Pollution due to plastics and microplastics in Lake Geneva and in the Mediterranean Sea

Florian FAURE, Marie CORBAZ, Hadrien BAECHER and Luiz Felippe DE ALENCASTRO[1]

Ms. received 16th August 2012, accepted 21th November 2012

Abstract
Aquatic pollution due to plastics, and especially microplastics, is becoming the subject of growing research together with an increasing awareness of their environmental harm. While most of the studies focus on oceans, the situation regarding lakes remains largely unknown, and Lake Geneva is no exception, as no studies on the subject are yet underway to our knowledge. This study is the synthesis of a two-step approach. Beaches, fishes and birds from Lake Geneva were investigated to assess the global plastic pollution. Microplastic pollution then became the main research focus, with a microplastics sampling and counting protocol being experimented with samples from the Mediterranean Sea and applied to Lake Geneva once under control. Macroplastics and microplastics have notably been found on the beaches and in the surface layer of Lake Geneva in significant quantities. These findings provide evidence of the importance of further research, both on the distribution of microplastics in Lake Geneva and on their interactions with the environment. They represent indeed a potential input channel for adsorbed pollutants or plastic components into the food chain through their intake by fauna and consecutive desorption.
Keywords: *Microplastics, Lake Geneva, Plastic Debris, Aquatic Pollution, Mediterranean Sea*

Résumé
Pollution par les plastiques et microplastiques dans le lac Léman et la Mer Méditerranée. – *La pollution aquatique due aux plastiques, et en particulier aux microplastiques, est un sujet d'étude gagnant en importance avec la prise de conscience croissante de leur impact environnemental. Si la plupart des études se concentrent sur la situation constatée dans les mers et les océans, la situation concernant les lacs demeure méconnue et le lac Léman ne fait pas exception, aucune étude n'étant menée sur le sujet à notre connaissance. La présente étude est la synthèse d'une approche en deux phases. Une étude préliminaire a été menée sur les plages, poissons et oiseaux du lac pour une première approche de la pollution par les plastiques. La pollution par les microplastiques a ensuite été ciblée, un protocole d'échantillonnage et de dénombrement des plastiques étant tout d'abord expérimenté sur des échantillons de la Méditerranée, puis appliqué au lac Léman une fois maîtrisé. Des macroplastiques comme des microplastiques ont été trouvés à la fois sur les plages et à la surface du lac en quantités non négligeables. Ces premiers résultats encouragent la poursuite de recherches plus poussées portant d'une part sur la distribution et l'importance de la pollution par les microplastiques dans le lac Léman, et d'autre part sur les interactions de ces microplastiques avec l'environnement. Ils représentent en effet une voie d'entrée potentielle dans la chaîne alimentaire pour leurs composants ou des polluants qui leur seraient adsorbés et dont leur ingestion par des animaux entraînerait la désorption.*
Mots-clés: *Microplastiques, Lac Léman, Débris plastiques, Pollution aquatique, Mer Méditerranée*

[1] *Ecole Polytechnique Fédérale de Lausanne, Central Environmental Laboratory. Bâtiment GR Station 2, CH-1015 Lausanne, Switzerland.* Phone +41 21 693 27 29, Fax +41 21 693 57 60. E-mail: felippe.dealencastro@epfl.ch

Introduction

Plastic and microplastic particles

"Plastics are man-made, non-metallic polymers of high molecular weight, made up from repeating macromolecules" (GESAMP 2010). Over 200 plastics families are produced using petroleum, natural gas or more recently bio-renewable materials, and their improper use or disposal can lead to their dissemination in the aquatic environment. A distinction is made between macro- and microplastics, the boundary generally accepted being 5 mm. This study deals both with macro and microplastics pollution: large plastic fragments are a source of microplastics, and can also be seen as indicators of microplastic pollution. Microplastics are themselves divided into two categories: primary microplastics are pellets used as feedstock in the plastics industry or as abrasives (cosmetics, air-blasting media), and secondary microplastics are fragments of degraded and broken larger plastic pieces (Arthur et al. 2009).

