MICROPLASTIC CONTAMINATION IN ARGENTINA: INSIGHTS ABOUT A SOURCE (WASTEWATER TREATMENT PLANT) AND A SINK (BEACH): 2 CASE STUDIES

Patrícia Isabel Nunes dos Reis

Dissertação para obtenção do Grau de Mestre em

Engenharia do Ambiente

Orientador(es): Doutora Martha Bargiela

Doutora Rita Fragoso

Júri:

Presidente: Doutora Cláudia Saramago de Carvalho Marques dos Santos Cordovil, Professora Auxiliar do(a) Instituto Superior de Agronomia da Universidade de Lisboa

Vogais: Doutora Rita do Amaral Fragoso, Professora Auxiliar do(a) Instituto Superior de Agronomia da Universidade de Lisboa, orientadora

Doutora Joana Raimundo Pimenta, Bolseira de Pós-Doutoramento do(a) Instituto Português do Mar e da Atmosfera, IP

2019

ACKNOWLEDGMENTS

First, I want to thank my thesis directors, from "Facultad de Agronomia – Universidad de Buenos Aires", Diego Wassner and Martha Bargiela for the support and for the effort in creating all the conditions I needed to perform my master thesis. Also, need to thank the teacher Rita Fragoso for accepting me and for all the advice and help during my master thesis.

I would like to show gratitude for the people from COMACO, and especially Walter who was always available to answer my doubts.

My major support in Argentina, Fio, who was a great listener and adviser and my adventure in this foreign country wouldn't be the same without her, so thank you! Also thank Harold, Lesther, and Martín for being such good friends and supporters! See you soon all of you!

À família que pude escolher, aos meus melhores amigos, André, Carolina e João, que também mesmo a milhares de quilómetros de distância, sempre me apoiaram e foram essenciais neste processo.

Um grande agradecimento aos meus pais que apoiaram muito nesta minha aventura no outro canto do mundo. Também agradeço ao meu Avô por ter apoiado.

RESUMO

Microplásticos (MPs) são um contaminante que, devido à sua natureza onipresente, está espalhado por todo o mundo, atingindo todos os ecossistemas e locais remotos. Como é um tópico recente na comunidade científica e sua eliminação ainda é um desafio, é importante compreender a sua concentração e monitorização. Alguns países não têm ou têm dados escassos acerca disto. Argentina, que compreende uma longa costa atlântica e gere um dos principais estuários da América do Sul, é altamente suscetível a libertar e transportar MPs, mas sua concentração ainda não foi amplamente estudada.

Esta tese visa contribuir para preencher a lacuna de conhecimento existente, apresentando dois estudos de caso: representando um deposito de potenciais microplásticos (PMPs) em três praias de Villa Gesell (Grande Buenos Aires); e uma fonte, uma ETAR comunitária na área da Grande Buenos Aires, para entender o transporte de PMPs para o ambiente. Os PMPs foram quantificados e classificados opticamente pela sua forma e cor.

Em Villa Gesell, os PMPs foram investigados em três praias diferentes com diferentes níveis antropogénicos, variando de 46,0±34,8 (DP) a 86,2±66,1 PMPs.Kg^{-1} areia seca. Não foi observada relação entre a quantidade de PMPs com o nível antropogénico, linhas de praia, matéria orgânica e granulometria da areia.

Na ETAR, a concentração de PMPs no influente foi de 12587±3073 PMPs.L-1 e sugeriu que a lagoa e o clarificador secundário pudessem remover PMPs. Contudo, ainda liberta para o ecossistema aquático uma quantidade de 9.1x10^{9} PMPs.dia^{-1}. Como os PMPs não foram eliminados, permaneceram nas lamas, atingindo uma quantidade de 2,7 ±2,9x10^{5} PMPs.kg^{-1} lama seca.

Os resultados desta tese mostram a importância de avaliar PMPs para entender a dimensão da contaminação, conscientizar sobre este problema que pode ter sérias consequências para a biosfera e motivar o desenvolvimento de estratégias para eliminar este contaminante.

Palavras-chave: Microplásticos; Sedimentos marinhos; Detritos de plástico; Estação de Tratamento de Águas Residuais; Lamas de ETAR.

ABSTRACT

Microplastics (MPs) are a contaminant which due to its ubiquitous nature is spread all over the world, reaching all the ecosystems and remote places. Since it’s a recent topic in the scientific community and its elimination is still a challenge, it’s important to access its concentration worldwide and monitoring. Some countries don’t have or have scarce data about it. Argentina, which comprises a long Atlantic coast and manages one of the major estuaries of South America is highly susceptible to release and transport MPs, but its concentration hasn’t been broadly studied yet.

This thesis aims to contribute to filling the existent knowledge gap by presenting two case studies: one representing a sink for Potential Microplastics (PMPs), three beaches from Villa Gesell (Great Buenos Aires); and a source, a communitarian Wastewater Treatment Plant (WWTP) in the Great Buenos Aires area, to understand the transport of PMPs to the environment. PMPs were quantified and classified optically by its shape and colour.

In Villa Gesell, PMPs were investigated in three different beaches with different anthropogenic loads, ranging from 46.0±34.8 (SD) to 86.2±66.1 PMPs.Kg^{-1} dry sand. No relation was observed between the amount of PMPs with anthropogenic load, wracklines, sand-size grain, and organic content.

In WWTP, the concentration of PMPs in the influent was 12587±3073 PMPs.L^{-1} and it’s suggested that lagoon system and secondary settler could remove PMPs. However, still releases to the aquatic ecosystem an amount of 9.1x10^{9} PMPs.day^{-1}. Since the PMPs were not eliminated, they remained in the sludge, reaching an amount of 2.7x10^{5}±2.9x10^{5} PMPs.kg^{-1} of dry sludge.

The results from this thesis show the importance of assessing PMPs to understand the dimension of the contamination, bring awareness on this problem that can have serious consequences to the biota, and motivate the development of strategies to eliminate this contaminant.

Keywords: Microplastics, Beach sediments, Plastic debris, Wastewater Treatment, Sewage Sludge.

RESUMO EXTENDIDO

Os microplásticos (MPs) são um contaminante com preocupação emergente para o ambiente que, dado às suas características intrínsecas, se encontra facilmente disperso pelo mundo, atingindo todos os ecossistemas e áreas mais remotas do planeta. MPs são partículas sintéticas não solúveis com dimensões entre 5 mm a 1 μm. Podem ser classificados como primários, em que há a produção propositada destas micropartículas, utilizadas em cosméticos por exemplo, como também secundários, sendo estes provenientes da degradação física, química ou biológica de pedaços maiores de plástico que se encontram no ambiente, como por exemplo provenientes de embalagens plásticas ou roupa sintética.

O plástico surgiu no século XX e revolucionou o estilo de vida das pessoas, onde o descartável passou a substituir o reutilizável. Contudo, mal se sabia dos efeitos que esta invenção do século passado iria provocar. O aparecimento deste contaminante não é recente, tendo sido detetado no início dos anos 70, contudo só recentemente é que a comunidade científica se debruçou sobre ele e passou a tentar compreender mais sobre o mesmo. É encontrado em todos os ecossistemas e dada que a sua eliminação a médio-longo prazo não é possível, os MPs encontram-se em constante interação entre os ecossistemas e acabam por gerar um ciclo em que se encontram em constante movimento e transformação. É definitivamente um contaminante perigoso que pode atuar de várias maneiras: como agente abrasivo, libertando componentes do plástico ou atuando como vetor de contaminantes e patógenos. Relativamente à saúde humana, ainda pouco se sabe o que provoca. Contudo já existem estudos que estimam a quantidade de MPs que nós humanos ingerimos semanalmente, atingindo uma média de cinco gramas, não fosse o caso de existirem alimentos contaminados como também a água engarrafada e da torneira se encontram igualmente contaminadas.

Por ser um assunto relativamente recente na comunidade científica, ainda não existe dados em certos lugares no mundo, e como a sua eliminação é um desafio, é importante ter conhecimento dos níveis de concentração deste contaminante emergente por todo o mundo e a sua monitorização. É o caso da Argentina, um país da América do Sul, que possui poucos estudos acerca deste tema. Sendo este pais portador de uma longa linha de costa atlântica de 4725 Km, na costa este do continente sul americano, sendo que esta costa apresenta altos nível de povoamento e industrialização. Também partilha um dos maiores estuários do continente, o estuário do Río de la Plata, por isso e com todas as dinâmicas hidrológicas do próprio continente, é um país suscetível de receber como também de emitir MPs para o ambiente, sendo que as suas concentrações são pouco conhecidas.

Esta tese tem como objetivo contribuir para preencher a lacuna de conhecimento que existe sobre este assunto neste pais, explorando assim a contaminação de possíveis microplásticos (PMPs). São examinadas duas perspetivas: uma que representa um deposito de PMPs, realizado em três praias do povoamento de Villa Gesel (Província de Buenos Aires); outra representa a perspetiva de emissão de PMPs para o ambiente, realizado numa estação de tratamento de águas residuais (ETAR) comunitário (Província de Buenos Aires). Em ambos os casos, os PMPs foram visualmente quantificados e classificados por tipo e cor, por isso é atribuido a designação de Potencial Microplástico (PMPs).

A metodologia utilizada neste trabalho vai em parte ao encontro, no caso das amostras de areia, ao método padrão da extração e análise de MPs (Frias et al., 2018) . As amostras foram digeridas com um oxidante forte, neste caso o Peróxido de Hidrogénio (H_2O_2) e seguidamente se realizou a extração de MPs numa matriz sólida com recurso a uma solução de densidade elevada, sendo que neste caso foi escolhida uma solução saturada de Cloreto de Sódio (NaCl $\approx 1.2 g.cm^{-3}$). O sobrenadante filtrado para filtros de microfibra de vidro. Nas amostras da ETAR comunitária, como ainda não existe estandardização do método e alguns dos métodos de recolha publicados podem promover à subestimação das partículas encontradas. Por isso estas serem amostras líquidas, estas foram oxidadas e filtradas no mesmo tipo de filtros. Também foram analisadas as lamas da ETAR e procedeu-se ao inverso do que foi mencionado nas amostras de areia, sendo que se procedeu à extração com a solução saturada de NaCl e depois se procedeu à oxidação com H_2O_2. Ambas as amostras foram observadas num microscópico, para a sua classificação e quantificação de acordo com os critérios descritos na metodologia desta tese.

Nas Praias de Villa Gesell, apresentando níveis de interação humana distintos, crescendo da Praia A para a C, sendo esta última a mais turística, foram investigados os níveis de contaminação de PMPs apresentado valores médios de 46.0 ± 34.8 (Desvio Padrão) $PMPs.Kg^{-1}$ areia seca para a Praia A, de 61.3 ± 44.8 e 86.2 ± 66.1 $PMPs.Kg^{-1}$ areia seca para as praias B e C, respetivamente. As amostras apresentaram heterogeneidade entre si, aparecendo amostras com quantidades bastante elevadas de PMPs, atingindo valores de 851.7 e 1132.6 $PMPs.Kg^{-1}$ areia seca, que foram consideradas como “outliers” e não foram consideradas para a estatística. Não existiram diferenças significativas entre a quantidade de PMPs e o nível antrópico da praia, algo que não é incomum, tendo sido já mencionado em alguns estudos, mostrando que a deposição de MPs pode ser feita através de fenómenos naturais, como a hidrodinâmica do local e da meteorologia. Alguns estudos mostram a diferença entre a quantidade de PMPs nas várias linhas de praia, mostrando a sua diferença, mas neste trabalho isso não se verificou e também não é incomum. Estas duas variáveis foram avaliadas e não se verifica interação entre as mesmas.

Também foi avaliado se existia alguma relação entre a granulometria e a quantidade de matéria orgânica das amostras de areia com a quantidade de PMPs, e verificou-se que não existia relação.

No caso da Estação de Tratamento de Água Residuais (ETAR) Comunitária em estudo, podemos verificar que o influente possuía uma quantidade estimada de 12587 ± 3073 PMPs.L^{-1}. Esta ETAR possuí pouca tecnologia, e possui duas rotas de tratamento de água residual, sendo uma constituída por um tratamento primário lagoa, tratando o equivalente a 65% do caudal que chega à ETAR, e é nesta etapa que se observa uma redução de 94.5%, relativamente á concentração de PMPs no influente, sugerindo que é na lagoa onde pode ocorrer a remoção deste contaminante. A restante parte é tratada num sistema composto por tratamento primário, biológico, decantador secundário e desinfeção, e deste modo observa-se uma percentagem de redução de 74.3%, pelo decantador secundário. Com estas duas vias de tratamento, estima-se que esta ETAR liberta uma grande quantidade de PMPs, chegando aos 9.11×10^{9} PMPs.dia^{-1} e 3.33×10^{12} PMPs por ano. Como a tecnologia presente não elimina os PMPs, estes acabam retidos nas lamas resultantes do processo, estimando uma quantidade de $2.7 \times 10^{5} \pm 2.95 \times 10^{5}$ PMPs.kg^{-1} ms. Neste caso as lamas são depositadas num aterro que se encontra nas imediações da ETAR.

Os resultados desta investigação servem para mostrar a importância de detetar concentrações de PMPs de modo a compreender a sua dimensão, em locais propícios a serem depósitos ou em locais que podem ser fontes terrestres deste contaminante para o ecosistema aquático. Na medida em que estes resultados possam motivar para desenvolvimento de novas políticas de redução de plástico e do seu devido encaminhamento para a reciclagem, criar alguma sensibilização sobre este problema que pode provocar consequências sérias para os ecossistemas. Também é importante que estes dados promovam o desenvolvimento de soluções para eliminar este contaminante do ambiente.

Palavras-Chave: Microplásticos, Sedimentos marinhos, Partículas Plásticas, Estação de Tratamento de Àguas Residuais, Lamas de ETAR.

INDEX

FIGURE INDEX

TABLE INDEX

APPENDIX INDEX

ABREVIATIONS

ETAR – Estação de Tratamento de Águas Residuais

H_2O_2 - Hydrogen Peroxide

MPs- Microplastics

Mt – Million tonnes

NaCl – Sodium Chloride

PE - Polyethylene

PET - Polyethylene terephthalate

PMPs – Potential Microplastics

PP – Polypropylene

PS - Polystyrene

PU- Polyurethane

PVC - Polyvinyl chloride

WWTPs - Waste Water Treatment Plants

1. INTRODUCTION

Microplastics (MPs) are considered as an important emerging global problem of the XXI century (Auta et al., 2017). Due to its minor size, which sometimes is not visible with the naked eye, and its potential to cause health issues has caused enlarged attention through the scientific community and general population (Anbumani and Kakkar, 2018; Pivokonsky et al., 2018). MPs are now a hot topic addressed in an exponentially growing number of publications, this year increased more than two hundred times the papers when compared with 2010. These synthetic particles are characterized by having a diameter of fewer than 5 millimeters until 1 µm (Frias and Nash, 2019). Additionally, according to its source, MPs can be classified as primary, being found in personal care products or being plastic pellets for example, which are purposefully made with MPs size. The ones that result by fragmentation of larger plastic particles subjected to physical, chemical and biochemical factors are classified as secondary MPs (Gündo and Çevik, 2018). From these two categories, the secondary ones are the most common in the ecosystem, deriving from the degradation of plastic waste and synthetic fabric washing (Magni et al., 2019). It is expected that in the next decades the population will increase and following that trend this problem will tend to aggravate, due to tendencies regarding plastic consumption and fast-fashion (Niinimäki, 2013), coupled with poor plastic waste management and inefficient removal of MPs (Auta et al., 2017).

MPs are a threat to ecosystems, they can be found in all of the 4 compartments: biosphere (Anbumani and Kakkar, 2018), atmosphere (Gasperi et al., 2018), geosphere (Scheurer and Bigalke, 2018) and hydrosphere (Olivatto et al., 2019). Most studies on this emerging pollutant focus on marine ecosystems, with a large percentage of the works reflecting its presence in coastal beaches, which can act as a source and a sink of MPs (Chubarenko et al., 2018). Only recently freshwater ecosystems were in focus (Wagner et al., 2014). For example, a source of pollution is the direct discharge of wastewater into the environment. The wastewater treatment plants (WWTPs) are not designed to eliminate MPs, even if they can reduce the direct emissions to the aquatic ecosystem, the number of particles discharged per m^3 of water is significant (Murphy et al., 2016). However, MPs eventually persist in the sewage sludge, used in some countries as fertilizer for agriculture, ending on nature, by runoff or leaching (Gündo and Çevik, 2018).

The MPs are definitely a hazardous contaminant, its toxicological mechanisms can be divided into three different pathways: the MPs itself, which can cause tissue abrasion or blockage of the gastrointestinal system for example (Wright et al., 2013); the chemical components of the plastic itself; and by the adsorption of other contaminants, such as heavy metals and PCBs (Wagner et al., 2014). Studies have already been done in aquatic species, to assess the toxicity of MPs.

For example in *Daphnia magna,* the exposure to secondary MPs caused mortality (Ogonowski et al., 2016) and European Sea Bass (*Dicentrarchus labrax*) presented damage in their digestive tract (Anbumani and Kakkar, 2018).

As far as human health is concerned, there is still a lack of knowledge about the effects of MPs (Anbumani and Kakkar, 2018). The human being is frequently exposed to these particles by breathing (Gasperi et al., 2018) or by the ingestion of contaminated foods and drinks, such as seafood (Anbumani and Kakkar, 2018) and bottled (Oßmann et al., 2018) and tap water (Pivokonsky et al., 2018). Therefore, studies suggest that MPs can cause inflammation, genotoxicity, oxidative stress, apoptosis and necrosis in human cells (Wright and Kelly, 2017).

Due to its recent concern and research, validation and standardization of analytical methods are still limited (Prata et al., 2019), and the use of different methods of sampling and extraction may complicate comparison between case studies. MPs distribution is not so well characterized in South America. Studies in Brazil, in Guanabara Bay (Rio de Janeiro), reported an amount of 12-1300 MPs.m^{-2} presenting a variety of types of MPs such as fragments, styrofoam and pellets (Neto and Carvalho, 2016). Besides that, there isn't information about the input of MPs to the environment by WWTPs in South America. Though, in developing countries such as Turkey (Seyhan) (Gündo and Çevik, 2018) and China (Liu et al., 2019), the input has been calculated as 26,555 ± 3175 MPs.m^{-3} (achieving a 73% removal rate) and 79.9 ± 9.3 to 28.4 ± 7.0 MPs.L^{-1} (achieving a 64.4% removal rate), respectively.

In Argentina, the dimension of this problem is not well known. There is a study that reflects the presence of MPs in Rio de La Plata (Pazos et al., 2018) in surface water, achieving a concentration of 164 and 114 MPs.m^{-3}. Therefore, the objective of this work is to investigate the abundance and type of the PMPs existing in beach sediments (Villa Gesell) and understand the input of PMPs that can be released to the environment from a communitarian WWTP. It aims to provide information about the dimension of this problem, encouraging the change of population´s habits and to help the future development of strategies to eliminate this contaminant.

2. BIBLIOGRAPHIC RESEARCH

2.1. – Synthetic materials and plastics

Synthetic materials, such as plastic, started to be developed at the beginning of the XX century, as an important invention to substitute natural materials that could become scarce with time, such as ivory, wood, steel, paper, and glass (Freinkel, 2012).

