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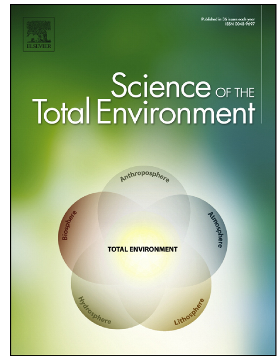

First evidence of microplastics in nine lakes across Patagonia (South America)

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First evidence of microplastics in nine lakes across Patagonia (South America)

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Abstract

Microplastics (MPs) on lakes have been reported mainly from Europe, Asia, and North America. Then, this study aimed to address the quantification and identification of MPs in nine lakes from the Argentine Patagonian Region. Blue colored fibers were dominant, with a size range between 0.2 and < 0.4 mm. The mean MPs concentration was 0.9 ± 0.6 MPs m^{-3}, suggesting a low pollution state when compared to other worldwide lakes. Raman microscopy analysis showed a predominance of Indigo Blue Polyethylene terephthalate (PET) particles. The upper-gradient runoff from urban settlements, textiles, and fisheries were identified as the main MPs sources and levels positively correlated with the higher area, shallower depth, and with an end-position in the watershed. These findings fill a gap in the geographical distribution knowledge, setting a baseline that emphasizes the need for better treatment of urban and fisheries wastes in continental lakes.

Keywords

Lakes; Patagonian Region; microplastics; pollution

1 Introduction

Since the 1950s, large-scale production of plastic has become widespread as it is used in a variety of applications (GESAMP, 2016). Plastic debris in aquatic systems has raised a global concern because of their wide distribution, permanence, and complex effect on the aquatic ecosystems. Plastics production reached 359 million tons worldwide in 2018 and is projected to keep growing (Plastics Europe, 2019), putting plastic pollution as an emerging contaminant that needs to be studied. Microplastics (MPs) are defined as synthetic polymers with an upper size limit of 5 mm and without a specified lower limit (Thompson et al. 2009). Those manufactured with a size of less than 5 mm present in medicines and personal care products are defined as primary MPs; meanwhile, the fragmentation of large plastic by photodegradation, physical, chemical, and biological interactions lead to the formation of secondary MPs (Cole et al., 2011; Browne, 2015).

According to Eriksen et al. (2013), the principal plastic pollution in aquatic systems comes from secondary MPs, with fibers and those of less than 1 mm being the most predominant. Due to extensive plastic usage and poor management, it is expected that up to 10 % of plastic fragments would end up in the marine environment (Cole et al., 2011; Rochman, 2015). Well established MPs sources are commercial and sport fishing, boats, textile industries, personal care products, air-blasting processes, improperly disposed plastics, and leachates from landfills (Cole et al., 2011; Li et al., 2018). Most of them will end up in the marine systems from rivers, but also will be concentrated in the lakes, mainly in those isolated or with endorheic watershed (Free et al., 2014; Alfonso et al., 2020).

MPs presence and distribution in lakes are affected by several external forces that modify their presence and transportation (with water flow or sinking to the bottom). Among them, we can cite climatic variables (wind-driven surface currents, storms, floods, runoff), geomorphological characteristics (water depth, area-shoreline development), anthropogenic activities (dam release, tourism, fisheries) and trophic state (degree of MPs fouling) (Fischer et al., 2016, Li et al., 2018; Wang et al., 2018; Meng et al., 2020).

MPs monitoring effort increased worldwide in the last years. Nevertheless, only a few studies have assessed MPs in freshwater systems worldwide and even less in Latin America (Blettler et al., 2017; Alfonso et al., 2020); in fact, this is the first research paper dealing with MPs in water from continental lakes in South America Patagonia. The Patagonian region in

Argentina is located at the southern end of this continent and to the east of the Andean Range. In this region, there are numerous lakes; some of them are in almost pristine areas, while others are significantly impacted by anthropogenic activities, such as water dam for hydroelectric production, fish-farming industry, and tourism. These water bodies, especially in the Patagonian plain, are almost the only source of water for human consumption and the development of the economic activities (livestock, agriculture, oil and gas extraction, and tourism). Despite the socio-economic importance and the need for preservation of these water bodies, their environmental quality has been poorly studied. Most of these lakes have only been sampled once in the context of regional baseline studies of lakes in the 1980s (Quirós and Drago, 1999) or the 1990s (Diaz et al., 2000, 2007). In the present work, which shows a significant survey effort covering an area of 50,000 km^2 in the Andean and extra-Andean region of the Argentinian Patagonia, the MPs pollution status of nine lakes was studied in the austral summer of 2018. This study aims to assess -for the first time- the concentration, distribution, and characteristics of MPs in nine lakes from the Patagonian Region, addressing their identification, source assessment and correlation with lake and watershed features.