About 80% of the plastics found in marine litter have a terrestrial source (Andrady 2011). The main terrestrial routes for marine plastic pollution are washed street litter, rubbish dumping, waste containers and dumps, manufacturing sites, plastic processing and transport and sewers (GESAMP 2010). Marine plastics also result from coastal tourism, fishing, marine vessels or marine industries (Cole et al. 2011). Microplastics themselves can arise through four mechanisms: deterioration of larger fragments, direct release into waterways, accidental loss of industrial raw material or discharge of macerated wastes (GESAMP 2010).

Marine debris, mainly composed of plastics, have been the subject of extensive researches (Cole et al. 2011), yet microplastics remain widely unknown (Doyle et al. 2011) although the number of recent publications in the scientific literature dealing with microplastics increases rapidly (GESAMP 2010). Research methodologies are also developed and improved, specific methods being tested and applied at various scales. Aquatic plastics as well as microplastics are ubiquitous (Barnes et al. 2009). However, they clearly appear to concentrate on coastlines and accumulate in oceanic gyres; in the water column, plastics tend to be found near the surface and this is particularly true for microplastics (Cole et al. 2011). The lack of studies and the variability in the research protocols make it difficult to document clear trends in the accumulation of microplastics through time. Concentrations of plastics in aquatic environments seem indeed to increase, although there are disagreements on the subject, especially for microplastics concentrations (Barnes et al. 2009; Cole et al. 2011).

Regarding lake pollution by plastics, only very few studies have been undertaken so far, with no relevant publication at the time this article is being published. This article encompasses two main research studies aimed at evaluating Lake Geneva's pollution by plastics and microplastics. In fact, this problem area has not been tackled so far by researches dealing with the Lake Geneva, mainly focused on micropollutants and biological, physical and chemical parameters (CIPEL 2012). Beaches, birds and fishes were first of all investigated mainly for large plastic pieces. The search for microplastics on the water surface layer was then led using a manta trawl, the protocol being experimented with samples from the Mediterranean and applied to samples from the lake itself.

Risks

Macroplastics present clear risks for the environment, leading to the death of countless fish, reptiles, birds and marine mammals (GESAMP 2010; Henry 2010). This occurs through accidental intake or by mistaking plastics for preys, leading to intestinal occlusion, suffocation or immobilization (Henry 2010). The impact of microplastics on the marine environment is less clear, but represents an increasing scientific concern (Barnes et al. 2009; Cole et al. 2011) due to their large availability among a wide range of marine organisms. Their effects mainly include physical harm, leaching of additives of the plastics themselves as well as desorption of persistent, bioaccumulating and toxic extraneous pollutants attached to the microplastics (Cole et al. 2011; GESAMP 2010). The latter are still the subject of numerous researches to assess the effective risks, as pollutants adsorption on the microplastics remains widely unknown as well as their fate, including their bioavailability and bioaccumulation potential.

Methodology

Plastic fragments: beaches and fauna

Two different protocols have been applied on the beaches of Lake Geneva (adapted from Costa et al. 2009). On various beaches a fixed surface was scraped off. The sand collected was sieved with 5 mm and 2 mm sieves. Water was added to the product of this sieving. The floating part was collected, dried and separated manually to extract the plastic fragments. These fragments were classified into different categories: fibers, pellets, hard plastics and polystyrene.

The second method consisted in collecting the coarse plastic fragments on the beaches. Those fragments were separated into four categories: hard plastics, soft plastics, membranes and polystyrene.
The fishes and birds were collected by a fisherman on Lake Geneva at various locations. The contents of the intestines were collected, dried and observed with a stereo microscope first dry and then in water to find plastic fragments.

Fig. 1. The Manta trawl used to sample microplastics. Equipped with a 300 μm sieve, its mouth is 60 cm wide and dips 25 cm into the water. Picture: Vasco Neuhaus.

