

Microplastic Footprints in Mountain Ecosystems: A Review of Current Evidence and Scientific Gaps

Hülya AYKAÇ ÖZEN^{1*} , Hamide Sena KANAT¹ 

¹Department of Environmental Engineering, Faculty of Engineering, Ondokuz Mayıs University, Samsun, Türkiye

Abstract

An increasing amount of information indicates that microplastic pollution is a widespread environmental problem that extends beyond urban and coastal settings to remote mountain ecosystems. Current studies on the prevalence, origins, and dispersion of microplastics in mountainous areas across the globe are summarized in this study. Research indicates that the main ways that microplastics enter high-altitude settings are through atmospheric deposition, travel, and nearby populated areas. Data on the temporal and spatial variability of microplastic pollution in mountainous regions are still scarce, despite increased awareness. Furthermore, little is known about the ecological effects of microplastics on ecosystem processes and mountain biota. Comprehensive evaluations are made more difficult by methodological differences between studies. This research identifies significant scientific deficiencies and emphasizes the necessity for established protocols, prolonged monitoring, and interdisciplinary strategies to clarify the magnitude and impacts of microplastic pollution in mountain ecosystems. Addressing these deficiencies is crucial for guiding conservation initiatives and alleviating plastic pollution in these susceptible ecosystems.

Keywords: Microplastic, Mountain, Atmosphere, Ecosystem, Pollution.

Received Date:
30.05.2025

Revision Date:
20.06.2025

Accepted Date:
26.06.2025

Published Date:
30.06.2025

***Corresponding Author:** Hülya AYKAÇ ÖZEN
hulya.aykac@omu.edu.tr
 0000-0003-4990-6682

Dağ Ekosistemlerinde Mikroplastik Ayak İzleri: Mevcut Kanıtlar ve Bilimsel Boşluklar Üzerine Bir İnceleme

Özet

Mikroplastik kirliliği yaygın bir çevre sorunu olarak ortaya çıkmıştır ve artan kanıtlar, kentsel ve deniz ortamlarının ötesinde, uzak dağ ekosistemlerine kadar uzanan varlığını ortaya koymaktadır. Bu derleme, dünya çapında dağlık bölgelerde mikroplastiklerin oluşumu, kaynakları ve dağılımına ilişkin mevcut araştırmaları sentezlemektedir. Çalışmalar, mikroplastiklerin yüksek rakımlı ortamlara öncelikle atmosferik birikim, turizm faaliyetleri ve komşu insan yerleşimleri yoluyla taşındığını göstermektedir. Artan farkındalığa rağmen, dağlık alanlardaki mikroplastik kirliliğinin mekansal ve zamansal değişkenliğine ilişkin veriler sınırlı kalmaktadır. Ayrıca, mikroplastiklerin dağ biyotası ve ekosistem süreçleri üzerindeki ekolojik etkileri yeterince anlaşılamamıştır. Çalışmalar arasındaki metodolojik tutarsızlıklar, kapsamlı değerlendirmeleri daha da karmaşık hale getirmektedir. Bu makale, kritik bilimsel boşlukları vurgulamakta ve dağ ekosistemlerindeki mikroplastik kirliliğinin kapsamını ve sonuçlarını daha iyi aydınlatmak için standartlaştırılmış protokollere, uzun vadeli izlemeye ve disiplinler arası yaklaşımlara duyulan ihtiyacın altını çizmektedir. Bu eksikliklerin giderilmesi, koruma stratejilerinin bilgilendirilmesi ve bu hassas ortamlarda plastik kirliliğinin azaltılması için elzemdir..

Anahtar Kelimeler: Mikroplastik, Dağ, Atmosfer, Ekosistem, Kirlilik.

Geliş Tarihi:
30.05.2025

Revizyon Tarihi:
20.06.2025

Kabul Tarihi:
26.06.2025

Yayın Tarihi:
30.06.2025

***Sorumlu Yazar:** Hülya AYKAÇ ÖZEN
hulya.aykac@omu.edu.tr
 0000-0003-4990-6682

To cite this article:

Aykaç Özen, H. & Kanat, H. S. (2025). Microplastic Footprints in Mountain Ecosystems: A Review of Current Evidence and Scientific Gaps, Positive Science International, 1 (1), 46-56.

