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回顾

di中的微塑料污染ﬀ不同的水环境和生物群：近期研究综述

Shahabaldin Rezaniaa⁎，Junboum Parka⁎，Mohd Fadhil医学博士Dinb，Shazwin Mat Taibb，,,

阿米里扎·塔莱埃霍扎尼奇、克里希纳·库马尔·亚达夫、海萨姆·卡米亚贝

一*部门 属于 韩国首尔国立大学土木与环境工程学院*

乙*部门 属于 环境的 工程， 教员 属于 马来西亚新罕布什尔州塔克诺洛吉大学土木工程81310号*

c类*部门 属于 伊朗伊斯法罕贾米理工学院土木工程*

丁*研究所 属于 环境 和 发展 研究， 邦德尔汗 大学， 占西 284128, 印度*

e类*部门 属于 工程， 联合技术手册 拉扎克 学校 属于 工程类 和 高级的 技术， 大学 特克诺洛吉 马来西亚， 马来西亚*

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## A R T I C L E I N F O公司

*关键词：*微塑性污染水环境生物群

海洋淡水

污水处理厂

## A B S T R A C T公司



微塑性塑料（MPs）是由塑料产生的，由于高度的碎片化，对我们的环境产生了负面影响。它们可以来自不同的来源，有不同的形式，如碎片、纤维、泡沫等。对于多磺酸粘多糖的检测，已经发展出许多不同功能的技术，如显微镜观察、密度分离、拉曼光谱和红外光谱分析。此外，由于多种海洋物种摄入多磺酸粘多糖，研究这种污染对生物群和人类的影响至关重要。因此，我们对海洋和淡水环境中，包括河流、湖泊和污水处理厂（WWTPs）中MPs污染的发生和分布进行了全面的综述。在未来的研究中，我们建议发展新的技术，在水环境和生物群中取样多磺酸粘多糖，并建议更多的研究是关于污水处理厂释放多磺酸粘多糖的。



1.   介绍

塑料材料是一种较年轻的材料，已有60多年的历史。然后，它们几乎覆盖了所有的水生环境（Van Cauwenberghe等人，2013年；Gündoğdu和切维克，2017年）。随着汤普森在英国普利茅斯大学（Plymouth University）研究海洋塑料，现代人对MPs的关注从2004年开始增加。他们在18个英国海滩的大部分样本中，以及早在20世纪60年代从北海采集的浮游生物样本中发现了多磺酸粘多糖（Thompson等人，2004）。

随着世界人口的不断增长，塑料的使用量不断增加，同时塑料的废弃物管理仍然是研究者关注的问题。据PlasticsEurope（2017）报告，2016年塑料产量约为3.35亿吨。这种产量的增加引起了人们对摄入塑料的生态后果和潜在的多磺酸粘多糖污染的担忧。MPs对水生环境及其生物群的影响有多大，这是一个问题（Villarrubia-Gómez等人，2017年；Xanthos和Walker，2017年）。

与海洋生态系统相比，对MPs污染的陆地生态系统（如城市环境）没有太大的关注（Dehghani等人，2017）。事实上，MPs的污染程度是

由于缺乏适当的废物管理，可能导致大量塑料在2025年之前从陆地进入海洋，因此未开发地区的含量较高（Jambeck等人，2015）。

塑料可分为三类：大MPs（1至<5 mm）、中塑性塑料（5至<25 mm）和大塑性塑料（大于等于25 mm）（Lee等人，2013年）。根据安德森等人的报告，MPs分为五类：碎片（硬的，锯齿状边缘的颗粒）、微颗粒（硬的，圆形的颗粒）、纤维（纤维或薄的均匀的塑料丝）、薄膜（薄的，二维的塑料薄膜）和泡沫（即泡沫塑料类型的材料）。（2017年）。尽管如此，它们可分为六种基本类型：聚乙烯（PE）、聚丙烯（PP）、聚酰胺（PA）、聚氯乙烯（PVC）、聚苯乙烯（PS）、聚氨酯（PUR）和聚对苯二甲酸乙二醇酯（PET）（Hidalgo Ruz等人，2012年；Van Cauwenberghe等人，2015a；Pitt等人，2018年）。据彼得斯等人说。（2017年），碎片是最不常摄入的多磺酸粘多糖，而它们是由多磺酸粘多糖降解产生的。降解多磺酸粘多糖和风化聚合物颗粒的粒径在50至5000μm之间，可用于海洋、淡水和河口环境（Peters和Bratton，2016）。表1显示了一些研究中不同类型MPs的大小、形状和颜色。

根据这一介绍，本次审查的目标是



⁎对应作者。

*E类-邮件 地址：* Shahab\_rezania89@yahoo.com（S.Rezania），junbpark@snu.ac.kr（J.Park）。

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## 表1

不同类型MPs在外观方面的比较。

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 类型 | 大小 | 形状 | 颜色 | 组合群 |
| 碎片 |  | 切屑/切屑 | 不同颜色 | 优势群 |
| 胶卷 | <0.1毫米 | 硬朗 | 不同颜色 | 不常见 |
| 泡沫 | 直径0.1 mm | 细长的形状，海绵状结构 | 白色/黄色 | 通常是PS和PE |
| 塑料颗粒    纤维 | 0.25–0.5毫米，  1–2毫米，  厚度为30μm， | 球形圆柱圆形 | 白色/灰色无色/半透明白色/透明 | 微珠聚乙烯  所有粒级 |

采纳者：（Kunz等人，2016；Van der Hal等人，2017）。

（1）淡水环境（湖泊和河流）、海洋和污水处理厂等环境中的MPS污染（2）生物群中MPS污染的评价和（3）基于现有差距的MPS损坏的对策和方法的建议席。

2.   微型塑料的来源

确定MPs来源对于减少社会、环境和经济影响至关重要（Pettipas等人，2016）。多磺酸粘多糖的来源可分为一级，如球团和二级，这是由较大的塑料碎片造成的。此外，污染源的分类可以是陆基的，如垃圾、微珠和海基的，如渔网、浮标（Browne，2015）。它们也可以由更大物体的碎片形成，这些碎片会导致更小的塑料碎片进入环境。不同研究中，MP含量和潜在来源的分类差异很大（Collignon等人，2012）。MPs可以起源于海外港口、工业生产场所、旅游和城市径流等人类活动、纺织业和污水处理厂（Dubaish和Liebezeit，2013；Cesa等人，2017）。此外，由不同来源制成的不同类型颗粒，如热塑性复合涂料制成的路面标记、合成纺织品制成的纤维以及塑料瓶和包装材料等大型垃圾碎片（Horton等人，2017）。甚至，MPs颜色的多样性也决定了MPs的多种来源（Yu等人，2016）。