2 Materials and methods

2.1 Study sites

The nine lakes studied are the Florentino Ameghino Dam (FAD), Pico 1 Lake (P1L), Los Niños Lake (LN), Vintter Lake (VI), Pico 4 Lake (P4L), La Plata Lake (LP), Fontana Lake (FO), Toro Lake (TO), Musters Lake (MU) (Fig. 1). All these water bodies are located in the Argentine Patagonia. This region - one of the most pristine areas from Argentina- is located at the southern end of South America and east of the Andean Range (43° 37'S - 45° 59'S and 66° 17 'W - 71°47' W). Due to the west-east altitudinal, precipitation, and temperature gradients (Coronato et al., 2017), the lakes are classified as Andean, localized towards the west near the Andean Range (P1L, LN, VI, P4L, LP, FO, and TO) and the extra-Andean, situated at the east in the Patagonian plain (DFA, and MU). They have a wide range of different morphometric and geographic features. The available information from previous studies was summarized in Table 1 (Quirós and Drago, 1985; Coronato, 1988; Quirós, 1998; Valladares, 2004; Díaz et al., 2007; Scordo, 2018). The Andean lakes contain a lower concentration of total phosphorus, chlorophyll *a* and total suspended solids with a greater diversity but less phytoplankton abundance than the extra-Andean ones (Izaguirre et al., 1990; Izaguirre, 1991; Quirós and Drago, 1999; Diaz et al., 2007). The former are usually oligotrophic and ultra-oligotrophic, and the later are mesotrophic and eutrophic (Quirós and Drago, 1999).

MU is located at the end of the Senguer River watershed, which originates in the FO and LP lakes. MU is the only lake of this study that has not an outflow, and water loss is mostly by evaporation. Also, it is the only one that presents a high population in its surrounding area, with Colonia Sarmiento, a city of 11,000 inhabitants located 5 km SouthEast from its southern coast (Table 1). MU supplies water to 254,000 inhabitants (INDEC, 2010) and, it is one of the few lakes in the country where fish-farming and commercial fisheries are allowed by the authorities (Chubut Secretary of Fishing, Argentina). FAD is a hydroelectric dam located in the lower basin of the Chubut River that also supplies water for agricultural irrigation downstream. The rest of the lakes are situated in sparsely populated areas and are mostly used as touristic destinations. From these, VI, which is geographically shared between Chile and Argentina, is the only one connected with the sea towards the Pacific Ocean. Except for P4L, motorboats for tourism are allowed in all lakes.

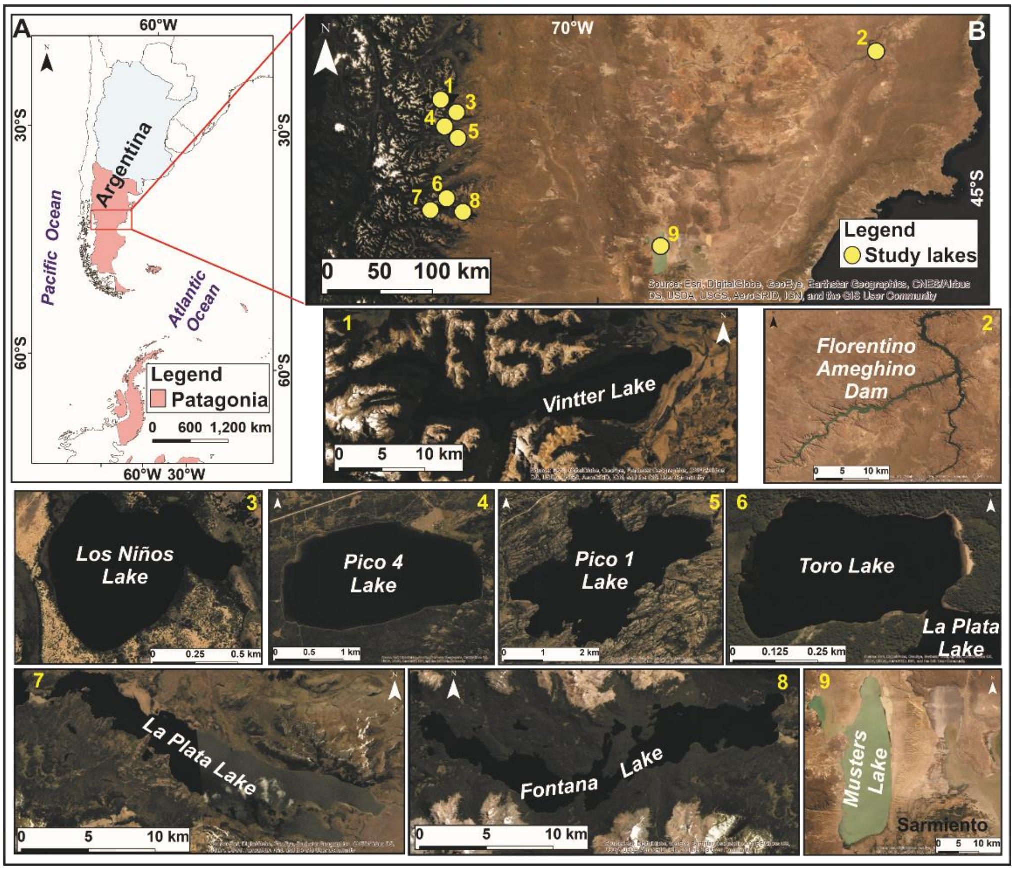

Figure 1. Map of **(A)** Localization of the study area in the Argentine Patagonia. (**B)** Localization of the study lakes in the study area. 1) Vintter Lake (VI). 2) Florentino Ameghino Dam (FAD). 3) Los Niños Lake (NI). 4) Pico 1 Lake (P1L). 5) Pico 4 Lake (P4L). 6) Toro Lake (TO). 7) La Plata Lake (LP). 8) Fontana Lake (FO). 9) Musters Lake (MU).