It started with the invention of Bakelite in the early of XX century (Geyer et al., 2017), and between the 20s and 30s started to appear all over the world the first lab-made synthetic materials that revolutionized the world, included some plastics which we use nowadays (Freinkel, 2012). Plastics are organic polymers and some of them were synthesized from petrol refinery sub-products, the ones that the industry wanted to rid of. As an example, Ethylene, this molecule can be combined to form the polymer known as Polyethylene, widely use on packaging (Freinkel, 2012). Another example is Propylene, which produces polypropylene, used as well for packaging and dippers (Freinkel, 2012).

It was after World War II which this synthetic product, plastics, started to be used in a higher amount all over the world (Geyer et al., 2017). Due to its intrinsic characteristics such as low density, low thermal and electrical conduction, durability and resistance allied to its low-cost production (Frias and Nash, 2019), it became a product which could be customized to fulfill the requirements of uncountable products, applications, and sectors (Plastics Europe 2018). This invention had as well an important contribution to the advance of medical technology, such as disposable equipment, blood transfusion, and storage. Besides, was an important contribution to the progress of food safety (Freinkel, 2012).

Subsequently, plastics arrived to change people’s lifestyle, being used in the most varied way in clothing, packaging, personal goods, household and construction materials (Cauwenberghe et al., 2015b). Although its amazing characteristics, they are persistent, which means that could stay in Nature (in the form of small debris) that could take many years to decompose (Nazareth et al., 2019). So, due to the exponential production and its dependence, linked with the lack of waste management, it became a pollution problem. In 2015 was estimated that could be around 4997 Mt of plastic “environmentally available”, which means the plastics that are somewhere in nature, taking into account all the plastic produced until 2015 against the plastic that was effectively recycled, incinerated and deposited in landfills. It was also projected that this number could reach 12000 Mt in 2050 (Geyer et al., 2017).

But it was at the end of the 60s that plastic litter started to be seen as pollution problem. In 1969, Kenyon and Kridler found plastic objects in *Laysan albatross* stomachs, a marine bird. In 1972 Carpenter *et al.* published the first report about microplastics in surface waters of southern New England and five years later Murray R. Gregory reported the presence of plastic nurdles in New Zealand beaches. However, it was required more than 30 years to start paying attention to microplastics and its different types again, introduced by Thompson *et al*. in 2004. It was the driving force to develop sampling and extraction techniques, increasing exponentially the number of reports about this topic.

In 2017, plastic world production achieved 348 Mt (not including PET, PA, and polyacrylic fibers), approximately more 4% than the production in 2016 (Plastics Europe 2018). This number will tend to increase if consumption habits won't change. The most produced type of nonfiber plastics are Polyethylene (PE) (36%), Polypropylene (PP) (21%) and Polyvinyl chloride (PVC) (12%), accompanied with Polyethylene terephthalate (PET), Polyurethane (PU) and Polystyrene (PS) presenting <10% each, being PE, PP, and PET widely used in packaging industry comprehending 42% of all nonfiber plastic use per sector (Geyer et al., 2017). In terms of fibers production, polyester is the winner, accounting for 70% of all polyester, polyamide and acrylic fibees (Geyer et al., 2017).

Nowadays, plastic is everywhere. The invention that revolutionized, changed the world, and improved our lifestyle was not expected to be an environmental threat to the environment.

2.2. – Microplastics

It was in 2004 when Thompson *et al.* started to pay attention again to microscopic plastic particles that they found on Plymouth beach, in the UK. Since that, the scientific community started as well to research more about this ubiquitous contaminant. So, microplastics (MPs) are a global pollution problem, since it can be found in remote areas of the planet like Antarctica (Reed et al., 2018), mountain tops, deep sea (Hanvey et al., 2017) and present a threat to living beings (Kim et al., 2018).

Generally, it's characterized by having a size fewer than 5 mm, a definition proposed by Arthur *et al.*, (2009).

Although with the development of research in this topic, researchers realize that this definition might not be inclusive and could cause some debate in the scientific community, so for that reason, Frias and Nash (2019) proposed the following definition:

> “Microplastics are any synthetic solid particle or polymeric matrix, with regular or irregular shape and with size ranging from 1 μm to 5 mm, of either primary or secondary manufacturing origin, which are insoluble in water”.

Primary MPs, known as “microplastics by design” (Cauwenberghe et al., 2015b), are the ones that are produced with a dimension < 5 mm. In this category includes virgin plastic pellets that can leak during its transportation or by industrial spillages and microbeads used as an exfoliating agent, shampoo, toothpaste in the cosmetic industry in certain countries (Conkle et al., 2018; Kelkar et al., 2019) .

The most prevalent MPs in the environment are classified as secondary. These MPs are originated when large pieces of plastic, such as consumer goods, plastic packaging and synthetic textiles (Kelkar et al., 2019) are subjected to physical, chemical and biological factors, promoting its degradation into micro debris (Gündo and Çevik, 2018).

MPs can be categorized according to their shape (Barrows et al., 2017; Hendrickson et al., 2018; Viršek et al., 2016):

- **Fragments** – Fragments from large plastic pieces, presenting an irregular shape and colour diversity, being a rigid particle and shows a 3-dimensional aspect (Figure 1-a);
- **Beads** – Includes virgin plastic pellets and microbeads with spherical morphology (Figure 1-b);
- **Thin Films** – It is typically malleable, presenting an irregular shape but showing thin thickness (Figure 1-c);
- **Foam** – Secondary MP with a sponge or bubble-like structure, for example, Styrofoam (Figure 1-d);
- **Fibers** – Resulted from washing synthetic fabric or fishing lines and ropes, appearing as cylindrical and uniform fiber (Figure 1-e).

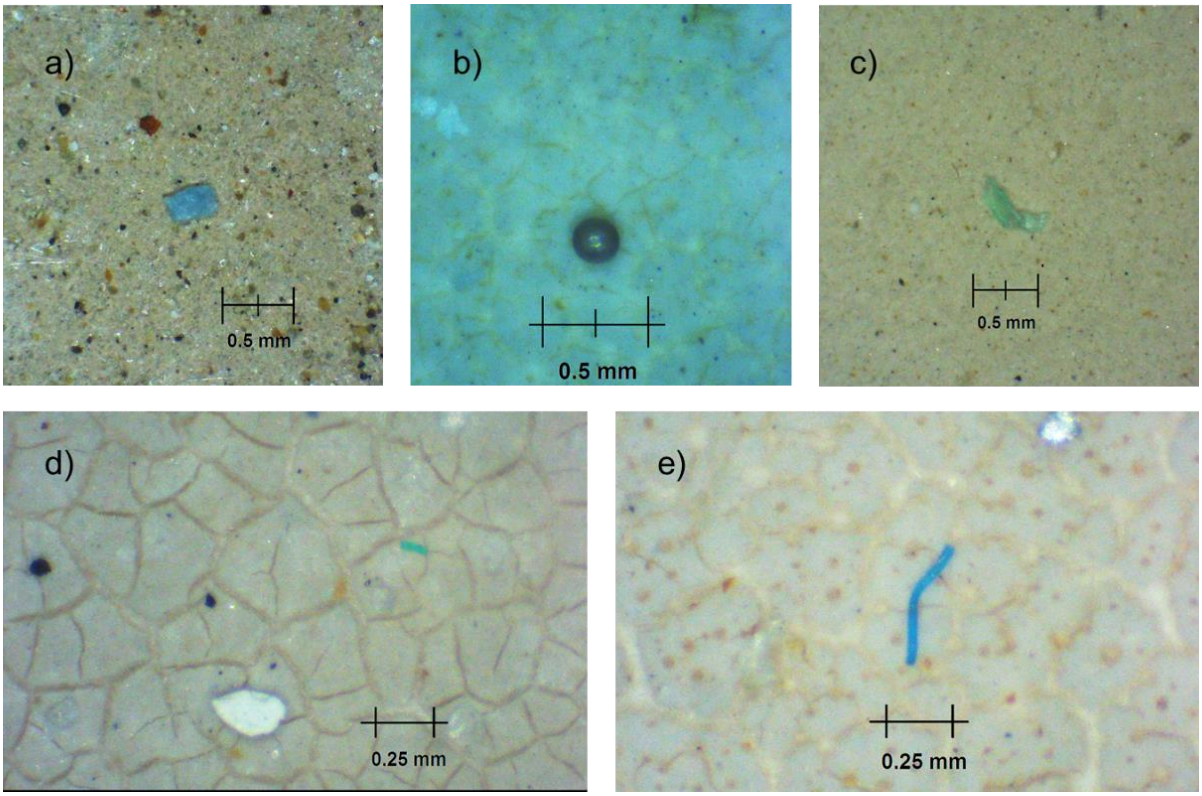


Figure 1 - Examples of microplastic types: a) Fragments; b) Beads; c) Thin Film; d) Foam; e) Fibre.

2.3. – Cycle of Microplastics

These small synthetic particles are widespread for all of the Earth four Spheres: biosphere (Anbumani and Kakkar, 2018), atmosphere (Gasperi et al., 2018), geosphere (Scheurer and Bigalke, 2018) and hydrosphere (Olivatto et al., 2019). It was thought that this contamination problem was affecting only populated areas until MPs were found in unhabitable areas of the planet like the poles (Reed et al., 2018), groundwater systems (Mintenig et al., 2019), mountain tops and deep-sea (Hanvey et al., 2017). Its widespread mobility is provided by their light-weight and insolubility (Hidayaturrahman and Lee, 2019), which make easy for the MPs to be transported by river flows, winds, atmospheric deposition (Rochman, 2018), extreme events or animals into the ocean, and by ocean currents to other parts of the earth (Antunes et al., 2018).

It is estimated that 80% of the MPs that reach the ocean has a land origin (Jambeck et al., 2015). Rivers act as a significant way of contamination to the aquatic environment (Hanvey et al., 2017). Recent studies demonstrated that Wastewater Treatment Plants (WWTPs) are a significant contributor as a land source MPs (Gündo and Çevik, 2018; Hidayaturrahman and Lee, 2019; Magni et al., 2019; Murphy et al., 2016) to freshwater systems or directly to the ocean. In this discharge, it can be included primary MPs from personal care products (microbeads) and secondary ones such as synthetic fiber from industry or household source (Ziajahromi et al., 2016). Inclusive, some reports show that a 6 kg load of laundry can discharge an average of 700,000 fibers into wastewater (Napper and Thompson, 2016). Another recent contribution found that a potential source is the presence of MPs in landfill leachates, resulted from plastic waste fragmentation, achieving from 0.42 to 24.58 MPs.L^{-1} (He et al., 2019).

Another land-based source is from agriculture, due to its extensive use of plastic (Briassoulis and Dejean, 2010) and consequently its degradation, and even worst, the utilization of wastewater sludge as a fertilizer, since the MPs can sediment during the wastewater treatment and achieve an average of, for example, $22.7x10^{3}$ MPs.Kg^{-1} of dry sludge (Li et al., 2018).

Soil interaction with microplastics is also a new field of research, some studies suggested that these particles can affect soil chemistry, and subsequently altering the degradation of organic matter (Abel et al., 2019). During its cycle, the MPs are transported and deposited like sediments, but MPs differ in terms of its form, density, and biofouling which could change MPs density (Stock et al., 2019a). The ones which are present in the water surface can be bioavailable to lower trophic organisms and then enter the food chain (Murphy et al., 2016).

Since their elimination isn’t possible or isn’t efficient, it ends up generating a cycle in which they are in constant movement and transformation. Besides the ones that are generated daily, the plastics that are present in the environment are more sensitive to degradation, transforming into smaller particles. It’s estimated that the load of MPs that reach the environment daily tends to rise, increasing its associated hazards.

Figure 2 represents a scheme of the MPs cycle, demonstrating all the interactions between the four spheres and humans. It is represented the flux of MPs, and how can be distributed through the environment.

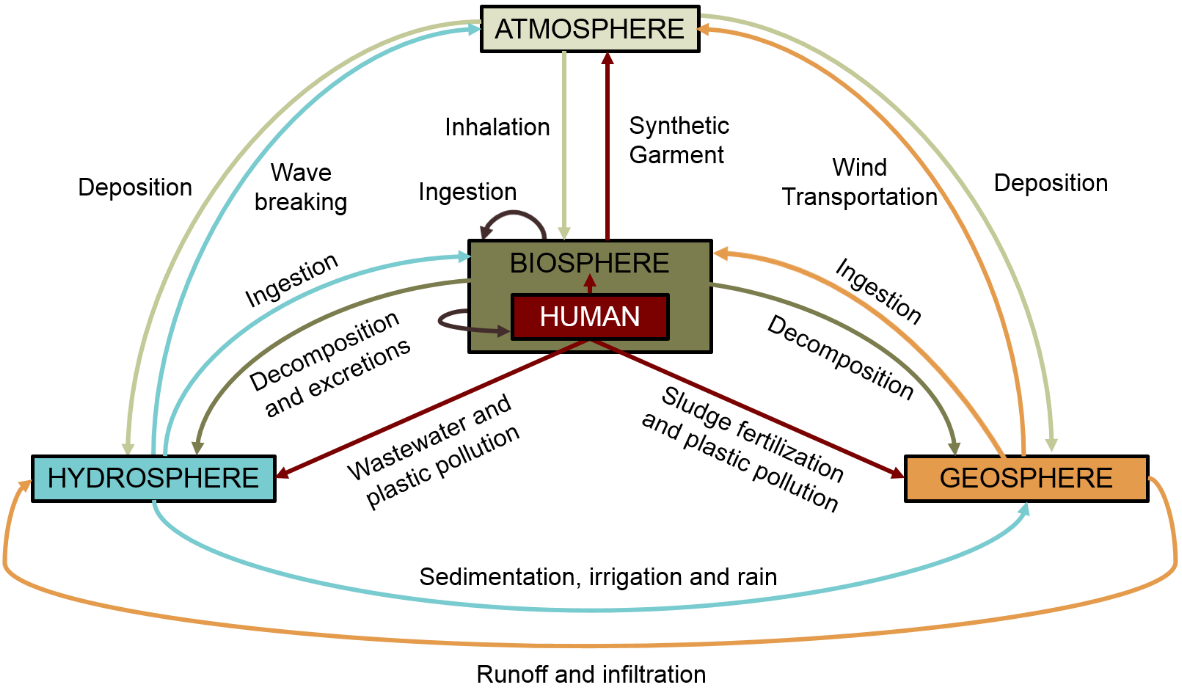


Figure 2 - A schematic representation of the MPs cycle, comprising all the interactions between the four spheres: Atmosphere, Hydrosphere, Geosphere, Biosphere. Human category was created to demonstrate its impact in all spheres. The arrows represent the flux of MPs through the categories.

2.3.1.– MPs in Costal ecosystems

Microplastics in the marine environment is the field in which over the last decades, had more reports (Stolte et al., 2015). During the MPs cycle, beaches can act as a source or sink of MPs (Chubarenko et al., 2018). As a source, the plastic litter present in those beaches can suffer degradation and then transformed into MPs, thus can enter the aquatic environment by water movements or wind (Hanvey et al., 2017). As a sink, either from land plastic degradation or from aquatic source, MPs get trapped in sand. Nowadays, sediment analysis is considered to be an indicator of the level of MPs contamination in marine ecosystems (Chubarenko et al., 2018).

The MPs distribution across the globe coastal ecosystems is widely heterogeneous. There are two main factors for this variation, an environmental one provided by winds, storms, different coastal morphodynamics (Pinheiro et al., 2019), and other natural effects, and an anthropogenic one, through by urban development, industry, and tourism (Shahul Hamid et al., 2018). But it is considered that environmental factors play a major role in the MPs distribution (Shahul Hamid et al., 2018).

A perfect example is from Lambra beach, in the Canary Islands (Herrera et al., 2018), which the most polluted beach in the study, even being a remote beach, reaching a maximum of 125 $g.m^{-2}$ of micro-debris due to coastal line orientation and local wind and wave conditions (Herrera et al., 2018).

Since this research field is relatively recent, it is difficult to observe a standard protocol meanwhile new improvements and new protocols are created, and for that reason sometimes it is difficult to compare data. Although, many efforts had been done to uniformize the MPs protocol, so in 2018 a collaborative work between partners of the Work Package 4 of the JPI-Oceans BASEMAN project, it was proposed a standardized protocol for monitoring microplastics in sediments (Frias et al., 2018).

2.3.2. – MPs in Wastewater Treatment Plants (WWTPs)

In the last few years, some attention was paid in the Wastewater Treatment Plants (WWTPs) as a potential receptor and source of MPs to the aquatic environment. People’s lifestyle have somehow influenced what WWTPs receive; for example, the fast-fashion consumption had increased due to its low prices, mainly because of the use of synthetic fabrics (Niinimäki, 2013). In 2018, synthetic fibre reached 62% of total worldwide fiber (Statista, 2018) consumption, contributing to a load of synthetic microfibers to the environment.

The evolution in the cosmetic industry had brought the appearance of plastic microbeads, which is as well a source of MPs. It’s estimated by Conkle et al. (2018) that a single use of 5 ml of facial scrub can release between 9000-126000 particles and a toothpaste use can contribute to 580-2200 particles to domestic wastewater. For the previous reason and public awareness, some countries and companies already banned the use of this micro litter present in cosmetics (Conkle et al., 2018; Murphy et al., 2016).

WWTPs can't eliminate MPs, even accomplishing a removal rate from 73% to 99% (Gündo and Çevik, 2018; Hidayaturrahman and Lee, 2019; Magni et al., 2019), it is relevant the number of MPs released accounting of the volumes treated every day. In South Korea, a recent study showed that the WWTP which have the major load of MP, with a removal rate of 99.1%, can release 139.98 billions MPs daily (Hidayaturrahman and Lee, 2019).

It’s presumed that in developing countries with high populated industrial communities, with low or none technology for wastewater management, could be the major contributors to discharging wastewater-based MPs (Ziajahromi et al., 2016). The retained MPs are in the sludge produced, that in some cases, can be used as landfilling or fertilizer in agriculture (Wagner et al., 2014), so they may become a terrestrial source to the environment (Magni et al., 2019) and enter in the MPs cycle.

Besides, there is strong proof which this micro debris can act as a carrier of contaminants and pathogens to the environment, and WWTPs hold several organic and inorganic contaminants that can interact with MPs by sorption (Ziajahromi et al., 2016).

In contrast with sediment procedural sampling, it isn’t still available as a standardized method for monitoring. So, it’s difficult to make data comparison since it is used different methods that could underestimate MPs number in wastewater across the globe.

2.4. - Health threat

As the appearance of this contaminant, more knowledge is generated to understand its interaction with living beings. It is a pollutant since it can be hazardous to organism and they can act in three different ways: the MPs itself, which can cause, for example, tissue abrasion or blockage of the gastrointestinal system (Wright et al., 2013); by the leaching of chemical compounds of the plastic itself (Ziajahromi et al., 2016); or carrying by sorption other contaminants such as industrial chemicals, pharmaceuticals, hormones, pathogens, pesticides and heavy metals (Wagner et al., 2014; Ziajahromi et al., 2016).