有色多磺酸粘多糖的存在证明它们来源于合成物质，可能富含微量有机物质。然后，根据形态将MPs分为一级（小尺寸制造）和二级（从较大的塑料中提取）。另一方面，可以根据形状和表面纹理（即，平滑边缘/纹理，对称形状分类为主要形状）将其分类为主要形状或次要形状（Estahbanadi和Fahrenfeld，2016）。

初级MPs源于塑料生产或回收过程中的溢出以及个人护理产品中的微清洁颗粒（Anderson等人，2017年）。这些产品，如面部磨砂膏，已被确定为潜在重要的MPs主要来源，尤其是海洋环境（Conkle等人，2018）。根据Estahbanadi和Fahrenfeld（2016）的研究，四种个人护理产品中MP的大小分布为63–125μm、125–250μm、250–500μm和500–2000μm（Browne，2015）。

二级MPs由大块塑料碎片制成，包括海洋垃圾、洗衣房排出的合成纤维、陆地垃圾和工业或农业垃圾。它们来源于通过机械力、热降解、光解、热氧化和生物降解过程（较大的塑料碎片）的碎裂（赵等人，2015）。因此，由于来源和途径的巨大多样性，二级MPs的识别非常困难（Stolte等人，2015）。此外，由于MPs的化学成分和较大的表面体积比，有必要对其成分进行研究（Wagner等人，2014）。

例如，化妆品中约93%的多磺酸粘多糖是聚乙烯，有些是由聚丙烯、聚乙烯-聚酯和尼龙制成的（Eriksen等人，2013年）。值得注意的是，微珠吸附之间存在一些显著差异

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并观察到聚乙烯颗粒的吸附作用。尽管如此，这些影响的方向是化妆品中的微珠往往吸附较低浓度的持久性有机污染物（POP），然后是聚乙烯颗粒（Napper等人，2015年）。

更多的工作已经做了使用多磺酸粘多糖作为物理磨料在做的产品。例如，根据安德森等人的报告，即使是容器也可能是MPs的来源，MPs来源于对容器的影响。（2017）和Tamminga等人报告的船舶运输办公室。（2018年）。事实上，为了防止环境污染，需要了解多磺酸粘多糖的来源和途径（Browne，2015）。

3.   检测技术

为了评价MPs污染，选择合适的识别方法至关重要。可靠的方法应在取样技术上达到一致性，并考虑到分析MPs形状和化学成分的重要性（Alomar等人，2016）。由于文献中所述的定量方法有限，因此迫切需要协调取样、提取、鉴定、评估和质量保证程序（Vandermersch等人，2015年；邱等人，2016年）。正如Wesch等人所讨论的。（2016年），应标准化微型纤维识别方法的最新发展，如采用光谱技术，以更有效地监测MPs。多磺酸粘多糖检测技术综述如下：

1） 目视识别：该方法对于从样品残留物中的其他有机或无机材料中分离MPs是必要的。目视评估有助于区分来自现场样本的MPs和来自实验室污染的MPs（Mathalon和Hill，2014）。这种方法可以检测出大的多磺酸粘多糖，而应使用解剖显微镜观察到较小的颗粒（Doyle等人，2011年）。据Lee等人报道。（2013年），未经显微镜观察和随后的光谱确认，无法识别和计数小于1 mm的颗粒。另外，对于小于500μm的聚合物类型的检测，由于识别水平低，不建议使用此方法。该方法也适用于20μm的透明小颗粒（Mintenig等人，2017）。

2） 密度分离及随后的C:H:N分析：在本方法中，通过不同密度分离的聚合物是精确的，而对于高密度聚合物的提取，本方法不适用。通过称量一定体积的溶液，可以得到颗粒的密度。密度分离对海洋沉积物很有用，因为多磺酸粘多糖比轻质塑料更容易下沉。该方法可通过C:H:N分析确定塑料颗粒的来源（Claessns等人，2013）。

3） 裂解GC/MS：通过上述方法，可用于聚合物类型的鉴定。将热解图结果与所选标准聚合物进行比较，可以得到相应的结果。因此，由于分析一个颗粒，不推荐使用此方法处理大量样品

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# 文本框: (McDermid and McMullen, 2004) (Morét-Ferguson et al., 2010) 文本框: (Song et al., 2015a), (Imhof et al., 2012).每次运行（Nuelle等人，2014年）。

（四）文本框: Reference文本框: (Hidalgo-Ruz et al., 2012)文本框: Long time and high eﬀort is needed. Not applicable for smaller particles.
Only small size particles can be manipulated manually that resulted in limitation of lower size particles analysis.
Fluorescent samples excited by the laser cannot be measured.
文本框: (Fries et al., 2013)文本框: Due to high absorption rate, black particles are not detectable.
The results of analyzing secondary MPs is unclear due to the size.
文本框: (Harrison et al., 2012) (Talvitie et al., 2017)拉曼光谱：基本上，拉曼光谱是识别海洋环境中最常见塑料类型的合适方法（Lenz等人，2015）。在这种方法中，只能测量非常小的塑料颗粒（尺寸小于1μm）。它的工作原理是用通常在500到800纳米之间的单色激光波长照射样品，并将结果与已知的聚合物光谱库进行比较，以确定粒子的组成（Young和Elliott，2016）。最近Schymanski等人。（2018）发现尺寸小于20μm的颗粒可以使用高分辨率的μ-拉曼光谱检测，效率大于80%。

