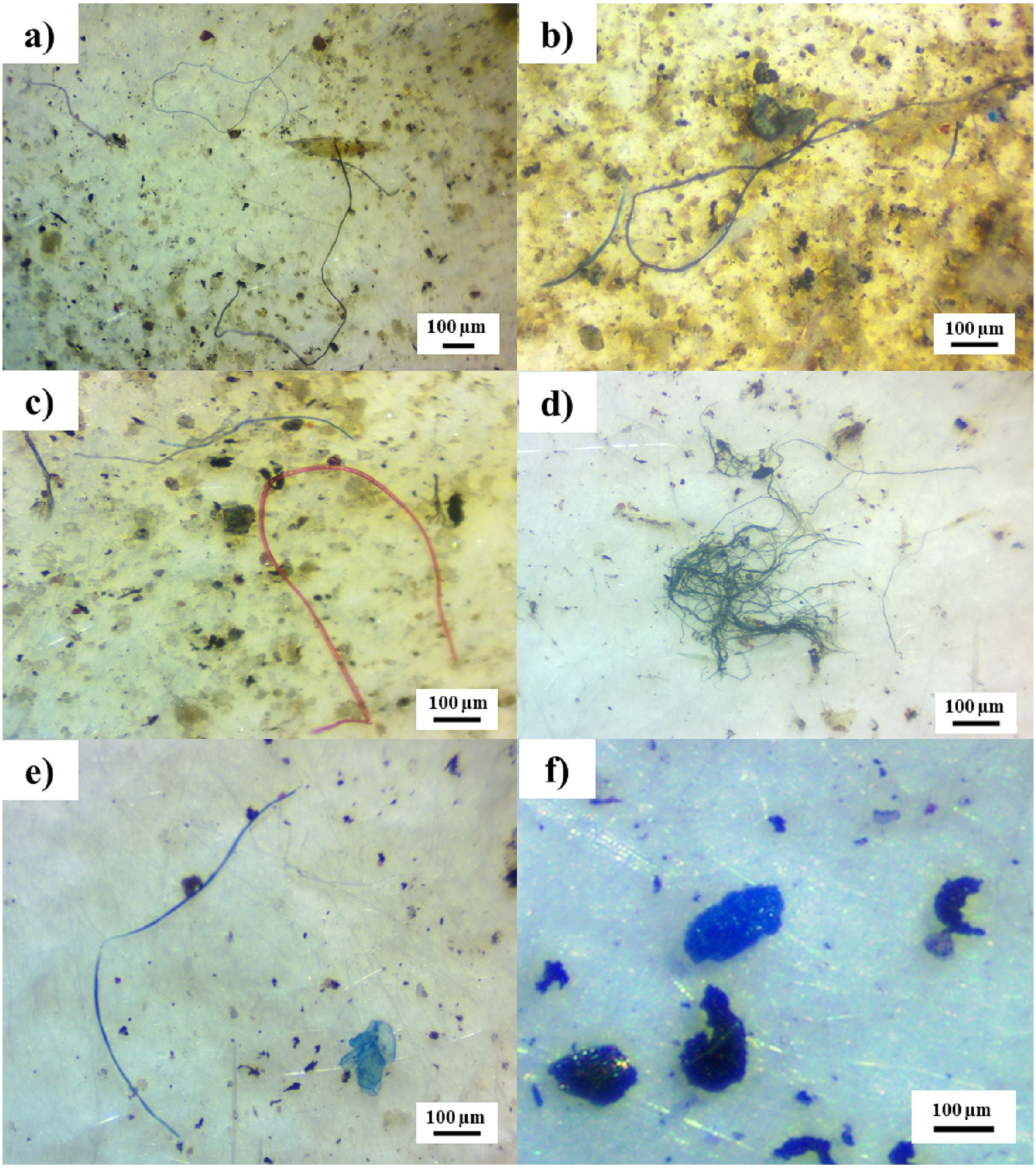

Fig. 3. Stereomicroscopic photographs of the MPs found in the snow samples collected at the Teide National Park. a) Multi-coloured microfibre: purple, blue and black (sample collected on 15th January 2021); b) blue microfibres and blue fragment (sample collected on 15th January 2021); c) red and blue microfibres (sample collected on 15th January 2021); d) black tangled mess (sample collected on 10th February 2021); e) blue microfibre and blue film (sample collected on 10th February 2021); f) blue fragments (sample collected on 10th February 2021).

particles >5 mm are not considered, n = 5). Such average size is lower than the ones previously found. With regards to the three samples collected in "climbing areas" (3100–3200 m a.s.l. sampled on 02/12/2022), a similar concentration to that found in "accessible areas" was determined (188 ± 164 items/L, 100 % of fibres with an average length of 743 ± 634 μm), though it should be taken into consideration the much lower number of samples compared to the other two samplings. In the three "climbing areas" samples, no particles of a size >5 mm were found.

For comparison purposes, Fig. 2 shows the box and whiskers plot of the concentration (fibres per L) in the three sampling periods. As can be seen from that figure, a significantly higher number of fibres ($p < 0.05$) was found in samples from "accessible and climbing areas", compared to that from "pristine areas". This could suggest a possible difference in the accumulation pattern or origin of the fibres in each sampling location. Furthermore, the fact that high concentration values have been found in "pristine areas", clearly indicates that wet deposition of MPs with snow has taken place. On the other hand, though no possible comparison with snow sampled in the same period in "pristine areas" can be made, the much higher concentration in "accessible areas" suggests that an important anthropogenic contribution has occurred after people arrival to enjoy the snow and to "climbing areas" during sports activities (trekking, sledding, climbing, etc.).