1. Introduction

The amount of plastic produced annually surpassed 367 million tons by the early 2020s, following a sharp surge in the 1950s [1]. The amount of plastic trash in the environment has also increased as a result of this production, with a sizable amount of that garbage decomposing into microplastics (MPs). Usually less than 5 mm in diameter, microplastics are synthetic polymer particles that fall into one of two categories: primary (i.e., purposefully made at small sizes, like microbeads in cosmetics) or secondary (formed through the degradation of larger plastic waste due to environmental effects) [2]. Microplastics were first mostly found in marine habitats, but they have since been found in terrestrial, atmospheric, and even remote areas where human activity has had little impact [3], [4]. This suggests that microplastics are pervasive pollutants that can travel great distances and have an impact on a variety of ecosystems, rather than being restricted to local pollution sources. It is evident from recent research conducted in mountainous places that microplastic pollution is a problem there as well.

Over 13 percent of the world's population lives directly in mountain regions, which make up about 24 percent of the planet's land area [5]. They provide almost 60% of the freshwater resources on Earth [6]. Mountain habitats, which are rich in biodiversity and are home to several endemic species, are becoming more and more endangered due to human activity and climate change. Environmental risk factors that contribute to these hazards include microplastics. In particular, tourists, trekkers and mountaineers pollute the environment with various wastes during their trips to the plateaus, whether intentionally or unintentionally. These include food packaging, cans, plastic bottles, paper and other solid waste materials. In addition, behaviors such as open defecation and urination also contribute to environmental pollution. Most of these wastes are macroscopic (visible to the eye) and can be easily recognized as being left by mountaineers and tourists. However, areas such as hostels, mountain huts and base camps in the highlands do not offer adequate solutions to collect such waste and prevent environmental pollution. As a result, these types of waste left behind by climbers and tourists constitute an important source of macro-, meso- and microplastic pollution, especially in remote mountainous areas.. Figure 1 presents the potential sources of MPs and their transport in high-altitude ecosystems.

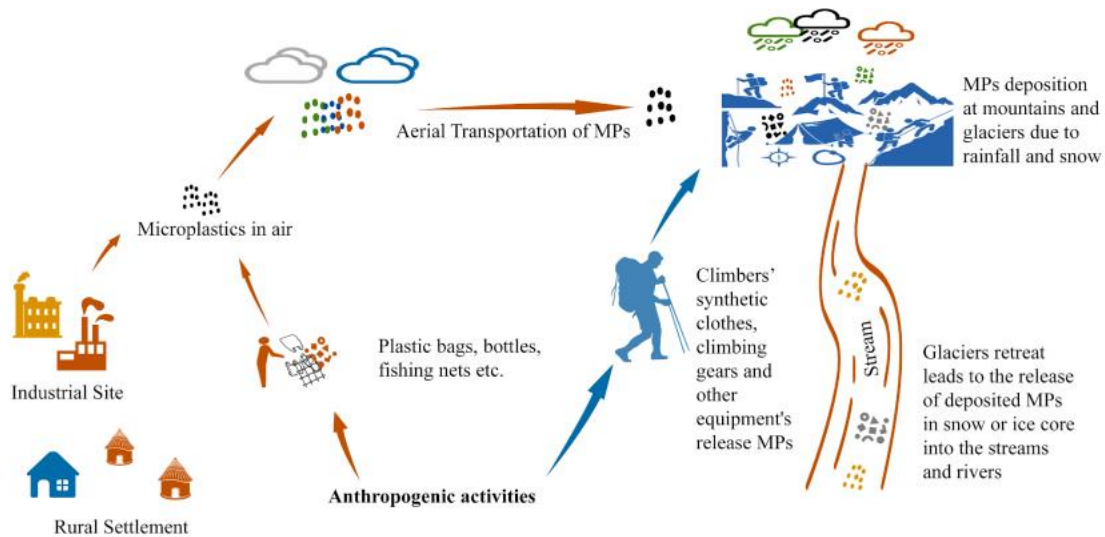


Figure 1. Sources of MPs in mountainous ecosystems and their transportation [7]

The main causes of microplastics in mountainous areas are surface runoff, tourism, and atmospheric transport (by wind, precipitation, and snowfall) [8], [9]. The widespread distribution and systemic character of this kind of pollution are demonstrated by the discovery of microplastics even in high-altitude regions remote from populated areas and industrial operations. For example, research in the French Pyrenees found that at sites distant from ground level, microplastic deposition rates were 365 particles/m² per day [8]. Similarly, in other mountainous systems including the Himalayas and the Alps, microplastic accumulations have been discovered in snow cover, glaciers, and soils [3], [9].

