Microplastics in sediments from the coastal area of the Boka Kotorska Bay on the Montenegrin coast

Neda BOŠKOVIĆ[*1], Danijela JOKSIMOVIĆ[1], Milica PEKOVIĆ[1], Oliver BAJT[2]
[1]Institute of Marine Biology, University of Montenegro, Put I bokeljske brigade 68, 85330 Kotor, Montenegro, *e-mail: nedaboskovic93@gmail.com
[2]National Institute of Biology, Marine Biology Station Piran, Fornače 41, 6330 Piran, Slovenia

ABSTRACT

This is the first survey to investigate the occurrence and extent of microplastic contamination in sediments collected during the autumn of 2019 at five locations from the coastal area of the Boka Kotorska Bay on the Montenegrin coast. Microparticles in sediments were isolated by density separation in saturated aqueous NaCl-solutions and visually analyzed using an Olympus SZX16 microscope. Microplastic debris extracted from five samples of sediments were counted. The primary shape types by number were: filaments (78.61 %), fragments (8.56 %), granules (7.22 %), and films (5.61). All five sites sampled in 2019 were contaminated with microplastic particles, in the following sequence: Dobrota (68.72 %) > Bijela (12.57 %) > Tivat (7.75 %) > Sveta Nedjelja (6.42 %) > Orahovac (4.55 %).

Keywords: microplastics, sediment, Boka Kotorska Bay, Montenegro

INTRODUCTION

Microplastics in aquatic ecosystems and especially in the marine environment represent pollution of increasing scientific and societal concern, and hence the assessment of its extent in the Montenegro marine environment.

Microplastics (MPs) are ubiquitous plastic particles smaller than five millimeters
(5 mm) in size (GESAMP, 2015). MPs were first scientifically recorded in North America along the coast of New England in the 1970s (Carpenter *et al*., 1972).There are two categories of MPs: primary and secondary. Primary MPs include plastic particles that are purposefully manufactured as small, while secondary MPs are resulting from the degradation of macroplastics due to mechanical, photolytic and/or chemical degradation processes in the marine environment (Masura *et al*., 2015).

MPs have been reported in the water column and marine sediments worldwide (Moore *et al*., 2001; Thompson *et al*., 2004; Law *et al*., 2010; Claessens *et al*., 2011). The accumulation of MPs in marine

sediments was documented, by the literature, for the first time in 2004 (Thompson *et al*., 2004). Particles accumulated in the sediment are accessible to benthic suspension and deposit feeders (Deudero *et al*., 2014; Van Cauwenberghe *et al*., 2015a) and other sediment-dwelling organisms (Moore, 2008; Wright *et al*., 2013). Reports of MPs in marine sediments worldwide are emerging, remarking the large spatial distribution of this contaminant and therefore the possible implications which MPs might have in marine habitat, food webs (Claessens *et al*., 2011; Vianello *et al*., 2013; Van Cauwenberghe *et al*., 2015a).

The purpose of our study was visual identification (number of, shape, type and colour of the particles) MPs in sediments collected during the autumn of 2019 at five locations from the coastal area of the Boka Kotorska Bay on the Montenegrin coast, and obtaining the first assessment of this type of pollution for the area.

MATERIAL AND METHODS

Samples of surface sediment were collected at five selected locations in the Boka Kotorska Bay, Montenegrin coastline: Dobrota, Orahovac, Sveta Nedjelja, Tivat and Bijela, during the autumn of 2019 (Fig. 1).

Sediment samples were collected for analysis using Van Veen grab, stored in the

Figure 1. Map of investigated area

aluminium container, frozen at -18 °C and freeze-dried at -40 °C for 48 h (CHRIST, Alpha 2-4 LD plus, Germany). For MPs density separation, we used a method proposed by Thompson *et al*. (2004). The method is based on the usage of the concentrated NaCl solution (1.2 g/dm^3). After sedimentation of 24 hours, the solution was decanted. The supernatant was sieved through the 63 μm steel sieve. The material retained on the sieve was rinsed with Mili-Q water to a glass Petri dish. The procedure was repeated two times for each sample. Then, the sediment samples were filtered using a vacuum pump on to fiberglass filters (Whatman GF-F, diam. 47 mm, nominal porosity 0.7 mm). These samples were analyzed under a microscope to identify and count the number of MPs particles and fibres, present in the sample. Visual analysis of particles was performed using an Olympus SZX16 imaging microscope (DP-Soft software). Pictures of the particles obtained under a microscope (Fig. 2) were taken using ImageJ software (ver. 2.0.0) and classified into four types (Claessens *et al*., 2011), according to their shape (filaments, granules, films and fragments).