MPs ingestion have been widely reported in marine species. Even though, not all of them react in the same way. For example, a study suggested that the copepod *Calanus helgolandicus* avoided ingesting algae that present similar size and/or shape of the MPs that were exposed, in a way to avoid ingesting plastic (Coppock et al., 2019). The same thing does not happen with the coral *Astrangia poculata,* in which wild samples were found with over 100 microparticles per polype, a further study suggested that these corals preferred eating MPs, affecting its food ingestion dynamics. In *Daphnia magna* was found that the exposure to secondary MPs caused mortality (Ogonowski et al., 2016).

The *Mytilus edulis* (Blue mussel) and *Arenicola marina* (Lugworm) doesn't shown any significant adverse effect in terms of cellular energy allocation with a high concentration of PS microbeads (Cauwenberghe et al., 2015a). European Sea Bass (*Dicentrarchus labrax*) presented damage in their digestive tract (Anbumani and Kakkar, 2018).

In relation to human being, it is a target of MP contamination, since they are regularly exposed by breathing (Gasperi et al., 2018) or by contaminated food, which its presence was already reported in beer (Wiesheu et al., 2016) , sugar (Mühlschlegel et al., 2017), salt (Kim et al., 2018), seafood (Anbumani and Kakkar, 2018), tap (Pivokonsky et al., 2018) and bottled water (Austin et al., 2018; Schymanski et al., 2018). More and more are explored about this particular subtopic, recently Cox *et al.* (2019) estimated that microplastic consumption and inhalation could range from 74000 to 121000 particles annually. WWF also reported this year an assessment with the collaboration of the University of Newcastle, suggesting that an average person could be consuming nearly 5 g of plastic every week (Wit and Bigaud, 2019).

Although the lack of knowledge, there are a few studies performed in human and mammals' cells. For example, human brain and epithelial cultures were exposed to PS microbeads and those presented a higher generation of reactive oxygen species (Schirinzi et al., 2017). Other studies proposed that MPs can cause inflammation, genotoxicity, neurotoxicity, apoptosis, and necrosis in human cells (Wang et al., 2019; Wright and Kelly, 2017). So, in the next few years, it's expected that the scientific community comprehends and understands the processes and mechanisms of the introduction and assimilation of this micro debris in the human organism and its ecotoxicological effects (Wang et al., 2019).

2.5. – MPs contamination in South America

Among the factors that contribute for MPs contamination in the environment, especially, population density, industrialization, low level of wastewater treatment and waste management plus poor development of environmental education (Ziajahromi et al., 2016), make South America a potential continent with high loads of MPs to the environment. MPs contamination have been reported in South America, and its abundance is higher in east coast (Shahul Hamid et al., 2018), specially due to highly populated and industrialized coast and, where the rivers run to the western tropical and sub-tropical, being associated as well with poor river basin management (Costa et al. 2015). In the case of the West coast, low abundance might have due to the dynamic nature of the East Pacific Ocean and by its less population density (Shahul Hamid et al., 2018).

But focussing on the East side coast, they are contaminated with different amounts and MPs types (Costa and Barletta, 2015). Especially in Brazil, there are some reports related to MPs contamination in bays and ocean coast. In Guanabara Bay (Rio de Janeiro) reported an amount of 12-1300 MPs.m^{-2} with a variety of MPs types (Neto and Carvalho, 2016). In Boa Viagem beach (Recife) it was done an investigation to understand the influence of geological protected zones as sinks of MPs which reported a significant difference between protected and unprotected zones, being the protected zones having a concentration of 642.6 ± 514.8 MPs.m^{-2} (Pinheiro et al., 2019).

Even though the existing works in South America, there is a need to assess MPs contamination and establish future regulation in this continent.

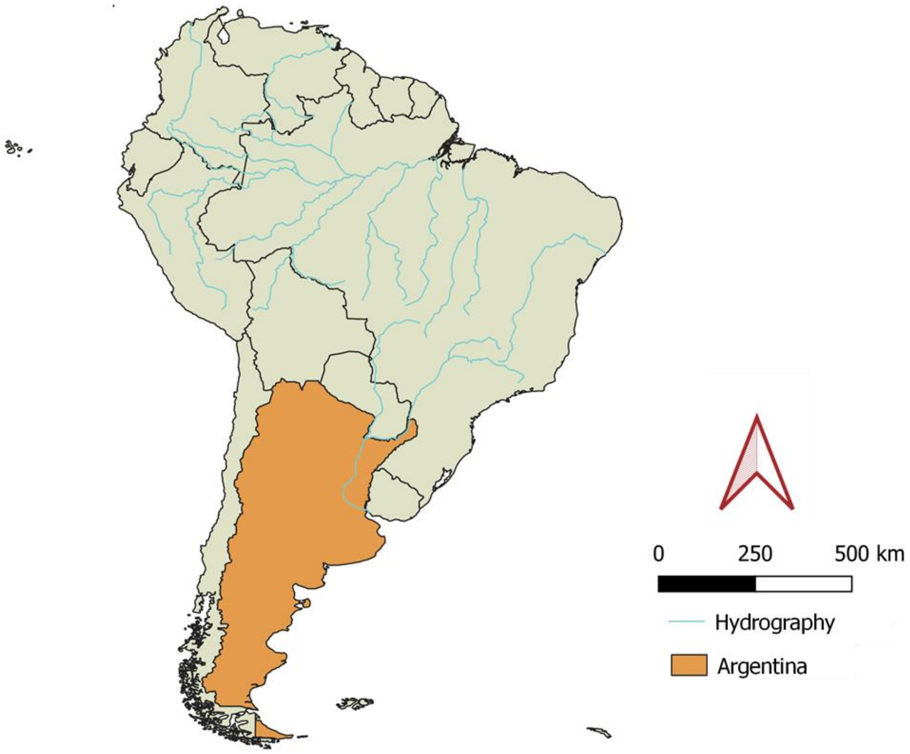


Figure 3 - South America map, with Argentina represented as orange and the blue lines represent the most important rivers in the continent

2.5.1. Argentina

Argentina is a country with a population of more than 40 million people, being around 39% concentrated in Buenos Aires Province (Instituto Geografico Nacional (AR), 2019). It has one of the largest estuaries of South America, Río de la Plata, which is highly exposed to human activities, urbanized areas, sewage dischargers and plastic pollution (Carman et al., 2015).

Rivers, such Luján and Riachuelo, and channel such Sarandi and Santo Domingo, plus the sewage effluent steaming from Buenos Aires city, are considered the sources of more than 80% of total pollution that receives Argentinean coast of Rio de la Plata (Pazos et al., 2018) and it is drained to the Atlantic Ocean.

The Argentinian Atlantic Coast has 4725 Km (Instituto Geografico Nacional (AR), 2019) with a high potential of being a sink and source of MPs. According to Ocean Conservacy clean-up data (2018) that were obtained in Argentine coast, the major type of trash found was Plastic Bags (30.37%), beverage bottles (11.9%) and food wrappers (10.14%), which could become a relevant source of a secondary type of MPs to the environment.

Concerning MP contamination in Argentina, there are few published reports, but research has been done in this area. The report with higher relevance was elaborated by Pazos et al. in 2018, which quantified the amount of MPs in Río de la Plata, achieving a concentration of 164 and 114 MPs.m^{-3} on surface water.

2.6.– Objectives

The general objective of this thesis is to investigate the abundance and type of the PMPs existing in beach sediments (Villa Gesell, Sink) and to understand the input of PMPs that can be released to the environment from a WWTP (Source).

In the case of beach sediments, the specific objectives are to explore the relationship between the amount of MPs with (1) the anthropogenic level of the beach, (2) wracklines (3) sand organic matter and (4) sand granulometry.

In the case of WWTP the study aimed to: (1) assess the efficiency of MPs removal in each treatment step and (2) provide the number of MPs released daily to the environment.

The development of the above mentioned case studies will contribute for a better understanding of the dimension of this problem, especially in a perspective of examples of source and a sink, moved by the importance of this information to stakeholders, to the encouragement of change in population´s habits and to help the future development of strategies to eliminate this contaminant.

3. METHODOLOGY

3.1. – Beach sediments – Villa Gesell

3.1.1.– Study area

The sample collection was performed in three different beaches in Villa Gesell (Figure 4), placed along the south-eastern Atlantic shoreline, belonging to Buenos Aires Province (Juárez and Isla, 1999). It occupies an extension of more than 20 km of the Atlantic coast and it's known for being a touristic summer place (Juárez and Isla, 1999). The selected beaches have different anthropogenic load, based in human access and influx : The less disturbed beach is located close to "Chacras del Mar" in Mar Azul (Zone A); The zone with an intermediate anthropogenic load is close to the "Soleado" beach in Mar de las Pampas (Zone B); And finally the most disturbed beach is located between the streets 105 and 110 in Villa Gesell town (Zone C).

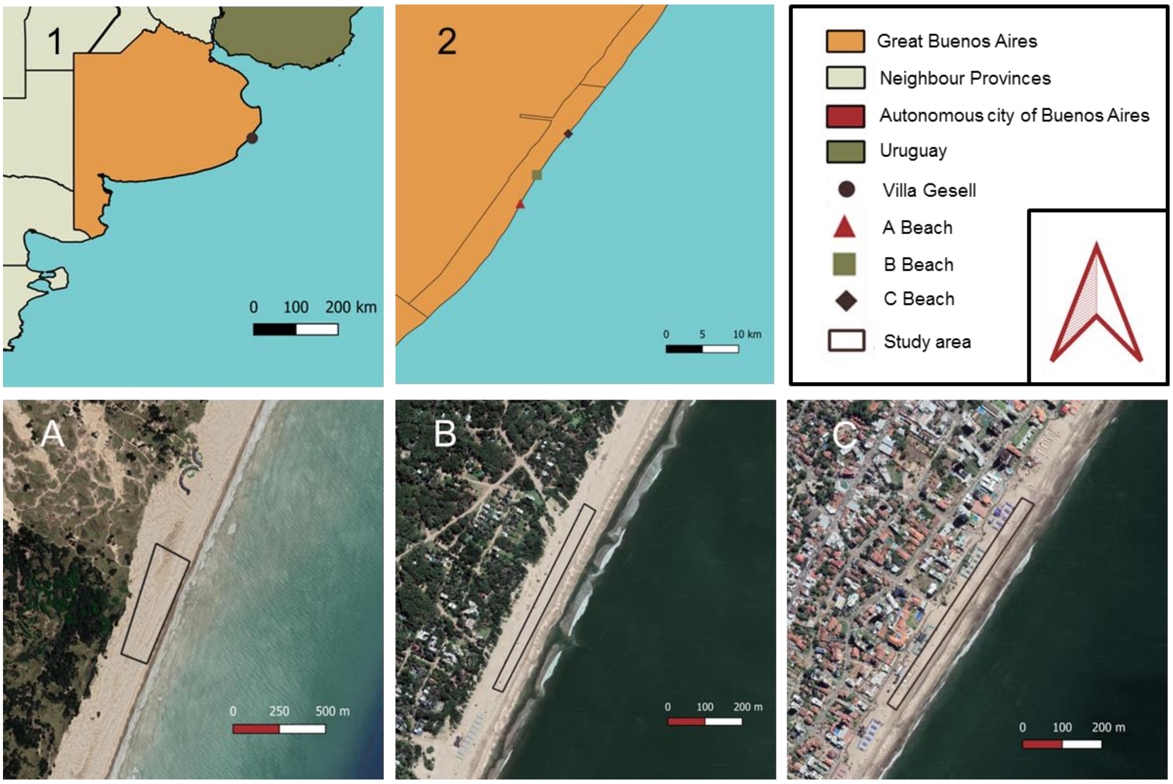


Figure 4 – The study area; 1: Map of Great Buenos Aires, showing the location of Villa Gesell (●); 2: Map of Municipality of Villa Gesell and sampling locations, A Beach (▲), B Beach (■) and C Beach (♦); A, B and C are Satellite Images (Provided by Google Satellite) and delimitated sampling area for A, B, and C Beach respectively.

3.1.2. - Sample collection

Sediment sampling was performed on February 11th and 12th of 2018 (a high tourism influx moment) on sandy beaches of Villa Gesell. For each beach, three wracklines were selected: “Base” zone, the line from last tide (B); “High” zone, in the dune line (H); and “Medium” zone (M), a line at the average distance between the previous sites. For each zone, six spots were pointed that were located at every 100 meters, covering a total of 600 meters.

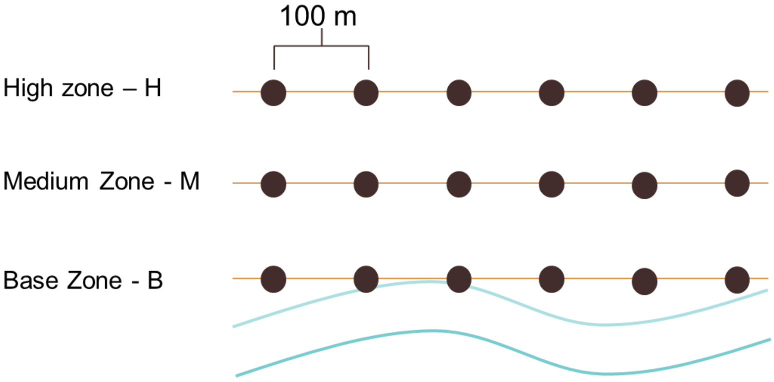


Figure 5 – Sampling transect scheme performed in each beach.

Core sampling was performed, using a metal cylinder with a Ø= 7 cm and 12 cm of depth (volume ≈ 4.62x 10^{-4} m^3), from the surface to the depth. The samples were stored in glass jars and then dried.

3.1.3.- Sample processing

Before processing, a small amount of some samples was weight to measure volatile solid content in a muffle furnace.

The dry samples (300 to ~700 g of sample) were digested with a solution (V=300-600 mL) of 20% Hydrogen Peroxide (H_2O_2), with an exposure time of 18 h. This reagent was chosen because it is widely used in microplastic research and it is an efficient oxidizer to remove organic matter that could interfere with the experiment (Stock et al., 2019b). The supernatant was transferred to a clean Erlenmeyer to be filtrated later.

For MPs extraction, a filtered table salt-saturated solution (~1.2 $g.cm^{-3}$) was used, allowing only the extraction of lower density MP particles. The solution was added to the sand and then the Erlenmeyer was stirred manually for 30 seconds, to ensure that MPs could be detached from the matrix and then it was let to settle for more than 1 hour. The supernatant was transferred to a clean separatory funnel (Figure 6). This procedure was repeated for 3 times.

Figure 6 - Separatory funnel for supernatant extraction

After extraction and filtration process, the resulted sand samples were dried and the grain size was analysed by sieving, using five distinct size meshes: 2 mm, 1mm, 0.5 mm, 0.380 mm, 0.125 mm. The fractions of each grain size were weighed.

3.1.4.- Sample Filtration

The supernatant resulted from the density separation and the supernatant from the digestion process were filtered using a glass vacuum filtration apparatus, through a 0.5 µm glass fiber filter (Ø47mm, Microclar), and all the material was rinsed for several times with filtered distilled water in order to remove any particle attached to the glass and the salt crystals. The filters were stored in closed glass Petri dishes and dried at room temperature for about 24h. It was filtrated a total of 37 samples plus 6 procedural blanks.

The glass apparatus used in this thesis is presented in Figure 7.

Figure 7 - Glass filtration apparatus

3.2. – COMACO WWTP

3.2.1.– Study Area

COMACO is a cooperative established in 1970 which is responsible for the water distribution and wastewater treatment for Martín Coronado town and some part of “Ciudad Jardín in Lomas del Palomar”. COMACO is in “Martín Coronado”, which belongs to “Tres de Febrero” division, on the west side of Great Buenos Aires.

This WWTP serves a population of approximately 35000 inhabitants, receives an average of 250-300 m^3h^{-1} and discharges 240 m^3 of treated wastewater per hour. The treatment layout (Figure 8) includes a lagoon system, responsible for 65% of the treatment in the plant. This treatment line includes a coarse screening, followed by primary settling treatment and then the lagoon. It has a retention time of 23h and has a capacity of 8400m^3.

The alternative route, in which the remaining 35% is treated consists in coarse screening, followed by primary settling treatment and pass through a percolator. After is directed to a secondary settling treatment and disinfection.

The sludge is provided by the solids that deposited in primary and secondary settling tanks. After air drying, the sludge is deposited in a landfill.

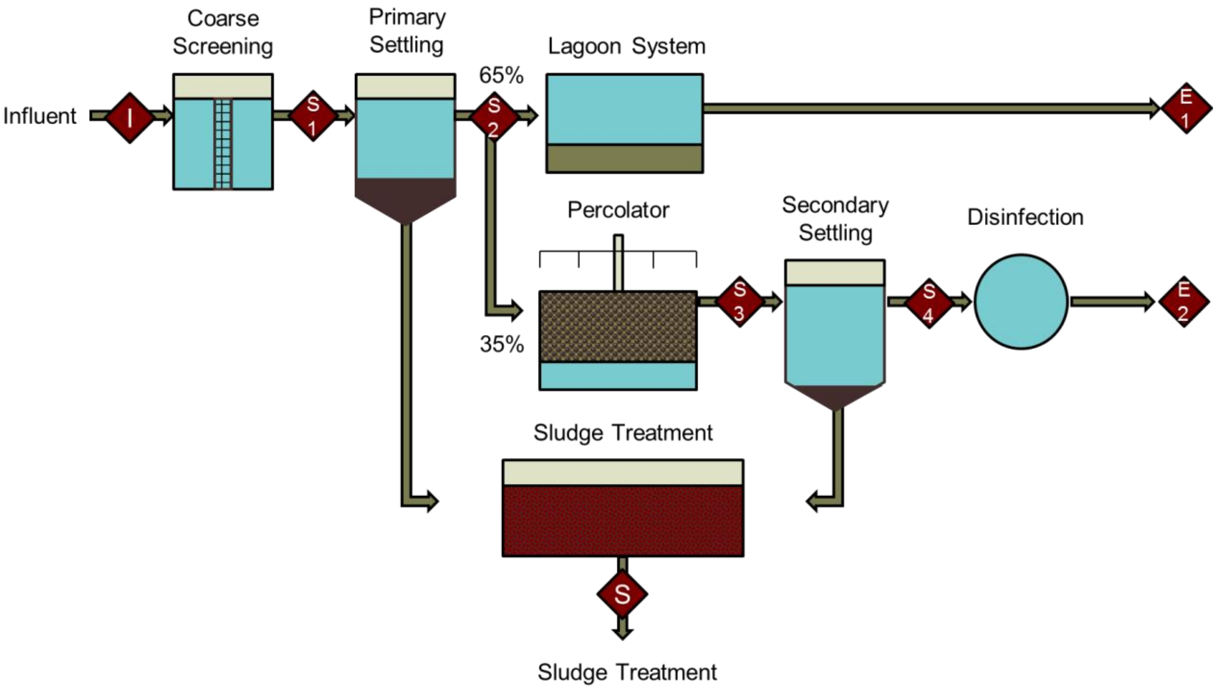


Figure 8 - WWTP layout with sampling points (♦)

3.2.2.– Sample Collection

Samples were taken in every stage of the treatment process shown in Figure 8, in 10th of May 2019:

I - Influent;

S1 – Influent after the 3 mm coarse screening – Effluent after the elimination of high dimension material, especially non-biodegradable materials;

S2 – Primary Settling Effluent – Effluent after the sedimentation of suspended solids of the effluent;

S3 – Percolator Effluent – Effluent after the biological treatment, which consists of the oxidation of the dissolved solids, to form a more stable effluent;

S4- Secondary Settling Effluent – Effluent after the sedimentation of suspended solids formed by the biological treatment;

E1 – Final Effluent after settling in a lagoon system;

E2 – Final Effluent after disinfection, to provide residual water without any type of microorganisms that could affect the watercourses;

S – Sludge.