五）文本框: Size limitation of higher than 1 mm.
Time-consuming with high rate of error > 20%. Ancient method and not too accurate.
红外光谱学：红外显微光谱学是一种将红外光谱学与显微技术相结合的工具，使用显微红外光谱和红外光谱带。这是一种低成本、易用的确定MPs聚合物类型的可靠方法（Browne等人，2010年；Lusher等人，2014年）。多磺酸粘多糖的检测是基于红外辐射对分子振动的刺激，它取决于物质的位置、分子结构和波长。塑料聚合物具有高规格的红外光谱，具有不同的能带模式，用于检测海洋中多磺酸粘多糖的成分和来源（Van der Hal等人，2017年）。表2显示了基于MPs的优点和局限性的检测方法的比较。

文本框: limitation文本框: MPs source, degradation stage, type, color and shape of particles can be detected easily.
Distinguishing diﬀerent size categories of MPs
文本框: Detection of polymer type but not a rigorous chemical analysis
Relatively more accurate than density separation
文本框: Facilitate the detection of even the smallest MPs. Accurate method to identify the abundance and polymer types of MPs.
An optimal technique for the identiﬁcation of MPs polymers with highly speciﬁc distinct band patterns
最近，Serranti等人。（2018）开发了一种基于高光谱成像（HSI）的创新方法，以便一次性对海洋MPs的聚合物类型、尺寸定义和形状特征进行分类。HSI可用于船用MPs的化学表征，其结果与FT-IR结果接近，且快速、可靠、无损，无需样品制备。对于MPs的识别，可以使用以下方法的组合：

*3.1条。组合方法*

文本框: Application/key point文本框: Using microscope too observe the composition
Materials retained in the sieve are collected (and sorted),
Separation based on diﬀerence in density and velocity of the sample
Comparison of polymer origin with their characteristic combustion products Sample is irradiated with a laser
wavelengths in the range of 500 to 800 nm
文本框: Infrared radiation causes molecular vibrations建议同时使用显微镜和光谱方法分析大量样品。为此，应使用第一个FTIR或拉曼光谱来创建基于样品的标准，以识别样品组中的主要和典型MPs。然后，立体显微镜可用于根据筛选结果计算MPs（Song等人，2015a）。最近，Herrera等人。（2018）建议采用密度分离与96%乙醇相结合的方法从海滩样品中提取多磺酸粘多糖。此外，为了分析淡水中的多磺酸粘多糖，使用不同的组合技术可以改善单一方法难以调查的数据（Li等人，2018）。

文本框: Table 2
Comparison of diﬀerent MPs detection techniques.
例如，Lóder和Gerdts（2015）使用基于焦平面阵列（FPA）的微FTIR光谱技术作为识别MPs颗粒聚合物来源的一种有希望的技术。该方法不仅能检测到肉眼可见的小于500μm的颗粒物。与其他方法相比，该方法还缩短了分析时间，因为检测时间小于9小时（Tagg等人，2015年）。

文本框: Procedure文本框: Density Separation with Subsequent C:H:N Analysis
Pyrolysis-GC/MS
提出了一种新的MPs提取方法，该方法基于次氯酸钠消解和超声分离膜中的MPs，适用于随后的拉曼光谱分析。它可以减少荧光问题，从而更好地识别鱼胃内容物中的生人颗粒，从而提高对海洋环境中多磺酸粘多糖污染的检测。因此，使用该方法可以更准确地测定摄入的MP的类型和数量（Collard等人，2015）。

文本框: Method文本框: Visual Identiﬁcation文本框: Sieving文本框: Raman Spectroscopy文本框: IR Spectroscopyclassens等人提出了另一种组合方法。（2013），用于从沉积物和无脊椎动物组织中提取多磺酸粘多糖。该方法包括通过淘析减少样品体积，然后使用高密度NaI溶液进行密度分离，该溶液对沉积物具有较高的提取效率。从动物组织中提取多磺酸粘多糖，采用化学消化法，效率高（94-98%）。总之，这些新方法给了我们

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# 全面了解海洋和生物群中多磺酸粘多糖的存在。在下文中，我们回顾了微生态在生物席和水生环境中的存在。

4.   水环境中的微塑料污染

由于与不同类型重金属和疏水性污染物等污染物的相互作用，多磺酸粘多糖污染被认为是对水环境和海洋生物的严重问题（Teuten等人，2009；Ma等人，2016；Vedolin等人，2017；F.Wang等人，2018）。在这篇综述中，我们将水环境分为三类：海洋，包括海滩和海洋，淡水，如河流和湖泊和污水处理厂。

*4.1.   海军陆战队（海滩和海洋）*

多磺酸粘多糖污染已在海洋生态系统中报告，如二聚体、开阔水域和生物（do Sul和Costa，2014；Auta等人，2017）。在北美、南美、安特-阿尔契卡、亚洲、大洋洲、欧洲、南部非洲以及地中海和极地的东西海岸，对海洋区域的多磺酸粘多糖进行了研究（Wessel等人，2016年；Waller等人，2017年；Obbard，2018年）。MPs在海洋环境中的命运和影响尚未完全确定（Avio等人，2017年）。克拉克等人发现。（2016），海洋环境中MPs的空间分布和长期命运仍不清楚。这取决于这些因素包括（1）其化学结构（2）密度与海水密度（3）易受天气影响（4）将添加剂并入其配方中（5）聚合物性质（6）生态影响和（7）破碎能力（Andrady，2017；Arias Andres等人，2018）。

根据文献，假设海洋中的大多数塑料是MPs，其中包括微型纤维（Mathalon and Hill，2014；Veerasingam et al.，2016）。例如，大西洋和地中海的MPs平均丰度高达每25 cm3 1 MP，回收深度为1176至4843 m（Van Cauwenberghe等人，2013）。La Daana等人。（2018）发现在北极中央盆地的地下水面（8～4369米）存在以席夫和合成聚合物为主导的MPS。

海滩是一个高度碎片化的塑料碎片库，将MPs颗粒运送回沿海水域，最终到达开阔海域（Fok等人，2017年）。据Herrera等人报道。（2017）加那利岛沿海地区海洋废弃物污染水平较高，主要取决于当地规模的风浪条件。发现的碎片类型主要是来自公海的塑料碎片和焦油。即使如此，中尺度海洋动力学对亚热带涡旋内海面的塑性碎片分布也有影响（Brach等人，2018）。表3显示了全球海洋环境中多磺酸粘多糖污染的最新研究。