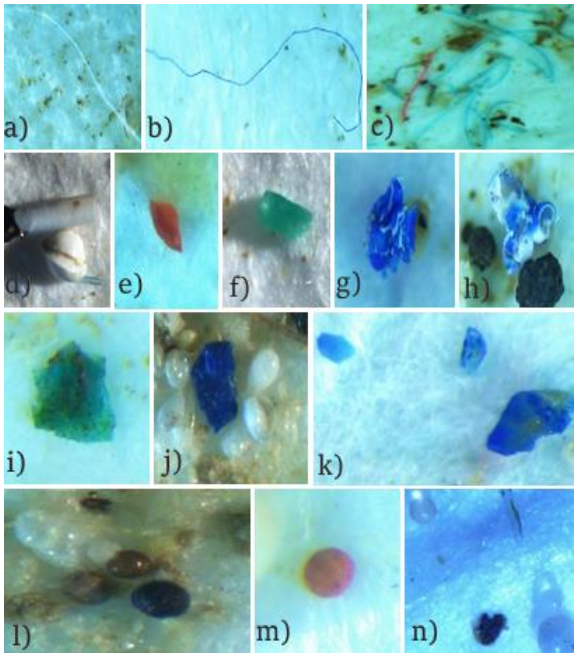

Figure 2. Pictures of the different types and colours of MPs particle in the sediment of the Boka Kotorska Bay, Montenegrin coast: (a-c) filaments; (d-h) fragments; (i-k) films and (l-n) granules

RESULTS AND DISCUSSION

Results of different types and colour of MPs particle in five sediment samples of Boka Kotorska Bay, expressed as total number of each class recovered per 100 g dry weight of sediment, are presented in Table 1. The number of filaments in the location Dobrota was the highest compared with all other examined locations. Filaments, fragments and films were present in the sediment at all locations, while granules were present in three locations (Sveta Nedjelja, Tivat and Bijela). Eight different colours of MPs were observed in the present study. In all five sampled, coloured particles were found. The most frequent MP colour observed for all studied locations was: blue > clear > black > red > blue-white > green > yellow > white.

The primary MPs shape types collected in the sediments of the Boka Kotorska Bay by number were: filaments (78.61 %), fragments (8.56 %), granules (7.22 %) and films (5.61 %), with filaments being the most dominant type of shape MPs (Fig. 3a). All five locations sampled in 2019 were contaminated with MPs particles.

Contamination of locations, based on percentage representation (%) of microplastic particles recovered per 100 g dry weight in five sediment samples, were as follows: Dobrota (68.72 %) > Bijela (12.57 %) > Tivat (7.75 %) > Sveta Nedjelja (6.42 %) > Orahovac (4.55 %) (Fig. 3b). The most contaminated location was Dobrota, while other locations contained a very small quantity of MPs.

Comparison of results from literature date is difficult and subject to uncertainty due to different sampling and analysis protocols implemented by researchers used for density separation, enumeration and identification method, and size of MPs, and to the lack of standardized normalization units (Abidli *et al*., 2018).

The comparison of MP concentrations in sediments of five sampling locations of the present study showed that higher levels were usually observed in areas of dense human population and high industrial activities as Dobrota (Andradi, 2011; Brovne *et al*., 2011; Van Cauvenberghe *et al*., 2015b).

Except for the location Dobrota, marine sediments in the present study were moderately polluted with MPs compared to heavily polluted regions like the Lagoon of Cabrera Island, Spain (Alomar *et al.*, 2016).