Considering that only three samples belonging to the second snowfall were collected in "climbing areas", it was also built a box and whisker plot of the number of fibres per litre of snow by including the results of such three samples together with the rest of the samples from the same snow period. Results can be seen in Fig. S1 of the Supplementary Material, where the three outliers in the "pristine + climbing" areas data set belong to such three samples. Still, significant differences were observed between both data sets.

Fig. 3 shows several photographs of the MPs found in some of the samples. As it can be seen in the figure, though fibres were the most abundant shape, comprising 99.4 % of the total, some fragments, tangled messes, and films were also found, contributing 0.6 % of the total.

Fig. 4 shows the histogram of the colour and size distribution of the total number of microfibres found (particles with a length > 5 mm are also included). Blue microfibres were the most abundant (53.1 %), followed by black (20.7 %), translucent white (12.6 %) and red (9.3 %), ranging the length between 250 and 1000 μm (average size was 1264 ± 1533 μm). For comparison purposes, Figs. S2, S3 and S4 of the Supplementary Material show the colour and size distribution of the three sampling sets, in which it can be observed a high degree of similarity between the samples collected at "accessible and pristine areas". In the first of them, 500–750 μm was the most abundant size, while for the second, 250–500 μm. In the case of the samples collected at "climbing areas", the pattern differs slightly, with a prevalence of blue (60.9 %) and black fibres (18.8 %), which can be attributed to the fact that only three samples were collected.

Regarding contamination control filters exposed during samples collection, they were also analysed in order to avoid a possible overestimation of the concentration of MPs. In the sampling carried out in "accessible areas", a total of 8 fibres were found with an average length of 857 ± 782 μm, mainly blue (37.5 %), black (37.5 %) follow by translucent white (25.0 %). In the second and third sampling in "pristine and climbing areas", a total of 15 fibres were found with an average length of 1299 ± 890 μm mainly blue (40.0 %), translucent white (40.0 %) follow by black (13.3 %) and red (6.7 %).

3.2. Microplastics composition analysis

A total of 364 fibres (20.3 % of the total) were analysed by μFTIR (see Experimental Section for more details). Fig. 5 shows the distribution of the microfibres composition from each sampling separately and combined. Analysis revealed that 228 particles (62.6 % of the total) corresponded to cellulosic materials. As previously indicated, as a result of the extremely high similarity between the FTIR spectra of natural (cotton or linen) and semisynthetic cellulose (viscose, rayon, etc.), they were all designated as