Microplastics

Samples from both the Mediterranean and Lake Geneva have been collected and analyzed using a protocol developed by the Algalita Foundation[2] and the 5-Gyres Institute[3]. The floating "Manta trawl", shown on Fig. 1 is specifically designed to sample the upper part of water bodies. Equipped with a plankton sieve (300 μm), this type of trawl have been widely used for microplastic research, allowing comparisons with previous research. The Oceaneye organization[4] has been leading both sampling campaigns, directly providing the Mediterranean samples.
In the lab, samples have been sieved through a 5 mm sieve, to distinguish macro- and microplastics. After drying and elimination of plankton and other non-plastic materials, the plastic pieces were counted through a stereo microscope and weighted in order to determine the broad plastic densities and typology. Plastic affiliation to rough plastic types and functions was based on their appearance, as was their identification as primary or secondary plastics.

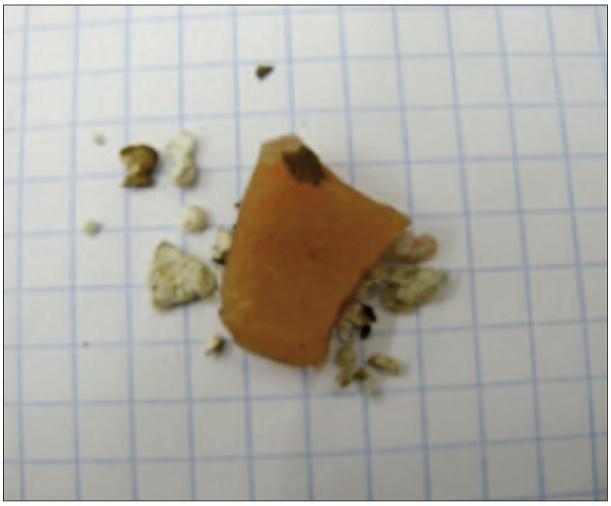

Fig. 2. Plastic pieces found on the beach of St Sulpice, high water line.

2 http://www.algalita.org/index.php [27.07.2012]
3 http://5gyres.org/ [27.07.2012]
4 http://www.oceaneye.eu/ [27.07.2012]

Table 1. Plastics found in the sand of the sampled beaches.

Beach	Quantity of floating material	Plastics found
St Prex	Low	1 hard blue plastic
St Sulpice (1)	Very important	1 Hard brown orange big plastic
St Sulpice (2)	Low	4 hard plastic particles 1 membrane
Vidy (dry sand) 2-5mm	Important	7 polystyrene pellets
Vidy (dry sand) <2mm	Important	2 polystyrene pellets
Vidy (water front) 2-5mm	Important	1 polystyrene pellet
Vidy (water front) <2mm	Low	1 transparent membrane
Preverenge (dry sand)	Important	1 hard beige plastic 2 fibers 2 polystyrene pellets
Preverenge (water front)	Low	1 polystyrene pellet 1 hard red plastic 1 green pellet

Outcomes

First campaign

Plastic fragments have been found on every beach analyzed during this first campaign. The coarse plastic fragments were numerous and all categories of plastics were found. For the sand samples, plastics have been found in each sample. In a volume of 1 liter as collected for this analysis the results varied from 1 to 7 plastics fragments in each sample.
Polystyrene is the particle found in the largest amount, as shown on Table 1 and Fig. 2.
As for the fish, 21 adult northern pikes (*Esox lucius*), 18 common roaches (*Rutilus rutilus*) and 2 common breams (*Abramis brama*) were emptied and analyzed. Ingested fish preys were found in the pikes, but no plastic pieces could be seen through the stereo microscope, nor in the other fish. Only 1 bird, a Black-necked Grebe (*Podiceps nigricollis*) was analyzed during this study, and no plastic was found.

Second campaign

Two samples from the Mediterranean were analyzed to test the lab protocol before adapting and applying it to Lake Geneva. They were collected along respectively 6.8 km and 8.1 km, trawling 4100 m² and 4844 m². A number of plastic particles could be found, as can be seen in Table 2.
These were both micro- and macroplastics, and both primary and secondary ones. A rough classification based on their aspects has been proposed, in order to identify possible bias in the count, such as oil patches or polystyrene debris left from trawlers. No significant error could be identified.
Among the collected samples on Lake Geneva, only one could be analyzed in the lab due to adverse sampling conditions: few samples could be collected, and all others were useless due to large amounts of pollens saturating the water surface during the sampling period, and thus the samples. The valid sample was collected along a distance of roughly 3.7 km, trawling about 2222 m² on Lake Geneva, between Vidy and Saint-Sulpice near Lausanne. Once dried and observed through the stereo microscope, a number of plastic particles have been counted as shown on Table 3.
Once again, both macroplastics (Fig. 3) and microplastics were found (Fig. 4), including primary and secondary microplastics.
As can be seen on Figs. 5 to 8, they differ both in type and composition. These plastics have been roughly sorted although they have not been classified.