Table 1. Results of MPs particle in five sediment samples of Boka Kotorska Bay

Location	Types of microplastics																
	filamenti				fragmenti							films			granules		
	C	B	R	BL	C	B	R	BW	W	G	Y	B	G	Y	C	R	BL
Dobrota	27	212	2	6	3	2	-	2	-	-	-	3	-	-	-	-	-
Orahovac	-	4	-	8	-	-	-	1	2	-	-	-	2	-	-	-	-
Sveta Nedjelja	4	2	2	-	-	2	2	3	2	-	-	3	-	-	2	2	-
Tivat	4	7	-	-	-	2	3	3	-	-	-	3	1	-	-	4	2
Bijela	6	7	3	-	-	-	2	-	-	2	1	2	3	4	4	9	4

* (C) – clear; (W) – white; (B) – blue; (BW) – blue-white; (BL) – black; (G) – green; (R) – red; (Y) – yellow

.

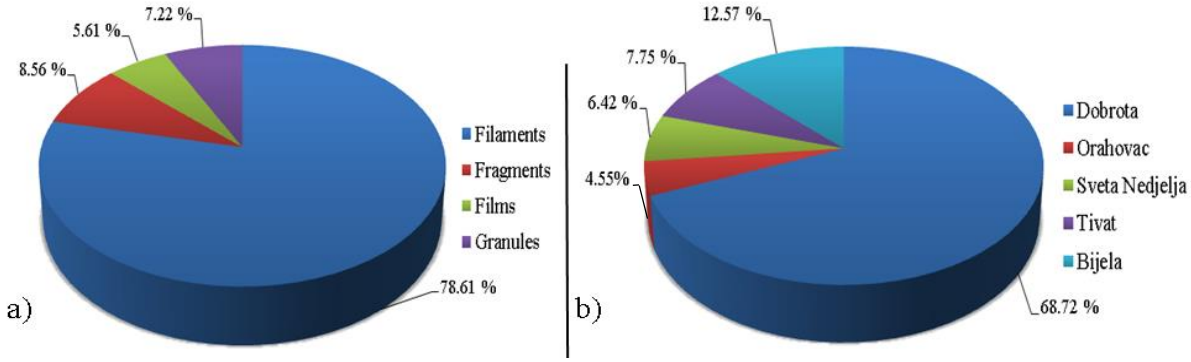

Figure 3. Percentage distribution (%) of MPs particle in sediments of the Boka Kotorska Bay, according to a) shape type and b) representation of microplastic particles in five sediment samples.

The concentrations of MPs in this study were higher than those measured in non-contaminated environments like the French, Belgian, and the Netherlands (North Sea coast), South of Portugal (Van Cauwenberghe *et al.*, 2015b; Frias *et al.*, 2016).

According to research conducted in the Central Adriatic Sea, Mistri *et al.* (2017) revealed that dominant types were filaments followed by fragments, what is confirmed with our results. The percentage of different shape types of MPs in this study was similar to the results from Italy (Mistri *et al.*, 2017). In the Telascica Bay (Eastern Adriatic), Blăsković *et al.* (2017) found that filaments represented 90% of all seafloor plastics.

The high number of fibres and fragments suggests the breakdown of larger plastic items into secondary MPs (through mechanical forces, by photolysis, thermo-oxidation, thermal degradation, via biodegradation processes) (Laglbauer *et al.*,

2014; Abidli *et al*., 2018). In the same context, Browne *et al*. (2011) showed that up to 80% of MPs in sediment was from wastewater effluent.

In the present study, MPs reported different colours, which is consistent with other studies on MPs (Nor and Obbard 2014; Zhao *et al*. 2014; Abidli *et al*., 2017) which implies that particles may have originated from multiple sources (Munari *et al*., 2017;
Abidli *et al*., 2018).

CONCLUSIONS

MPs were found in all five sampling locations from the Boka Kotorska Bay, Montenegrian coast. Marine sediments in the present study are moderately polluted with MPs compared with literature data. The comparison of the high MP contamination registered in location Dobrota to the other locations of the present study showed that higher levels were usually observed in areas with high population density and high industrial activities i.e., with magnified anthropogenic activity. Also, Dobrota is located in the most secluded part of the Bay of Kotor, which means that it is a place with reduced contact with the open sea.