The study of microplastics in alpine environments is still in its infancy. It is challenging to comprehend long-term environmental implications because the majority of current research has been done over small geographic areas and brief observation periods. Furthermore, the comparability of results from various investigations is restricted by the absence of defined sampling and analytical techniques [10]. The dispersion of microplastics as well as their biological impacts on the creatures that live in mountain habitats need to be studied. The purpose of this paper is to present a thorough analysis of the body of research on microplastic contamination in mountainous areas, pinpoint methodological and geographic research gaps in this area, and provide a detailed evaluation of the possible effects of microplastics on mountain ecosystems. The study aims to highlight through this assessment that microplastics are a complex environmental problem that impacts terrestrial, high-altitude, and marine systems.

2. Definition and Sources of Microplastics in Mountain Ecosystems

Microplastics can be categorized based on their chemical makeup, shape, and place of origin (Figure 2). Microplastics are separated into two groups according to where they come from: While secondary microplastics are created when larger plastic materials deteriorate as a result of physical abrasion, UV rays, and environmental wear, primary microplastics are particles that are directly

manufactured in microscopic sizes and are found in products like plastic pellets, cleaning solutions, and cosmetic microbeads [11]. Microplastics come in a variety of shapes, including fibers, pieces, films, foams, and granules. Polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), and polyvinyl chloride (PVC) are the most prevalent polymer kinds in terms of their chemical makeup. Low-density polymers like PE and PP may float in surface waters for extended periods of time, whereas high-density polymers like PVC have a tendency to settle. These polymers display distinct environmental characteristics.

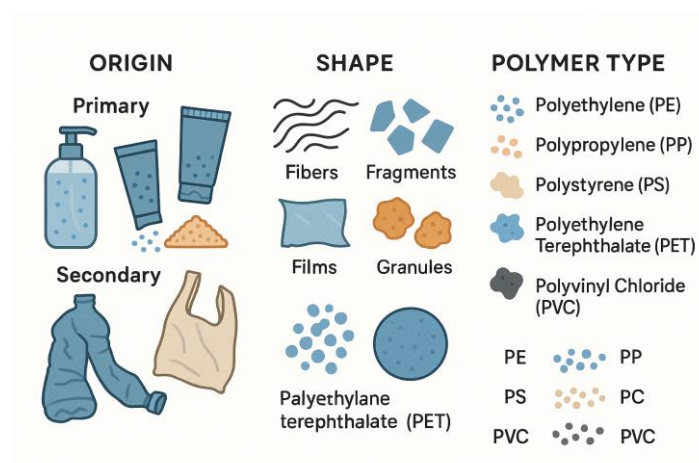


Figure 2. Microplastics categorized by their origin, shape, and polymer composition.

Despite the perception of clean environments, new research has revealed that alpine locations are also heavily polluted by microplastics. Both long-distance transport methods and local activities are responsible for the microplastics' presence in these areas. Both short- and long-distance microplastic transport can occur in the atmosphere; fibrous microplastics, in particular, are easily transported by the wind and deposited onto soils or water systems through precipitation events such as rain, snowfall, or dew. According to Allen et al. (2019), studies conducted in the Pyrenees Mountains revealed a daily deposition rate of 365 microplastic particles/m², even 100 kilometers from urban centers. According to Bergmann et al. (2019), microplastics that are deposited with snow have the potential to enter freshwater systems during glacial and snowmelt processes, which could lead to their seasonal remobilization and redistribution. Mountainous environments are frequently popular tourist destinations, and places like ski resorts, hiking routes, and campgrounds greatly increase microplastic pollution by using synthetic apparel and equipment, plastic-packaged food, and poor waste management techniques [12]. During friction or washing, synthetic textiles (such as polyester, acrylic, and nylon) release fibers that can be released into the environment through surface runoff or the air. The importance of this source is demonstrated by the regular finding of fibrous microplastics in air samples [13]. Transportation-related activities also contribute, particularly through the tire wear particles (TWP) that cars produce. These particles' metallic additions and polymer-based components make them hazardous to the environment both chemically and physically [14]; the steep, narrow mountain roads allow rains to quickly carry these

particles into valleys and river systems. Additionally, open burning or uncontrolled disposal of solid waste causes plastic particles to disperse in the environment, and the absence or insufficiency of wastewater treatment systems in mountain settlements and tourist facilities can result in the direct release of microplastics into soil or water systems [15]. Microplastics can be produced by the mechanical degradation of agricultural geotextiles used for flood control, erosion control, and plastic mulch films used in high-altitude farming [16]. This source is especially pertinent to agricultural regions along mountain foothills. Mountain habitats have special chances to learn about the behavior of microplastics in environmental processes. While snow cover and glaciers can serve as temporary reservoirs by periodically storing and releasing microscopic particles, steep slopes allow particles to be transported quickly with surface water. Microplastics can linger for a long time in soils that are rich in organic matter and have fine grains. Because of all these features, mountain ecosystems can be both a source and a destination for the spread of microplastics.

