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Color-based analytical assessment of microplastic contamination in surface waters from the Black Sea (Bulgaria)

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Abstract. Microplastic (MP) contamination in surface waters is a growing environmental concern; however, information on MP color and size distribution in the Black Sea remains limited. This pilot study examined surface water samples from five coastal sites along the Bulgarian Black Sea coast. The findings establish baseline data on MP color and size characteristics and underscore the need for further research into the environmental behavior and management of colored MPs.

Key words: Black Sea, waters, microplastics, contamination.

Introduction

Since 1950, global plastic production has surpassed 8 billion tons, with approximately 80% of the plastic produced annually ultimately becoming waste (Özpolat et al., 2026). Current estimates suggest that more than 460 million tons of plastic are generated worldwide each year, of which nearly 20 million tons are discharged into the marine environment (Richon et al., 2023). In the absence of effective mitigation measures, these inputs are projected to increase markedly by 2040 (Richon et al., 2023).

Microplastics (MPs) are defined as plastic particles originating from macroplastics through various degradation processes, including ultraviolet radiation, mechanical abrasion by wave action, and chemical degradation, with sizes ranging from 1 µm to 5 mm (Ratnayake et al., 2024). In addition to these processes, MPs may also be intentionally manufactured at small sizes. Accordingly, MPs are classified as primary MPs, which are produced directly in small dimensions (Osman et al., 2023), and secondary MPs, which result from the fragmentation of larger plastic items (Duan et al., 2021). These particles encompass a wide range of polymer types with diverse structural and chemical characteristics, leading to considerable variability in their shapes, colors, and sizes (Qayoom et al., 2026).

MPs are distributed within aquatic environments through processes such as flotation, transport, suspension in the water column, or deposition onto sediments, driven by wind and current dynamics (Zhang, 2017). From an ecological perspective, MPs are of concern not only because of their physical impacts on organisms, but also due to their capacity to adsorb hydrophobic contaminants and enter food webs, thereby functioning as vectors for chemical exposure (Terzi et al., 2024).

The Black Sea is particularly susceptible to plastic accumulation due to its semi-enclosed nature, limited water exchange, and extensive drainage basin dominated by major rivers, such as the Danube, Dniester, and Dnieper. Regional assessments indicate that the abundance of floating MPs in the Black Sea is approximately twice that observed in the Mediterranean Sea, with the Danube alone contributing up to 4.2 tons of plastic per day (Cincinelli et al., 2021). It is estimated that

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nearly 90% of plastic inputs originate from land-based sources, primarily riverine discharges, urban effluents, wastewater overflows, and mismanaged solid waste (Terzi et al., 2025a). High population densities along the coastline and uncontrolled discharges further intensify the risk of plastic accumulation (Eryaşar et al., 2022; Dağtekin et al., 2025; Terzi et al., 2025a,b).

As a part of our previous work on sediments (Yancheva et al., 2025), the present study aims to report the colors of MPs in surface water samples from five locations along the southern Bulgarian Black Sea coast.

Materials and methods

Five sampling locations situated near the town of Sozopol along the southern Bulgarian Black Sea coast were selected: Smokinia Beach (Location 1), Harmanite Beach (Location 2), the Central City Beach of Sozopol (Location 3), Midenia Beach (Location 4), and Gradina Beach (Location 5) (Yancheva et al., 2025). These sites are highly frequented by both national and international tourists during the summer season. At each location, 3 replicate surface water samples were collected, with an approximate volume of 1 L per sample. Sampling was conducted once during the summer of 2025 using sterile glass bottles. The samples were stored in an insulated cooler box with cooling elements (4°C) and transported to an external accredited laboratory, where they were subsequently processed for MP extraction and analysis.

The seawater surface samples were then subjected to preliminary treatment to oxidatively degrade organic matter using a solution of 10% potassium hydroxide (KOH) and 15% hydrogen peroxide (H_2O_2). Following complete digestion of the organic material, MPs were separated by density using centrifugation in saturated sodium or zinc chloride solutions, depending on the expected polymer type. The upper layer of the supernatant, containing the polymer particles, was filtered through a gold-coated membrane filter (aluminum or gold) with a pore size of 0.8 μm with the aid of a high-pressure vacuum pump.