Table 1. Values of the main morphological and geographical characteristics of each lake and primary watershed information obtained from the literature.

	Area (km^2)	Volume (km^3)	Mean depth (m)	Max depth (m)	Watershed Area (km^2)	Watershed position	Affluent	Effluent	Population (n)	Distance (km)
FAD	65	1.6	24.6	61.5	29,000	end	Yes	Yes	156	0.3
P1L	12	0.49	41	na	62.64	header	No	Yes	1,299	9.8
LN	0.7	na	4.3	na	3.92	header	No	Yes	1,299	20.1
VI	135	na	na	300	1,220	header	No	Yes	1,299	25.7
P4L	5.3	na	6.8	na	9.93	header	No	Yes	44	3.6
LPL	76	4.8	70.5	183	553.9	header	No	Yes	1,693	69.3
FO	81.5	3.58	44	119	578.5	header	No	Yes	1,693	41.7
TO	0.06	na	10.7	15.1	8.91	header	No	Yes	1,693	71.6
MU	414	8.3	20	38.5	42,000	end	Yes	No	11,124	5.5

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2.2 Sample collection and analysis

Sampling was carried out in December 2018. For MPs analysis, a representative sample was taken, filtering approximately 50 m^3 of water through one horizontal trawling across the longest central section of each lake with a net of 38 µm mesh size. The trawling conditions were always at 3.7 km h^{-1} velocity and 20 cm depth to avoid differences among samples. Navigation parameters (speed, distance) were controlled with a Garmin echo sounder with GPS (model GPSMAP® 721). Also, all samplings were taken under low wind speed conditions to avoid wind current effects on net filtration efficiency. As these are lakes which in general have long water residence times (Diaz et al., 2007), inner currents were considered despicable. As we test in previous samplings that the performance of the fluximeter with a net of this dimensions was not the expected, water volume was calculated using the distance of each trawling (approximately 1000 m) and the size of the net mouth (25 cm diameter) according to the following equation:

$$\text{Volume} = \pi \times r^2 \times d \quad (1)$$

where *r* is the net ratio (m), and *d* is the trawling distance. Filtered water samples were stored in previously conditioned glass bottles at -20°C until their processing. Once at the lab, to determine MPs presence, characteristics, and concentration, organic matter from samples was dissolved in 30 % H_2O_2 in a temperature-controlled heating plate at 40 ºC for 9 hours. Then, samples were filtrated with 8-µm pore size Whatman paper filters and, the retained particles were analyzed under a stereomicroscope (Nikon SMZ1500). We considered as plastic each item following the following conditions: be homogeneously colored, be shiny and not matte, lack of cellular/organic structures, be equally thick throughout its length, and, in case of fibers had to have 3-dimensional bending (Lusher et al., 2013; Ronda et al., 2019). Each MPs was photographed and classified into six categories: fiber, film, fragment, foam, rubber, and pellets. Also, we determined the maximum length (mm) and color.

2.3 Raman microscopy

We employed Raman microscopy to interrogate the chemical identity of a random subsample of MP particles (15 % from). Particles were fixed onto a glass substrate employing double-sided tape and were sequentially observed using 5X and 20X Leica objectives, whereas spectra were taken with a 50X (0.75 NA) Leica objective. Raman spectra were acquired in a Renishaw in Via reflex system equipped with a charge- coupled device detector of 1,040 × 256 pixels. A 785 nm diode laser (300 mW) was used as an excitation source in combination with a grating of 1,200 grooves mm^{-1} and slit openings of 65 μm, which yield a spectral resolution of 4 cm^{-1}. The laser power was kept below 5 % to avoid sample damage. The spectra were acquired in the range of 100–3300 cm^{-1} using 2 s exposure time and four accumulating scans. Regular confocality was sufficient to differentiate the Raman scattering of the sample from the substrate. The only post data treatment was baseline correction, carried out using the WiRE™ software. Finally, the spectra obtained were compared to our polymer database to identify the components present in the subsample.

2.4 Quality controls

In order to avoid laboratory MPs contamination, all working surfaces and materials were cleaned with alcohol and checked under the stereoscope microscope before use. Also, we worn laboratory coats, cotton clothing, and nitrile gloves for all procedures. Petri dishes with blanks control filters were air-exposed during the proceedings to discard airborne contamination. The

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same protocol for samples was followed for the blanks during the entire analytical method. Airborne contamination was found to be negligible (0 to 1 MPs found in blanks).