Approximately 400 mL of wastewater and sludge were taken in triplicate and stored in clean glass jars. The samples were frozen until its use.

3.2.3.– Sample Processing

Initially, a larger quantity was processed, either for water and sludge samples, but due to practical constraints, with such a high number of particles to quantify, then homogeneous subsample of 50-150 mL of wastewater and 2.5-5 g of dry sludge were used.

3.2.3.1. – Wastewater

Samples with a volume of 50 to 150 mL were poured in clean Erlenmeyer and digested with 25% (v/v) H_2O_2 for 18h.

3.2.3.2. - Sludge

Initially, sludge samples were dried and determined its total solids, and an amount of sample was burnt in muffle to determine its volatile solid content (Environmental Protection Agency, 2001). To homogenize the dried sample a metal mortar was used. After several trials with other methodologies, which led to an organic matter highly saturated filter (Interfering with optical classification), it was used an adaptation of Liu et al. (2019) protocol for MP extraction. 2.5-5 g of the sample by triplicated were mixture with 20 mL of filtered distilled water and transferred to a water-bath (50ºC) for 5 hours. The samples were let rest for 2h and the supernatant was transferred into a clean Erlenmeyer. The remaining sludge was mixed with filtered table salt-saturated solution (~1.2 g cm^{-3}) to extract MPs. It was stirred manually for 30 seconds, then settled for more than 1 hour and the supernatant was transferred to an Erlenmeyer.

This procedure was repeated three times. The collected supernatant was digested with H_2O_2 for 18h until reaching a final concentration of 25% (v/v).

3.2.4.– Sample filtration

The supernatant resulting from the digestion process of dried sludge was filtered using a glass vacuum filtration apparatus, through a 0.5 μm glass fiber filter (Ø47mm, Microclar), and then all the material was rinsed for several times with filtered distilled water in order to remove any particle attached to the glass and the salt crystals. The wastewater samples were directly filtered after digestion and rinsed several times with filtered distilled water. The filters were stored in closed glass Petri dishes and dried at room temperature for about 24h. It was filtrated a total of 25 samples plus 3 procedural blanks.

3.3. – MPs identification

MPs were identified optically, using a microscope OLYMPUS CH-series engaged with external light, using a magnification lens of 40x for sediment samples and 100x for wastewater and sludge samples.

For MPs optical identification, the following criteria were used (Barrows et al., 2017; Chubarenko et al., 2018; Norén, 2007):

- No cellular or organic structures are visible;
- Fibers are equally thick throughout their entire length and should not be tapered at the end;
- Colored particles are homogenously colored;
- Fibers are not segmented, or appear as twisted flat ribbons;
- In case of doubt, a hot needle was used and approached to the particle, if it “wiggles” a bit or melt, then it is a potential MP;
- The MPs were identified according to its shape (Fibre, Fragment, Bead, Thin Film, and Foam) and color.

Since these particles were not chemically identified, the term potential MP (PMPs) is applied. The particles were photographed with the aid of the stereomicroscope LABOMED Luxeo 4D and the Microscope Olympus AmScope CX31.

3.4. – Contamination control

Due to the possibility of sample contamination, some precaution measures were taken. A cotton lab coat was obligatorily used, and cotton or natural fiber clothes were used as much as possible. All glass material was thoroughly rinsed with filtered distilled water and covered with aluminium foil between uses to minimize air exposure.

It was not possible to proceed with the experiment in an isolated laboratory, but along with the previous measures, procedural blanks, using a paper filter, were done along any batch preformed. It was performed six procedural blanks along with PMPs sediment analysis and three along with wastewater and sludge samples batch.

The results are presented in the Appendix 6 and Appendix 15.

3.5. – Statistical Analysis

Average data is represented by mean value ± standard deviation.

For Villa Gesell samples, to understand the variations in PMPs distribution among the three different beaches, one-way ANOVA was performed under a level of statistical significance of $\alpha=0.05$. The same was performed to understand the variations between the PMPs distribution among the wracklines in each beach. Two-way ANOVA was performed to understand if there is some relationship between the factors “Beach” and respective “Wracklines”, under a level of statistical significance of $\alpha=0.05$.

In WWTP samples, to evaluate the differences in the amounts of PMPs in each treatment step, one-way ANOVA analysis of variance with the level of statistical significance of $\alpha=0.05$ was performed.

Before carrying out the statistical analyses mentioned above, Kolmogorov–Smirnoff test was performed to evaluate the normal distribution and the Levene's test ($\alpha=0.05$) to assess the homogeneity of variances. All statistical analyses were carried out using the Microsoft Excel software 2019 version.

3.6. – Method Limitations

As referred in bibliographic research, the lack of standard methods may result in incomparable data. For example, the use of different extraction solutions for solids matrixes may underestimate the number of MPs extracted.

In the protocol adopted in this work density separation using Sodium Chloride (NaCl) was chosen, which is included in the list of recommended extraction solutions by Frias et al. (2018), for being low cost and not hazardous. Table 1 lists the plastic types that can be separated according to its density by NaCl (marked with "+"). If observed the Argentinean plastic demand data from 2012, this separation can cover more than 70% of the polymer type demand.

Table 1 - Separation of polymer type by NaCl (Costa et al., 2019) and Argentinean plastic demand (Plast Europe, 2012)

Polymer Type	**Density (g cm^{-3})**	**NaCl 1.2 g cm^{-3}**	**Argentinean Plastic Demand % (2012)**
PP	0.9-0.91	+	20.6
PE	0.92-0.97	+	43.1
PA	1.02 – 1.05	+	n.d.
PS	1.04-1.1	+	5.8
Acrylic	1.09-1.20	+	n.d.
PMA – Polymethyl acrylate	1.17-1.20	+	n.d.
PU	1.2	+	n.d.
PVC	1.16-1.58	+/-	14.6
PVA -Polyvinyl alcohol	1.19-1.31	+/-	n.d.
Alkyd	1.24-2.3	-	n.d.
PET	1.37-1.45	-	15.9
POM - Polyoxymethylene	1.41-1.61	-	n.d.

However, the classification method by optical identification has as well some limitations and it is widely discussed in methodology reviews. Visual sorting is considered a subjective method, which varies with the individual visual perception, experience, and level of fatigue (Prata et al., 2019). The characteristics of the particles found can lead to underestimation, such as white fragments can be classified as sediment, or overestimation, for example, some biologic material can be confused for black fragments (Prata et al., 2019). MPs recovery can be influenced by their color, for example, yellow, pink, red, orange and transparent have low recovery percentages, as they can be mistaken as biological particles and sediments (Hanvey et al., 2017).

4. RESULTS

4.1 – Villa Gesell Beach Sediments

For this data analysis, PMPs results were extrapolated for PMPs per Kg^{-1} of dry sand for better data comparison with other studies.

A total of 41 samples were analysed and a total of 2419 PMPs were found. The most common PMPs found to belong to the category of Fibers (65.2%). Only beach A had a higher amount of fragments, 38.3%, followed by 25.3% of fibers. The remaining beaches B and C presented a higher amount of fibers with 76.1% and 70.3% respectively (Figure 9).

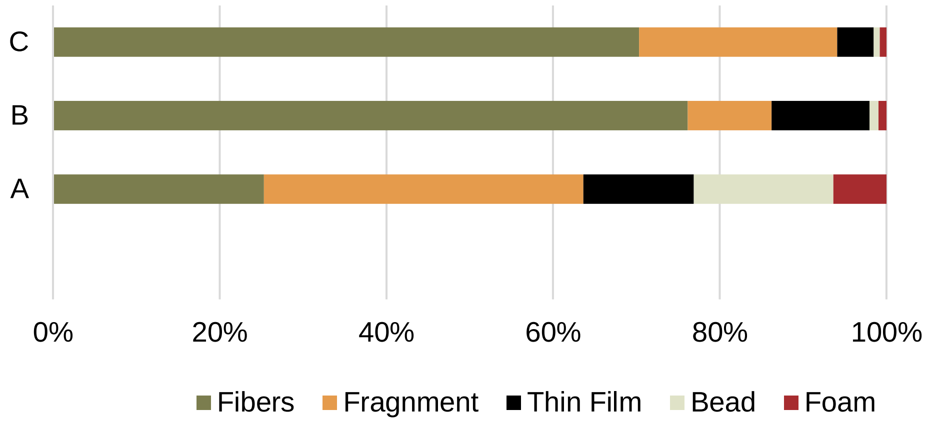


Figure 9 - Bar plot of the relative abundance average type of the PMPs found, expressed in percentage, for each beach sampled

The largest number of PMPs were found in samples from beach B, wrack high line and beach C wrack base line, presenting an amount of 851.7 and 1132.6 PMPs.Kg^{-1} dry sand, respectively. These samples were considered as an "outlier" since they present a high amount of PMPs comparatively with the other samples, especially these had a high number of transparent fibers. These samples were not considered in the next statistics.

In every beach the most found color in all samples was transparent (A- 29.4%; B-42.78%; C-33.39%), due to the presence of fibers and fragments. Following these uncolored particles, blue and pink are common, having a relative amount of 20.59% and 7.84% for beach A, 16.58% and 14.71% for beach B and 21.68% and 7.49% for beach C, respectively.

Figure 10 shows some examples of the particles found in sediment samples.

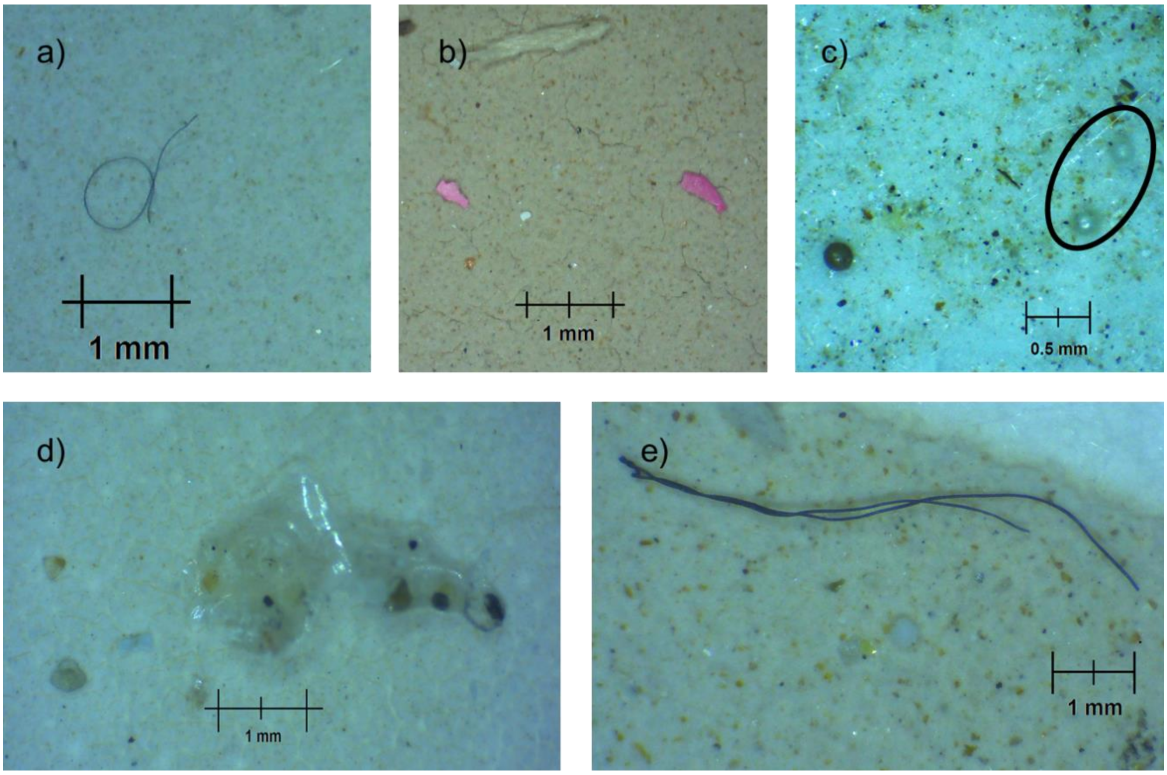


Figure 10 - Example of PMPs found in sediment samples: a) Blue fiber (C Beach); b) Pink fragments (B Beach); c) The microbeads: one brown and two transparent -Oval Black circle(A Beach); d) Transparent thin film (C Beach); e) Two black Fibers (A Beach)

The A Beach presented an overall PMPs average of 46.0 ± 34.8 (SD), B Beach with 61.33 ± 44.80 and C Beach with 86.20 ± 66.10 PMPs.Kg^{-1} dry sand. There was not a significant difference between the PMPs in the different beaches.

Figure 11 presents the distribution of PMPs along each wrackline. At each beach, the comparison between line positions and PMPs, shows no significant differences (p>0.05).

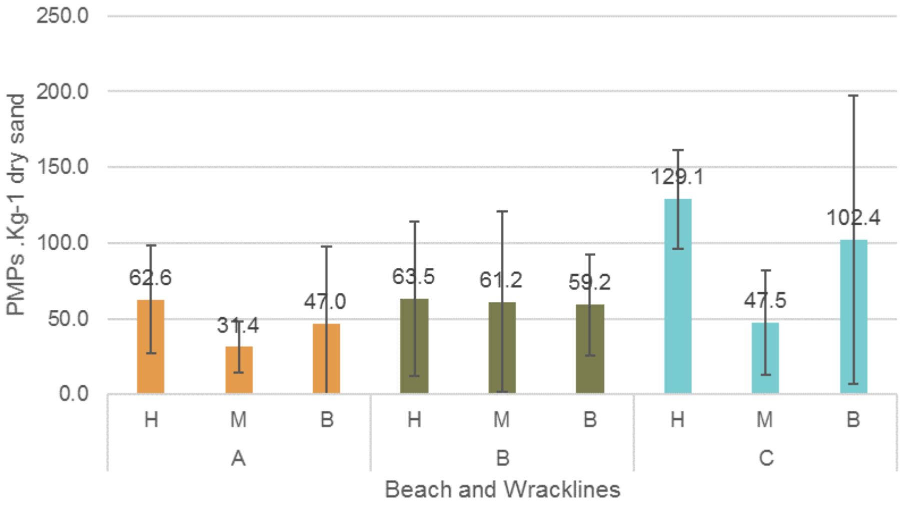


Figure 11 - Bar plot of the average (numbers) of PMPs.Kg^{-1} Dry sand at each beach sampled and from each position, ""Base" zone (B); "High" zone (H); and "Medium" zone (M). (error bars = standard deviation).

To evaluate the relationship between the number of MPs with the anthropic level of the beach and wracklines, ANOVA with 2 factors was performed. Evaluating the interference between the factors “Beach” and “Wrackline”, there is no interaction from the “Beach” factor that could influence the “Wrackline” factor ($p=0.55$).

The sediment grain sizes and organic matter content were examined to see if there was a relationship to the amount of PMPs, and no significant correlations were found. All the data is presented in Appendix 4 and 5.

Although it was an effort to minimize airborne exposure, when this was not possible, the procedural blank filter was done. In background contamination only fibers and fragments appeared (Appendix 6), presenting 3.0 ± 0.9 PMPs. The samples presenting less than 2 PMPs.kg^{-1} had PMPs types that were not found in the procedural blanks, such as beads, thin films, and foam.

4.2 – COMACO Wastewater treatment plant

For this data analysis, wastewater results were extrapolated for PMPs per L, and sludge for PMPs per kg^{-1} of dry mass, to allow data comparison with other studies.

The WWTP, as described in the methodology chapter, has 2 treatment routes. For both routes, the influent sample, I, contained an average of 12587 ± 3073 PMPs L^{-1} The lagoon system system route treats 65% of the daily influent and comprised steps of I, S1, S2, and E1. Figure 12 is presenting the average amount of PMPs in each treatment step.

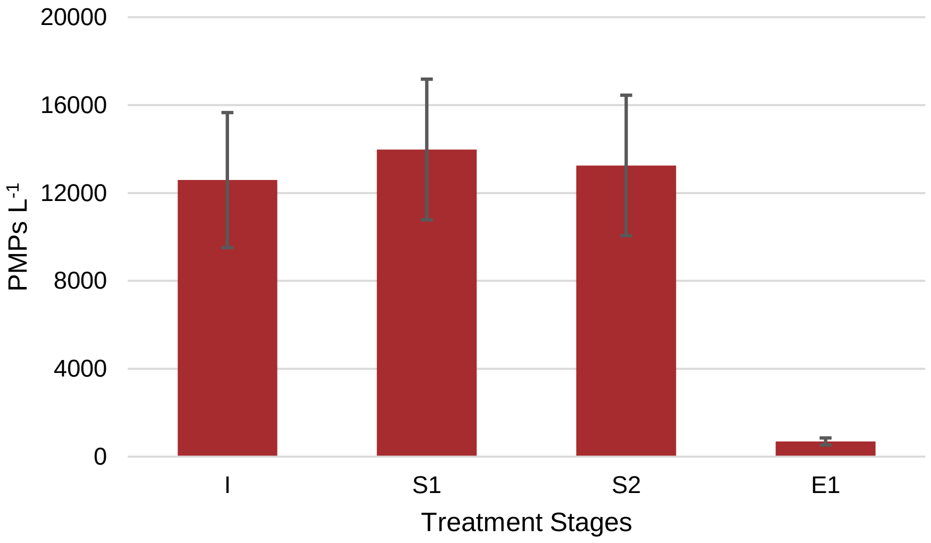


Figure 12 - Bar plot of the number of potential microplastic PMPs.L^{-1} at each liquid fraction site sampled from the main treatment route (error bars = standard deviation).

It can be observed that in this main treatment route that E1 has less 94.5% PMPs comparing with the influent concentration. No significant difference in PMPs concentration between the treatment steps I, S1, S2 (p=0.86).

Figure 13 presents the average amount of PMPs after each treatment step of the second treatment route. PMPs amount in E2 is 3237.8 ± 1752.3 PMPs L^{-1} achieving a reduction of 74.3%, comparing with the influent amount. The PMPs amount was reduced significantly after step S4 (Secondary Settling). No significant difference in PMPs concentration between the treatment steps I, S1, S2 and S3 (p=0.96). In treatment step S4 and Final effluent E2, which finishes with chlorination, there is not a significant difference between PMPs amount (p=0.6).