Fig. 3. Macroplastics found in Lake Geneva using the Manta trawl.

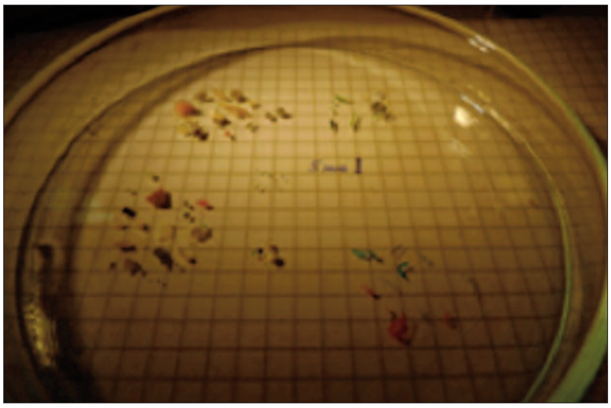

Fig. 4. Microplastics found in Lake Geneva using the Manta trawl.

Table 2. Plastics found in the Mediterranean samples.

Sample	Plastics	Polystyrene	Oil	Total	Weight [g]	Density [parts/km²]
5, macros	59	0	0	59	1.510	20228
5, micros	1290	0	89	1379	0.887	314609
9, macros	8	0	1	109	0.838	1651
9, micros	126	3	28	157	0.453	14389

Table 3. Plastics found in Lake Geneva.

Plastic particles	Total	Weight [g]	Density [parts/km²]
Macros	17	0.07	7649
Micros	107	0.024	48146

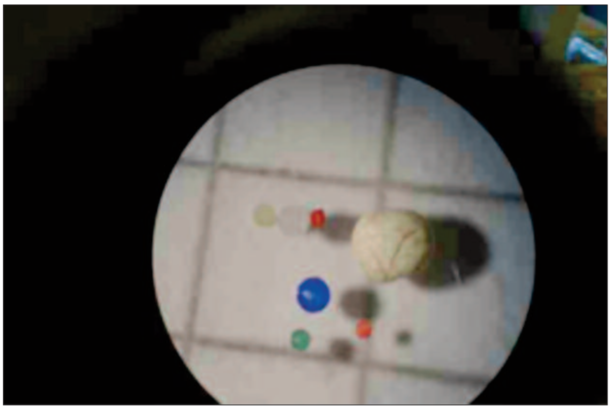

Fig. 5. Primary microplastics and polystyrene pebble from Lake Geneva.

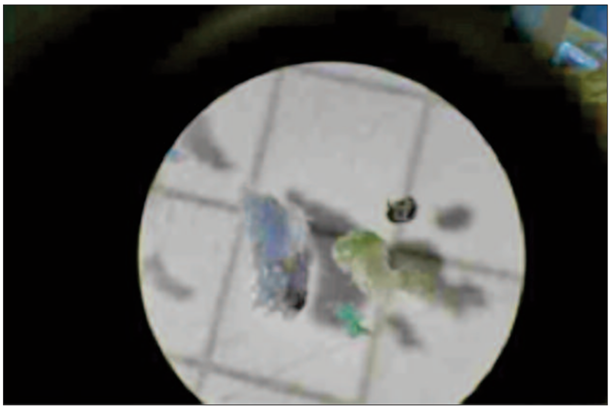

Fig. 7. Secondary microplastics from Lake Geneva.