2.5 Statistical analyses

Spearman correlation analysis (r) was performed to assess possible relations between the concentration of MPs, human population, precipitation, and morphometric data of the lakes and watersheds, according to Zar (2010) with the software STATISTICA (ver. 7.0, StatSoft, Tulsa, OK, USA).

3 Results and discussion

3.1 Occurrence and distribution of microplastics

All the lakes presented MPs in their water samples (Figs. 2 and 3). The mean MPs concentration was 0.9 ± 0.6 MPs m^{-3}, with the minimum value in FAD (0.3 MPs m^{-3}) and the maximum in VI (1.9 MPs m^{-3}). There is only one precedent of MPs in water samples in South America, an endorheic small shallow lake from the Pampean Region (Alfonso et al., 2020), which showed a higher concentration of particles (up to 180 MPs m-3). These are the first MPs concentration records in water samples from Patagonian freshwater lakes in South America. The differences in MPs concentrations between studies are explained as the Pampean Region is a very anthropized agro-industrial area, with higher populations and urban settlements than Patagonia.

When MPs concentrations were compared between the studied lakes, the order of the lakes from highest to lowest concentration was as follows: VI > TO > MU > FO > P4L > LP > P1L > LNI > FAD (Fig. 2). No significant correlations were found from the analysis between MPs levels and precipitation, area, shoreline, mean depth, watershed size, distance to urban settlements, and human population. This might be related to the low number of measurements (9) in this study. Nevertheless, we believed the description of the patterns observed are still valid, especially in an area where no previous information is available. The FAD, which presented the lowest concentration, is also one of the lakes with the lowest area, the human population (which is also downstream of the dam) and precipitation value (Fig. 2). Also, despite being at the end of the Chubut River watershed, it crosses Patagonia plain from West to East through a sparsely populated region. This suggests that the runoff contribution of MPs from urban settlements could be lesser than in the rest of the lakes. Besides, FAD outflow is controlled by a hydroelectric industry, and the dam might be reducing the dynamic of the discharge, increasing the water residence time, which might favor the biofouling and sedimentation of MPs. According to Meng et al. (2020), residence time and the trophic state determine the biofouling rates on MPs, being higher in those systems with higher residence times and nutrients concentrations. Also, it states that the relatively larger surface-to-volume ratio of fibers (the main MPs registered) made them more prone to biofouling and sink. In the case of FAD, it presents these features, being a eutrophic lake with high residence time (Quirós et al., 1988; Quirós and Drago, 1999). Nevertheless, further studies should be made in the future to corroborate these assumptions.

TO is the smallest and shallow of all studied lakes (Table 1, Fig. 2b,c) being fed by runoff in an area where the annual precipitation is 1200 mm (Fig. 2a), with a connection with LP lake (Table 1, Fig. 1), and significant affluence of tourists (It has a camping area on its coast visited by anglers). Furthermore, TO, as well as LP, and FO lakes are important for sport fishing where motorboats are allowed. Meanwhile, VI was one of the lakes with the highest areas (Fig. 2b), also fed by surface runoff with annual precipitation of 2000 mm (Fig. 2a) and one effluent the Corcovado River, which ends in the Pacific Ocean (Table 1). According to this, the runoff of

MPs and the tourism affluence and sport fishing could partially explain the higher MPs values found in VI and TO lakes. Also, the high area (and therefore shoreline) in VI could input more MPs from the surrounding; meanwhile, the shallow condition of TO could result in a high input of MPs in lower volume respect to the rest of the lakes (Table 1).

MU presents the largest area and one of the shallower mean depths (Fig. 2 b and c). It is positioned at the end of the largest watershed in this study fed by the Senguer River. It has no effluent, accumulating MPs from all the watershed, including TO, LP, and FO lakes, which are all of them hydrologically connected (Table 1). The high MPs concentration at MU can also be related to commercial fishing being allowed on its water and its location 5 km downstream from a large agricultural-livestock valley and Colonia Sarmiento city, with more than 11,000 inhabitants (Fig. 2d) (INDEC, 2010). Wang et al. (2017) registered a positive correlation between MPs concentration and distance to urban areas; nevertheless, here, we did not found any significant correlations ($r = 0.48$ $p = 0.17$). This could be explained in part by the low number of inhabitants in Patagonian urban areas compared with Wuhan city, one of the largest cities in China.

All the studied lakes are located in remote areas where waste management is usually precarious, with minimal plastic recycling, which could contribute to the deterioration of these aquatic systems. According to Eckert et al. (2018), urban areas have more intense human activity with higher economic levels than rural areas, and the number of microplastics sources and emissions are high. However, there are often better wastewater and solid waste treatment facilities in urban than rural areas, finding higher MPs concentrations in the latter. Yin et al. (2020) analyzed the MPs comparing urban and rural areas, finding higher values in the rural areas, referring to the difference in environmental protection measures between areas as the leading cause.