*4.2.   淡水（河湖）*

偏远地区内陆湖泊的MPs存在对环境产生了负面影响，并成为一个全球性问题（Zhang等人，2016）。顺便说一句，多磺酸粘多糖广泛分布于淡水水域和沉积物中，自几年前以来，它们的存在及其对环境的影响受到了更多的关注（Eerkes Medrano等人，2015年；Vaughan等人，2017年）。它们漂浮在地表水中，停留在湖底的沉淀物中。虽然，沉积物比水更稳定，但其在沉积物中的传输速度比在地表水中的传输速度慢（Nel等人，2018年）。因此，可以得出结论，污染源距离与沉积物中多磺酸粘多糖污染水平之间存在直接的相关性（Su等人，2016）。

由于最近甚至在饮用水中也观察到了淡水系统中多磺酸粘多糖污染的严重性，因此有必要对这一问题进行研究（Li等人，2018）。此外，多磺酸粘多糖污染严重

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海洋环境是对人类和动物生命的潜在威胁，应制定一些计划，以减少MPs在城市地区（如淡水）的影响（Eriksen等人，2013年）。因此，不应忽视淡水系统作为海洋环境MPs主要来源的作用（Sighicelli等人，2018）。对河流系统和流域的研究可以为人们提供知识，以了解解决淡水中MPs污染的需要（Miller等人，2017）。根据收集到的数据，开展了许多研究，以估计和调查世界各地河流和湖泊等淡水中的多磺酸粘多糖污染，如表4所示。

*4.3.   废水处理厂*

污水处理厂的松露被认为是MPs的主要来源，因为市政和工业松露含有宏观和微观塑料。使用不同技术在水处理系统中去除大型塑料，但未指定保留小型MP（Mani等人，2015）。虽然，关于污水处理厂MPs污染的研究还不多，但需要像海洋环境建议的那样给予足够的关注（Prata，2018）。根据Murphy等人的报告。（2016）MPs污染环境的主要原因之一是污水处理排放的市政松露。它们含有高水平的个人护理产品，带有塑料微珠。例如，奥尔登堡安装的后处理装置可以在较高水平上降低MP和合成纤维的负荷（Mintenig等人，2017年）。同时，在从污水处理设施接收松露的采样点之间，微纤维的存在和丰度有所不同（Reynolds和Ryan，2018）。微珠的设计目的是通过污水处理厂设施进行处理。

尽管如此，该系统仍无法移除制造的MPs。据统计，每天约有8万亿个微珠通过污水处理厂释放到水环境中（Rochman等人，2015年）。目前，第三级污水处理厂也被视为微垃圾和MPs的来源（Talvitie等人，2017年）。相反，Carr等人。（2016）报告称，二级和三级污水处理厂排放的松露对海洋和地表水环境中的MPs负荷贡献最小。表5显示了最近对污水处理厂MPs污染的研究。

5.   生物区系中的微塑性污染

许多生物（鲸鱼、贝类、海龟）吞下塑料碎片，塑料碎片会积聚在生物群的消化系统中（Matsuguma等人，2017）。如文献所述，鲸目动物在二次摄食过程中会意外吞下塑料，这是在用先前吞食过碎片的猎物喂养动物时发生的。这意味着，微凋落物中巨凋落物的降解也会导致许多其他海洋动物的入侵（Di-Méglio和Campana，2017）。埃斯皮诺萨等人。（2018）发现席夫碱对PVC或PE的持续暴露可破坏Sh Le-嗜酸性细胞中氧化应激引起的免疫系统。因此，PVC比PE显示出更多的鱼白细胞变化。在另一项研究中，在第一次取样时发现摄入MPs的数量最高，表明在实验期间塑料颗粒没有在蛤蜊中积聚（Näkki等人，2017年）。*白樱蛤属 巴尔蒂卡*

一旦海洋生物席损坏，体内可能会发生严重的物理和毒理学问题。因此，应研究多磺酸粘多糖对不同水生物种健康的影响。这些影响分为：a）物理（与颗粒的形状、颜色和尺寸有关）和b）化学（与添加剂和/或吸附化学污染物的存在有关）（Karami等人，2017a；Rainieri等人，2018）。例如，一些参数，如污染水平、位置和当地人类活动，对MPs在鱼肌肉中的积累非常重要（Akhbarizadeh等人，2018）。

多磺酸粘多糖通过海洋生物的摄入进入食物链

|  |  |  |  |  |  |
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|  | 文本框: 195 |  |  |  |  |
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|  |  | | 文本框: MArinePollutionBulletin133(2018)191–208 | | |