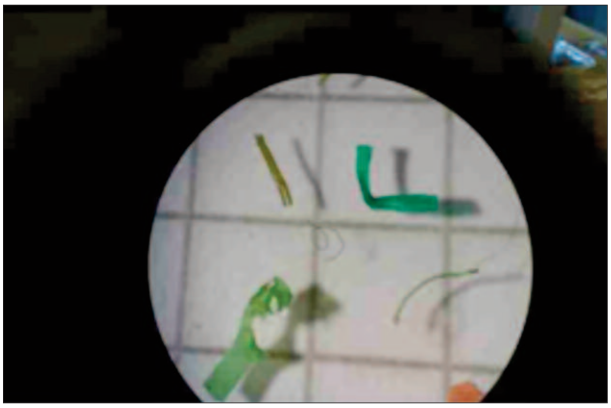

Fig. 6. Micro plastic fibers from Lake Geneva.

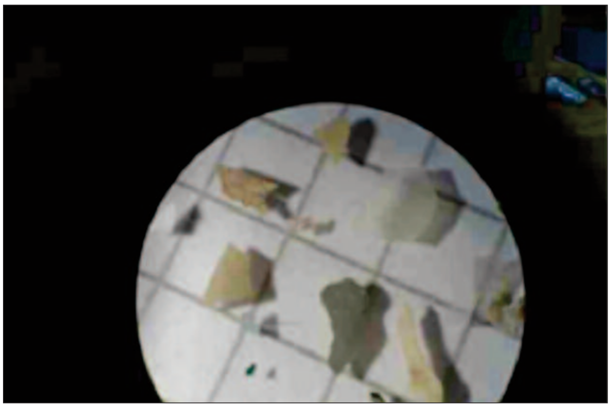

Fig. 8: Secondary microplastics from Lake Geneva.

Discussion

Although this study is affected by a few uncertainties, some conclusions can be drawn from these findings.

Discussion of the first results

Concerning the sand analysis, bias is mainly due to the size and the number of samples collected at each location. The volume of sand collected in this analysis is relatively low: the collection operation could be redone with greater surfaces scraped from the first layer, and a more systematic sampling. Beaches other than sand beaches, such as pebble beaches, could also be investigated to such purpose, and in addition microplastics should be looked for. As for the fish, pikes occupying a high trophic level probably have a lower chance of ingesting plastics directly and probably mistaking them for the fish they hunt. Fish that are lower in the trophic chain are more likely to mistake microplastics for algae or daphnia and could be the subject of further studies. Ducks and gulls are also likely to ingest plastics, especially dabbling ducks that could mistake floating plastics for food. Fig. 9 suggests such behavior to be rather common on Lake Geneva: gull faeces containing large proportions of plastic fragments can be found throughout the lake's coasts. The origin of this debris (terrestrial and aquatic) should nevertheless be clarified before drawing further conclusions. Obtaining remains of animals from the Lake was extremely complicated, numerous contacts having led to no results: wildlife conservation administrations and organizations, birds veterinaries, etc. This obstacle should be resolved within larger and broader research supported by public institutions.

The samples from the Mediterranean can be considered as reliable, their collection being closely controlled. Their analysis may nevertheless slightly underestimate the number of plastics because of the large proportion of plankton contained in the samples. When plankton, algae and other foreign matter was eliminated, some plastic pieces may have been lost; the same bias is probable with the samples from Lake Geneva, due to the large proportion of pollens. The fact that only one valid sample was collected on Lake Geneva, and on a rather short distance, requires conclusions to be drawn with caution. The particles density in particular may not be representative of the average Lake's density due to local phenomena; temporal and seasonal variations are also to be taken into account, as well as the weather, regarding water flow and plastic distribution.

Fig. 9. Common gull faeces found in Vidy, containing mainly polystyrene.

Impacts and recommendations

Plastics from the Lake may have diverse origins: coastal anthropic activities, tributaries, on-water activities etc. The fact that secondary microplastics can be found suggests that the plastics' residence time is long enough for plastics to degrade. Primary microplastics also indicate that microplastics sources can be found high upstream oceans. Controlling theses sources might be a track to decrease the quantity of incoming plastics in the oceans. Plastics are indeed most likely to travel down to the Mediterranean through the Rhone River, at least floating plastic materials. During this journey the microplastics are also likely to degrade and break up into smaller fragments, creating *inter alia* more secondary microplastics. Their rather long residence time in Lake Geneva, theoretically amounting to about 11 years (CIPEL 2012), also offers opportunities for plastics degradation.