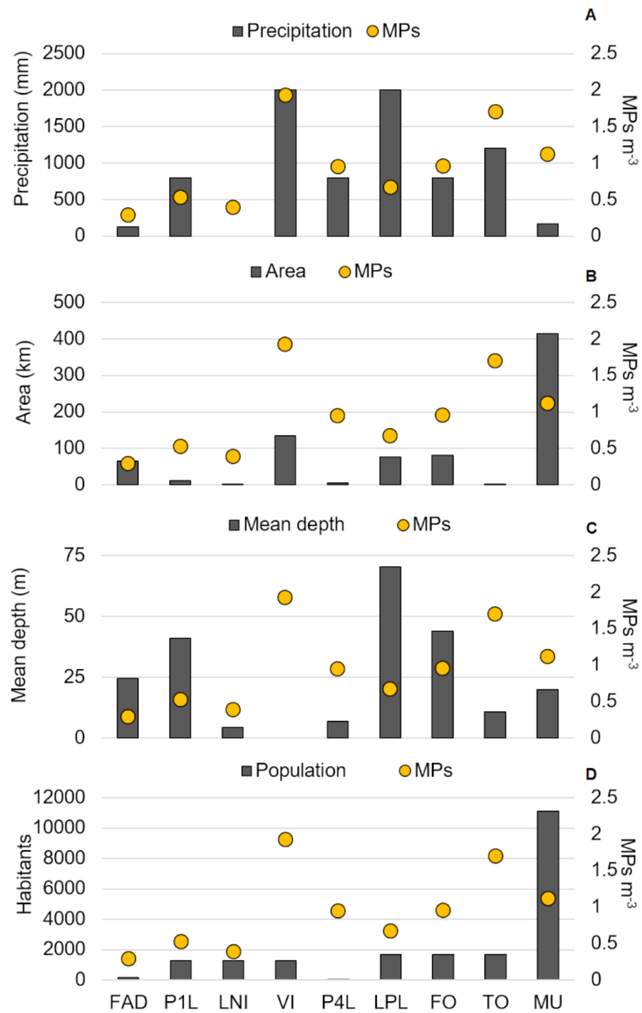

Figure 2. Microplastics concentrations (MPs m^{-3}) and **(A)** precipitation (mm), **(B)** lake area (km^2), **(C)** mean depth (m) and, **(D)** the number of inhabitants in each lake during December 2018.

Some limitations arise when comparing results due to the diversity of expression units (MPs m^{-3} or MPs km^{-2}) and mesh pore size used for water samples. Studies in larger shallow lakes from China (50 µm mesh pore size) registered higher MPs concentrations from 900 to

4,650 MPs m^{-3} in Dongting and Hong lakes, respectively (Wang et al., 2018); between 1,660 and 8,925 MPs m^{-3} were found in 20 urban lakes from Wuhan (Wang et al., 2017), and up to 34,000 MPs m^{-3} was reported in the largest freshwater lake from China (Yuan et al., 2019).

In Italy, the MPs concentrations in the Bolsena and Chiusi lakes sampled with a 300 µm was 2.51 and 3.02 MPs m^{-3}, respectively (Fischer et al., 2016). There is only one analysis performed in the Ross Sea (Antarctica) pumping seawater through glass fiber filters of 1 µm pore size. It demonstrated MPs levels in subsurface near-shore and off-shore coastal water, and obtained similar values to those found in this study, registering 0.17 ± 0.34 MPs m^{-3} (Cincinelli et al., 2017). Therefore, MPs concentrations in the Patagonian lakes are low in comparison to other lakes worldwide. We hypothesize that the low numbers of inhabitants in such an extensive territory (2.3 inhabitants per km^2), is the main cause that explains the differences in MPs concentrations. Nevertheless, as plastic disposal management in Patagonia is weak, and tourism affluence is significant, plastic waste management measures should be more rigorous to avoid the future increase of plastic pollution in such almost pristine habitats.

3.2 Microplastics classification and identification

In the present study, we found a dominance of fibers (Fig. 3a and 4), the blue color (Fig. 3b), and a size range of ≤ 1 mm (Fig. 3c). The fiber category dominates in all sites (Fig. 3a), ranging from 66.7 % in TO to 96.4 % to P4L. These results coincide with those found in other studies in diverse aquatic systems from Argentina and the world, where the fibers dominate the MPs shape (Wang et al., 2017, 2018; Anderson et al., 2018; Pazos et al., 2018; Arias et al., 2019; Alfonso et al., 2020). Nevertheless, according to Cole et al. (2014), we need to consider that such a trend could be the result of an operator bias towards fibrous MPs because they are relatively easier to identify. As in these lakes, fish-farming and fisheries are common, the

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dominance of microfibers could be attributed in part to fishing nets, ropes and canvas, which follow-on intensive weathering can lead to the generation of secondary microplastics (Wang et al., 2017). Also, synthetic fibers from clothes are one of the primary sources of microfibers cited in MPs studies from aquatic systems worldwide (Rochman et al., 2015; De Falco et al., 2018). Considering the lack of sewage discharge from urban settlements in Patagonian lakes, the surface runoff, and atmospheric deposition could be potential sources of plastic fibers as in other lakes worldwide (Dris et al., 2015; Fischer et al., 2016; Mason et al., 2016; Wang et al., 2017, 2018) even in remote locations (Stanton et al., 2019)