The filtered samples were analyzed using a mid-infrared spectrometer. Initially, the instrument captures visible-light images of each filter to localize particles on the filter surface. Infrared scanning was then performed at a fixed wavelength of 1442 nm to identify organic particles and support the automated detection of potential MP particles. After identification, the instrument conducts pointwise spectral measurements for each particle. The quantum cascade laser (QCL) employed sequentially generates infrared beams in the 975–1800 cm^{-1} range, covering the characteristic absorption bands of most polymers. The resulting spectra were compared against a spectral library to reliably determine polymer composition. The instrument software calculated a match quality index (HQI) to evaluate the degree of fit between the acquired spectra and reference library spectra. The higher HQI values indicate a closer correspondence, with a value of 1 representing a perfect match. In this study, MPs with an HQI ≥ 0.8 were automatically accepted, thereby minimizing false positives and false negatives through cosine similarity comparison. Spectra yielding an HQI < 0.8 were excluded from further consideration and classified as "unknown" following Bernard et al. (2025). The quantitative results were expressed both as the number of identified particles per sample and as the estimated mass, calculated based on the measured surface area and density of each polymer type. The particle size range, which was monitored, was classified into five categories similarly to our previous results on sediments (Yancheva et al., 2025): < 50 μm, 51–100 μm, 101–300 μm, 301–1000 μm, and 1001-5000 μm. Nevertheless, only the colors of the largest MPs could be reliably determined using a microscope (Leica DM 2000 LED, Germany), and these observations are therefore addressed in the subsequent discussion.

The samples were analyzed at an external accredited laboratory, meaning strict quality assurance and quality control (QA/QC) procedures were implemented to minimize contamination and ensure the reliability of the data. Nitrile gloves were worn to minimize contamination during the sampling and laboratory processes. All glassware and equipment were thoroughly rinsed with filtered deionized water and covered with aluminum foil to minimize contamination from airborne particles. Procedural blanks were included with every batch of water samples, and replicate analyses were conducted to ensure analytical consistency. All reagents were prepared using ultrapure water, and sample processing was performed in a clean environment with minimal air disturbance (Manullang et al., 2024).

The MP abundances were quantified as the number of particles per liter (counts/L). All analyses were performed using Microsoft Excel (Microsoft, USA), and the results are presented as mean values ± standard deviation.

Results and Discussion

All samples collected from the investigated locations exhibited a high abundance of MPs. The highest concentration of MP particles was recorded at Location 3, corresponding to the central urban beach in Sozopol, which represents a highly frequented tourist destination during the summer season for both Bulgarian and international visitors. The results for this location indicated a total of 2047060 particles, of which only 8 (0.0004%) belonged to the largest size class (1001–5000 µm). This was followed by the second most contaminated location (Location 5) with 50480 particles, including 2 particles (0.004%) within the 1001–5000 µm size range. The following sites contained 12240 (Location 1) and 12005 particles (Location 2), with 1 (0.008%) and 4 (0.033%) particles, respectively, falling into the largest size class. Finally, the least contaminated location (Location 4) with 8570 particles showed 2 particles (0.023%) within this size fraction. In line with our previous sediment results (Yancheva et al., 2025), the colors of particles in the 1001–5000 µm size range were also determined in the surface samples. At the most contaminated location (Sozopol beach), 5 particles were blue, 2 were white, and 1 was transparent. At the remaining locations, the following distributions were observed: 2 particles were blue; 1 particle was black; among 4 particles, 2 were blue, 1 was transparent, and 1 was white; and finally, 2 particles were as follows: black and transparent.

We agree with Jiang et al. (2025) that many previous studies have extensively characterized MP pollution with respect to polymer composition, particle size, and morphological characteristics in different matrices (waters, sediments, fish, etc.). Nevertheless, the environmental relevance of MP color remains poorly investigated. Color may influence the vertical distribution of MPs, with light-colored, low-density particles tending to accumulate in surface waters, whereas darker particles are more likely to settle in sediments due to biofilm adhesion and density modification as explained by Jalón-Rojas et al. (2022). Furthermore, pigment composition influences ultraviolet (UV) light absorption and consequently affects degradation processes (Zhao et al., 2022). Thus, transparent and white MPs, which lack light-absorbing additives, undergo rapid chain scission under solar radiation, producing increasing numbers of smaller particles. In contrast, black MPs display UV-shielding properties that can prolong environmental persistence (Su et al., 2023).