表3

海洋中的多磺酸粘多糖污染（2013年以来的最新研究）。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 位置 | 样品类型 | 样品收集 | 检测方法/预处理类型 | MP范围/平均值 | MPs浓度 | MPs的类型/尺寸/颜色 | 评论 | 参考 |
| 纳东附近的六个海滩 | 泡沫塑料是 | 水 | 微观筛分 | – | 27606粒/m2 | MPs包括 | 议员们的丰裕度是 | （Lee等人，2013年） |
| 河口，南 | 最丰富的项目 |  | 随后的观察 |  | 对于大型MPs | 完整的塑料， | 与 |  |
| 韩国 | 在MPs和 |  | 光谱法 |  |  | 碎片和 | 丰富的中塑性材料， |  |
|  | 中塑性碎屑 |  | 决心 |  |  | 泡沫塑料。 |  |  |
| 休闲海滩 | 消费者和 | 沉积物 | 塑料碎片 | 小颗粒 | 155.33±63.48- | MPs累积 | 海滩上75%的塑料 | （Jayasiri等人。， |
| 印度孟买 | 家庭相关 |  | 风干和 | （1-20毫米）为 | 米-2 | 变化的 | 沉积物大小在 | [2013](#_bookmark83)) |
|  | 材料 |  | 个体塑料 | 以 |  | 重量 | 范围1-20 mm |  |
|  |  |  | 粒子排序， | 41.85% |  | （7.30-25.73%）和 |  |  |
|  |  |  | 称重 | 微型塑料 |  | 数 |  |  |
|  |  |  |  | （1-5毫米） |  | （32.56-55.33%） |  |  |
| 斯洛文尼亚的海滩 | 塑料64%，纸张 | 沉积物 | 合并 | 中密度是 | 133至155.6 | 大多数议员 | 旅游业之间没有关系 | （Laglbauer等人。， |
|  | （19%），其次是 |  | 倾析 | 1.25项目m和−2 | 颗粒kg−1 | （74%）较大 | 活动和海洋废弃物 | [2014](#_bookmark91)) |
|  | 玻璃和陶瓷 |  | 反过滤 | 重量 |  | 超过1毫米的蓝色， | 抽样分布 |  |
|  | （11%），金属（2%）， |  |  | 4.45克米。−2 |  | 红色和黄色。 | 时间。 |  |
|  | 橡胶（1%） |  |  |  |  |  |  |  |
| 北欧，北海海岸 | 大多数是PP， | 沉积物 | 筛分，密度 | 纤维范围从 | 2.3颗粒kg/干 | 半透明的 | 小的发生 | （Deki ffe等人。， |
| 德国， | 接着是PE，PET， |  | 分离，视觉 | 0.5毫米至几厘米 | 沉积物 | 纤维，（黑色，棕色 | 潜在的议员没有 | [2014](#_bookmark50)) |
|  | PVC、PS和PA。 |  | 显微镜和气体 | 在长度上，用 |  | 米色） | 与可见光相关 |  |
|  |  |  | 色谱法/ | 直径 |  |  | 塑料碎片。 |  |
|  |  |  | 质谱法 | 小于100μm。 |  |  |  |  |
| 东北大西洋 | 纤维，碎片， | 水 | 拉曼 | 94%的样本 | 2.46颗粒m−3 | 蓝色，黑色，橙色 | 大多数人 | （Lusher等人。， |
|  | 珠子，泡沫 |  |  | 含塑料 |  | 而瑞德 | 样本来自 | [2014](#_bookmark104)) |
|  | 大多数是纤维 |  |  | 与大小 |  | 占主导地位。 | 离海岸的距离和 |  |
|  | 增长95.9% |  |  | 1.25至 |  |  | 城市地区。 |  |
|  |  |  |  | 2.5毫米 |  |  |  |  |
| 新斯科舍省哈利法克斯港 | 纤维含量最高 | 沉积物 | 盐水浮选 | – | 20至80 MPs/10克 | 球形微纤维 | 五次提取后， | （马萨隆和 |
|  | 沉积物 |  | 解决方案和 |  | 沉积物 | 色彩鲜艳 | 大多数议员 | 希尔，2014年） |
|  |  |  | 过滤 |  |  | 形式。 | 恢复。 |  |
| 德国波罗的海海岸 | 二级主生产计划 | 沉积物 | 密度分离， | MPs 43–132纤维/ | 0–7粒/kg | 主要颜色 | MPs浓度 | （Stolte等人，2015年） |
|  | 作为朋友和 |  | 微观筛分 | 千克沉淀物 | 沉积物 | 是蓝色的，紫罗兰色的，还是 | 0–7粒/kg和 |  |
|  | 碎片 |  | 可视化和 |  |  | 绿色 | 2–11纤维/kg干沉积物。 |  |
|  |  |  | 红外光谱 |  |  |  |  |  |
| 韩国金海湾 | 油漆树脂颗粒 | 水 | 显微镜和 | 粒子数 | 88±68粒/L | 绿色、蓝色和红色 | 飘逸的MP丰度 | （Song等人。， |
|  | 有75%的人 |  | 红外光谱 | 从33到 |  |  | 在地表水中 | 2015年b） |
|  | 球体14%，纤维 |  |  | 83粒/L。 |  |  | 全球最高。 |  |
|  | 5.8%，PS 4.6%，以及 |  |  |  |  |  |  |  |
|  | 床单1.6% |  |  |  |  |  |  |  |
| 东南海岸线 | 二级主生产计划 | 沉积物 | 解剖 | – | 在沉积物中 | 蓝色/黑色和红色 | 合成纤维 | （内尔和 |
| 南非 | 作为朋友和 | 和水 | 显微镜 |  | 688.9±348.2和 | 占主导地位 | 一个重要的来源 | 弗罗内曼，2015年） |
|  | 碎片 |  |  |  | 3308±1449和 | 颜色 | 污染。 |  |
|  |  |  |  |  | 水 |  |  |  |
|  |  |  |  |  | 257.9±53.36和 |  |  |  |
|  |  |  |  |  | 1215±276.7分- |  |  |  |
|  |  |  |  |  | 克/米−3 |  |  |  |
| 南部太平洋海岸 | 纤维状多磺酸粘多糖 | 沉积物 | 密度分离， | 平均值 | 48至69 MPs/30克 | 主色 | 旅游业的影响 | （Retama等人。， |
| 墨西哥 |  |  | 然后是过滤 | 厚度为4.247 | 沉积物 | 是 | MPs沿 | [2016](#_bookmark142)) |
|  |  |  | 以及目视检查 | 至50.2μm，以及 |  | 白色>黑色> | 海岸是直接的 |  |
|  |  |  |  | 总长度范围 |  | 蓝色>红色>浅色 | 与海洋生物生存有关 |  |
|  |  |  |  | 0.004266–4.491微米 |  | 棕色的 | 有机体。 |  |
| 卡米洛和卡胡库海滩， | 大多数 | 沉积物 | 筛分、显微镜 | 大多数议员 | –色频分布 | | | （扬和艾略特， |
| 夏威夷 | 碎片是聚乙烯 |  | 观察和 | （95.9%）大小为 | 没有明显的差别 | | | [2016](#_bookmark187)) |
|  | 还有一些PP |  | 拉曼 | 2–4毫米。 | 在两个海滩之间。 | | |  |