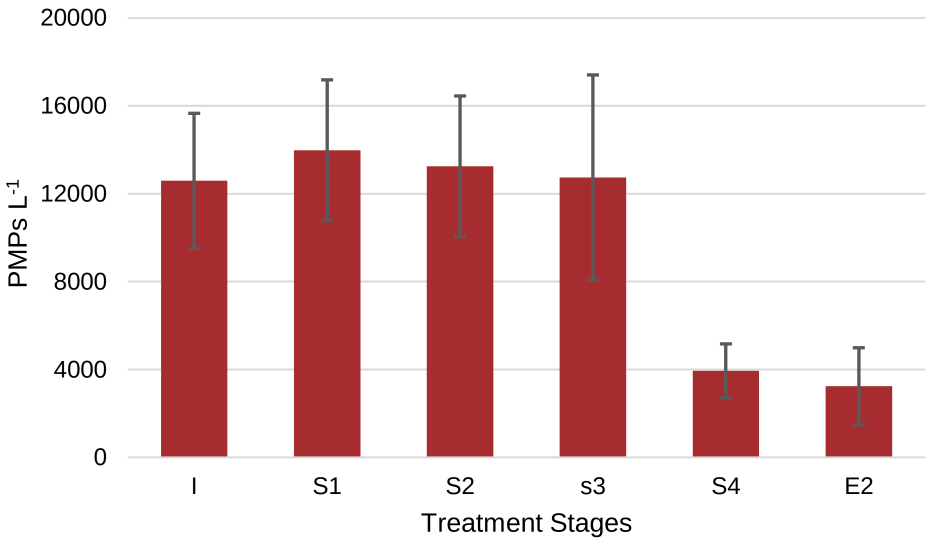


Figure 13 - Bar plot of the number of potential microplastic PMPs.L^{-1} at each liquid fraction site sampled from the second treatment route (error bars = standard deviation).

This WWTP discharges an average of 240 m^3.h^{-1}, so it is estimated that per hour an amount of 1.08x10^8 PMPs from E1 plus 2.72x10^8 PMPs from E2 can be released, reaching a total of 9.11x10^9 PMPs released to the environment every day.

Regarding sludge samples, average water content was 75.33 ± 2.38% and average volatile solids content was 43.86 ± 3.17%. The average PMPs content in dry sludge is 2.74x10^5 ± 2.95x10^5 PMPs kg^{-1}, reporting 6.76x10^4 ± 7.28x10^4 PMPs kg^{-1} of wet sludge, which destination is landfill deposition.

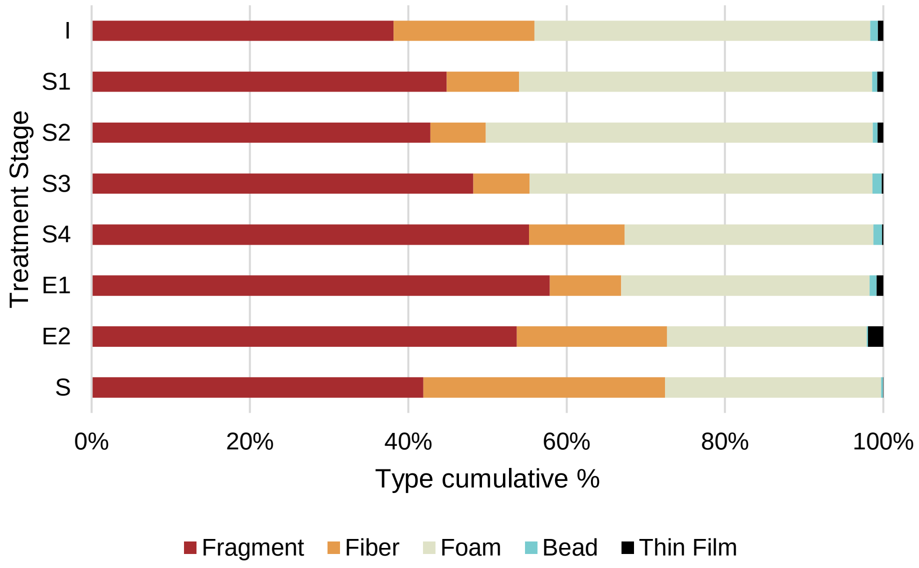


Figure 14 - Bar plot of the average type of the PMPs found, expressed in percentage, for each treatment stage sampled

The PMPs were visually classified by type. Observing Figure 14, the most frequent PMPs in all treatment steps is Fragments (38.14 to 57.9%), followed by potential Foam (Figure 15) with 25.2 to 48.86%. Fibers were 7.0 to 30.5%. In lower frequency, beads and thin films were also quantified.

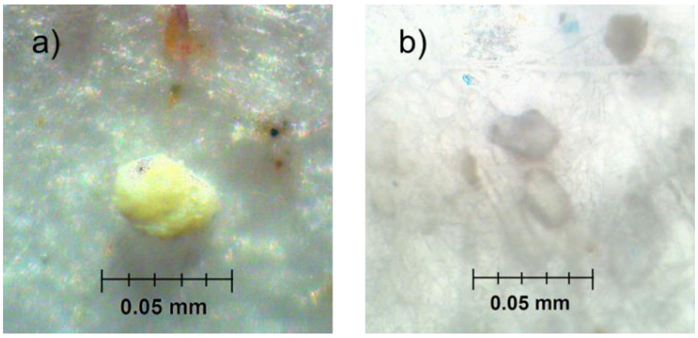


Figure 15 - Examples of potential foam

During the observation, it was found a great amount of smaller microplastics. Although it was not possible to perform a size classification, a category of PMPs < 0.01 mm was created, only based on visual observation and approximated size and characteristics. Figure 16 a), b) and d) show some examples of PMPs included in this size class. From all the PMPs counted, this fraction corresponds to 36.8%. The influent sample presented 28.76 ± 5.8% and the effluent sample E1 presented 52.68 ± 13.86% and E2 48.04 ± 3.14%. There is a significant difference between the amount of smaller PMPs in I and E1 (p=0.007) but in the case of I and E2 the p-value was slightly higher than the significance level of 0.05, p=0.051.

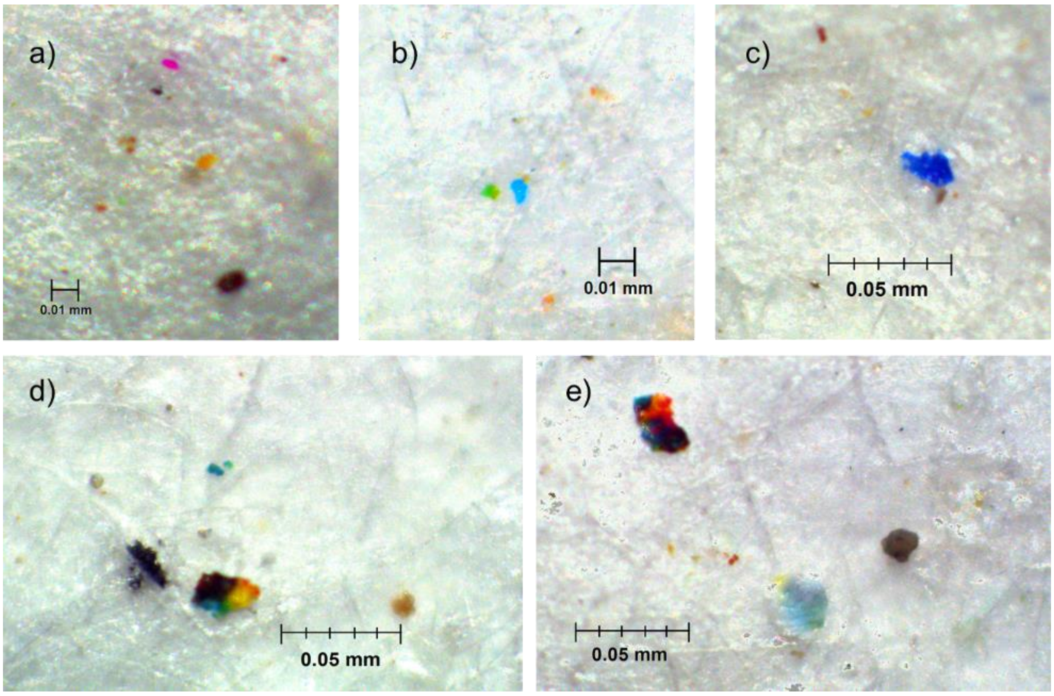


Figure 16 - Examples of found fragments in wastewater samples

From all the PMPs visually identified, the most common color found was white, with 37.32%, due to the high amount of potential foam identified, followed by blue with 29.01%, and by red and pink with 9.91% and 8.14% respectively.

Other colors were identified as well, such as yellow, black, green, colorful and others. The term colorful was applied when a PMPs with more than one color was identified, presented in Figure 16 d) and e).

In terms of possible contamination, the procedural blanks done along with any batch were not significant due to the high quantity of PMPs found in the samples. All data is presented in the Appendix chapter.

5. DISCUSSION

5.1.- Villa Gesell Beach sediments

In the last century, plastics came to change people’s lifestyle but this invention presents an important environmental concern (Hanvey et al., 2017). Being some of them imperceptible to the human eye, sometimes it is not possible to assess with clarity the concentration of this contaminant everywhere.

In this study, three beaches from Villa Gesell were investigated, each one representing different anthropogenic loads, crescent from Beach A to C, being C a touristic and accessible beach. There was high heterogeneity between the amount of PMPs in the 41 samples analysed, ranging from 1.36 to 1132.57 PMPs.Kg^{-1} Dry sand. The samples with a high number of PMPs, presented a high number of transparent fibers and were considered as outliers, that do not appear to be cellulose fibers as those have a higher density (1.5 g.cm^{3}) (Lares et al., 2018) than the NaCl used for density extraction (≈1.2 g.cm^{3}).

From all PMPs detected, the majority were fibers, the same type that is presented in the studies of Alomar et al. (2016), Abidli et al., (2018) and Alves and Figueiredo (2019). This was the most abundant type in B and C beaches. This suggests that these microfibers could be from local sewage discharges (Alomar et al., 2016) since they are more close to the urbanized areas. The presence of a high amount of fibers in the marine environment is a concern since it could enhance the biomagnification and bioaccumulation through the trophic chain by ingestion (Perez-Venegas et al., 2018). At last, most of the PMPs found are classified as secondary PMPs, presenting a global high percentage comparing with primary PMPs such as microbeads.

Even though the most common color identified in all beaches was transparent, that was probably provided by clear plastic from packaging, fishing lines and clothing (Cole et al., 2014). Colors such as blue and pink were common to find in these beaches, due to its distinctive color comparing with biological material, presenting a high optical recovery (Hanvey et al., 2017).

The quantification yielded on average 46.0 ± 34.7 for A beach, 61.3 ± 44.8 for B beach and finally 86.2 ± 66.1 PMPs.Kg^{-1} Dry sand for C beach. Comparing these values with the papers considered in this thesis (Table 2), all Beaches presented a low amount of PMPs, it still lower than what was found, for example in Guanabara Bay in Brazil. The concentration of MPs in the environment are extremely heterogeneous because it can vary with the season, industrial areas, ports, winds, currents and other natural phenomena (Antunes et al., 2018; Cauwenberghe et al., 2015b).

Table 2 - Studies detecting microplastic in beach sediments

Site	Method	Concentration	Dominant Type	Reference
Spain	Top layer (3.5 cm) from core sampler; Sieve separation; Distilled water extraction	0.90 ± 0.10 MPs.g^{-1}	Filaments	(Alomar et al., 2016)
Portugal	top 2–3 cm, 50x50 cm Squares. NaCl extraction	2-1964 MPs m^{-2}	Pellets	(Antunes et al., 2018)
Tunisia	top layer 2-3 cm, 0.25mx0.25m quadrats. NaCl Density separation.	141.20±25.98 and 461.25±29.74 MPs.Kg^{-1} dry sand	Fibers	(Abidli et al., 2018)
Argentina	**Core Sample Ø= 7x12 cm of depth; NaCl Density separation.**	**A-** 46.0 **± 34.7** **B- 61.3 ± 44.8** **C- 86.2 ± 66.1** MPs.Kg^{-1} dry sand	**A-Fragments** **B- Fibers** **C-Fibers**	**This study**
Brazil, Guanabara Bay	5 cm of top layer; NaCl Density separation	528 ± 30 MPs.Kg^{-1} dry sand	Fiber	(Alves and Figueiredo, 2019)

The progress in MPs scientific research leads to more standardized methodologies, but sometimes, comparison between studies can be difficult. In the studies considered in this thesis, the most common method used was with core or quadrat sampling, which only explore until 5 cm. Carson *et al.* (2011) studied how MPs can be distributed along with sediment depth and 50% of all MPs were in the 5 cm of the top layer and 95% in the 15 cm top. It could be possible that the results of this study might be much lower compared with the ones showed in Table 2.

PMPs contamination is not significantly different between the three different beaches, the same fact was mentioned in "Snapshot of microplastics in the coastal areas of the Mediterranean Sea" (Martellini et al., 2018) and happened in the studies by Laglbauer *et al.* (2014) and Herrera *et al.* (2018), performed in Slovenia and in Canary Island in Spain respectively. This could be one more evidence that the PMPs distribution may be more influenced by coastal morphodynamics (Pinheiro et al., 2019) and also currents, tides and winds (Hanvey et al., 2017) and also geological structures such as beach rocks providing in this case a higher rate of MPs accumulation in coastal beaches (Pinheiro et al., 2019).

Even though there is an evidence that samples can be distinguished by environmental locations, tidal (B), intertidal (H) and costal (H) zones (Stock et al., 2019b), some studies do not show any significant difference between beach lines (Dekiff et al., 2014) as in this study.

As Alves and Figueiredo (2019) reported, no significant correlations were found between the PMPs concentration and the sediment grain sizes and organic matter contents.

The contamination control is shown in the Appendix chapter and the number is much less than 10% of the overall PMPs found, this is a percentage recommended by Lusher *et al.* (2015) as a good indicator of contamination control.

5.2.– COMACO Wastewater Treatment Plant

This study shows how a WWTP can contribute to the discharge of a great amount of PMPs to the environment, even if the WWTP presents high removal efficiency (94.5% and 74.3%). Therefore, the WWTP studied is an important source of PMPs.

All samples presented a high amount of PMPs leading to difficulties in filters analysis and for that, it was necessary to decrease the volume of the sample analysed. The influent presented an estimated concentration of 12587±3073 PMPs.L^{-1}, much higher than most of the results from the papers considered in this thesis. Only in a recent study in South Korea, a high concentration of MPs was found in one of the WWTP studied, achieving an amount of 31400 MPs.L^{-1}. In both treatment routes, the majority of the PMPs found were fragments, but in this last case from Korea, most MPs found were Microbeads. Other studies considered in this thesis, in Table 3, presented a low concentration of MPs, from 2.5 to 26.56 MPs.L^{-1}, and in these studies was used the sieving method, which can lead to underestimation, because only MPs > 65 μm were considered. The removal efficiency of the WWTP under study is in accordance with other authors (Table 3).

Regarding the PMPs assessment along with the treatment steps, no significant difference was found between the Influent and the steps S1, S2, S3, so probably these steps may not contribute to PMPs removal. However, according with the lower PMPs concentration, it is suggested that the secondary decanter tank (S4) and the lagoon system (E1) may contribute to the PMPs removal. Since this plant does not use any type of flocculant, the PMPs are removed by physical sedimentation.

The first case is likely that in the percolator, which occurs biological oxidation, biofouling may occur, contributing for easy sedimentation in the next step S4 (Sun et al., 2019). The effluent from the last step of the second route, E2, does not differ significantly from the results from S4, indicating that the step of chlorination does not contribute to MPs removal. Although, Chlorination contributes to physical and chemical modifications in MPs, and in some plastic types can form chlorine-carbon bonds, which are known to increase toxicity (Kelkar et al., 2019).

In the lagoon system, the 23h retention time leads to sedimentation providing higher PMPs removal efficiency. Although, a monitorization campaign should be carried out to validate these assumptions.

It is estimated that this WWTP can discharge an amount of 9.11x10^{9} PMPs per day from the two treatment routes, reaching 3.33x10^{12} PMPs per year, being a considerable source of contamination of this ubiquitous type of pollutant.

Table 3 – Studies performed in WWTPs

Site	Method	Influent MPs.L^{-1}	Effluent MPs.L^{-1}	Removal rate	Dominant Type	Reference
Italy	Steel sieved - 5 mm, 2mm and 63 µm.	2.5±0.3	0.4±0.1	84%	73% Fibres	(Magni et al., 2019)
South Korea WWTP B and C	Direct sample filtration (Filter pore size - 1.2µm)	31400	297	99.1%,	70.4% Microbeads	(Hidayaturrahman and Lee, 2019)
		5840	66	98.9%	53.4% Fragments	
Argentina	**Direct sample filtration (Filter pore size – 0.5 µm)**	**12587± 3073**	**E1 -691.1 ± 161.9**	**-**	**Fragments 38.14-57.9 %.**	**This study**
			E2 - 3237.8 ± 1752.3	**-**		
Turkey	Mesh Filtration 65 µm	26.555 ± 3.175	6.999 ± 0.764	73 %	Fibres	(Gündo and Çevik, 2018)
China	Steel sieved 47µm	79.9	28.4	64.3%	Fibres and Fragments	(Liu et al., 2019)
Scotland	Steel sieved 65 µm	15.70 ± 5.20	0.25 ± 0.04	98.4%	Flakes 67.3%	(Murphy et al., 2016)

As the removal of MPs from the liquid phase leads to their accumulation in the sludge formed along with the treatment layout, this study also investigated the PMPs concentration in sludge samples. The sludge produced in the WWTP under study did not have direct application in agriculture, instead, it is landfilled, contributing to the contamination of the resulting leachates (He et al., 2019). The average PMPs content in dry sludge is $2.74 \times 10^5 \pm 2.95 \times 10^5$ PMPs.kg^{-1}, only considering PMPs with density lower than 1.2 g.cm^{-3} (Saturated salt solution).

Comparing with other studies (Table 4), this WWTP sludge presents a higher amount of PMPs, but that is related to the high input of PMPs that reach the WWTP. Different methodologies and pore filter size can affect the estimation of MPs.

Table 4 - Studies performed in WWTPs sludges.

Site	Method	Concentration MPs.Kg^{-1} dry sludge	Dominant Type	Reference
China	NaCl extraction, Filter (pore size 37 µm) and Digestion	1.60 - 56.4x10^{3}	63% Fibres	(Li et al., 2018)
Sweden	Sieved by 300 µm mesh	16.7±1.96 x10^{3}	72% Fibres	(Magnusson and Norén, 2014)
Argentina	**NaCl extraction, Digestion and Filter (pore size 0.5 µm)**	**2.74x10^{5} ± 2.95x10^{5}**	**41.9% Fragments**	**This study**
China	Centrifuging, NaCl and NaI extraction, Digestion and Filter (pore size 0.8 µm)	**2.403 ± 0.314 x 10^{5}**	**33.5-56.7% Fibers**	(Liu et al., 2019)

High variance in the results may be attributed to a lack of homogenization of MPs in the solid matrix and to possible underestimation PMPs visually identified. Even after the extraction and digestion process, a high amount of organic matter was present, providing a complex matrix that could lead to underestimation of the observed PMPs (Figure 17).