3. Detection of Microplastics in Mountain Ecosystems: Current Evidence

Mountainous areas are important to the environment because of their rich biodiversity, impact on water resources, and ability to regulate the climate. Nevertheless, the consequences of microplastic (MP) pollution are now present in these delicate systems. By 2020, 367 million tons of plastic will be produced worldwide each year [1], and plastic particles have reached previously unreachable geographic locations. In this regard, the fact that microplastics are found in mountain systems illustrates how global contemporary environmental contamination is. The pervasiveness of microplastics in these ecosystems has been amply illustrated by field research carried out in mountainous regions on several continents (Figure 3).

The protocols that are used in microplastic studies include sampling, pretreatment, and analysis were given in Table 1. Sampling from eight lakes revealed MP concentrations ranging from 2 to 17.1 MP/L in water and 12.1 to 152.6 MP/kg in sediments, with polyester, polyethylene (PE), and polypropylene (PP) identified as the dominant polymers in Pakistan's Gilgit-Baltistan region [17]. Similarly, in Poland's Tatra National Park, microplastics were observed in 11 lakes at densities of 25–179 MP/m³, with PP, PET, and natural cellulose among the most common types [18]. In Spain's El Teide National Park, FTIR-analyzed snow samples from high human activity areas showed elevated levels of 167–188 MP/L [19].

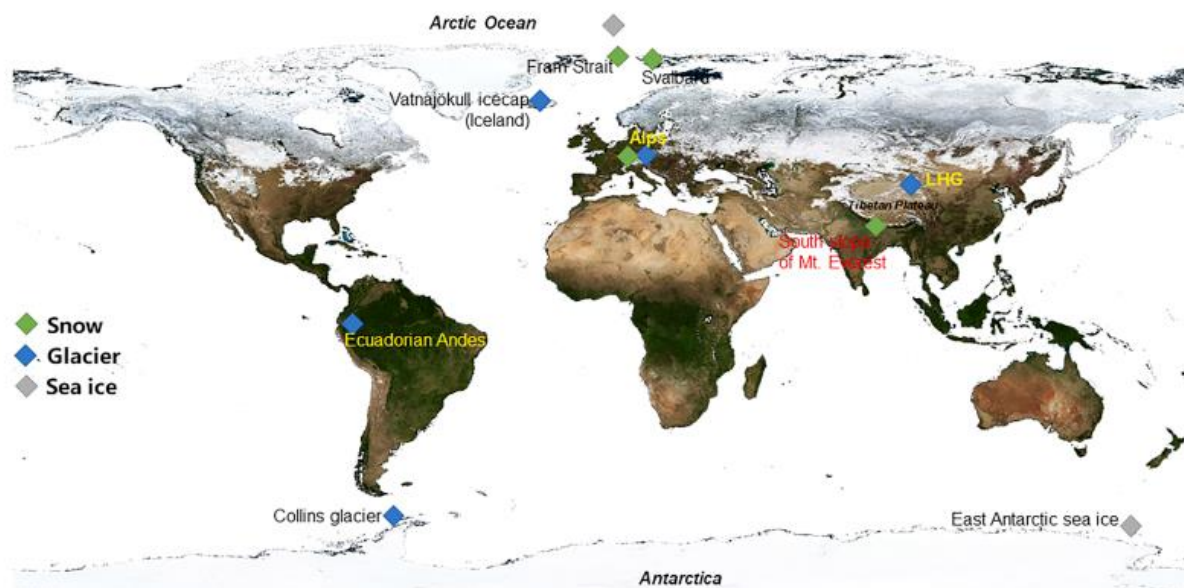


Figure 3. Microplastic studies in the snow in the typical cryospheric regions [20]

On the Forni Glacier in Italy, 74.4 ± 28.3 MP/kg of microplastics were detected in supraglacial sediments, with polyester, polyamide, PE, and PP identified as the main polymers [21]. Snow samples from the Aosta Valley (Western Alps) and regions like the Carpathian and Sudetes Mountains also showed microplastic concentrations ranging from 0.39 to 4.91 MP/L or higher, with P, and PET commonly identified [22]. In China's Qilian Mountains, water samples from five rivers showed an average of 0.48 ± 0.28 MP/L, with fibers and PP as the predominant form and polymer [23]. In Switzerland's Sassolo Lake, concentrations of 2.6 MP/L in water and 514 fibers/kg in sediments were recorded; while around Lake Dimon in Italy, low levels of PET were reported [24], [25]. In India's Nainital Lake, MP concentrations ranged from 8.6 to 56 MP/L in water and 0.4 to 10.6 MP/g in sediments [26]. In the tropical Antisana Glacier (Ecuador), snow and ice cores were sampled, and a new standardized sampling method was proposed [27].