()*继续的 在 下一个 第页*

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|  | 文本框: 196 |  |  |  |  |
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|  |  | | 文本框: MArinePollutionBulletin133(2018)191–208 | | |

表3（）*继续的*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 位置 | 样品类型 | 样品收集 | 检测方法/预处理类型 | MP范围/平均值 | MPs浓度 | MPs的类型/尺寸/颜色 | 评论 | 参考 |
|  |  |  |  |  |  | 主色是 |  |  |
|  |  |  |  |  |  | 白色/透明 |  |  |
|  |  |  |  |  |  | 后面是蓝色 |  |  |
|  |  |  |  |  |  | 绿黑/灰 |  |  |
|  |  |  |  |  |  | 红/粉黄 |  |  |
|  |  |  |  |  |  | 橙棕色和 |  |  |
|  |  |  |  |  |  | 紫色。 |  |  |
| 墨西哥湾北部 | PP和PE含量最高 | 沉积物 | 组合 | MPs丰度 | 13.2±2.96和 | 线的形状， | 聚乙烯和脂肪族聚酰胺 | （Wessel等人。， |
| 河口 | 大量的 |  | 筛分密度  分离和视觉 | 范围从5到117  每平方米件数 | 50.6±9.96兆帕  每平方米 | 硬质薄膜和泡沫  蓝色，绿色和 | 数量最少。 | [2016](#_bookmark184)) |
|  |  |  | 排序 |  |  | 多数白人 |  |  |
| 台湾北部海岸 | 大多数是PE | 沉积物 | 同步加速器 | 大多数是 | 484和532 | 大多数人 | 显著的负趋势 | （Kunz等人，2016年） |
|  | 和PP |  | 红外光谱 | 按大小分类  0.25至4毫米。 | 颗粒每  0.0125立方米 | 是白色，灰色和  透明的。 | 介于  粒子及其数目 |  |
| 斯洛文尼亚的一部分 | 超过80%的 | 水 | 筛分和 | 总干重 | 406×103粒/ | 平均值 | 观察。  这个地区有着重要的意义 | （Gajšt等人，2016年） |
| 亚得里亚海北部 | 颗粒物为聚乙烯 |  | 体视显微镜 | 粒子的 | 平方公里 | MP丰度 | 位置和时间 |  |
|  |  |  | 识别、图像 | 4.7g颗粒和 |  | 从所有的样本中 | MP污染的变化。 |  |
|  |  |  | 近红外光谱分析 | 小于5 mm英寸 |  | 472×103±20- |  |  |
|  |  |  |  | 大小 |  | 1×103粒/  平方公里 |  |  |
|  |  |  |  |  |  | （6,29±2,68分）- |  |  |
| 卡塔尔 | 聚丙烯 | 水 | 显微镜和红外光谱 | 尺寸范围从 | 0.71颗粒m−3 | 克/米）。  大多数是蓝色的 | 议员们证明 | （卡斯蒂略等人。， |
|  |  |  |  | 125 μm至1.82 mm，直径150μm  至15.98毫米。 |  | 不透明的白色 | 基于羰基存在的氧化  在FTIR分析中。 | [2016](#_bookmark37)) |
| 地中海，西班牙 | 细丝 | 沉积物 | 筛分，密度 | 议员们分成两个 | 100.78±55.49至 | MPs颜色是 | 没有明显的趋势 | （Alomar等人。， |
|  | 超过60%的MPs。 |  | 分离和 | 粒级： | 897.35±103.31分 | 大部分是黑色或蓝色 | 沉积物粒度之间 | [2016](#_bookmark15)) |
|  |  |  | 显微镜 | 2毫米>x>1毫米 | MPs/kg干 |  | 和MPs沉积 |  |
|  |  |  | 观察 | 和 | 沉积物。 |  | 沉积物。 |  |
|  |  |  |  | 1毫米>x> |  |  |  |  |
|  |  |  |  | 0.5毫米 |  |  |  |  |
| 印度果阿海岸 | 聚乙烯和聚丙烯  优势聚合物 | 水 | 立体镜  显微镜和 | – | – | 主色  议员是白人 | 证明了MPs特性  它们可能起源于 | （韦拉辛格）  等，2016年） |
|  |  |  | 红外衰减 |  |  | 接着是黄色。 | 来源于海洋。 |  |
|  |  |  | 总计 |  |  |  |  |  |
|  |  |  | 反射（ATR） |  |  |  |  |  |
|  |  |  | 光谱学 |  |  |  |  |  |
| 中国渤海 | 聚乙烯 | 沉积物 | 密度分离， | – | 102.9–163.3件/ | 紫色，黑色，绿色， | 所含表面样品 | （Yu等人，2016年） |
|  | 醋酸乙烯），低密度聚乙烯 | （沙子） | 显微镜和红外光谱 |  | 千克沙子 | 粉红色和棕色 | MPs浓度较高 |  |
|  | （光密度PE和 |  |  |  |  | 主色 | 比深度样本更重要。 |  |
|  | 附言） |  |  |  |  |  |  |  |
| 苏格兰奥克尼，斯卡帕流 | 45%为聚乙烯 | 沉积物 | 密度分离， | – | 平均值为730 | 主色 | 没有统计数据 | （布卢门罗德 |
|  | （四氟） |  | 过饱和氯化钠 |  | 2300公斤沉积物−1 | 是 | 显著差异 | 等，2017年） |
|  | 乙烯，15%聚乙烯或 |  | 旋光和红外光谱 |  | （数据仓库） | 蓝色>黑色> | 平均粒子和 |  |
|  | 10%PA，8%PS和 |  |  |  |  | 紫色=白色> | 纤维浓度。 |  |
|  | 3%聚丙烯腈 |  |  |  |  | 红色>棕色> |  |  |
|  |  |  |  |  |  | 绿色 |  |  |
| 加里宁格勒海滩 | 碎片 | 沉积物 | 光学显微镜 | MPs范围从 | 1.3和36.3项 | 紫色、红色和 | MPs范围从 | （Esiukova，2017年） |
| 俄罗斯地区 | 合成纤维和 |  |  | 370±1290至 | 每公斤干沙 | 黄色的是 | 370±1290至 |  |
|  | 塑料薄膜；泡沫  塑料PS和塑料 |  |  | 7330±18800毫克  每平方米 |  | 主色 | 7330±18800毫克  每平方米。 |  |