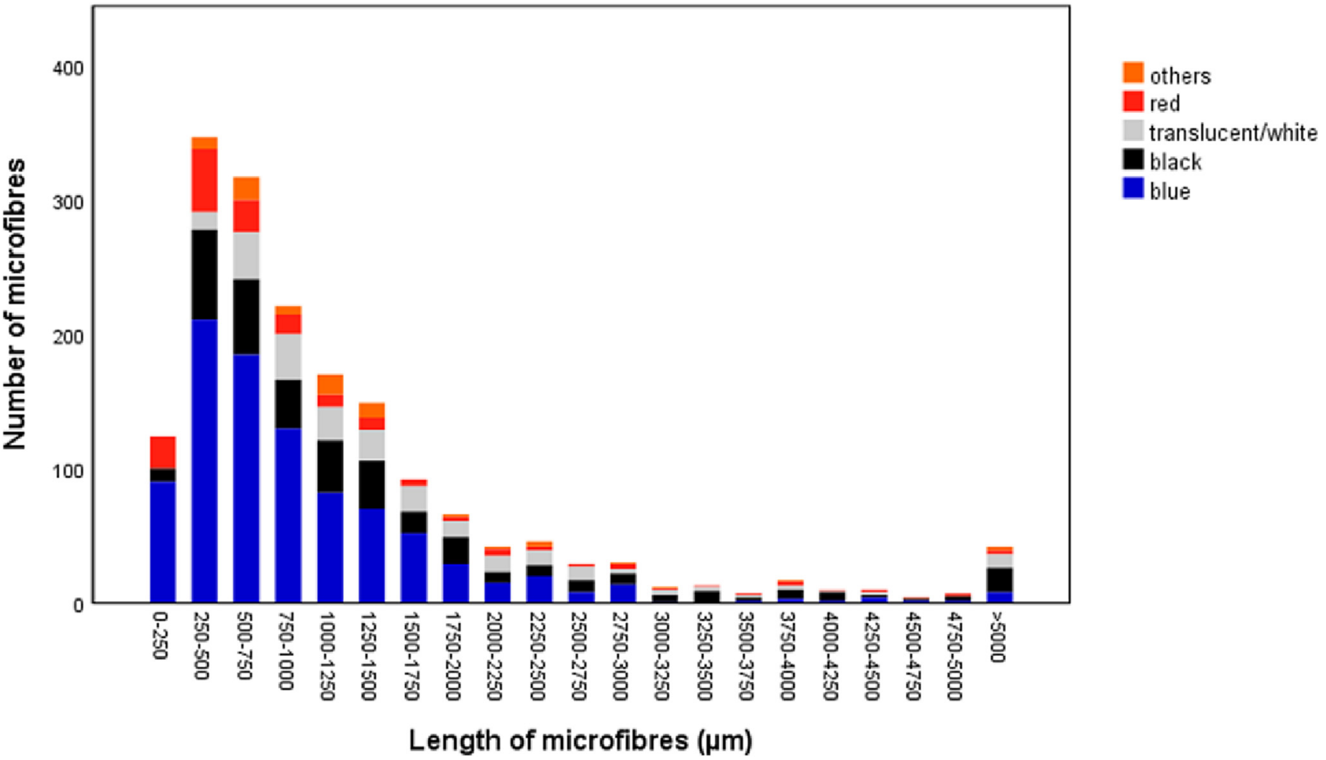

Fig. 4. Histogram of the size and colours distribution of the total number of fibres found in the Teide National Park collected at the three sampling areas in January and February 2021. Note that the range indicated as 0–250 μm includes only fibres with a length between 75 and 250 μm as a result of the visualization limit of 75 μm (see experimental section for details).

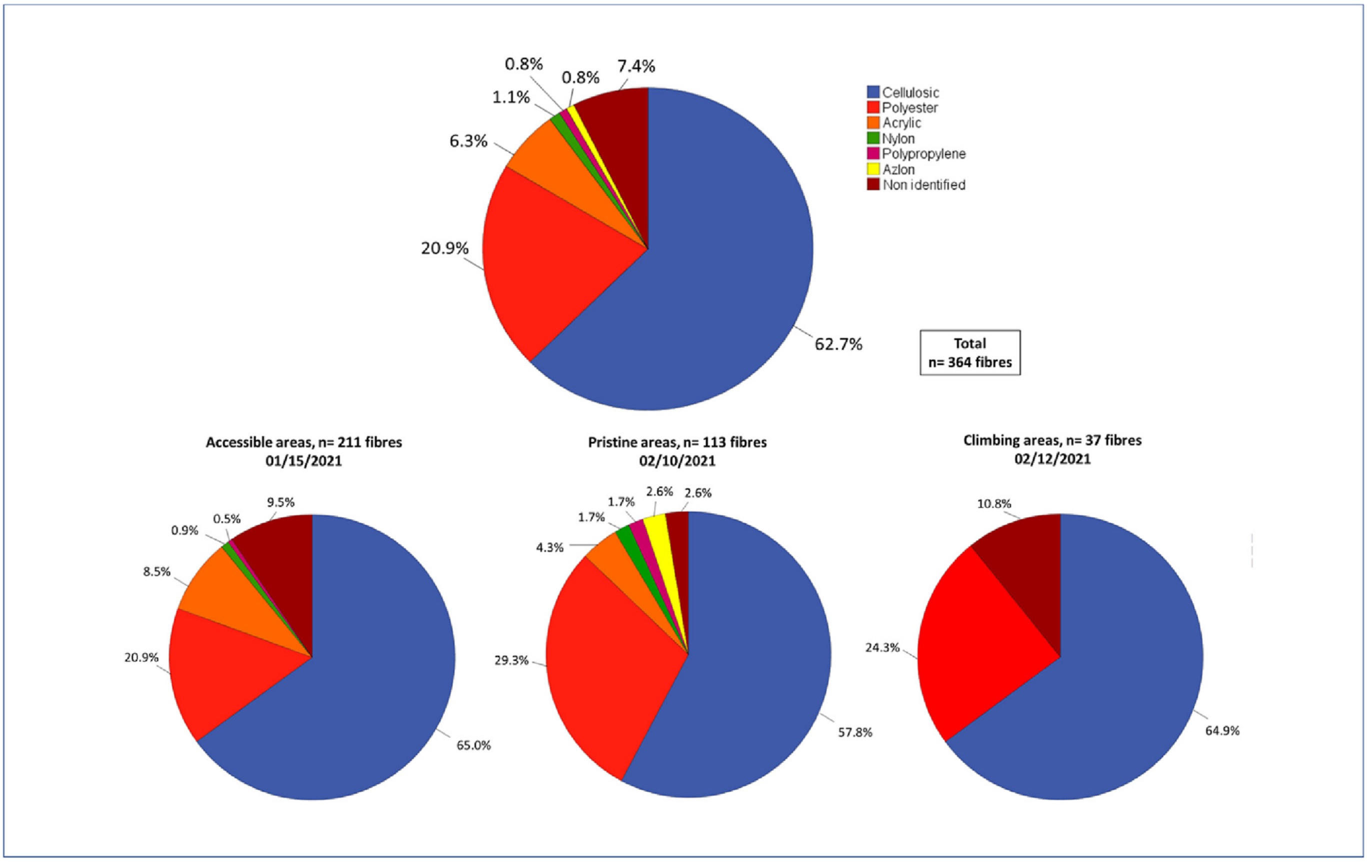

Fig. 5. Distribution of the composition of the microfibres found in the snow of the Teide National Park during this study (n = 364). "Cellulosic" includes natural and semisynthetic cellulose (see Experimental Section for details).