According to all of these findings, mountain ecosystems are actively involved in the global plastic circulation because microplastics are incorporated into them not only from a variety of sources (such as tourism, transportation, and atmospheric transport), but also in a variety of forms (such as fibers, fragments, and films) and polymer types. In conclusion, these investigations from different mountain systems and continents unequivocally demonstrate that microplastics enter mountain ecosystems through both long-distance atmospheric transport and local sources (tourist, transportation, and communities). It is now indisputable that these ecosystems contribute to the global plastic cycle.

Table 1. Documented Occurrence of Microplastics in Mountainous Ecosystems Worldwide

Study Area	Method	Findings	Sampling Date	Reference
Dimon Lake, Italy (Carnic Alps)	Water, sediment, fish, and snow samples collected. Optical analysis of MPs ($>10\ \mu\text{m}$).	No MPs in water. Low PET in snow samples (0.11 ± 0.19 items/L).	2019 and 2020	Pastorino et al., 2021
Gilgit-Baltistan, Pakistan	Water and sediment samples from 8 lakes. Atmospheric transport analyzed.	Water: 2–17.1 MP/L; Sediment: 12.1–152.6 MP/kg. Predominant: polyester, PE, PP.	May–August 2020	Mehboob et al., 2024
El Teide National Park, Spain	63 snow samples from 3 areas. Analyzed with FTIR.	Highest MP concentration in human-impacted areas ($167\text{--}188$ items/L).	10–12 February 2021	Villanova-Solano et al., 2023
Forni Glacier, Italy	Supraglacial sediment samples collected.	74.4 ± 28.3 MP/kg sediment. Common: polyester, polyamide, PE, PP.	20–24 July 2018	Ambrosini et al., 2019
Sierra Nevada, Spain	35 glacial lakes investigated with citizen science contributions.	MPs found in all lakes; mostly fragments and fibers.	Not specified	Godoy et al., 2022
Nainital Lake, India	Samples from 16 sites (water and sediment). SEM-EDX analysis.	Water: 8.6–56 MP/L; Sediment: 0.4–10.6 MP/g.	February 2023	Jain et al., 2024
Qilian Mountains, China	Water samples from 5 rivers. Raman and microscopy analysis.	MPs in all samples (0.48 ± 0.28 MP/L); fibers and PP dominant.	August 2020	Liu et al., 2023
Antisana Glacier, Ecuador	Snow and ice core sampling. New sampling methodology proposed.	Standardized method for MP sampling in tropical glaciers proposed.	February 2020	Cabrera et al., 2020
Aosta Valley, Western Italian Alps	Snow samples from 4 areas; analyzed with μ -FTIR.	0.39–4.91 MP/L; PE, PET, HDPE most frequent.	7–11 September 2019	Parolini et al., 2021
Tatra National Park, Poland	Water samples from 11 lakes. Color, shape, and polymer type analyzed.	MPs: 25–179 items/ m^3 ; PP, PET, cellulose dominant.	Not specified	Kieltyk et al., 2024
Carpathian & Sudetes Mountains, Poland	44 snow samples from 3 mountain trails. FTIR analysis.	Higher MP content on more accessible trails; PE, PP, PET dominant.	February 2023	Lasota et al., 2023
Lake Sassolo, Switzerland	Water and sediment samples; density separation with NaI and FTIR.	Water: 2.6 MP/L; Sediment: 514 fibers/kg. PE and PP dominant.	6 June 2019	Negrete Velasco et al., 2020
Altai Mountains & West Siberian Plain, Russia	Surface water samples from 6 lakes. SEM/EDS analysis.	4–26 MP/L; fragments and films dominant. MPs found even in protected areas.	Summer 2020.	Malygina et al., 2021