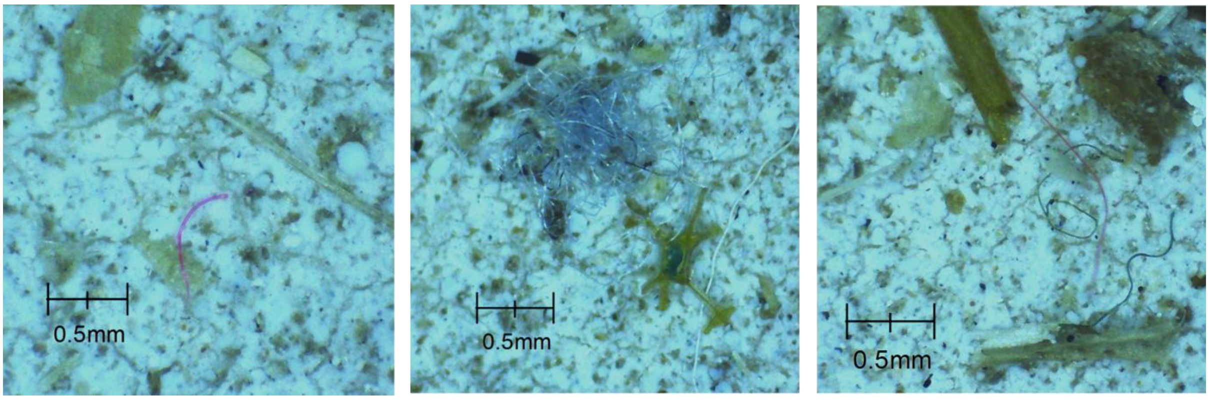


Figure 17 - PMPs founded in sludge samples and the complex matrix founded

Both wastewater and sludge samples presented a high number of fragments, resulting from the fragmentation of bigger plastic particles.

One of the most interesting findings in this study was the high amount of potential foam visually identified, being the second most frequent type of MPs found. In each filter, this potential foam had the same visual characteristics, specially the white ones. Some samples were tested with the hot needle method and melted immediately. It had the same visual characteristics comparing with a Styrofoam package. This could be investigated in the future, specially to understand if it’s provided by packages, which is frequently used in Argentina.

From the total PMPs, 36.8% correspond to smaller microplastics, with a size < 0.01 mm. Although it was not possible to perform a size classification of all samples, this result supports the importance of sampling procedures in WWTPs as some studies used sieve sampling which can underestimate the MPs extracted due the size of the sieve used.

Also, a significant difference between the amount of PMPs < 0.01 mm in Influent and Effluent was observed, which can suggest that the higher the size of PMPs, the higher is the probability of settling, although an appropriate monitorization should be carried out to analyse this question. Relative to the PMPs colors, besides the high amount of white PMPs classified as potential foam, the most common colors founded were blue, red and pink. To access a possible source of blue fragments, especially because they show similar aspects, it was asked if exists some blue pipes in the plant, but the answer was negative.

6. CONCLUSION

This thesis shows that Argentina is susceptible to PMPs deposition in beaches, along its Atlantic Coast and a releaser of PMPs into the aquatic environment.

The PMPs come from synthetic materials used in our daily life, such as clothing, packaging, personal care products, among others, presenting an alarming threat to the ecosystems.

The heterogeneity of samples found in Villa Gesell Beaches shows that the deposition is not related with human presence in those beaches, but with environmental factors, such as transportation from other sources of MPs with wind-wave action. Although the level of contamination found in this work is much lower than the ones obtained by other authors, it is still an alarming diagnosis since the MPs do not disappear from nature but persists for a long period of time.

Regarding the WWTPs samples, the level of contamination with PMPs is high when compared with other studies, and the discharge of treated wastewater should be taken in account as it can affect the aquatic ecosystems and contribute to the widespread of this micro debris. In a WWTP with low technology, the lagoon system treatment could reduce a relevant amount of PMPs, although they remained in the bottom, being accumulated every day. It is suggested by Sun *et al.* (2019) that performing surface skimming and/or using flocculating agents, may improve the MPs removal from wastewater and it could be a recommendation for this WWTP.

From a conservation point of view, these results have consequences for the ecosystems, affecting the biodiversity.

Future studies are needed to find solutions to develop technologies to eliminate from the environment of this persistent contaminant.

.

7. BIBLIOGRAPHY AND WEB SOURCES

Abel, A.D.S.M., Lau, C.W., Kloas, W., Bergmann, J., Bachelier, J.B., Faltin, E., Becker, R., Görlich, A.S., Rillig, M.C., 2019. Microplastics Can Change Soil Properties and A ff ect Plant Performance. Environ. Sci. Technol. 53, 6044–6052. https://doi.org/10.1021/acs.est.9b01339

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). Estuar. Coast. Shelf Sci. 205, 1–9. https://doi.org/10.1016/j.ecss.2018.03.006

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. https://doi.org/10.1016/j.marenvres.2016.01.005

Alves, V.E.N., Figueiredo, G.M., 2019. Microplastic in the sediments of a highly eutrophic tropical estuary. Mar. Pollut. Bull. 146, 326–335. https://doi.org/10.1016/j.marpolbul.2019.06.042

Anbumani, S., Kakkar, P., 2018. Ecotoxicological effects of microplastics on biota : a review. Environ. Sci. Pollut. Res. 25, 14373–14396.

Antunes, J., Frias, J., Sobral, P., 2018. Microplastics on the Portuguese coast. Mar. Pollut. Bull. 131, 294–302. https://doi.org/10.1016/j.marpolbul.2018.04.025

Arthur, C., Baker, J., Bamford, H., Barnea, N., Lohmann, R., McElwee, K., Morishige, C., Thompson, R., 2009. Executive summary. Proc. Int. Res. Work. Occur. Eff. fate microplastic Mar. debris 7–17.

Austin, H.P., Allen, M.D., Donohoe, B.S., Rorrer, N.A., Kearns, F.L., Silveira, R.L., Pollard, B.C., Dominick, G., Duman, R., El Omari, K., Mykhaylyk, V., Wagner, A., Michener, W.E., Amore, A., Skaf, M.S., Crowley, M.F., Thorne, A.W., Johnson, C.W., Woodcock, H.L., McGeehan, J.E., Beckham, G.T., 2018. Characterization and engineering of a plastic-degrading aromatic polyesterase. Proc. Natl. Acad. Sci. 201718804. https://doi.org/10.1073/pnas.1718804115

Auta, H.S., Emenike, C.U., Fauziah, S.H., 2017. Distribution and importance of microplastics in the marine environment : A review of the sources , fate , effects , and potential solutions. Environ. Int. 102, 165–176. https://doi.org/10.1016/j.envint.2017.02.013

Barrows, A.P.W., Neumann, C.A., Pieper, C., Berger, M.L., Shaw, S.D., 2017. Guide to Microplastic Identification, a Comprehensive Methods Guide for Microplastics Identification and Quantification in the Laboratory. Mar. Environ. Res. Inst. 1–15.

Briassoulis, D., Dejean, C., 2010. Critical review of norms and standards for biodegradable agricultural plastics part I. Biodegradation in soil. J. Polym. Environ. 18, 384–400. https://doi.org/10.1007/s10924-010-0168-1

Carman, V.G., Machain, N., Campagna, C., 2015. Legal and institutional tools to mitigate plastic pollution affecting marine species : Argentina as a case study. Mar. Pollut. Bull. 92, 125–133. https://doi.org/10.1016/j.marpolbul.2014.12.047

Carpenter, E.J., Anderson, S.J., Harvey, G.R., Miklas, H.P., Peck, B.B., 1972. Polystyrene Spherules in Coastal Waters. Sciences (New. York). 159, 0–1.

Carson, H.S., Colbert, S.L., Kaylor, M.J., McDermid, K.J., 2011. Small plastic debris changes water movement and heat transfer through beach sediments. Mar. Pollut. Bull. 62, 1708–1713. https://doi.org/10.1016/j.marpolbul.2011.05.032

Cauwenberghe, L. Van, Claessens, M., Vandegehuchte, M.B., 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. https://doi.org/10.1016/j.envpol.2015.01.008

Cauwenberghe, L. Van, 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. https://doi.org/10.1016/j.marenvres.2015.06.007

Chubarenko, I.P., Esiukova, E.E., Bagaev, A. V, Bagaeva, M.A., Grave, A.N., 2018. Science of the Total Environment Three-dimensional distribution of anthropogenic microparticles in the body of sandy beaches. Sci. Total Environ. 628-629, 1340–1351. https://doi.org/10.1016/j.scitotenv.2018.02.167

Cole, M., Webb, H., Lindeque, P.K., Fileman, E.S., Halsband, C., Galloway, T.S., 2014. Isolation of microplastics in biota-rich seawater samples and marine organisms. Sci. Rep. 4, 1–8. https://doi.org/10.1038/srep04528

Conkle, J.L., Báez Del Valle, C.D., Turner, J.W., 2018. Are We Underestimating Microplastic Contamination in Aquatic Environments? Environ. Manage. 61, 1–8. https://doi.org/10.1007/s00267-017-0947-8

Coppock, R.L., Galloway, T.S., Cole, M., Fileman, E.S., Queirós, A.M., Lindeque, P.K., 2019. Microplastics alter feeding selectivity and faecal density in the copepod, Calanus helgolandicus. Sci. Total Environ. 687, 780–789. https://doi.org/10.1016/j.scitotenv.2019.06.009

Costa, M.F., Barletta, M., 2015. Microplastics in Coastal and Marine Environments of the Western Tropical and Sub-Tropical Atlantic Ocean. Environ. Sci. Process. Impacts. https://doi.org/10.1039/C5EM00158G

Cox, K.D., Covernton, G.A., Davies, H.L., Dower, J.F., Juanes, F., Dudas, S.E., 2019. Human Consumption of Microplastics. Environ. Sci. Technol. 53, 7068–7074. https://doi.org/10.1021/acs.est.9b01517

Dekiff, J.H., Remy, D., Klasmeier, J., Fries, E., 2014. Occurrence and spatial distribution of microplastics in sediments from Norderney. Environ. Pollut. 186, 248–256. https://doi.org/10.1016/j.envpol.2013.11.019

Environmental Protection Agency, 2001. METHOD 1684 - Total, Fixed, and Volatile Solids in Water, Solids, and Biosolids EPA-821-R-01-015.

Freinkel, S., 2012. Plástico, Un idilio tóxico. Tusquets Editores, S.A. 1. Buenos Aires

Frias, J., Pagter, E., Nash, R., Connor, I.O., 2018. Standardised protocol for monitoring microplastics in sediments. JPI-Oceans BASEMAN Proj. https://doi.org/10.13140/RG.2.2.36256.89601/1

Frias, J.P.G.L., Nash, R., 2019. Microplastics : Finding a consensus on the definition. Mar. Pollut. Bull. 138, 145–147. https://doi.org/10.1016/j.marpolbul.2018.11.022

Gasperi, J., Wright, S.L., Dris, R., Collard, F., Mandin, C., Guerrouache, M., Langlois, V., Kelly, F.J., Tassin, B., 2018. ScienceDirect Microplastics in air : Are we breathing it in ? Curr. Opin. Environ. Sci. Heal. 1, 1–5. https://doi.org/10.1016/j.coesh.2017.10.002

Geyer, R., Jambeck, J.R., Law, K.L., 2017. Production , use , and fate of all plastics ever made. Sci. Adv. 3, 25–29.

Gregory, M.R., 1977. Plastic pellets on New Zealand beaches. Mar. Pollut. Bull. 8, 82–84. https://doi.org/10.1016/0025-326X(77)90193-X

Gündo, S., Çevik, C., 2018. Microplastics in municipal wastewater treatment plants in Turkey : a comparison of the influent and secondary effluent concentrations. Environ. Monit. Assess. 190, 1–10.

Hanvey, J.S., Lewis, P.J., Lavers, J.L., Crosbie, N.D., De, K.P., Clarke, B.O., Pete, P.E.T., 2017. Analytical Methods A review of analytical techniques for quantifying microplastics in sediments. Anal. Methods 9, 1369–1383. https://doi.org/10.1039/C6AY02707E

He, P., Chen, L., Shao, L., Zhang, H., Lü, F., 2019. Municipal solid waste (MSW) land fi ll : A source of microplastics ? -Evidence of microplastics in land fi ll leachate 159, 38–45. https://doi.org/10.1016/j.watres.2019.04.060

Hendrickson, E., Minor, E.C., Schreiner, K., 2018. Microplastic Abundance and Composition in Western Lake Superior As Determined via Microscopy, Pyr-GC/MS, and FTIR. Environ. Sci. Technol. 52, 1787–1796. https://doi.org/10.1021/acs.est.7b05829

Herrera, A., Asensio, M., Martínez, I., Santana, A., Packard, T., Gómez, M., 2018. Microplastic and tar pollution on three Canary Islands beaches: An annual study. Mar. Pollut. Bull. 129, 494–502. https://doi.org/10.1016/j.marpolbul.2017.10.020

Hidayaturrahman, H., Lee, T., 2019. A study on characteristics of microplastic in wastewater of South Korea : Identification , quantification , and fate of microplastics during treatment process. Mar. Pollut. Bull. 146, 696–702. https://doi.org/10.1016/j.marpolbul.2019.06.071

Jambeck, J.R., Geyer, R., Wilcox, C., R. Siegler, T., Perryman, M., Andrady, A., Narayan, R., Law, K.L., 2015. Plastic waste inputs from land into the ocean. Science (80-.). 347, 768–771. https://doi.org/10.1126/science.1260352 Dumping

Juárez, V., Isla, F., 1999. Evolución Histórica del Núcleo Urbano de Villa Gesell. Rev. Geográfica 125, 49–60.

Kelkar, V.P., Rolsky, C.B., Pant, A., Green, M.D., Tongay, S., Halden, R.U., 2019. Chemical and physical changes of microplastics during sterilization by chlorination. Water Res. 163, 114871. https://doi.org/10.1016/j.watres.2019.114871

Kenyon, K.W., Kridler, E., 1969. Laysan Albatrosses swallow indigestible matter. Auk 86, 339–343. https://doi.org/10.2307/4083505

Kim, J., Lee, H., Kim, S., Kim, H., 2018. Ecotoxicology and Human Environmental Health Global Pattern of Microplastics (MPs) in Commercial Food- Grade Salts : Sea Salt as an Indicator of Seawater MP Pollution. https://doi.org/10.1021/acs.est.8b04180

Laglbauer, B.J.L., Franco-Santos, R.M., 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. https://doi.org/10.1016/j.marpolbul.2014.09.036

Lares, M., Ncibi, M.C., Sillanpää, M., Sillanpää, M., 2018. Occurrence , identification and removal of microplastic particles and fibers in conventional activated sludge process and advanced MBR technology 133, 236–246. https://doi.org/10.1016/j.watres.2018.01.049

Li, X., Chen, L., Mei, Q., Dong, B., Dai, X., Ding, G., Zeng, E.Y., 2018. Microplastics in sewage sludge from the wastewater treatment plants in China. Water Res. 142, 75–85. https://doi.org/10.1016/j.watres.2018.05.034

Liu, X., Yuan, W., Di, M., Li, Z., Wang, J., 2019. Transfer and fate of microplastics during the conventional activated sludge process in one wastewater treatment plant of China. Chem. Eng. J. 362, 176–182. https://doi.org/10.1016/j.cej.2019.01.033

Lusher, A.L., Hernandez-Milian, G., O'Brien, J., Berrow, S., O'Connor, I., Officer, R., 2015. Microplastic and macroplastic ingestion by a deep diving, oceanic cetacean: The True's beaked whale Mesoplodon mirus. Environ. Pollut. 199, 185–191. https://doi.org/10.1016/j.envpol.2015.01.023

Magni, S., Binelli, A., Pittura, L., Giacomo, C., Della, C., Carla, C., Gorbi, S., Regoli, F., 2019. Science of the Total Environment The fate of microplastics in an Italian Wastewater Treatment Plant. Sci. Total Environ. 652, 602–610. https://doi.org/10.1016/j.scitotenv.2018.10.269

Magnusson, K., Norén, F., 2014. Screening of microplastic particles in and down-stream a wastewater treatment plant. IVL Swedish Environ. Res. Inst. C 55, 22. https://doi.org/naturvardsverket-2226

Martellini, T., Guerranti, C., Scopetani, C., Ugolini, A., Chelazzi, D., Cincinelli, A., 2018. Trends in Analytical Chemistry A snapshot of microplastics in the coastal areas of the Mediterranean Sea. Trends Anal. Chem. 109, 173–179. https://doi.org/10.1016/j.trac.2018.09.028

Mintenig, S.M., Löder, M.G.J., Primpke, S., Gerdts, G., 2019. Low numbers of microplastics detected in drinking water from ground water sources. Sci. Total Environ. 648, 631–635. https://doi.org/10.1016/j.scitotenv.2018.08.178

Mühlschlegel, P., Hauk, A., Walter, U., Sieber, R., 2017. Lack of evidence for microplastic contamination in honey. Food Addit. Contam. Part A 0. https://doi.org/10.1080/19440049.2017.1347281

Murphy, F., Ewins, C., Carbonnier, F., Quinn, B., 2016. Wastewater Treatment Works (WwTW) as a Source of Microplastics in the Aquatic Environment. Environ. Sci. Technol. 50, 5800–5808. https://doi.org/10.1021/acs.est.5b05416

Napper, I.E., Thompson, R.C., 2016. Release of synthetic microplastic plastic fi bres from domestic washing machines : Effects of fabric type and washing conditions. Mar. Pollut. Bull. 112, 39–45. https://doi.org/10.1016/j.marpolbul.2016.09.025

Nazareth, M., Marques, M.R.C., Leite, M.C.A., Castro, Í.B., 2019. Commercial plastics claiming biodegradable status: Is this also accurate for marine environments? J. Hazard. Mater. 714–722. https://doi.org/10.1016/j.jhazmat.2018.12.052

Neto, A.B., Carvalho, D.G. De, 2016. Ocean & Coastal Management Microplastic pollution of the beaches of Guanabara Bay , Southeast Brazil. Ocean Coast. Manag. 128, 10–17. https://doi.org/10.1016/j.ocecoaman.2016.04.009

Niinimäki, K., 2013. Sustainable Fashion : New Appoaches. Aalto University, Helsinki, Finland.

Norén, F., 2007. Small plastic particles in Coastal Swedish waters. N-Research 11.