"cellulosic". Apart from them, 20.9 % of the analysed fibres were PES (74 of the 364 selected particles), followed by acrylic microfibres (6.3 %), nylon -which is a polyamide (PA)- (1.1 %), PP (0.8 %) and azlon (0.8 %), while a 7.4 % of the selected microfibres could not be identified due to the lack of sufficient matching percentage (< 70 %). Concerning the composition of the microfibres from each sampling set, in general, the distribution is similar, with a clear dominance of cellulosic polymers, followed by PES. As it also happened for the shapes, sizes and colours, there is a higher similarity between the distributions of the microparticles found in snow collected at "accessible areas" and at "pristine areas" and less with those of "climbing areas", probably as a result of the lower number of samples collected in this case, which makes difficult a reliable comparison.

According to the 2021 Market Report of Textile Exchange (Textile Exchange, 2021), the global fibre production has reached 109 million tons in 2020, 52 % of the global production are PES fibres (many of which are currently obtained from the recycling of PET bottles), followed by cotton, a natural cellulosic fibre, with 26.4 %, and PA, the second most used synthetic fibre, with a 5.4 %. Other manmade cellulosic fibres (e.g., viscose) compile for a 6.5 % of the total, while other synthetic fibres like PP, acrylic or elastane, represent 5.7 % of total production. Therefore, the composition pattern of the microfibres found in this study agrees with the current market production of fibres. In fact, the polymers most frequently detected in this work, PES, acrylic and PA, are very common in winter clothes, which can also explain their presence to high concentration in "accessible areas". Previous research has demonstrated that the direct release of microfibres from wearing garments to air is of equal importance to releases to water as a result of laundering (De Falco et al., 2020). In that work it was estimated that 1 billion MPs could be released from a person wearing 1 kg (e.g., a coat) of PES clothing per year, equating to 2.8 million MPs released per day.

3.3. Comparison with previous studies

Table 2 compiles several works in which MPs in snow samples have been determined throughout the world, in most cases from high altitude locations. Although full comparison cannot be achieved since the orography, weather conditions, proximity to populations, etc. are different, as well as the sampling procedures, some general assessments can be developed.

First of all, it should be indicated that most of the studies have sampled between 250 mL and 2 L of snow using glass or stainless-steel bottles and many of them have assessed MPs morphology, size, colour and composition. Microfibres have been the shapes most frequently found (Abbasi et al., 2022; Ambrosini et al., 2019; Aves et al., 2022; Bergmann et al., 2022; Cabrera et al., 2020; Napper et al., 2020; Parolini et al., 2021; Pastorino et al., 2021; Zhang et al., 2021), which agrees with previous studies concerning the determination of MPs in air (Cai et al., 2017; Dris et al., 2015; Liu et al., 2019).

Regarding the concentration found in the "pristine areas" of the present study (51 ± 72 items/L), it is slightly higher than those reported in snow from Antarctica (Aves et al., 2022), Iran (Abbasi et al., 2022), or the Everest (Napper et al., 2020), and lower than those found in a glacier of the Italian Alps (Ambrosini et al., 2019; Parolini et al., 2021; Pastorino et al., 2021) or the Ecuadorian Andes (Cabrera et al., 2020). When considering "accessible or climbing areas" (167 ± 104 items/L and 188 ± 164 items/L, respectively), MPs amount is much higher probably as a result of a direct and intensive anthropogenic activity -trekking, sledding, etc.-, as previously mentioned.

With regards to the colour distribution, there is a wide variability among studies, though some of them agree with the fact that blue microfibres are highly abundant (Ambrosini et al., 2019; Aves et al., 2022; Cabrera et al., 2020; Parolini et al., 2021; Pastorino et al., 2021), which is also coincident with our findings.

Table 2
Comparison of the results obtained in this study with previous ones in which the occurrence of MPs has been determined in snow.