4. Research Gaps and Future Research Recommendations

Research on microplastic pollution in mountainous ecosystems has made it abundantly evident that these pollutants are not limited to urban, coastal, or industrial settings; rather, they can pass through surface runoff, atmospheric transport, and local human activity to reach ecologically sensitive systems at high elevations [8]. But according to a survey of recent research, scientific understanding of the existence of microplastics in mountainous areas is still few, dispersed, and methodologically

inconsistent [28], [29]. Table 2 summarizes the primary research gaps found in studies of microplastics in mountain ecosystems. The absence of standardized techniques for identifying and describing microplastics is one of the main research gaps. Sample volumes, filter pore sizes (from 10 to 300 μm), sampling seasons, and analytical techniques (e.g., FTIR, Raman spectroscopy, SEM-EDX) vary significantly amongst investigations. A thorough understanding of the true environmental distribution of microplastics is hampered by this variability, which also restricts the comparability of research. Furthermore, the majority of research only looks at particles larger than 50 μm , paying little attention to smaller, possibly more hazardous nanoplastics (less than 1 μm) [30]. The regional spread of studies on microplastics represents a second significant research gap. The European Alps, the Pyrenees, the Himalayas, and certain parts of North America are the focus of the great bulk of studies. The Andes in South America, the eastern high plateaus of Africa, the Caucasus, high-altitude areas of Turkey (such as the Taurus Mountains and Eastern Black Sea), and Central Asian Mountain belts like the Tien Shan and Pamirs, on the other hand, continue to be systematically underexplored [31]. This local bias hinders comparative environmental assessments and severely limits the ability to evaluate the worldwide sensitivity of mountain ecosystems to microplastics. Third, research aimed at pinpointing the origins of microplastics found in mountainous environments is lacking. Few research specifically look into the sources of the particles, such as atmospheric transport, regional tourism, local waste management, or transportation infrastructure, even though several studies indicate their existence [8], [13]. For more precise source tracing, sophisticated instruments like molecular tracers, atmospheric transport models (e.g., HYSPLIT, FLEXPART), and isotopic analysis techniques are required [4]. Furthermore, little is known about cryospheric mechanisms including re-entry into circulation during seasonal melt, trapping in glacier systems, and microplastic transport via snowfall [3], [21]. A shortage of information on the biological and ecotoxicological impacts of microplastics in mountain ecosystems represents another important gap. Although a few previous research have documented the consumption of microplastic by aquatic species or the decomposition of tissue in soil worms, the majority of these investigations were carried out in lab settings with small sample numbers [32], [33]. Comprehensive research has not yet been done on the long-term sublethal effects of microplastics across trophic levels, their possible effects on sensitive and endemic species, and their toxicity-enhancing interactions with other pollutants (such as pesticides, heavy metals, and persistent organic pollutants) [34]. Lastly, single-time sampling is the foundation of most microplastic studies in hilly regions. This makes it more difficult to evaluate how time-dependent variables, like fluctuations in snow cover, glacier melt, seasonal visitor numbers, and weather conditions, affect the buildup and movement of microplastics [13]. However, the distribution of microplastics in mountainous areas can change significantly during the year based on hydrological and meteorological factors. Long-term, seasonal, and time-series monitoring studies are therefore essential to comprehending the behavior of microplastics in the environment and their potential for accumulation. All of these conceptual, spatial, and methodological flaws impede the creation of science-

based environmental policy for mountain ecosystems and add to the paucity of information on microplastic pollution in these areas.

Table 2. Key research gaps in mountain microplastic studies

Category	Details
Methodological Gaps	Inconsistent analysis protocols <50 µm particles often excluded
Geographical Imbalance	Focus on Europe & Himalayas Africa, Andes, Anatolia underrepresented
Source Uncertainty	Lack of local vs. atmospheric distinction Few source tracking models
Ecological Impacts	Limited data on endemic species No synergy analysis with co-pollutants
Temporal Limitations	Mostly one-time sampling Lack of seasonal or time-series data

In addition to their vital role in sustaining biodiversity, mountain ecosystems offer vital ecosystem services including regulating the climate and conserving water resources. As a result, future study should prioritize the sustainable management and preservation of mountain ecosystems. First and foremost, it is crucial to conduct thorough and extended monitoring of how climate change is affecting mountain ecosystems. This includes being aware of changes in species distribution, vegetation shifts, and hydrological regime adjustments. Furthermore, it is important to support interdisciplinary research to assess the stresses that human activities—such as mining, tourism, and deforestation—impose on these delicate ecosystems. Innovative methods in habitat restoration and conservation biology are needed to stop the loss of biodiversity. Studies on genetic diversity should be carried out to evaluate a species' capacity for adaptation, and conservation plans should be updated appropriately. In order to ensure sustainability, it is also essential to integrate ancient knowledge systems with contemporary science and empower local populations in ecosystem management. In order to address the issues facing mountain ecosystems, future research must take a comprehensive approach, creating models and policy proposals that incorporate biological, socioeconomic, and climatic elements. Ultimately, to guarantee the preservation of mountain ecosystems, appropriate management practices and awareness-raising initiatives must be put into place in addition to scientific studies.