This study gives a first insight into MP pollution and provides information on the spatial distribution of MP particles in the Boka Kotorska Bay. The results of MP contamination in this study are just preliminary and require further and detailed analyzes to confirm whether all found particles are microplastics or natural materials. The obtained results represent the beginning of research that will continue in order to obtain chemical identification the types of MPs polymers using Infrared Spectroscopy (FTIR-ATR).

ACKNOWLEDGEMENTS

This research resulted within the PROMIS (No 3173) project funded by the Ministry of Science of Montenegro.

REFERENCES

Abidli, S., Antunes, J. C., Ferreira, J. L., Lahbib, Y., Sobral, P., & Trigui El Menif, N. (2018): Microplastics in sediments from the littoral zone of the north Tunisian coast (Mediterranean Sea). Estuarine, Coastal and Shelf Science, 205, 1-9.

Abidli, S., Toumi, H., Lahbib, Y. & Trigui El Menif, N. (2017): The First Evaluation of Microplastics in Sediments from the Complex Lagoon-Channel of Bizerte (Northern Tunisia). Water Air Soil Pollut., 228:262.

Alomar, C., Estarellas, F. & Deudero, S. (2016): Microplastics in the Mediterranean Sea: deposition in coastal shallow sediments, spatial variation and preferential grain size. Mar. Environ. Res., 115, 1–10.

Andrady, A. L. (2011): Microplastics in the marine environment. Mar. Pollut. Bull. 62, 1596–1605.

Blasković, A., Fastelli, P., Čižmek, H., Guerranti, C. & Renzi, M. (2017): Plastic litter in sediments from the Croatian marine protected area of the natural park of Telaščica bay (Adriatic Sea). Mar. Pollut. Bull. 114, 583–586.

Browne, M.A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway, T.S., Thompson, R.C. (2011). Accumulation

of microplastic on shorelines worldwide: sources and sinks. Environ. Sci. Technol., 45, 9175–9179.

Carpenter, E.J., Anderson, S.J., Harvey, G.R., Miklas, H.P. & Peck, B.B. (1972): Polystyrene spherules in coastal waters. Science, 17(4062):749-750.

Claessens, M., Meester, S.D., Landuyt, L.V., Clerck, K.D. & Janssen, C.R. (2011): Occurrence and distribution of microplastics in marine sediments along the Belgian coast. Mar. Pollut. Bull. 62, 2199–2204.

Deudero, S., Nadal, M.A., Estarellas, F. & Alomar, C. (2014): Microplastic exposure in pelagic fishes and holothurians: a Mediterranean case study. In: 2nd International Ocean Research Conference. Barcelona 17-21.

Frias, J.P.G.L., Gago, J., Otero, V. & Sobral, P. (2016): Microplastics in coastal sediments from Southern Portuguese Shelf waters. Mar. Environ. Res., 114:24-30.

GESAMP (2015): Sources, fate and effects of microplastics in the marine environment: a global assessment (Kershaw, P.J., ed.). (IMO/FAO/UNESCO-IOC/UNIDO/WMO/ IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 90, 96 p.

Laglbauer, B.J.L., Melo Franco-Santos, R., Andreu-Cazenave, M., Brunelli, L., Papadatou, M., Palatinus, A., Grego, M. & Deprez, T. (2014): Macrodebris and microplastics from beaches in Slovenia. Mar. Pollut. Bull. 89, 356–366.

Law, K.L., Moret-Ferguson, S., Maximenko, N.A., Proskurowski, G., Peacock, E.E., Hafner, J. & Reddy, C.M. (2010): Plastic accumulation in the North Atlantic subtropical Gyre. Science 329, 1185e1188.

Masura, J., Baker, J., Foster, G. & Arthur, C. (2015): Laboratory methods for the analysis of microplastics in the marine environment: recommendations for quantifying synthetic particles in waters and sediments. NOAA Technical Memorandum NOS-OR&R-48.