Location (year)	Altitude (m a.s.l.)	Number of locations (samples analysed)	Items/L	Shape	Fibres length	Colours	Chemical composition	Reference
Europe (Swiss Alps, North Germany) and Artic Pole (2019)	–	22 locations (n = 22)	$9.8 \cdot 10^3 \pm 6.9 \cdot 10^3$	Fibres (−)	65–14,314 μm	Black (4.6 %) Blue (14.3 %) Dark blue (11.4 %) Purple (11.0 %) Red (8.4 %) White (30.4 %) Others (19.9 %)	PE PP PS PC PA PVC Cellulose PES Acrylates/PU/varnish/lacquer (hearfer varnish) Polychloroprene Polylactide acide Polycaprolactone Ethylene-vinyl-acetate PA Rubbers	(Bergmann et al., 2022)
Ablation tongue of Forni Glacier, Italian Alps, Europe (2019)	2580 m a.s.l	1 location (n = 6)	Cryconite (70.5 ± 32.9 items/kg) Supraglacial debris (78.3 ± 30.2 items/kg)	Fibres (65.2 %) Fragments (34.8 %)	(−)	Black (31.0 %) Blue (22.0 %) Light blue (9.0 %) Red (17.0 %) Transparent (17.0 %) Violet (4.0 %)	PES (39.0 %) PA (9.0 %) PE (9.0 %) PP (4.0 %) Unknown (39.0 %)	(Ambrosini et al., 2019)
Everest (2019)	5300–8440 m a.s.l.	6 locations (n = 11)	Average: (30 ± 11) Everest Base Camp (79) Camp I (13) Camp II (12) Lobuche (14) South Col (3) Balcony (12)	Fibres (94.6 %) Fragments (5.4 %)	36–3800 μm	Red (36.7 %) Blue (36.7 %) Clear (13.3 %) Black (10.0 %) Purple (3.3 %)	PES (56.0 %) Acrylic (31.0 %) Nylon (9.0 %) PP (5.0 %) -data for both stream and snow samples-	(Napper et al., 2020)
Antisana glacier, Ecuadorian Andes, South America (2020)	5753 m a.s.l.	1 location (n = 15)	101.2 ± (−)	Fibres (71.5 %) Fragments (7.8 %) Others (1.0 %)	60–2500 μm	Transparent (51.0 %) Blue (30.0 %) White (9.0 %) Red (6.0 %) Cream (3.0 %) Others (1.0 %)	(−)	(Cabrera et al., 2020)
Tibetan Plateau (2018)	4460–5600 m a.s.l.	2 locations (n = 10)	(−)	Fibres (−) Fragments (−) Films (−)	<10 μm–>100 μm	(−)	PA (26.7 %) PE (13.9 % Rubber (9.7 %) PET (8.4 %) Polyacetal (6.5 %) PS (5.2 %) PC (3.4 %) Varnish (3.3 %) Unknown (8.6 %) Others -PMMA, PVC, PP, PTFE, etc.- (14.3 %)	(Zhang et al., 2021)
Western Italian Alps (2019)	>2500 m a.s.l.	4 locations (n = 12)	Miserin (4.9 ± 2.5) Deffeyes (2.5 ± 1.5) Malatrà (1.5 ± 1.5) Cuney (0.4 ± 0.4)	Fibres (39.0 %) Fragments (61.0 %)	83–1910 μm	White (50.0 %) Blue (28.0 %) Light blue (11.0 %) Pink (5.5 %) Purple (5.5 %)	PE (39.0 %) PET (17.0 %) HDPE (17.0 %) Polyester (11.0 %) LDPE (5.3 %) PP (5.3 %) Polyurethane (5.3 %)	(Parolini et al., 2021)
Dimon Lake, Carnic Alps (2020)	1872 m a.s.l.	3 locations (n = 12)	0.11 ± 0.19	Fragment (100 %) Only 1 item found	220 μm	Blue (100 %)	PET (100 %)	(Pastorino et al., 2021)
Tabriz, Iran (2021)	1350 m a.s.l	29 locations (n = 34)	20 ± (−)	Fibres (89.6 %) Films (3.2 %) Fragments (2.6 %) Spherules (4.6 %)	<100 μm–>1000 μm	White-transparent (12.4 %) Yellow-orange (3.2 %) Red-pink (14.4 %) Black-grey (44.8 %) Blue-green (25.3 %)	Nylon (27.0 % Cellulose/viscose (18.9 %) PP (10.8 %) PES/PET (8.1 %) Ethylene vinyl acetate (8.1 %) PS (5.4 %) Polyphenolsulfone (5.4 %) PVC (2.7 %) PE (2.7 %)	(Abbasi et al., 2022)

Table 2 (*continued*)

Location (year)	Altitude (m a.s.l.)	Number of locations (samples analysed)	Items/L	Shape	Fibres length	Colours	Chemical composition	Reference
							PU (2.7 %) PA (2.7 %) Silicone (2.7 %) Silk (2.7 %)	
Ross Island region, Antarctica (2019)	–	19 locations (n = 19)	29.4 ± 4.7	Fibres (61.0 %) Fragments (39.0 %) Films (1.0 %)	139–3510 μm	Blue (55 %) Pink (23 %) Others (22 %)	PET (41 %) Copolymers (17 %) PMMA (9 %) PVC (9 %) PA (6 %) PE (4 %) Alkyd (4 %) Cellulose nitrate (4 %) Others -PTFE, PP, etc.- (6 %)	(Aves et al., 2022)
El Teide National Park, Canary Islands, Spain (2021)	2150–3200 m a.s.l	3 locations (n = 63)	First storm (Accessible areas) 167 ± 104 Second storm (Pristine areas) 51 ± 72 Second storm (Climbing areas) 188 ± 164	Fibres (99.4 %) Fragments (0.2 %) Tangled messes (0.2 %) Films (0.2 %)	80–26,741 μm	Blue (52.6 %) Black (20.7 %) Translucent/white (12.4 %) Red (9.2 %) Pink (1.2 %) Fluorescent yellow (0.9 %) Grey (0.9 %) Purple (0.7 %) Green (0.4 %) Yellow (0.4 %) Orange (0.5 %) Brown (0.1 %)	Cellulosic (62.7 %) PES (20.9 %) Acrylic (6.3 %) Nylon (1.1 %) PP (0.8 %) Azlon (0.8 %) Non identified (7.4 %)	This study

HDPE: High density polyethylene; PA: Polyamide; PE: Polyethylene; PES: Polyester; PET: Polyethylene terephthalate; PMMA: Poly(methyl methacrylate); PP: Polypropylene; PU: Polyurethane; PVC: Polyvinyl chloride; PS: Polystyrene.

Finally, there is also a wide composition of polymers that have been found in the different works, though fibres from the detachment of fabrics (i.e. PES, nylon, acrylic, etc.) were the most abundant, which also agrees with our work. Concerning cellulosic fibres (either natural or semisynthetic), few studies have reported their presence (Abbasi et al., 2022; Aves et al., 2022; Bergmann et al., 2022) since, very frequently, they are not taken into consideration even though previous works have shown they are highly present in the atmosphere (Finnegan et al., 2022). However, in those works, the concentrations found are much lower than the ones reported for the Teide National Park. If cellulosic fibres are not considered, the composition and percentage distribution of the fibres found in this work agree most with that found by Napper et al. in the Everest, being PES, acrylic, nylon and PP fibres (in that same order) the most abundant (Napper et al., 2020).