The presence of plastics is alarming, and the risks are multiple as previously stated. The presence of different additives as Bisphenol-A or phtalates in plastics can be a threat to the biota when ingested. Moreover, hydrophobic micro-pollutants adsorption on the smaller plastic fragments in particular is still largely misunderstood but appear to serve as high accumulation potential transport medium (Mato et al. 2001). Plastic transport and dissemination following the water routes can also be of interest. The possible release of these pollutants while ingested by birds or fishes can be a potential bio-assimilation and bioaccumulation route that should be further investigated. The fact that such microplastics can be found elsewhere than in seas and oceans should make scientists aware of the fact that the microplastics problem might have greater distribution and impacts than generally believed.

Further microplastics sampling will be undertaken on Lake Geneva and analyzed to validate these results, and better assess the microplastics distribution and composition. The protocol using the Manta trawl as in this study can be generalized in order to obtain more global results and pave the way to documented comparisons. Researches on the adsorption of micropollutants on microplastics and their potential release and absorption in fauna (birds and fish) would also be most interesting to develop. A more precise study of plastics ingestion by these animals would be necessary to evaluate the real risks and impacts of such phenomena. A new research program is to be launched in fall 2012 in order to collect plastics in the surface layer of Lake Geneva, and analyze the adsorbed micropollutants.

Acknowledgments

Many thanks to Alain Schmid, fisherman in Saint-Sulpice, for providing the fish and bird samples, and the Conservation de la Faune et de la Nature du Canton de Vaud for the contacts and support. The OceanEye organization and especially Pascal Hagmann, its founder and skipper, has been a major actor of this study, providing the samples from the Mediterranean and helping in organizing the Geneva Lake microplastics sampling campaign.

Bibliographie

- **Andrady AL.** 2011. Microplastics in the Marine Environment. Marine Pollution Bulletin, 62:1596-1605.
- **Arthur C, Baker J, Bamford H.** (eds.). 2009. Proceedings of the International Research Workshop on the Occurrence, Effects and Fate of Micro-plastic Marine Debris, Sept 9-11, 2008. NOAA Technical Memorandum NOS-OR&R-30.
- **Barnes DKA, Galgani F, Thompson RC, Barlaz M.** 2009. Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society, B(364): 1985-1998.
- **CIPEL** 2012. Rapport de la Commission Internationale des Eaux du Léman contre la pollution (CIPEL). Campagne 2011.
- **Cole M, Lindeque P, Halsband C, Galloway TS.** 2011. Microplastics as Contaminants in the Marine Environment: A review. Marine Pollution Bulletin, 62: 2588-2597.
- **Costa MF, Ivar Do Sul JA, Silva-Cavalcanti JS, Araújo MCB, Spengler Â, Tourinho PS.** 2009. On the Importance of Size of Plastic Fragments and Pellets on the Strandline: a Snapshot of a Brazilian Beach. Environmental Monitoring and Assessment, 168: 299-304.
- **Doyle MJ, Watson W, Bowlin NM, Sheavly SB.** 2011. Plastic Particles in Coastal Pelagic Ecosystems of the Northeast Pacific Ocean. Marine Environmental Research, 71: 41-52.
- **GESAMP** (2010, IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection); BOWMER T. and KERSHAW P.J. (Eds), 2010. Proceedings of the GESAMP International Workshop on plastic particles as a vector in transporting persistent, bio-accumulating and toxic substances in the oceans. GESAMP Rep. Stud. No. 82, 68pp.
- **Henry M.** 2010. Pollution du milieu marin par les déchets solides: État des connaissances. Perspectives d'implication de l'Ifremer en réponse au défi de la Directive Cadre Stratégie Marine et du Grenelle de la Mer. IFREMER, Brest.
- **Mato Y, Isobe T, Takada H, Kanehiro H, Ohtake C, Kaminuma T.** 2001. Plastic Resin Pellets as a Transport Medium for Toxic Chemicals in the Marine Environment. Environmental Science and Technology, 35: 318-324.