Mistri, M., Infantini, V., Scoponi, M., Granata, T., Moruzzi, L., Massara, F., De Donati, M. & Munari, C. (2017): Small plastic debris in sediments from the Central Adriatic Sea: Types, occurrence and distribution. Mar Pollut. Bull. 124, 435–440.

Moore, C.J. (2008): Synthetic polymers in the marine environment: a rapidly increasing, long-term threat. Environ. Res. 108, 131e139.

Moore, C.J., Moore, S.L., Leecaster, M.K. & Weisberg, S.B. (2001): A comparison of plastic and Plankton in the North Pacific Central Gyre. Mar. Pollut. Bull. 42, 1297e1300.

Munari, C., Infantini, V., Scoponi, M., Rastelli, E., Corinaldesi, C. & Mistri M. (2017): Microplastics in the sediments of Terra Nova Bay (Ross Sea, Antarctica). Mar. Pollut. Bull. 122, 161–165.

Nor, N. H. M. & Obbard, J. P. (2014): Microplastics in Singapore's coastal mangrove ecosystems. Mar. Pollut. Bull. 79, 278–283.

Thomson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W.G., Mcgonigle, D. & Russell,

A.E. (2004): Lost at sea: where is all the plastic? Science 304, 838.

Van Cauwenberghe, L., Claessens, M., Vandegehuchte, M. & Janssen, C.R. (2015a): Microplastics are taken up by mussels (Mytilus edulis) and lugworms (Arenicola marina) living in natural habitats. Environ. Pollut. 199, 10–17.

Van Cauwenberghe, L., Devriese, L., Galgani, F., Robbens, J. & Janssen, C.R. (2015b): Microplastics in sediments: a review of techniques, occurrence and effects. Mar. Environ. Res. 111, 5–17.

Vianello, A., Boldrin, A., Guerriero, P., Moschino, V., Rella, R., Sturaro, A. & Da Ros, L. (2013): Microplastic particles insediments of Lagoon of Venice, Italy: first observations on occurrence, spatial patterns and identification. Estuar. Coast. Shelf Sci. 130, 54–61.

Wright, S.L., Thompson, R.C. & Galloway, T.S. (2013): The physical impacts of microplastics on marine organisms: a review. Environ. Pollut. 178, 483e492.

Zhao, S., Zhu, L., Wang, T. & Li, D. (2014): Suspended microplastics in the surface water of the Yangtze Estuary System, China: first observations on occurrence, distribution. Mar. Pollut. Bull. 86, 562–5.

Received: 10. 05. 2019.
Accepted: 25. 06. 2019.

Mikroplastika u obalnom sedimentu Bokokotorskog zaliva na crnogorskom primoriju

Neda BOŠKOVIĆ, Danijela JOKSIMOVIĆ, Milica PEKOVIĆ, Oliver BAJT

SAŽETAK

Ovo istraživanje po prvi put mapira i ispituje pojavu i stepen kontaminacije mikroplastike u sedimentu koji je sakupljen sa pet lokacija u priobalnom dijelu Bokokotorskog zaliva na crnogorskom primoriju tokom jeseni 2019. godine. Mikroplastične čestice u sedimentu su izolovane razdvajanjem gustine primjenom zasićenog rastvora NaCl i vizuelno analizirane koristeći optički mikroskop Olympus SZX16. Na ovaj način ekstrahovane mikroplastične čestice iz sedimenta sa svih pet lokacija su izbrojane prema primarnim oblicima na sledeći način: filamenti (78.61 %), fragmenti (8.56 %), granule (7.22 %) i filmovi (5.61). Takođe, iz dobijenih rezultata smo sagledali i kontaminaciju mikroplastikom prema mjestu uzorkovanja sa sledećom procentualnom zagađenošću: Dobrota (68.72 %) > Bijela (12.57 %) > Tivat (7.75 %) > Sveta Nedjelja (6.42 %) > Orahovac (4.55 %).

Ključne riječi: mikroplastika, sediment, Bokokotorski zaliv, Crna Gora