3.4. Possible sources of microplastics in the snow samples

As previously indicated, the atmosphere is the less studied environmental compartment regarding the occurrence and spatial distribution of MPs. Most of the works developed to understand MPs sources and transport are based on dry or wet deposition processes (Pastorino et al., 2022; Sridharan et al., 2021). Little is still known about the movement of MPs in the atmosphere and the extent to which MPs can be transported with atmospheric air masses (González-Pleiter et al., 2020). As an example of one of these studies, González-Pleiter et al. (González-Pleiter et al., 2020) investigated the presence of MPs in aircraft sampling campaigns flying within and above the planetary boundary layer of Madrid (the only study of these characteristics, that, to the best of our knowledge, has been carried out in Spain). Results have shown that MPs were present with concentrations ranging from 1.5 MPs/m^3 above rural areas to 13.9 MPs/m^3 above urban areas. Atmospheric transport and deposition simulation indicated that MPs (which were mostly microfibres in rural areas and fragments in urban areas) could be transported >1000 km without being deposited (González-Pleiter et al., 2020). This study, as well as other ones which have shown that MPs are mainly released from urban areas (González-Pleiter et al., 2020; Sridharan et al., 2021), may support the fact that long-distance transport and deposition could take place in this oceanic island, though specific studies should be develop to demonstrate this issue. Besides, previous works have established that the wind can transport large dust particles over long distances, i.e. 3500 km from the Sahara to the North Atlantic (van der Does et al., 2022).

Additionally, the island of Tenerife has around 2000 km^2 and nearly 1 million inhabitants, with several cities relatively close to the Teide National Park, which could contribute to MPs presence in this part of the island; short-distance transport could be taking place, though suitable studies should be developed to confirm this issue. The fact that microfibres were the prevalent morphotypes and no other shapes like films, fragments or foams were found, suggest that their main origin could be related to fabrics used in populated areas.

Besides, when considering the samples collected in the first sampling, it should also be taken into account that these samples (which have the same profile in terms of shapes, colours, size and composition) were collected one week after the opening of the park to the public, with clearly visible evidences of human activities (trekking, sledding, etc.) which may justify a higher concentration of MPs in those samples compared to the second sampling. Even though, more studies are necessary to clarify this issue.

4. Conclusions

Little is still known about the occurrence and movement of MPs in the atmosphere and the extent to which these contaminants can be transported and deposited with atmospheric air masses, being necessary the development of more studies that help to clarify this important issue, especially in remote areas.

The analysis of snow samples from two storm episodes at the Teide National Park, in the island of Tenerife (Spain), has shown an important amount of MPs deposition in this area, among which blue and black microfibres of 250–750 μm length prevail. Most of the analysed microfibres have a cellulosic nature (either natural or semisynthetic), followed by synthetic polymers like PES, PA and acrylic. These results agree with previous/

similar works in the literature and suggest that those contaminants could be released from fabrics.

From the results of this study, it could be inferred that the Teide National Park acts as a receptor of MPs, both from local and long-distance sources. Besides MPs wet deposition from the atmosphere, human outdoor activities in snow (trekking, sledding, etc.) appear to be introducing important amounts of MPs in the park, matching previous results reported in other regions of the world; however, more studies should be developed to further confirm this issue. Once snow melts, MPs could move down into the soil potentially reaching groundwater or being mobilized to other parts of the territory with runoff flow, with its subsequent physicochemical and biological effects in soil and water resources as several studies have indicated.

Future research should be conducted in order to widen knowledge regarding MP pollution in this national park, which is a World Heritage Site, with high biodiversity and, therefore, important biological implications. Such future studies may involve MPs determination in soil and groundwater, the development of additional dry or wet deposition studies and atmospheric transport and deposition simulation in the region. Studies like the one proposed in this work, help to identify the degree of pollution in these areas and to take further actions to improve their conservation.

CRediT authorship contribution statement

Cristina Villanova-Solano: Methodology; Validation; Formal Analysis; Investigation; Data curation Writing-Original Draft; Writing Review & Editing; Visualization.

Cintia Hernández-Sánchez: Conceptualization; Methodology; Investigation; Writing-Original Draft; Writing Review & Editing; Visualization.

Francisco J. Díaz-Peña: Conceptualization; Methodology; Investigation; Visualization.

Javier González-Sálamo: Conceptualization; Methodology; Investigation; Writing-Original Draft; Writing Review & Editing; Visualization.

Miguel González-Pleiter: Methodology; Validation; Investigation; Writing Review & Editing; Visualization.

Javier Hernández-Borges: Conceptualization; Methodology; Investigation; Resources; Writing-Original Draft; Writing Review & Editing; Visualization; Supervision; Project administration; Funding acquisition.

Data availability

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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References

Abbasi, S., Alirezazadeh, M., Razeghi, N., Rezaei, M., Pourmahmood, H., Dehbandi, R., Mehr, M.R., Ashayeri, S.Y., Oleszczuk, P., Turner, A., 2022. Microplastics captured by snowfall: a study in Northern Iran. Sci. Total Environ. 822, 153451. https://doi.org/10.1016/j.scitotenv.2022.153451.