|  | 碎片 |  |  |  |  |  |  |  |
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表3（）*继续的*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 位置 | 样品类型 | 样品收集 | 检测方法/预处理类型 | MP范围/平均值 | MPs浓度 | MPs的类型/尺寸/颜色 | 评论 | 参考 |
| 提尔黑海沿岸， | 灯丝>88% | 沉积物 | 筛分和立体 | MPs大小介于5之间 | 从42到 | 主色 | 没有统计数据 | （Cannas等人。， |
| 意大利 | 碎片<9% |  | 显微镜 | 和10毫米 | 1069件/公斤 | 是黑色，蓝色和 | 塑料水平的差异 | [2017](#_bookmark34)) |
|  | 在每个样本中 |  |  | 最小值介于 |  | 清楚的 | 样品浓度 |  |
|  |  |  |  | 0.5和1.0毫米。 |  |  | 不同的起源。 |  |
| 俄罗斯波罗的海海峡 | 纤维含量较高 | 沉积物 | 密度分离， | 大小范围从 | 34±10 MPs/kg | – | MPs平均浓度 | （佐布科夫和 |
|  | 而不是 |  | 湿过氧化物 | 0.15至0.43毫米 | 数据仓库 |  | 34±10项/kg干重。 | Esiukova，2017年） |
|  | 碎片和胶片 |  | 氧化作用 |  |  |  |  |  |
| 特拉诺瓦湾（罗斯海， | 纤维最多 | 沉积物 | 体视显微镜  显微镜和 | 塑料颗粒 | 1至90件/m2 | 黄色、白色和 | 最高MPs数和 | （Munari等人。， |
| 南极洲） | 42.8%，其次是电影35%，以及  碎片22.2% |  | 红外光谱 | 样品范围从0.3到22毫米  长度 |  | 黑色是主要颜色 | 重量为676.5±536.4 m碎片−2  3.03±2.85克米，−2 | [2017](#_bookmark117)) |
|  |  |  |  |  |  |  | 分别是。 |  |
| 波斯霍尔木兹海峡 | 大多数是女性 | 沉积物 | 流态化/ | 宽度范围从 | 2至1258 par/kg英寸 | 主色 | 回收率最高的聚合物 | （Naji等人，2017b） |
| 海湾 |  |  | 飞行和红外光谱 | 0.02至4.69毫米 | 不同的海滩 | 是透明的， | 是PE和PET。 |  |
|  |  |  | 分析 | 长度从0.14到 |  | 黄色、蓝色和 |  |  |
|  |  |  |  | 50.00毫米 |  | 黑色 |  |  |
| 以色列地中海沿岸 | 碎片是 | 水 | 微观的 | MPs尺寸0.3–5 mm | 7.68±2.38分- | 浅色（白色 | 无明显差异 | （范德哈尔等人。， |
| 水域 | 支配者 |  | 观察 |  | 克/立方米 | 或者透明的）是 | 在品种和 | [2017](#_bookmark170)) |
| 莱凡提东北海岸 | 93.6–97.7%    碎片是 | 沉积物 | 密度分离， | 塑料尺寸范围 | 0.376件/m2 | 主色    在15种颜色中， | 观察到六种颜色的丰富性。  没有统计数据 | （Gündoĝdu和 |
| 土耳其 | 占优势60% |  | 然后是过滤 | 粒子 |  | 最主要的颜色 | 重要关系 | 切维克，2017年） |
|  |  |  | 微观的 | 坚决的 |  | 是反式的- | 介于 |  |
|  |  |  |  | 为300μm–3 cm，  平均尺寸 |  | 起源。形状  是为了 | 种类和塑料碎片  数量。 |  |
|  |  |  |  | 2.9毫米 |  | 不规则>平面>- |  |  |
|  |  |  |  |  |  | 拉长>球形- |  |  |
|  |  |  |  |  |  | 里卡尔>圆柱形。 |  |  |
| 卡塔尔湾海岸线 | 低密度聚乙烯 | 沉积物 | 筛分，密度 | 尺寸范围 | 36和 | 蓝色占优势 | 有一个异类 | （Abayomi等人。， |
|  | 聚丙烯 |  | 分离和 | 1和5毫米 | 228粒m−2 | 75%然后 | 类型、颜色分布 | [2017](#_bookmark12)) |
|  |  |  | 过滤 |  |  | 黑色9.9%，红色 | 以及MPs的大小。 |  |
|  |  |  |  |  |  | 6.3%， |  |  |
|  |  |  |  |  |  | 绿色4.4%，灰色 |  |  |
| 土耳其列凡提海岸 | 聚乙烯、聚酯和聚丙烯 | 水 | ATR-FTIR分析 | 平均86.3公斤/ | 2.6件/m2 | 2.2%  – | 塑料类型（PE、PET、PP） | （Gündoĝdu等人。， |
|  | 占主导地位。 |  |  | 平方公里重量 |  |  | 显示重要性 | [2017](#_bookmark73)) |
|  |  |  |  | 塑料。 |  |  | 关于 |  |
|  |  |  |  |  |  |  | 物种多样性和 |  |
|  |  |  |  |  |  |  | 富足。 |  |
| 广东南部沿海 | PS泡沫和 | 沉积物 | 筛分和ATR | 近98%的 | 0.1589–5.5884个 | – | 平均值和中位数 | （Fok等人，2017年） |
| 中国 | 碎片 |  | 红外光谱 | 碎片由0.315–5 mm的MPs组成 | 塑料碎片重量（g/m2） |  | 多磺酸粘多糖的丰度高达6675±7021（±SD）和  3146±4181（±MAD）  项目/平方米 |  |
| 波斯湾，伊朗 | 聚乙烯、尼龙和聚酯 | 沉积物 | 密度分离， | 56%的议员 | 61±49粒/ | 透明，白色， | 波斯湾不是 | （Naji等人，2017a） |
|  |  |  | 旋光和红外光谱 | 尺寸类别 | kg/干沉积物。 | 绿色和红色 | 被列为 |  |
| 中国渤海 | 聚乙烯、聚丙烯和聚苯乙烯 | 水 | 显微镜和红外光谱 | 1–4.7毫米长。  55%的议员 | 0.33±0.34分- | 主导色。  主色 | MP污染。  钓鱼线和漂浮物 | （Zhang等人。， |
|  |  |  |  | 范围为0.3–5 mm | 克/立方米。 | 白色，透明，绿色 | 泡沫占优势。 | [2017](#_bookmark190)) |
|  |  |  |  |  |  | 和黄色 |  |  |
|  |  |  |  |  |  | 分别是。 |  |  |