The predominance of blue MPs (9 out of 17) observed in this study (Fig. 1) is consistent with findings reported in several other studies (Wang et al., 2022; Öztekin et al., 2024; Bertoli et al., 2026; Kholis et al., 2026). Blue has been identified as one of the most frequently reported colors of MPs in environmental samples. This color is widely used in the clothing and textile industries, particularly in products such as jeans and shirts, and is also common in fishing-related materials (Ge et al., 2024). Furthermore, some studies suggest that blue MPs may resemble plankton in color, which could increase the likelihood of their ingestion by fish (Öztekin et al., 2024). Additionally, different marine organisms may exhibit specific color preferences, potentially leading to selective ingestion of MPs based on color (Kholis et al., 2026). The second most dominant color was transparent (2 out of 17 MPs), and black (2 out of 17 MPs). Transparent is a very common color of MPs, and it typically originates from degraded packaging materials, plastic bags, and bottles (Turner, 2018). Carbon black is a widely used pigment that enhances the durability and resistance of plastic products intended for long-term use, such as drainpipes, kitchen-ware, waste bins, as well as food packaging, toys, and electronic devices. However, its application is less suitable for short-lived polymer products, including bottle caps and packaging materials. The presence of carbon black is also common in plastics used in marine equipment - such as fishing nets, buoys, and lobster pots - which frequently contribute to marine litter when lost or discarded (Turner, 2018).

Only 1 MP particle was found to be white in the present study. White (milky) color is also very common in MPs, coming from polystyrene foam products and packaging debris (Turner, 2018). In addition, according to Rigi et al. (2026) the base and natural color of plastics are usually white or transparent.

Interestingly, while no red or green MP particles were detected in the surface water samples, these colors were present in the sediment samples in our previous study (Yancheva et al., 2025). This pattern likely reflects differences in particle density and vertical transport: denser or biofilm-encrusted particles tend to sink and accumulate in sediments, whereas lighter-colored particles remain suspended in the water column. Such findings highlight the role of color and density in influencing the distribution and fate of MPs in aquatic environments.

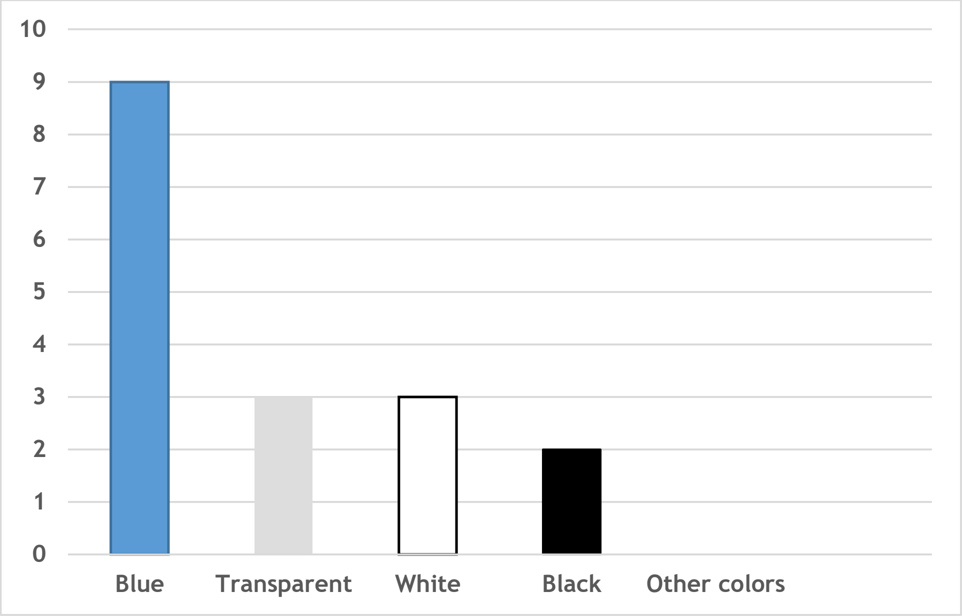

Fig. 1. Colors of MPs in surface water samples from the southern Bulgarian Black Sea (class range 1001–5000 µm). The results are presented in the number of particles per color.

Conclusions

Despite extensive studies on polymer type, size, and morphology, the ecological significance of MP color, as well as the environmental impacts of released colorants and paints, remains poorly understood. What is more, colored MPs may also pose ecological risks, as their appearance can lead them to be mistaken for prey by aquatic organisms, potentially entering food webs. In the Black Sea, for example, these processes may contribute to local MP accumulation and affect regional marine ecosystems. Our findings underscore the need for targeted monitoring and improved management strategies to mitigate the environmental and ecological risks posed by colored MPs.