Aeschlimann, M., Li, G., Kanji, Z.A., Mitrano, D.M., 2022. Potential impacts of atmospheric microplastics and nanoplastics on cloud formation processes. Nat. Geosci. 15, 967–975. https://doi.org/10.1038/s41561-022-01051-9.

Allen, S., Allen, D., Moss, K., Roux, G.Le, Phoenix, V.R., Sonke, J.E., 2020. Examination of the ocean as a source for atmospheric microplastics. PLoS One 15, e0232746. https://doi.org/10.1371/JOURNAL.PONE.0232746.

Allen, S., Allen, D., Phoenix, V.R., Le Roux, G., Durántez Jiménez, P., Simonneau, A., Binet, S., Galop, D., 2019. Atmospheric transport and deposition of microplastics in a remote mountain catchment. Nat. Geosci. 12, 339–344. https://doi.org/10.1038/s41561-019-0335-5.

Ambrosini, R., Azzoni, R.S., Pittino, F., Diolaiuti, G., Franzetti, A., Parolini, M., 2019. First evidence of microplastic contamination in the supraglacial debris of an alpine glacier. Environ. Pollut. 253, 297–301. https://doi.org/10.1016/j.envpol.2019.07.005.

Aves, A.R., Revell, L.E., Gaw, S., Ruffell, H., Schuddeboom, A., Wotherspoon, N.E., Larue, M., Mcdonald, A.J., 2022. First evidence of microplastics in Antarctic snow. Cryosphere 16, 2127–2145. https://doi.org/10.5194/TC-16-2127-2022.

Baeza-Martínez, C., Olmos, S., González-Pleiter, M., López-Castellanos, J., García-Pachón, E., Masiá-Canuto, M., Hernández-Blasco, L., Bayo, J., 2022. First evidence of microplastics isolated in European citizens'lower airway. J. Hazard. Mater. 438, 129439. https://doi.org/10.1016/j.jhazmat.2022.129439.

Bergmann, M., Mützel, S., Primpke, S., Tekman, M.B., Trachsel, J., Gerdts, G., 2022. White and wonderful? Microplastics prevail in snow from the Alps to the Arctic. Sci. Adv. 5, eaax1157. https://doi.org/10.1126/sciadv.aax1157.

Brahney, J., Hallerud, M., Heim, E., Hahnenberger, M., Sukumaran, S., 2020. Plastic rain in protected areas of the United States. Science 368, 1257–1260. https://doi.org/10.1126/science.aaz5819.

Cabrera, M., Valencia, B.G., Lucas-Solis, O., Calero, J.L., Maisincho, L., Conicelli, B., Massaine Moulatlet, G., Capparelli, M.v, 2020. A new method for microplastic sampling and isolation in mountain glaciers: a case study of one antisana glacier, Ecuadorian Andes. Case Stud. Chem. Environ. Eng. 2, 100051. https://doi.org/10.1016/j.cscee.2020.100051.

Cai, L., Wang, J., Peng, J., Tan, Z., Zhan, Z., Tan, X., Chen, Q., 2017. Characteristic of microplastics in the atmospheric fallout from Dongguan city, China: preliminary research and first evidence. Environ. Sci. Pollut. Res. 24, 24928–24935. https://doi.org/10.1007/s11356-017-0116-x.

De Falco, F., Cocca, M., Avella, M., Thompson, R.C., 2020. Microfiber release to water, via laundering, and to air, via everyday use: a comparison between polyester clothing with differing textile parameters. Environ Sci Technol 54, 3288–3296. https://doi.org/10.1021/acs.est.9b06892.

Dris, R., Gasperi, J., Rocher, V., Saad, M., Renault, N., Tassin, B., 2015. Microplastic contamination in an urban area: a case study in Greater Paris. Environ. Chem. https://doi.org/10.1071/EN14167i.

Finnegan, A.M.D., Süsserott, R., Gabbott, S.E., Gouramanis, C., 2022. Man-made natural and regenerated cellulosic fibres greatly outnumber microplastic fibres in the atmosphere. Environ. Pollut. 310, 119808. https://doi.org/10.1016/J.ENVPOL.2022.119808.

González-Pleiter, M., Edo, C., Aguilera, Á., Viúdez-Moreiras, D., Pulido-Reyes, G., González-Toril, E., Osuna, S., de Diego-Castilla, G., Leganés, F., Fernández-Piñas, F., Rosal, R., 2020. Occurrence and transport of microplastics sampled within and above the planetary boundary layer. Sci. Total Environ. 143213. https://doi.org/10.1016/j.scitotenv.2020.143213.

Hidalgo-Ruz, V., Gutow, L., Thompson, R.C., Thiel, M., 2012. Microplastics in the marine environment: a review of the methods used for identification and quantification. Environ. Sci. Technol. 46, 3060–3075. https://doi.org/10.1021/es2031505.

Jenner, L.C., Rotchell, J.M., Bennett, R.T., Cowen, M., Tentzeris, V., Sadofsky, L.R., 2022. Detection of microplastics in human lung tissue using μFTIR spectroscopy. Sci. Total Environ. 831, 154907. https://doi.org/10.1016/j.scitotenv.2022.154907.