An important factor that contributes to the differences in the MPs concentrations reported worldwide is that visual identification should be accompanied by the determination of the composition of the particles. Therefore, a random subsample of MPs (42 items) was analyzed for polymer identification under Raman spectroscopy. Examples of the obtained Raman spectra are shown in Figure 5. The success of its visual identification was 90% indicating high reliability of our data. From the analyzed MPs, 38.3 % were identified as polyethylene terephthalate (PET), 11.8 % as polyurethane (PU) (although these kinds of spectra also showed some peaks according to the PET spectra), 2.9 % as polypropylene (PP) and 2.9 % as polystyrene (PS). The remaining 44.1 % of the MPs generated spectra characteristic of an artificial dye known as Indigo Blue and was associated with blue and black fibers. Indigo Blue is a pigment widely used in textile industries (e.g., polyester, rayon, cotton) (Turner et al., 2019). The polymers identified for the Patagonian lakes were also cited in many other MPs studies worldwide (Zhao et al., 2015; Zhang et al., 2016), providing information to trace the potential sources of plastic debris. The polymer PET is increasingly used in the textile industry to produce clothes, nonwoven fabrics, and carpets (Park et al., 2004), pointing out textiles and clothing as an important source of MPs pollution in

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these lakes. Also, as PET is commonly used for made plastic bottles, food wrappers, and bags, the waste produced by tourists should be considered as a relevant source, according to Thushari et al. (2017). PU is a versatile material that appears in a large number of everyday household items, rubber parts, thermal insulation in buildings, protective coatings, athletic footwear soles, among others. In this study, there was not a 100 % coincidence with the PU spectra, but most of the peaks suggest that they are microplastics with this composition. Also, PU was associated with black MPs, suggesting that rubber parts, footwear, or protective coatings could be the source. PP is used in both household and industrial applications, with a variety of applications that include packaging for consumer products, plastic parts for various industries, and textiles. Finally, PS is the third-most produced polymer for packaging applications, cosmetics, and insulation materials (Teng et al., 2019). Nevertheless, PP and PS here were found in a very low proportion.

Respect to the Indigo Blue spectra, this was found in several MPs studies associated with blue and black fibers as in this study, also becoming a difficulty when Raman polymer identification was applied (Duncan et al., 2018; Turner et al., 2019; González-Pleiter et al., 2020). Synthetic regenerated cellulosic fibers (SRCF) are widely used in textile industries. These are made from natural sources (e.g., wool, cotton, or cellulose derivatives) and altered by industrial processing adding artificial additives (e.g., dyes, bleaching agents, softening, or stiffening additives, flame-retardants or light stabilizers) (O'Brien et al., 2015). Therefore, we should consider that the Indigo Blue fibers found in the Patagonian lakes could not be made of plastic and be SRCF. Nevertheless, their persistence in the aquatic environments, because of their crystalline structures, added to the possible chemical risk associated with their additives (UNEP, 2016), allows them to treat as persistent organic pollutants, as MPs.

MPs exhibited a range of colors in all sites (Figs. 3b and 4), dominating the color blue (42 %), followed by the color black (37 %). These results are in agreement with other MPs studies where blue and black colors prevailed in MPs samples (Duncan et al., 2018; Wang et al., 2018; Peller et al., 2019; Alfonso et al., 2020). Also, we found that a considerable part of the blue and black fibers found in the lakes was associated with the Indigo Blue dye related to synthetic textiles, one of the common sources of microfibers (MFs) in aquatic systems.