5. Conclusion

Recent scientific evidence increasingly highlights the presence of microplastic pollution in mountain ecosystems, challenging traditional perceptions of these areas as pristine environments. Key pathways facilitating the introduction of microplastics into mountainous regions include atmospheric deposition, tourism-related activities, transportation infrastructure, inadequate waste and wastewater management, and certain agricultural practices. Moreover, the steep topography and complex hydrometeorological dynamics significantly influence the transport and accumulation of microplastics,

while snowpacks and glaciers serve as temporary reservoirs. These interacting factors complicate efforts to understand the spatial and temporal distribution of microplastics in such environments. Despite growing awareness, current research remains limited regarding the biological effects of microplastics, their long-term fate, and their broader implications for ecosystem functionality in mountain regions. Addressing these knowledge gaps necessitates comprehensive field investigations and modeling efforts grounded in interdisciplinary approaches. Such research will not only inform targeted conservation strategies for mountain ecosystems but also contribute to the development of effective global frameworks for combating microplastic pollution.

Author Contributions

Hülya Aykaç Ozen: " Writing – original draft, Investigation, Conceptualization. Hamide Sena Kanat: Writing – original draft, Investigation

Conflict of Interest

The authors declare that they have no conflict of interest.

References

- [1] PlasticsEurope, "Plastics – the Facts 2021: An analysis of European plastics production, demand and waste data", 2021.
- [2] J. P. Frias ve R. Nash, "Microplastics: Finding a consensus on the definition", *Marine pollution bulletin*, vol. 138, pp. 145-147, 2019.
- [3] M. Bergmann, S. Mützel, S. Primpke, M. B. Tekman, J. Trachsel, ve G. Gerdts, "White and wonderful? Microplastics prevail in snow from the Alps to the Arctic", *Science advances*, vol. 5, no. 8, pp. eaax1157, 2019.
- [4] J. Brahney, M. Hallerud, E. Heim, M. Hahnenberger, ve S. Sukumaran, "Plastic rain in protected areas of the United States", *Science*, vol. 368, no. 6496, pp. 1257-1260, 2020.
- [5] FAO, "Mountain forests in a changing world: Realizing values, addressing challenges.", *Food and Agriculture Organization of the United Nations*, 2011.
- [6] D. Viviroli, H. H. Dürr, B. Messerli, M. Meybeck, ve R. Weingartner, "Mountains of the world, water towers for humanity: Typology, mapping, and global significance", *Water resources research*, vol. 43, no 7, 2007.
- [7] S. Padha, R. Kumar, A. Dhar, ve P. Sharma, "Microplastic pollution in mountain terrains and foothills: A review on source, extraction, and distribution of microplastics in remote areas", *Environmental Research*, vol. 207, no. 112232, 2022.
- [8] S. Allen *vd.*, "Atmospheric transport and deposition of microplastics in a remote mountain catchment", *Nature geoscience*, vol. 12, no 5, pp. 339-344, 2019.
- [9] Y. Zhang, S. Kang, S. Allen, D. Allen, T. Gao, ve M. Sillanpää, "Atmospheric microplastics: A review on current status and perspectives", *Earth-Science Reviews*, vol. 203, no. 103118, 2020.
- [10] A. A. Koelmans, M. Kooi, K. L. Law, ve E. Van Sebille, "All is not lost: deriving a top-down mass budget of plastic at sea", *Environmental Research Letters*, vol. 12, no. 11, pp. 114028, 2017.
- [11] A. L. Andrady, "Microplastics in the marine environment", *Marine pollution bulletin*, vol. 62, no 8, pp. 1596-1605, 2011.
- [12] J. Lasota, E. Błońska, W. Piaszczyk, ve S. Tabor, "Microplastic on Mountain Trails—a Case Study from the Carpathian and Sudetes Mountains in Poland", *Water, Air, & Soil Pollution*, vol. 234, no 9, pp. 612, 2023.
- [13] R. Dris *vd.*, "A first overview of textile fibers, including microplastics, in indoor and outdoor environments", *Environmental pollution*, vol. 221, pp 453-458, 2017.