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References

Bernard, N., Metian, M., Oberhaensli, F., Sznaider, F., Ruberto, L., Vodopivez, C., Cormack, W.M., & Hernandez, C.A. (2025). Identification and quantification of microplastics in the Antarctic coastal waters using laser direct infrared (LDIR). *Marine Pollution Bulletin*, 221, 118534. doi: 10.1016/j.marpolbul.2025.118534

Bertoli, M., Pastorino, P., Anselmi, S., Bentivoglio, T., Esposito, G., Goriup, G., Elia, A.C., Prearo, M., Renzi, M., & Pizzul, E. (2026). Microplastic contamination across trophic levels in a lowland spring watercourse of Northwestern Italy: New insights and biomonitoring implications. *Journal of Contaminant Hydrology*, 276, 104726. doi: 10.1016/j.jconhyd.2025.104726

Cincinelli, A., Scopetani, C., Chelazzi, D., Martellini, T., Pogojeva, M., & Slobodnik, J. (2021). Microplastics in the Black Sea sediments. *Science of the Total Environment*, 760, 143898. doi: 10.1016/j.scitotenv.2020.143898

Dağtekin, M., Kasapoğlu, N., Ok, M., İlhan, S., Büyükdeveci, F., Erik, G., Özsandıkçi, U., Mısır, D.S., & Gündoğdu, S. (2025). Assessment of spatiotemporal distribution of benthic marine litter for the southern Black Sea coasts of Türkiye. *Marine Pollution Bulletin*, 216, 117940. doi: 10.1016/j.marpolbul.2025.117940

Duan, J., Bolan, N., Li, Y., Ding, S., Atugoda, T., Vithanage, M., Sarkar, B., Tsang, D.C.W., & Kirkham, M.B. (2021). Weathering of microplastics and interaction with other coexisting constituents in terrestrial and aquatic environments. *Water Research*, 196, 117011. doi: 10.1016/j.watres.2021.117011

Eryaşar, A.R., Gedik, K., & Mutlu, T. (2022). Ingestion of microplastics by commercial fish species from the southern Black Sea coast. *Marine Pollution Bulletin*, 177, 113535. doi: 10.1016/j.marpolbul.2022.113535

Ge, X., Xu, F., Li, B., Liu, L., Lu, X., Wang, L., Zhang, Y., Li, J., Li, J., & Tang, Y. (2024). Unveiling microplastic distribution and interactions in the benthic layer of the Yangtze River Estuary and East China Sea. *Environmental Science & Ecotechnology*, 20, 100340. doi: 10.1016/j.ese.2023.100340

Jalón-Rojas, I., Romero-Ramírez, A., Fauquembergue, K., Rossignol, L., Cachot, J., Sous, D., & Morin, B. (2022). Effects of biofilms and particle physical properties on the rising and settling velocities of microplastic fibers and sheets. *Environmental Science & Technology*, 56(12), 8114-8123. doi: 10.1021/acs.est.2c01302

Jiang, T., Chai, G., Guo, Q., Peng, H., Guo, Y., Zhang, X., Lin, Y., Cui, H., Cui, X., & Tong, Y. (2025). Color-categorized microplastics in rivers and lakes: Global distribution, driving mechanisms, and ecological risks unveiled by interpretable machine learning. *Journal of Environmental Chemical Engineering*, 13, 120037. doi: 10.1016/j.jece.2025.120037

Kholis, N., Manullang, C.Y., Anuar, S.T., Atmadipoera, A.S., Zuraida, R., & Patria, M.P. (2026). Microplastic concentration in the water column of the Banggai Sea, Central Sulawesi, Indonesia. *Water Biology and Security*, 100553. doi: 10.1016/j.watbs.2026.100553

Manullang, C.Y., Patria, M.P., Haryono, A., Anuar, S.T., Fadli, M., Susanto, R.D., & Wei, Z. (2024). Vertical distribution of microplastic along the main gate of Indonesian throughflow pathways. *Marine Pollution Bulletin*, 199, 115954. doi: 10.1016/j.marpolbul.2023.115954

Osman, A.I., Hosny, M., Eltaweil, A.S., Omar, S., Elgarahy, A.M., Farghali, M., Yap, P.S., Wu, Y.S., Nagandran, S., Batumalaie, K., Gopinath, S.C.B., John, O.D., Sekar, M., Saikia, T., Karunanithi, P., Hatta, M.H.M., & Akinyede, K.A. (2023). Microplastic sources, formation, toxicity and remediation: a review. *Environmental Chemistry Letters*, 21(4), 2129-2169. doi: 10.1007/s10311-023-01593-3