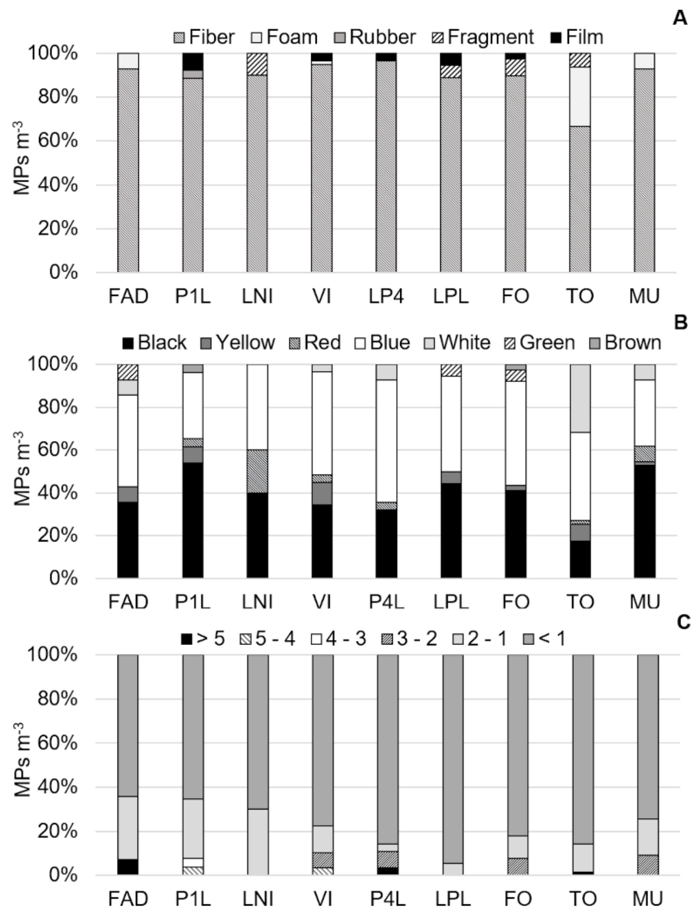

Figure 3. The percentage of microplastics items by (A) category, (B) color, and (C) size (millimeters) in each lake during December 2018.

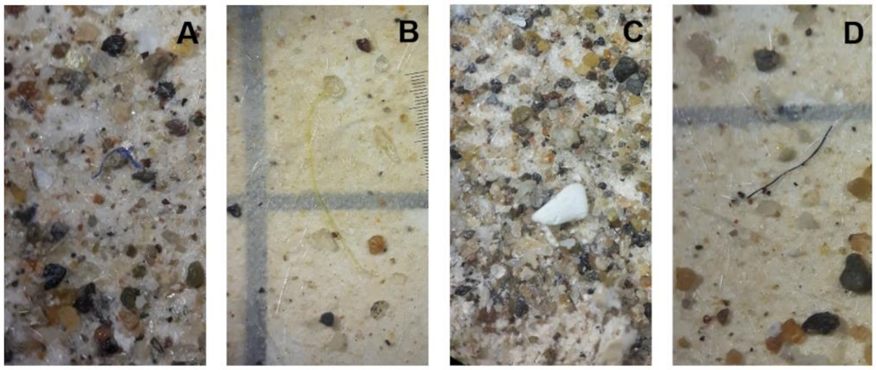

Figure 4. Photographs of typical microplastics collected from the nine Patagonian lakes: **(A)** Indigo Blue fiber, **(B)** Yellow fiber **(C)** White foam, and **(D)** Black fiber.

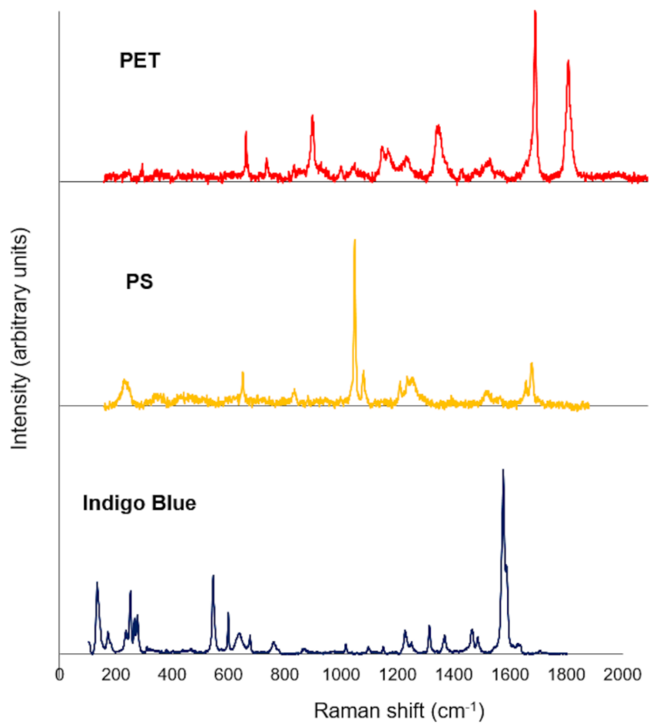

Figure 5. Examples of the MPs Raman spectra found for the Patagonian lakes during December 2018. PET: Polyethylene Terephthalate; PS: Polystyrene; Indigo Blue: Indigo Blue dye.

Finally, the MPs with a size of < 1 mm dominated in all sites (70.7 %) (Fig. 3c), coinciding with those cited in other studies (Free et al., 2014; Fisher et al., 2016; Anderson et al., 2017;

Alfonso et al., 2020). The use of a net with 38 µm of pore size helped to avoid the underestimation of MPs in the lower sizes categories (Conkle et al., 2018). This fraction was presented with more detail in Fig. 6. Those MPs with sizes between 0.2 mm and less than 0.4 mm dominated in all lakes except for FAD and P1L lakes, where the size fraction between 0.4 and less than 0.6 mm prevailed. According to Cole et al. (2014), while MPs greater than 0.3 mm may be of significance to fish if ingested, smaller particles as those prevailing in this study may have ecological relevance to filter-feeding zooplankton. This information is crucial considering that in MU fish-farming and commercial fishing are allowed, and is one of the lakes with higher MPs values and, with fibers dominating the MPs shape category. Besides, TO, LP, and FO lakes, which are interconnected (Fig. 1), also are important sites for sport fishing in the Chubut Province and are at the headwater of Senguer River watershed, which ends in MU.