- [14] S. Wagner, T. Hüffer, P. Klöckner, M. Wehrhahn, T. Hofmann, ve T. Reemtsma, “Tire wear particles in the aquatic environment-a review on generation, analysis, occurrence, fate and effects”, *Water research*, vol. 139, pp. 83-100, 2018.
- [15] M. N. Miranda, A. M. Silva, ve M. F. R. Pereira, “Microplastics in the environment: A DPSIR analysis with focus on the responses”, *Science of the Total Environment*, vol. 718, no. 134968, 2020.
- [16] F. De Falco vd., “Evaluation of microplastic release caused by textile washing processes of synthetic fabrics”, *Environmental Pollution*, vol. 236, pp. 916-925, 2018.
- [17] M. Mehboob, R. Dris, B. Tassin, J. Gasperi, M. U. Khan, ve R. N. Malik, “Microplastic assessment in remote and high mountain lakes of Gilgit Baltistan, Pakistan”, *Chemosphere*, vol. 365, no. 143283, 2024.
- [18] P. Kiełtyk vd., “Sources Affecting Microplastic Contamination in Mountain Lakes in Tatra National Park”, *Resources*, vol. 13, no 11, pp. 152, 2024.
- [19] C. Villanova-Solano, C. Hernández-Sánchez, F. J. Díaz-Peña, J. González-Sálamo, M. González-Pleiter, ve J. Hernández-Borges, “Microplastics in snow of a high mountain national park: El Teide, Tenerife (Canary Islands, Spain)”, *Science of the Total Environment*, vol. 873, no. 162276, 2023.
- [20] Y. Zhang vd., “Current status and future perspectives of microplastic pollution in typical cryospheric regions”, *Earth-Science Reviews*, vol. 226, no. 103924, 2022.
- [21] R. Ambrosini, R. S. Azzoni, F. Pittino, G. Diolaiuti, A. Franzetti, ve M. Parolini, “First evidence of microplastic contamination in the supraglacial debris of an alpine glacier”, *Environmental pollution*, vol. 253, pp. 297-301, 2019.
- [22] S. Montecinos, S. Tognana, M. Pereyra, L. Silva, ve J. P. Tomba, “Study of a stream in Argentina with a high concentration of microplastics: preliminary analysis of the methodology”, *Science of the Total Environment*, vol. 760, no. 143390, 2021.
- [23] Q. Liu vd., “Homogenization of microplastics in alpine rivers: Analysis of microplastic abundance and characteristics in rivers of Qilian Mountain, China”, *Journal of Environmental Management*, vol. 340, no. 118011, 2023.
- [24] A. de J. Negrete Velasco vd., “Microplastic and fibre contamination in a remote mountain lake in Switzerland”, *Water*, vol. 12, no 9, pp. 2410, 2020.
- [25] P. Pastorino vd., “First insights into plastic and microplastic occurrence in biotic and abiotic compartments, and snow from a high-mountain lake (Carnic Alps)”, *Chemosphere*, vol. 265, no. 129121, 2021.
- [26] Y. Jain vd., “Microplastic pollution in high-altitude Nainital lake, Uttarakhand, India”, *Environmental Pollution*, vol. 346, no. 123598, 2024.
- [27] M. Cabrera vd., “A new method for microplastic sampling and isolation in mountain glaciers: A case study of one antisana glacier, Ecuadorian Andes”, *Case Studies in Chemical and Environmental Engineering*, vol. 2, pp. 100051, 2020.
- [28] J. Gasperi vd., “Microplastics in air: are we breathing it in?”, *Current Opinion in Environmental Science & Health*, vol. 1, pp. 1-5, 2018.
- [29] A. A. Horton, A. Walton, D. J. Spurgeon, E. Lahive, ve C. Svendsen, “Microplastics in freshwater and terrestrial environments: Evaluating the current understanding to identify the knowledge gaps and future research priorities”, *Science of the total environment*, vol. 586, pp. 127-141, 2017.
- [30] G. T. Gimiliani ve G. Izar, “Difficulties in comparison among different microplastic studies: the inconsistency of results and lack of guide values”, *Environmental Toxicology and Chemistry*, vol. 41, no 4, pp. 820-821, 2022.
- [31] C. M. Free, O. P. Jensen, S. A. Mason, M. Eriksen, N. J. Williamson, ve B. Boldgiv, “High-levels of microplastic pollution in a large, remote, mountain lake”, *Marine pollution bulletin*, vol. 85, no 1, pp. 156-163, 2014.
- [32] M. C. Rillig ve A. Lehmann, “Microplastic in terrestrial ecosystems”, *Science*, vol. 368, no 6498, pp. 1430-1431, 2020.
- [33] N. B. Hartmann vd., “Are we speaking the same language? Recommendations for a definition and categorization framework for plastic debris”, 2019.
- [34] S. L. Wright, R. C. Thompson, ve T. S. Galloway, “The physical impacts of microplastics on marine organisms: a review”, *Environmental pollution*, vol. 178, pp. 483-492, 2013.