Özpolat, H.B., Bakan, G., Cüce, H., Kalipci, E., Temel, F.A., Şimşek, A., Derel, M.A., & Ustaoğlu, F. (2026). Current status and comparative risk assessment of microplastic pollution in surface water and sediment from the Black Sea coastline using geospatial analysis. *Journal of Hazardous Materials*, 502, 141046. doi: 10.1016/j.jhazmat.2026.141046

Öztekin, A., Üstün, F., Bat, L., & Tabak, A. (2024). Microplastic contamination of the seawater in the Hamsilos Bay of the Southern Black Sea. *Water, Air, & Soil Pollution*, 235, 325. doi: 10.1007/s11270-024-07138-w

Qayoom, I., Jan, F.Z., Rashid, I., Bhat, G.A., Ambili, A., & Sarangi, C. (2026). A review of microplastic contamination in the cryosphere. *iScience* 29, 114414. doi: 10.1016/j.isci.2025.114414

Ratnayake, A.S., Gunawardhana, G.M.S.S., & Perera, U.L.H.P. (2024). The biography of microplastics (MPs): occurrences, sources, weathering/degradation, characterization, ecological/human risks, removal methods, policy development, and current trends and future perspectives. *Anthropocene Coasts*, 7(1), 30. doi: 10.1007/s44218-024-00064-8

Richon, C., Kvale, K., Lebreton, L., & Egger, M. (2023). Legacy oceanic plastic pollution must be addressed to mitigate possible long-term ecological impacts. *Microplastics and Nanoplastics*, 3(1), 25. doi: 10.1186/s43591-023-00074-2

Rigi, A.A., Ghayebzadeh, M., Taghipour, H., Khatibi, A.D., Keikhaee, R., Azizi, N., Kamani, H., & Mohamadi, L. (2026). Microplastics in small semi-industrial desalination stations and bottled waters: Human exposure and emerging health concerns. *Science of the Total Environment*, 1016, 181378. doi: 10.1016/j.scitotenv.2026.181378

Su, J., Ruan, J., Luo, D., Wang, J., Huang, Z., Yang, X., Zhang, Y., Zeng, Q., Li, Y., Huang, W., Cui, L., & Chen, C. (2023). Differential photoaging effects on colored nanoplastics in aquatic environments: Physicochemical properties and aggregation kinetics. *Environmental Science & Technology*, 57(41), 15656–15666. doi: 10.1021/acs.est.3c04808

Terzi, Y., Gündoğdu, S., Tekman, M.B., Gedik, K., Ustaoğlu, D., Ismail, N.O., Altinpinar, I., Öztürk, R.Ç., & Aydın, İ. (2024). How much do we know about the microplastic distribution in the Mediterranean Sea: a comprehensive review. *Marine Pollution Bulletin*, 208, 117049. doi: 10.1016/j.marpolbul.2024.117049

Terzi, Y., Öztürk, R.Ç., Eryaşar, A.R., Yandı, İ., Şahin, A., Yılmaz, F., Gedik, K., & Gündoğdu, S. (2025a). Riverine microplastic discharge along the southern Black Sea coast of Türkiye. *Environmental Research Letters*, 20, 024061. doi: 10.1088/1748- 9326/adaf47

Terzi, Y., Gündoğdu, S., Yandı, İ., Altinpinar, I., Öztürk, R.Ç., & Gedik, K. (2025b). Marine litter on the Turkish Black Sea shoreline: abundance, composition, and sources. *Waste Management*, 205, 115027. doi: 10.1016/j.wasman.2025.115027

Turner, A. (2018). Black plastics: Linear and circular economies, hazardous additives and marine pollution. *Environment International*, 117, 308-318. doi: 10.1016/j.envint.2018.04.036

Wang, X., Zhu, L., Liu, K., & Li, D. (2022). Prevalence of microplastic fibers in the marginal sea water column off southeast China. *Science of the Total Environment*, 804, 150138. doi: 10.1016/j.scitotenv.2021.150138

Yancheva, V., Stoyanova, S., Georgieva, E., & Valkanov, K. (2025). Which color are you?: A pilot study on microplastic accumulation in sediments from the Bulgarian Black Sea. *Ecologia Balkanica*, 17(2), 40-45. doi: 10.69085/eb20252040

Zhang, H. (2017). Transport of microplastics in coastal seas. *Estuarine, Coastal and Shelf Science*, 199, 74–86. doi: 10.1016/j.ecss.2017.09.032

Zhao, X., Wang, J., Yee, Leung, K.M., & Wu, F. (2022). Color: an important but overlooked factor for plastic photoaging and microplastic formation. *Environmental Science & Technology*, 56(13), 9161-9163. doi: 10.1021/acs.est.2c02402

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