Ocean Conservacy, 2018. International Cleanup 2018 Report 1–28. Available in: https://oceanconservancy.org/wp-content/uploads/2018/07/Building-A-Clean-Swell.pdf

Ogonowski, M., Schür, C., Jarsén, Å., Gorokhova, E., 2016. The Effects of Natural and Anthropogenic Microparticles on Individual Fitness in Daphnia magna. PLoS One 11, 1–20. https://doi.org/10.1371/journal.pone.0155063

Olivatto, G.P., Clara, M., Martins, T., Montagner, C.C., Henry, T.B., Carreira, R.S., Bay, G., 2019. Microplastic contamination in surface waters in Guanabara Bay , Rio de Guanabara Atlantic Ocean. Mar. Pollut. Bull. 139, 157–162. https://doi.org/10.1016/j.marpolbul.2018.12.042

Oßmann, B.E., Sarau, G., Holtmannspötter, H., Pischetsrieder, M., Christiansen, S.H., Dicke, W., 2018. Small-sized microplastics and pigmented particles in bottled mineral water. Water Res. 141, 307–316. https://doi.org/10.1016/j.watres.2018.05.027

Pazos, R.S., Bauer, D.E., Nora, G., 2018. Microplastics integrating the coastal planktonic community in the inner zone of the Río de la Plata estuary (South America) * 243, 134–142. https://doi.org/10.1016/j.envpol.2018.08.064

Perez-Venegas, D.J., Seguel, M., Pavés, H., Pulgar, J., Urbina, M., Ahrendt, C., Galbán-Malagón, C., 2018. First detection of plastic microfibers in a wild population of South American fur seals (Arctocephalus australis) in the Chilean Northern Patagonia. Mar. Pollut. Bull. 136, 50–54. https://doi.org/10.1016/j.marpolbul.2018.08.065

Pinheiro, L.M., Monteiro, R.C.P., Ivar, J.A., Costa, M.F., 2019. Do beachrocks a ff ect microplastic deposition on the strandline of sandy beaches ? Mar. Pollut. Bull. 141, 569–572. https://doi.org/10.1016/j.marpolbul.2019.03.010

Pivokonsky, M., Cermakova, L., Novotna, K., Peer, P., Cajthaml, T., Janda, V., 2018. Science of the Total Environment Occurrence of microplastics in raw and treated drinking water. Sci. Total Environ. 643, 1644–1651. https://doi.org/10.1016/j.scitotenv.2018.08.102

PlasticsEurope, 2018. Plastics – the Facts 2018 - An analysis of European plastics production, demand and waste data 1–60. Available in: https://www.plasticseurope.org/en/resources/publications/619-plastics-facts-2018

Prata, J.C., da Costa, J.P., Duarte, A.C., Rocha-santos, T., 2019. Methods for sampling and detection of microplastics in water and sediment : A critical review Density separation. Trends Anal. Chem. 110, 150–159. https://doi.org/10.1016/j.trac.2018.10.029

Reed, S., Clark, M., Thompson, R., Hughes, K.A., 2018. Microplastics in marine sediments near Rothera Research Station , Antarctica. Mar. Pollut. Bull. 133, 460–463. https://doi.org/10.1016/j.marpolbul.2018.05.068

Rochman, B.C.M., 2018. Microplastics research — from sink to source in freshwater systems. Science (80-.). 360.

Scheurer, M., Bigalke, M., 2018. Microplastics in Swiss Floodplain Soils. https://doi.org/10.1021/acs.est.7b06003

Schirinzi, G.F., Pérez-Pomeda, I., Sanchís, J., Rossini, C., Farré, M., Barceló, D., 2017. Cytotoxic effects of commonly used nanomaterials and microplastics on cerebral and epithelial human cells. Environ. Res. 159, 579–587. https://doi.org/10.1016/j.envres.2017.08.043

Schymanski, D., Goldbeck, C., Humpf, H., Fürst, P., 2018. Analysis of microplastics in water by micro-Raman spectroscopy : Release of plastic particles from different packaging into mineral water. Water Res. 129, 154–162. https://doi.org/10.1016/j.watres.2017.11.011

Shahul Hamid, F., Bhatti, M.S., Anuar, N., Anuar, N., Mohan, P., Periathamby, A., 2018. Worldwide distribution and abundance of microplastic: How dire is the situation? Waste Manag. Res. 36, 873–897. https://doi.org/10.1177/0734242X18785730

Stock, F., Kochleus, C., Bänsch-Baltruschat, B., Brennholt, N., Reifferscheid, G., 2019a. Sampling techniques and preparation methods for microplastic analyses in the aquatic environment – A review. TrAC - Trends Anal. Chem. 113, 84–92. https://doi.org/10.1016/j.trac.2019.01.014

Stock, F., Kochleus, C., Beate, B., Brennholt, N., Reifferscheid, G., 2019b. Sampling techniques and preparation methods for microplastic analyses in the aquatic environment – A review. Trends Anal. Chem. 113, 84–92. https://doi.org/10.1016/j.trac.2019.01.014

Stolte, A., Forster, S., Gerdts, G., Schubert, H., 2015. Microplastic concentrations in beach sediments along the German Baltic coast. Mar. Pollut. Bull. https://doi.org/10.1016/j.marpolbul.2015.07.022

Sun, J., Dai, X., Wang, Q., van Loosdrecht, M.C.M., Ni, B.J., 2019. Microplastics in wastewater treatment plants: Detection, occurrence and removal. Water Res. 152, 21–37. https://doi.org/10.1016/j.watres.2018.12.050

Thompson, Richard C ; Olsen, Ylva ; Mitchell, Richard P ; Davis, Anthony ; Rowland, Steven J ; John, Anthony W G ; Mcgonigle, Daniel ; Russell, A.E., 2004. Lost at sea: where is all the plastic? Science (80-.). 304, 2004. https://doi.org/doi:10.1126/science.1094559

Viršek, M.K., Palatinus, A., Koren, Š., Peterlin, M., Horvat, P., Kržan, A., 2016. Protocol for Microplastics Sampling on the Sea Surface and Sample Analysis 1–9. https://doi.org/10.3791/55161

Wagner, M., Scherer, C., Alvarez-muñoz, D., Brennholt, N., Bourrain, X., Buchinger, S., Fries, E., Grosbois, C., Klasmeier, J., Marti, T., Rodriguez-mozaz, S., Urbatzka, R., Vethaak, A.D., Winther-nielsen, M., Reifferscheid, G., 2014. Microplastics in freshwater ecosystems : what we know and what we need to know 1–9.

Wang, W., Gao, H., Jin, S., Li, R., Na, G., 2019. The ecotoxicological effects of microplastics on aquatic food web, from primary producer to human: A review. Ecotoxicol. Environ. Saf. 173, 110–117. https://doi.org/10.1016/j.ecoenv.2019.01.113

Wiesheu, A.C., Anger, P.M., Baumann, T., Niessner, R., Ivleva, N.P., 2016. Analytical Methods beverages † 5722–5725. https://doi.org/10.1039/c6ay01184e

Wit, W. de, Bigaud, N., 2019. Assessing plastic ingestion from nature to people (AN ANALYSIS for WWF). WWF – World Wide Fund Nat.

Wright, S.L., Kelly, F.J., 2017. Plastic and Human Health: A Micro Issue? Environ. Sci. Technol. 51, 6634–6647. https://doi.org/10.1021/acs.est.7b00423

Wright, S.L., Thompson, R.C., Galloway, T.S., 2013. The physical impacts of microplastics on marine organisms : A review. Environ. Pollut. 178, 483–492. https://doi.org/10.1016/j.envpol.2013.02.031

Ziajahromi, S., Neale, P.A., Leusch, F.D.L., 2016. Wastewater treatment plant effluent as a source of microplastics: review of the fate, chemical interactions and potential risks to aquatic organisms. Water Sci. Technol. 74, 2253–2269. https://doi.org/10.2166/wst.2016.414

WEB SOURCES

Instituto Geográfico Nacional – Argentina (2019), 'Poblacion'; Accessed in: 26th of August 2019, in http://www.ign.gob.ar/NuestrasActividades/Geografia/DatosArgentina/Poblacion2.

M. Garside, Statista (2018), 'Distribution of fiber consumption worldwide in 2018, by type of fiber'; Accessed in: 5th of September 2019, in: https://www.statista.com/statistics/741296/world-fiber-consumption-distribution-by-fiber-type/.

Plast Europe (2012), 'Argentina: Standard Thermoplastics 2012'; Accessed in: 22th of April 2019, in https://www.plasteurope.com/news/ARGENTINA_t222448/.

8. APENDIX

8.1. VILLA GESELL

Appendix 1 - Table with the results from PMPs quantification in Villa Gesell Beaches, reported by PMPs.Kg^{-1} and its distribution by type. Outlier's are represented in Bold

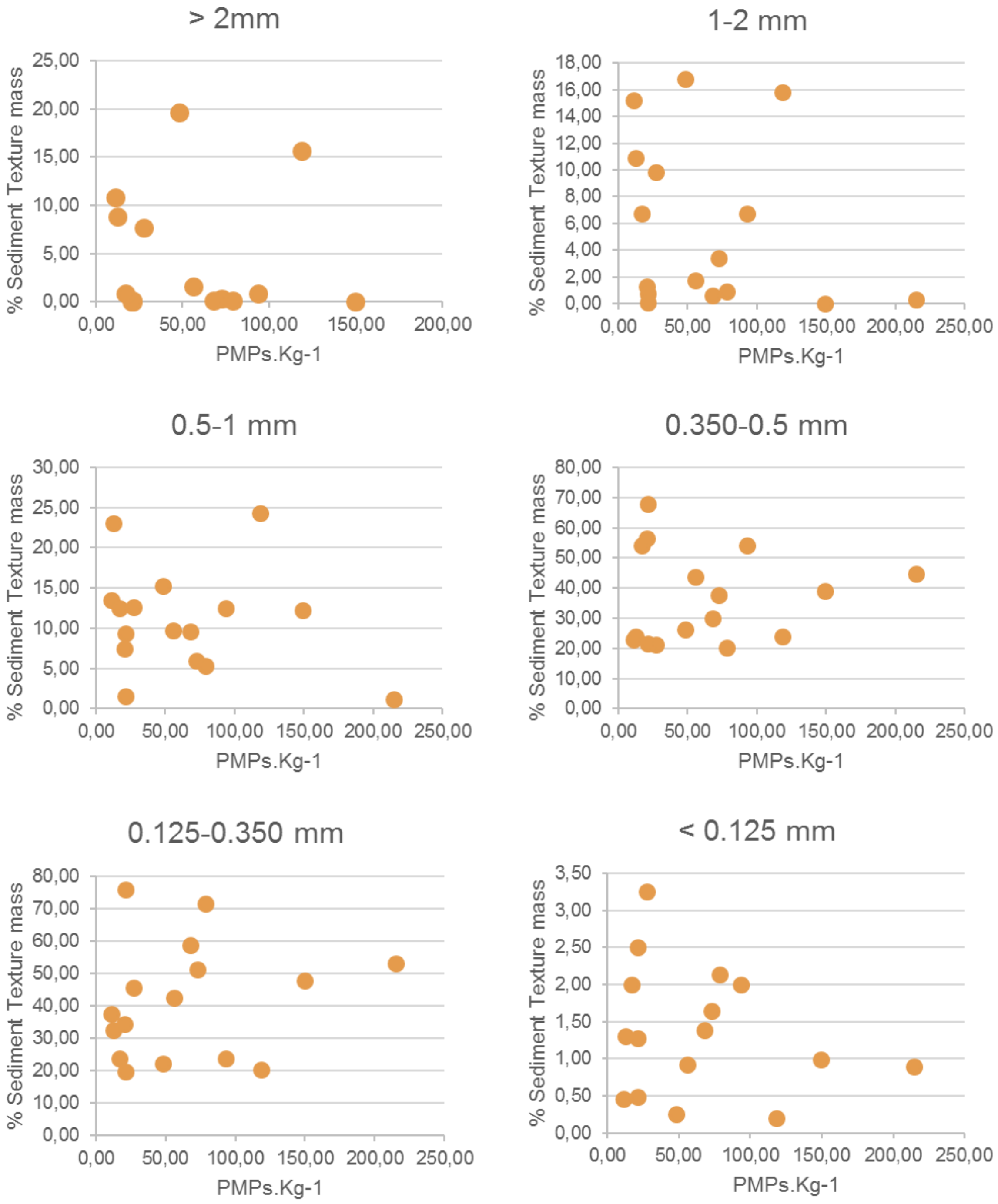
Beach	Sample	PMPs.kg^{-1}	Fibers	Fragment	Thin Film	Bead	Foam	Total
A	1H	1.36	0	0	0	0	1	1
	2H	66.54	0	20	6	25	0	51
	4H	72.99	10	10	0	2	0	22
	5H	79.01	7	26	2	16	6	57
	6H	93.30	23	15	10	22	4	74
	1M	21.06	0	10	4	0	0	14
	2M	23.84	2	0	11	0	5	18
	3M	47.44	0	19	13	3	2	37
	4M	12.58	0	5	3	0	1	9
	5M	56.17	9	7	0	0	1	17
	6M	27.60	0	16	0	0	5	21
	2B	9.71	4	2	1	0	0	7
	3B	48.41	22	13	0	0	0	35
	4B	11.32	0	6	1	0	1	8
	6B	118.69	26	7	3	0	0	36
B	1H	21.38	0	6	9	0	1	16
	3H	49.18	0	20	15	1	2	38
	4H	**851.71**	**654**	**0**	**1**	**2**	**0**	**657**
	5H	120.03	85	0	0	1	1	87
	1M	43.33	0	18	10	0	5	33
	2M	149.68	40	4	0	1	0	45
	4M	25.73	3	0	12	3	0	18
	6M	26.21	0	11	8	0	0	19
	3B	84.60	0	35	22	0	0	57
	5B	71.71	0	6	37	3	1	47
	6B	21.41	3	4	7	0	0	14
C	3H	157.50	100	12	3	0	0	115
	4H	136.31	75	15	1	1	0	92
	5H	93.60	20	32	4	1	1	58
	1M	42.82	0	27	5	1	0	33
	3M	94.91	57	0	15	0	0	72
	4M	17.12	0	8	2	0	3	13
	5M	68.15	0	48	0	2	0	50
	6M	14.42	8	0	2	0	1	11
	1B	142.84	68	24	5	0	0	97
	2B	215.22	45	19	1	0	0	65
	4B	48.70	0	27	4	0	2	33
	5B	**1132.58**	**317**	**21**	**0**	**1**	**1**	**340**
	6B	2.84	0	0	1	1	0	2

Appendix 2 - PMPs colour distribution in A and B Beach

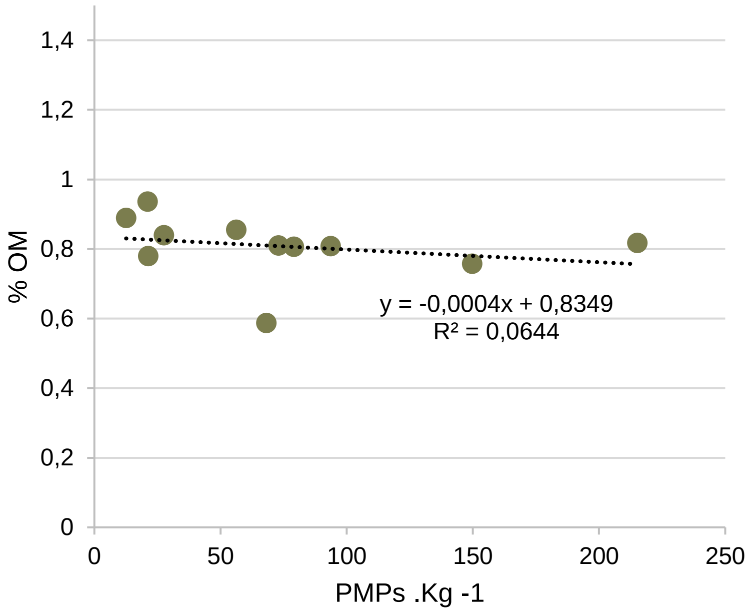
Beach	Sample	Blue	Red	Green	Black	White	Pink	Brown	Transparent	Beige	Yellow	Orange	Purple	Grey	Coloufull
A	1H	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	2H	2	0	1	0	3	2	8	20	11	0	3	0	1	0
	4H	7	2	0	0	2	2	3	5	1	0	0	0	0	0
	5H	15	1	1	0	8	1	7	11	9	3	1	0	0	0
	6H	9	2	0	4	6	7	8	23	7	7	0	0	1	0
	1M	5	1	0	0	1	1	0	6	0	0	0	1	0	0
	2M	0	1	0	0	6	0	0	11	0	0	0	0	0	0
	3M	8	1	0	0	7	1	0	15	0	0	4	0	1	0
	4M	0	0	0	1	1	0	0	5	0	1	0	0	0	1
	5M	7	1	1	0	1	0	0	5	1	0	0	0	1	0
	6M	9	2	0	0	6	3	0	1	0	0	0	0	0	0
	2B	0	0	1	2	0	1	0	1	0	0	1	1	0	0
	3B	10	2	2	2	1	4	0	6	1	2	1	2	2	0
	4B	0	0	0	0	2	5	0	1	0	0	0	0	0	0
	6B	12	1	0	5	0	5	0	10	0	1	0	0	2	0
B	1H	0	0	2	0	3	4	0	7	0	0	0	0	0	0
	3H	11	2	2	1	3	7	1	8	0	3	0	0	0	0
	4H	0	2	0	0	0	1	0	654	0	0	0	0	0	0
	5H	8	4	0	3	1	0	2	59	0	9	0	0	1	0
	1M	1	0	1	0	5	9	0	11	0	0	5	0	1	0
	2M	8	3	1	6	0	7	1	11	0	0	1	0	6	1
	4M	1	0	1	0	0	5	1	10	0	0	0	0	0	0
	6M	1	0	2	0	2	3	0	8	0	1	2	0	0	0
	3B	25	5	0	0	0	9	0	13	0	2	2	0	1	0
	5B	0	2	0	1	2	10	1	29	1	0	0	0	1	0
	6B	0	0	0	0	1	8	0	4	0	0	1	0	0	0

Appendix 3 - PMPs color distribution in C Beach

Beach	Sample	Blue	Red	Green	Black	White	Pink	Brown	Transparent	Beige	Yellow	Orange	Purple	Grey	Coloufull
C	3H	12	2	3	7	0	3	0	64	0	10	1	0	9	4
	4H	50	3	4	15	0	3	0	15	0	1	0	0	1	0
	5H	2	1	7	1	2	2	0	25	0	16	1	0	1	0
	1M	29	1	0	0	0	3	0	0	0	0	0	0	0	0
	3M	3	1	0	2	0	6	2	48	0	0	0	0	10	0
	4M	3	0	9	0	0	1	0	0	0	0	0	0	0	0
	5M	0	0	3	0	25	0	2	1	0	3	0	0	16	0
	6M	2	0	0	0	1	0	0	7	0	1	0	0	0	0
	1B	25	0	1	5	0	5	3	29	0	25	0	1	3	0
	2B	11	7	1	11	1	12	1	14	1	0	0	0	6	0
	4B	1	1	1	0	2	13	0	11	0	0	1	3	0	0
	5B	24	4	1	4	1	3	0	300	0	2	0	0	1	0
	6B	1	1	0	0	0	0	0	0	0	0	0	0	0	0



Appendix 4 - Relation between PMPs and the different fractions (%m/m) of sediment texture - > 2mm; 1-2 mm; 0.5-1 mm; 0.350-0.5 mm; 0.350-0.125 mm; <0.125 mm.