Liu, K., Wu, T., Wang, X., Song, Z., Zong, C., Wei, N., Li, D., 2019. Consistent transport of terrestrial microplastics to the ocean through atmosphere. Environ. Sci. Technol. 53, 10612–10619. https://doi.org/10.1021/acs.est.9b03427.

Marine &amp, Environmental Research Institute, 2017. Guide to Microplastic Identification.

Napper, I.E., Davies, B.F.R., Clifford, H., Elvin, S., Koldewey, H.J., Mayewski, P.A., Miner, K.R., Potocki, M., Elmore, A.C., Gajurel, A.P., Thompson, R.C., 2020. Reaching new heights in plastic pollution—preliminary findings of microplastics on Mount Everest. One Earth 3, 621–630. https://doi.org/10.1016/j.oneear.2020.10.020.

Parolini, M., Antonioli, D., Borgogno, F., Gibellino, M.C., Fresta, J., Albonico, C., De Felice, B., Canuto, S., Concedi, D., Romani, A., Rosio, E., Gianotti, V., Laus, M., Ambrosini, R., Cavallo, R., 2021. Microplastic contamination in snow from Western Italian Alps. Int. J. Environ. Res. Public Health 18, 768. https://doi.org/10.3390/ijerph18020768.

Pastorino, P., Pizzul, E., Bertoli, M., Anselmi, S., Kušće, M., Menconi, V., Prearo, M., Renzi, M., 2021. First insights into plastic and microplastic occurrence in biotic and abiotic compartments, and snow from a high-mountain lake (Carnic Alps). Chemosphere 265, 129121. https://doi.org/10.1016/j.chemosphere.2020.129121.

Pastorino, P., Prearo, M., Pizzul, E., Elia, A.C., Renzi, M., Ginebreda, A., Barceló, D., 2022. High-mountain lakes as indicators of microplastic pollution: current and future perspectives. Water Emerg.Contam.Nanoplast. 1, 3. https://doi.org/10.20517/WECN.2022.01.

Pérez-Reverón, R., Álvarez-Méndez, S.J., González-Sálamo, J., Socas-Hernández, C., Díaz-Peña, F.J., Hernández-Sánchez, C., Hernández-Borges, J., 2023. Nanoplastics in the soil environment: analytical methods, occurrence, fate and ecological implications. Environ. Pollut. 317, 120788. https://doi.org/10.1016/j.envpol.2022.120788.

Priya, K.L., Renjith, K.R., Joseph, C.J., Indu, M.S., Srinivas, R., Haddout, S., 2022. Fate, transport and degradation pathway of microplastics in aquatic environment — a critical review. Reg. Stud. Mar. Sci. 56, 102647. https://doi.org/10.1016/j.rsma.2022.102647.

Roblin, B., Ryan, M., Vreugdenhil, A., Aherne, J., 2020. Ambient atmospheric deposition of anthropogenic microfibers and microplastics on the Western periphery of Europe (Ireland). Environ. Sci. Technol. 54, 11100–11108. https://doi.org/10.1021/acs.est.0c04000.

Shao, L., Li, Y., Jones, T., Santosh, M., Liu, P., Zhang, M., Xu, L., Li, W., Lu, J., Yang, C.-X., Zhang, D., Feng, X., BéruBé, K., 2022. Airborne microplastics: a review of current perspectives and environmental implications. J. Clean. Prod. 347, 131048. https://doi.org/10.1016/j.jclepro.2022.131048.

Sridharan, S., Kumar, M., Singh, L., Bolan, N.S., Saha, M., 2021. Microplastics as an emerging source of particulate air pollution: a critical review. J. Hazard. Mater. 418, 126245. https://doi.org/10.1016/J.JHAZMAT.2021.126245.

Tan, J., Tan, J., Fu, J.S., Carmichael, G.R., Itahashi, S., Tao, Z., Huang, K., Huang, K., Dong, X., Yamaji, K., Nagashima, T., Wang, X., Liu, Y., Lee, H.J., Lin, C.Y., Ge, B., Kajino, M., Zhu, J., Zhang, M., Liao, H., Wang, Z., 2020. Why do models perform differently on particulate matter over East Asia? A multi-model intercomparison study for MICS-Asia III. Atmos. Chem. Phys. 20, 7393–7410. https://doi.org/10.5194/ACP-20-7393-2020.

Teide National Park, 2022. Mount Teide National Park Climbing, Fauna Flora... | Tenerife [WWW Document]. URL (accessed 12.13.22) https://www.webtenerife.co.uk/what-see/teide-national-park/?_ga = 2.60666413.1694066284.1670958578-1374112566.1670958578.

Textile Exchange, 2021. Preferred Fiber & Materials, Market Report 2021 [WWW Document]. URL (accessed 12.13.22) https://textileexchange.org/app/uploads/2021/08/Textile-Exchange_Preferred-Fiber-and-Materials-Market-Report_2021.pdf.

van der Does, M., Knippertz, P., Zschenderlein, P., Giles Harrison, R., Stuut, J.-B.W., 2022. The mysterious long-range transport of giant mineral dust particles. Sci. Adv. 4, eaau2768. https://doi.org/10.1126/sciadv.aau2768.

Zhang, Y., Gao, T., Kang, S., Allen, S., Luo, X., Allen, D., 2021. Microplastics in glaciers of the Tibetan Plateau: evidence for the long-range transport of microplastics. Sci. Total Environ. 758, 143634. https://doi.org/10.1016/j.scitotenv.2020.143634.