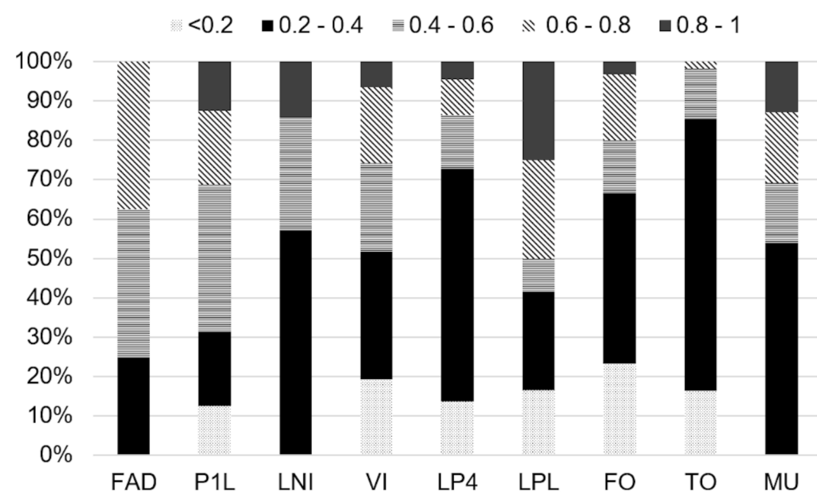

Figure 6. Percentage of MPs sizes less than 1 mm in the categories: < 0.2 mm, 0.2 mm to < 0.4 mm, 0.4 mm to < 0.6 mm, 0.6 mm to < 0.8 mm and, 0.8 mm to < 1 mm registered in each lake in the study.

4 Conclusions

This study is the second measuring MPs in water samples focused in South America (after Alfonso et al., 2020) and the first reporting microplastics in the great lakes from the Patagonia Region. All the lakes presented MPs in water samples, with a mean concentration value of 0.9 MPs m^{-3}. When compared with other worldwide lakes reports, Patagonian lakes presented low MPs concentrations. The minimum value was registered at the dam FAD (0.3 MPs m^{-3}) and the maximum at VI (1.9 MPs m^{-3}), the only lake with a connection to the Pacific Ocean, contributing to sea MPs pollution. Among the registered MPs, blue fibers were dominant, with a low size distribution between 0.2 and < 0.4 mm. These MPs present a potential risk for the first levels of the food chain (plankton, fish, and birds). Raman microscopy analysis showed that 38.3% were polyethylene (PET), 11.8% polyurethane (PE), 2.9% as polypropylene (PP), and 2.9% polystyrene (PS), while the remaining 44.1% of the MPs generated spectra characteristic of artificial dyes known as Indigo Blue, a dye compound widely used in textile industries.

Source assessment identified the runoff from near up-gradient urban settlements (> 1000 inhabitants), clothes, textiles, waste associated with tourism, and the development of farming-fish and commercial or sport fisheries as potential main MPs sources. MPs levels positively correlated to the anthropized shorelines, shallow depth and, an end-position in the watershed. The present findings set a baseline and emphasize the need for better treatment of urban and fisheries waste to reduce the number of MPs that ends on rivers and lakes from Patagonia and the world.

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Declaration of competing interests

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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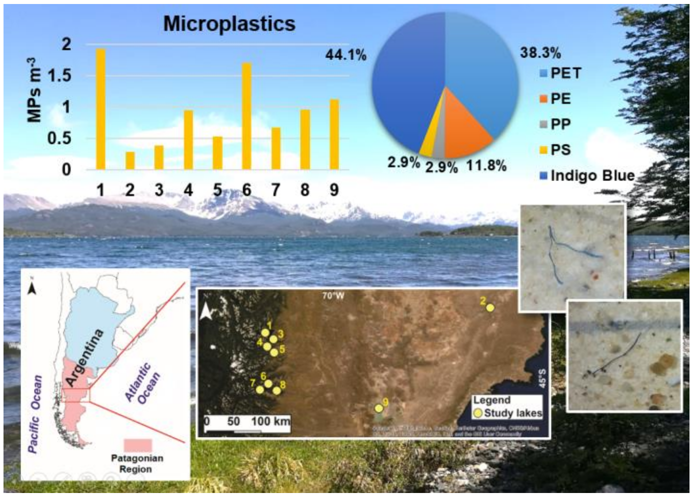

Graphical abstract

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Highlights

- Dominant microplastics were blue fibers with a size between 0.2 and < 0.4 mm
- The mean concentration was 0.9 MPs m^{-3}
- Patagonian lakes showed low MPs pollution when compared to lakes worldwide
- Fibers runoff or airborne deposition from urban settlements were the primary sources
- Raman identification yielded spectra compatible with Indigo Blue, PET, PU, PS and PP

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