Appendix 5 - Relation between PMPs.Kg^{-1}and the Sand Organic Matter (%)

Appendix 6 - PMPs Found in the procedural blanks from Villa Gesell beach sediment analisis

Blanks Sample	Fibers	Fragments	Total
1	4	0	4
2	1	1	2
3	2	0	2
4	3	0	3
5	3	1	4
6	3	0	3
		Average	3
		SD	0.89442719

8.2. - COMACO WWTP

Appendix 7 - PMPs distribution by color and type for Sample I. Bold numbers are the PMPs classified with a size <0.01 mm

Sample - Vol	Types | Color	Blue		Black		Red		Grey		Yellow		Pink		White		Green		Transparent		Colourfull		Lilac		Orange		Brown		Beige		Total Type	Per liter
I1 - 50 mL	Fragment	68	**84**	1	**0**	16	**46**	0	**1**	10	**0**	13	**0**	0	**0**	6	**0**	1	**0**	18	**3**	0	**0**	8	**0**	1	**0**	0	**0**	276	5520
	Fibre	48	**6**	9	**3**	8	**1**	15	**1**	2	**0**	0	**1**	0	**0**	2	**0**	66	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	163	3260
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	113	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	113	2260
	Bead	1	**1**	1	**0**	0	**1**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	6	120
	Thin Film	1	**0**	2	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	5	100
	Total	209		16		72		17		12		15		114		8		68		21		1		8		1		1		563	11260
I2 - 50 mL	Fragment	11	**74**	6	**0**	11	**44**	1	**0**	6	**5**	14	**13**	1	**0**	1	**2**	1	**0**	6	**0**	1	**0**	0	**5**	0	**0**	1	**0**	203	4060
	Fibre	14	**11**	4	**19**	0	**15**	2	**1**	6	**0**	2	**1**	0	**0**	0	**0**	4	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	80	1600
	Foam	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	505	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	506	10120
	Bead	0	**0**	0	**4**	0	**3**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**1**	0	**0**	8	160
	Thin Film	1	**0**	5	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	8	160
	Total	112		38		73		5		17		30		506		3		5		7		2		5		1		1		805	16100
I3 - 50 mL	Fragment	18	**69**	1	**0**	9	**49**	1	**0**	10	**3**	13	**46**	1	**0**	1	**2**	6	**0**	2	**0**	0	**1**	8	**0**	0	**0**	1	**0**	241	4820
	Fibre	32	**12**	10	**1**	2	**0**	17	**1**	4	**0**	5	**0**	0	**0**	0	**0**	9	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	93	1860
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	2	**0**	0	**0**	180	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	182	3640
	Bead	0	**0**	3	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	4	80
	Thin Film	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	0
		131		15		61		19		19		64		181		3		15		2		1		8		0		1		520	10400

Appendix 8 - PMPs distribution by color and type for Sample S1. Bold numbers are the PMPs classified with a size <0.01 mm

Sample	Types | Color	Blue		Black		Red		Grey		Yellow		Pink		White		Green		Transparent		Colourfull		Lilac/Purple		Orange		Brown		Beige		Total Type	Per Liter
S1.1 - 50 mL	Fragment	19	**95**	0	**0**	16	**86**	0	**0**	6	**1**	16	**7**	1	**0**	6	**4**	7	**0**	5	**0**	0	**0**	1	**0**	0	**0**	0	**0**	270	5400
	Fibre	28	**6**	8	**0**	3	**1**	4	**0**	1	**0**	5	**0**	0	**0**	1	**0**	12	**0**	0	**0**	4	**0**	1	**0**	1	**0**	0	**0**	75	1500
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	376	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	376	7520
	Bead	0	**0**	0	**3**	0	**1**	0	**0**	0	**0**	0	**0**	1	**0**	1	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	7	140
	Thin Film	0	**0**	1	**0**	1	**0**	1	**0**	0	**0**	4	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	7	140
	Total	148		12		108		5		8		32		378		12		20		5		4		2		1		0		735	14700
S1.2 - 50 mL	Fragment	32	**172**	17	**1**	14	**104**	1	**0**	3	**3**	11	**13**	0	**0**	5	**5**	5	**0**	14	**0**	1	**0**	9	**4**	1	**0**	0	**0**	415	8300
	Fibre	19	**11**	12	**16**	2	**6**	4	**0**	1	**0**	11	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**1**	0	**0**	0	**0**	0	**0**	84	1680
	Foam	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	331	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	332	6640
	Bead	0	**0**	1	**1**	0	**0**	0	**0**	0	**0**	0	**0**	0	**1**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	4	80
	Thin Film	0	**0**	2	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	3	60
	Total	235		50		126		5		7		35		332		10		7		14		3		13		1		0		838	16760
S1.3 - 50 mL	Fragment	19	**119**	0	**0**	9	**12**	0	**0**	5	**7**	17	**38**	0	**0**	9	**1**	1	**0**	14	**0**	0	**0**	0	**3**	0	**0**	2	**0**	256	5120
	Fibre	7	**5**	1	**7**	0	**1**	3	**0**	0	**0**	2	**1**	0	**0**	0	**0**	4	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	32	640
	Foam	16	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	211	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	227	4540
	Bead	0	**0**	0	**3**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	3	60
	Thin Film	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	2	**0**	2	**0**	1	**0**	0	**0**	0	**0**	0	**0**	6	120
	Total	167		11		22		3		12		58		211		10		7		16		1		3		1		2		524	10480

Appendix 9 - PMPs distribution by color and type for Sample S2. Bold numbers are the PMPs classified with a size <0.01 mm

Sample	Types | Color	Blue		Black		Red		Grey		Yellow		Pink		White		Green		Transparent		Colourfull		Lilac/Purple		Orange		Brown		Beige		Total Type	Per Liter
S2.1- 75 mL	Fragment	28	**125**	1	**0**	0	**62**	0	**0**	1	**0**	10	**33**	0	**0**	12	**1**	4	**0**	6	**1**	0	**0**	0	**0**	0	**0**	0	**0**	284	3786.667
	Fibre	7	**2**	3	**8**	3	**8**	2	**0**	2	**0**	1	**0**	0	**0**	0	**0**	5	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	42	560
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	309	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	309	4120
	Bead	1	**0**	0	**0**	0	**1**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	2	26.66667
	Thin Film	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	0
	Total	163		12		74		2		3		44		309		13		9		8		0		0		0		0		637	8493.333
S2.2- 75 mL	Fragment	27	**170**	4	**0**	14	**76**	1	**0**	16	**4**	14	**10**	0	**0**	5	**1**	2	**0**	4	**1**	0	**0**	0	**3**	0	**0**	0	**0**	352	4693.333
	Fibre	17	**19**	1	**3**	4	**5**	1	**0**	0	**0**	1	**0**	0	**0**	0	**0**	1	**0**	0	**0**	2	**0**	0	**0**	0	**0**	0	**0**	54	720
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	660	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	660	8800
	Bead	0	**1**	0	**2**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**1**	4	53.33333
	Thin Film	1	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	4	53.33333
	Total	235		11		99		2		20		25		660		6		4		6		2		3		0		1		1074	14320
S2.3- 50 mL	Fragment	31	**119**	0	**0**	7	**18**	0	**0**	4	**1**	7	**50**	8	**0**	1	**1**	3	**0**	6	**0**	0	**1**	1	**1**	0	**0**	1	**0**	260	5200
	Fibre	12	**1**	4	**6**	2	**8**	6	**0**	2	**0**	2	**1**	0	**0**	0	**0**	7	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	52	1040
	Foam	2	**0**	0	**0**	0	**0**	0	**0**	3	**0**	0	**0**	431	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	436	8720
	Bead	0	**0**	0	**5**	1	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	7	140
	Thin Film	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	5	**0**	2	**0**	0	**0**	0	**0**	0	**0**	0	**0**	7	140
	Total	165		15		36		6		10		60		440		2		15		8		2		2		0		1		762	15240
S2.4 - 50 mL	Fragment	26	**244**	0	**0**	3	**29**	1	**0**	7	**12**	18	**88**	0	**0**	3	**6**	2	**0**	3	**0**	1	**7**	0	**0**	0	**0**	0	**0**	450	9000
	Fibre	15	**11**	16	**1**	4	**0**	2	**4**	5	**0**	2	**0**	0	**0**	1	**0**	8	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	70	1400
	Foam	2	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	210	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	213	4260
	Bead	0	**0**	0	**4**	0	**1**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	5	100
	Thin Film	6	**0**	2	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	10	200
	Total	304		23		37		7		24		109		210		11		10		4		8		1		0		0		748	14960

Appendix 10 - PMPs distribution by color and type for Sample S3. Bold numbers are the PMPs classified with a size <0.01 mm

Sample	Types | Color	Blue		Black		Red		Grey		Yellow		Pink		White		Green		Transparent		Colourfull		Lilac/Purple		Orange		Brown		Beige		Total Type	Per Liter
S3.1- 150 mL	Fragment	47	**286**	0	**0**	7	**55**	5	**0**	4	**5**	23	**75**	0	**0**	5	**8**	0	**0**	2	**0**	3	**5**	1	**0**	0	**0**	0	**0**	531	3540
	Fibre	1	**18**	4	**16**	1	**2**	1	**1**	1	**0**	3	**0**	0	**0**	3	**0**	1	**0**	0	**0**	2	**0**	0	**0**	0	**0**	0	**0**	54	360
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	515	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	515	3433.333
	Bead	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	0
	Thin Film	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	2	**0**	0	**0**	0	**0**	0	**0**	0	**0**	3	20
	Total	352		21		65		7		10		101		515		16		1		4		10		1		0		0		1103	7353.333
S3.2 - 50 mL	Fragment	53	**177**	0	**0**	44	**23**	2	**0**	6	**2**	16	**62**	0	**0**	2	**8**	5	**0**	6	**0**	0	**0**	1	**0**	0	**0**	0	**0**	407	8140
	Fibre	15	**6**	3	**8**	2	**2**	6	**0**	3	**0**	1	**0**	0	**0**	1		4	**0**	0	**0**	2	**0**	0	**0**	0	**0**	0	**0**	53	1060
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	287	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	287	5740
	Bead	0	**1**	3	**3**	0	**0**	0	**0**	0	**0**	0	**0**	0	**4**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	12	240
	Thin Film	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	2	40
	Total	252		17		71		8		11		79		291		11		10		7		2		1		1		0		761	15220
S3.3 - 50 mL	Fragment	24	**146**	0	**0**	8	**34**	0	**0**	3	**18**	12	**75**	0	**0**	1	**1**	1	**0**	7	**2**	2	**0**	3	**0**	0	**0**	0	**0**	337	6740
	Fibre	8	**1**	10	**9**	3	**2**	8	**1**	3	**0**	7	**0**	0	**0**	0	**0**	13	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	65	1300
	Foam	1	**0**	0	**0**	0	**0**	0	**0**	1	**0**	1	**0**	366	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	369	7380
	Bead	0	**0**	0	**7**	0	**0**	0	**0**	0	**0**	0	**0**	0	**3**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	10	200
	Thin Film	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	20
	Total	180		26		47		9		25		95		369		2		14		10		2		3		0		0		782	15640

Appendix 11 - PMPs distribution by color and type for Sample S4. Bold numbers are the PMPs classified with a size <0.01 mm

Sample	Types | Color	Blue		Black		Red		Grey		Yellow		Pink		White		Green		Transparent		Colourfull		Lilac/Purple		Orange		Brown		Beige		Total Type	Per Liter
S4.2- 100 mL	Fragment	13	**73**	0	**0**	10	**67**	0	**0**	5	**1**	2	**0**	0	**0**	3	**0**	2	**0**	3	**0**	0	**0**	2	**0**	0	**0**	0	**0**	181	1810
	Fibre	10	**5**	0	**11**	2	**2**	0	**1**	2	**0**	1	**0**	0	**0**	3	**0**	5	**0**	0	**0**	2	**0**	1	**0**	0	**0**	1	**0**	46	460
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	26	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	26	260
	Bead	0	**0**	0	**2**	0	**1**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	3	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	6	60
	Thin Film	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	0
		101		13		82		1		8		3		26		6		10		3		2		3		0		1		259	2590
S4.1- 50 mL	Fragment	17	**111**	1	**0**	2	**31**	0	**0**	4	**5**	10	**45**	0	**0**	0	**0**	1	**0**	1	**0**	0	**1**	1	**1**	0	**0**	0	**0**	231	2310
	Fibre	10	**4**	8	**1**	0	**0**	22	**1**	5	**0**	6	**0**	0	**0**	1	**0**	15	**0**	0	**0**	1	**0**	0	**0**	0	**0**	1	**0**	75	750
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	188	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	188	1880
	Bead	0	**0**	0	**3**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**1**	0	**0**	4	40
	Thin Film	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	2	20
	Total	142		13		33		24		14		61		188		1		16		1		3		2		1		1		500	5000
S4.3- 150 mL	Fragment	51	**168**	0	**0**	4	**55**	0	**0**	5	**11**	16	**40**	0	**0**	1	**2**	1	**0**	2	**0**	0	**0**	0	**4**	0	**0**	1	**0**	361	2406.667
	Fibre	4	**6**	10	**1**	0	**2**	2	**0**	0	**0**	0	**0**	0	**0**	0	**0**	5	**0**	0	**0**	1	**0**	1	**0**	0	**0**	0	**0**	32	213.3333
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	236	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	236	1573.333
	Bead	0	**0**	0	**2**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	4	26.66667
	Thin Film	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	0
	Total	229		13		61		2		17		56		236		3		7		2		1		5		0		1		633	4220

Appendix 12 - PMPs distribution by color and type for Sample E1. Bold numbers are the PMPs classified with a size <0.01 mm

Sample	Types | Color	Blue		Black		Red		Grey		Yellow		Pink		White		Green		Transparent		Colourfull		Lilac/Purple		Orange		Brown		Beige		Total Type	Per Liter
E1.1- 300 mL	Fragment	8	**48**	0	**0**	2	**7**	0	**0**	1	**0**	0	**12**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	79	263.3333
	Fibre	2	**0**	7	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	6	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	16	53.33333
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	58	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	58	193.3333
	Bead	0	**0**	0	**1**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	3.333333
	Thin Film	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	0
	Total	58		8		9		0		1		13		58		1		6		0		0		0		0		0		154	513.3333
E1.2- 100 mL	Fragment	2	**21**	0	**0**	0	**3**	0	**0**	1	**0**	1	**3**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	1	**0**	33	330
	Fibre	4	**0**	2	**5**	0	**0**	3	**0**	0	**0**	0	**1**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	16	160
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	22	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	22	220
	Bead	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	0
	Thin Film	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	2	20
	Total	28		7		3		3		1		5		22		0		2		1		0		0		0		1		73	730
E1.3- 150 mL	Fragment	1	**16**	1	**0**	1	**14**	0	**0**	0	**5**	1	**11**	1	**0**	0	**1**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	52	520
	Fibre	1	**1**	1	**7**	0	**0**	0	**0**	0	**1**	0	**0**	0	**0**	0	**0**	6	**0**	0	**0**	0	**0**	0	**0**	0	**1**	0	**0**	18	180
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	11	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	11	110
	Bead	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	0
	Thin Film	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	2	20
	Total	20		9		15		0		6		13		12		1		6		0		0		0		1		0		83	830

Appendix 13 - PMPs distribution by color and type for Sample E2. Bold numbers are the PMPs classified with a size <0.01 mm

Sample	Types | Color	Blue		Black		Red		Grey		Yellow		Pink		White		Green		Transparent		Colourfull		Lilac/Purple		Orange		Brown		Beige		Total Type	Per Liter
E2.1-150 mL	Fragment	17	**63**	0	**0**	11	**31**	1	**0**	1	**0**	3	**0**	0	**0**	5	**0**	2	**0**	2	**0**	3	**0**	1	**0**	0	**0**	0	**0**	140	933.3333
	Fibre	13	**0**	7	**0**	4	**0**	3	**0**	0	**0**	0	**0**	0	**0**	1	**0**	10	**0**	0	**0**	1	**0**	0	**0**	0	**0**	2	**0**	41	273.3333
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	4	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	4	26.66667
	Bead	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	6.666667
	Thin Film	1	**0**	2	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	5	33.33333
		94		9		47		4		1		3		4		6		14		2		4		1		0		2		191	1273.333
E2.2-100 mL	Fragment	7	**92**	3	**0**	5	**30**	0	**0**	0	**3**	5	**20**	0	**0**	0	**2**	3	**0**	0	**3**	0	**0**	0	**3**	0	**0**	0	**0**	176	1760
	Fibre	4	**6**	1	**5**	3	**0**	1	**1**	1	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	3	**0**	0	**0**	0	**0**	0	**0**	26	260
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	172	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	172	1720
	Bead	0	**0**	0	**2**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**2**	0	**0**	5	50
	Thin Film	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	10
		109		12		38		2		4		25		173		2		4		3		3		3		2		0		380	3800
E2.3-100 mL	Fragment	18	**101**	2	**0**	16	**95**	0	**0**	5	**7**	32	**9**	0	**0**	1	**0**	1	**0**	0	**0**	1	**0**	1	**4**	0	**0**	0	**0**	293	2930
	Fibre	3	**1**	6	**9**	4	**0**	1	**4**	1	**0**	1	**2**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	34	340
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	130	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	130	1300
	Bead	0	**0**	0	**1**	0	**0**	0	**0**	0	**0**	0	**0**	1	**1**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	3	30
	Thin Film	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	4	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	4	40
		123		18		115		5		13		48		132		1		2		0		1		5		0		1		464	4640

Appendix 14 - PMPs distribution by color and type for Sample S. Bold numbers are the PMPs classified with a size <0.01 mm

Sample	Types | Color	Blue		Black		Red		Grey		Yellow		Pink		White		Green		Transparent		Colourfull		Lilac/Purple		Orange		Brown		Beige		Total Type	Per Dry Kg
S 1 - 5.10g	Fragment	106	**310**	0	**0**	18	**104**	1	**0**	32	**19**	60	**82**	1	**0**	7	**15**	0	**0**	15	**0**	2	**0**	0	**0**	0	**0**	37	**0**	809	15862.75
	Fibre	22	**11**	45	**32**	7	**8**	13	**0**	6	**0**	19	**4**	0	**0**	3	**0**	126	**0**	1	**0**	1	**0**	1	**0**	4	**0**	0	**0**	303	5941.176
	Foam	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	175	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	175	3431.373
	Bead	0	**0**	2	**14**	0	**0**	0	**0**	0	**0**	0	**2**	0	**1**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	1	**0**	21	411.7647
	Thin Film	5	**0**	1	**1**	0	**0**	0	**0**	0	**0**	2	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	9	176.4706
	Total	454		95		137		14		57		169		177		25		126		16		3		1		5		38		1317	25823.53
S2 - 2.55 g	Fragment	96	**143**	1	**0**	28	**30**	3	**0**	26	**9**	21	**55**	1	**0**	11	**1**	1	**0**	17	**0**	1	**3**	1	**0**	0	**0**	58	**0**	506	198431.4
	Fibre	45	**1**	93	**1**	16	**4**	29	**0**	16	**0**	42	**0**	1	**0**	4	**0**	235	**0**	0	**0**	2	**0**	0	**0**	3	**0**	0	**0**	492	192941.2
	Foam	7	**0**	0	**0**	0	**0**	0	**0**	0	**0**	3	**0**	523	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	533	209019.6
	Bead	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	0
	Thin Film	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	0
	Total	292		95		78		32		51		121		525		16		236		17		6		1		3		58		1531	600392.2
S3 =5.05g	Fragment	150	**273**	2	**0**	26	**77**	2	**0**	30	**3**	39	**16**	0	**0**	3	**4**	15	**0**	9	**0**	1	**0**	4	**3**	0	**0**	0	**0**	657	130099
	Fibre	33	**4**	70	**0**	11	**4**	22	**0**	11	**0**	16	**2**	1	**0**	4	**0**	76	**0**	0	**0**	6	**0**	0	**0**	2	**0**	0	**0**	262	51881.19
	Foam	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	60	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	61	12079.21
	Bead	0	**0**	4	**1**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	7	1386.139
	Thin Film	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	1	198.0198
	Total	462		77		119		24		44		73		61		11		92		9		7		7		2		0		988	195643.6

Appendix 15 - PMPs Found in the procedural blanks from WWTP sample processing

Blank	Fibre	Fragment	Total
1	2	1	3
2	13	1	14
3	8	2	10
		Average	9
		SD	5.6