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*S。 礼萨尼亚 et公司 艾尔。                                                                                                                                                                                                                                         米一右我n个e类第页o型陆上通信线u型t型我o型n个乙u型陆上通信线e类t型我n个133(2018)191–208*

# 文本框: Reference文本框: (Courtene-Jones et al., 2017)文本框: Western coasts of Mediterranean zone were less prone to MP accumulations. This study reported the highest MPs pollution in inner continental shelf worldwide. MPs concentration based on particle per m3 were lower than other oceans worldwide. MPs abundance in mudﬂat was higher than sandy shore sediments. 文本框: (Lots et al., 2017)文本框: (Di Mauro et al., 2017)文本框: (Cincinelli et al., 2017)文本框: (Lo et al., 2018)（Cressey，2016年；Abidli等人，2017年）。这种情况威胁到捕食者和人类的健康，他们食用来自受污染生态系统的动物（Guilhermino等人，2018）。据赖特等人报道。（2013年），摄入塑料和多磺酸粘多糖对各种海洋物种（如海龟、鱼类幼虫和哺乳动物）会产生各种后果。此外，一些席损坏的物质，如POPs存在于MPS结构中，也可以被海洋生物（Ster等人，2017）摄取。

文本框: Type/size/color of MPs文本框: Remarks文本框: There was a hypothesis that MPs are exist in the global deep-sea.文本框: Mostly ﬁber and fragments.文本框: Mostly ﬁber and fragments.文本框: Fiber and fragment were the by 57.2% and 37.6%, respectively.从颗粒到动物体内的浸出化学品的毒性取决于暴露途径和在环境中颗粒堆积的环境条件（NoBrE等人，2015；Win等人，2018）。一般假设沿海地区的生物群因摄入多磺酸粘多糖而受到更大的影响（Steer等人，2017）。摄食率的变化可能是由于首选栖息地的不同以及风、洋流输送塑料碎片和摄食行为的影响（Foekema等人，2013年；Murphy等人，2017年）。多磺酸粘多糖与沉积物和一些浮游生物的体积分数相似，通过直接和间接摄入被海洋生物摄取（Gall和Thompson，2015）。多磺酸粘多糖与正常摄食过程中鱼卵、蚯蚓和软体动物的摄食有关，与其他碎屑物（如沙子和木头）的摄食有关（Peters和Bratton，2016）。

文本框: MPs concentration文本框: 70.8 particles m−3文本框: 72 ± 24 to
1512 ± 187 kg/dry sediment
4.8 to 18.4 particles m−3
文本框: 0.0032 to
1.18 particles per m3
文本框: 0.58 to 2116 items kg−1/dry sediment对贻贝的研究表明，多磺酸粘多糖从肠道转移到循环系统（Browne等人，2008）。温度和pH值等肠道条件是提高海洋生物解吸速率和增加潜在生物利用度的重要因素。因此，在较低的pH值和较高的温度下，解吸速率会增加（Bakir等人，2014年）。由Hall等人发现。（2015）摄入的包裹在珊瑚肠系膜组织中的多磺酸粘多糖在其肠道内保留至少24小时，可能损害其健康。*巩膜炎*

文本框: Detection method/ pretreatment type文本框: MP range/average文本框: SEM and FTIR文本框: Sizes ranged from a
0.4 mm for (PET) to a maximum of
8.3 mm for microﬁber.
The majority of MPs size was < 1 mm
文本框: Density separation, and stereo- microscope Microscope and FTIR文本框: 86.03% had size
between 0.001 and
0.01 mm2
文本框: FTIR文本框: –文本框: Sieving, microscope and FTIR文本框: –根据Claessens等人的建议。（2013），缺乏从（软）有机组织中提取塑料颗粒的合适技术，这证明了人们对海洋器官中存在多磺酸粘多糖的兴趣。Miller等人。（2017）指出，在海洋样品中检测多磺酸粘多糖最常用的技术是目视检查、密度测定和酸消化。例如，在与贻贝相关的研究中，通常使用酸消化法，这种方法对组织的完全消化具有非常大的破坏性（Vandermersch等人，2015）。如Lusher等人所报告。（2017），生物群摄入多磺酸粘多糖的提取方法有分离、净化、消化和密度分离。因此，为了保证数据和分析的准确性，这些方法必须标准化。尽管如此，从生物体中提取塑料的技术仍然需要改进，以获得更高的结果准确度。

文本框: Sample collection文本框: Water文本框: Sediment文本框: Water文本框: Water文本框: SedimentTherefore, there is a need to develop methods to evaluate the plastic exposure in free-ranging marine wildlife particularly exposed to MPs ingestion (Savoca et al., 2018). The digestive method for MPs particles protocol for MPs detection is: (1) no cellular or organic structures are visible; (2) if the particle is a ﬁber, it should be equally thick, not taper towards the ends and have a three-dimensional bending; (3) homo- geneously colored/clear particles (Norén, 2007).

文本框: Table 3 (continued)文本框: Sample type文本框: North Atlantic Ocean, Scotland文本框: PET, microﬁbers文本框: Diﬀerent beaches across Europe文本框: Fibers文本框: Northern Gulf of Mexico文本框: PE文本框: Ross Sea (Antarctica)文本框: PE and PP文本框: Beaches in eastern waters of Hong Kong文本框: PE, PP and PET
were > 70%
Some researchers developed new protocols and method for analysis of ingested MPs by Biota. For instance, Karlsson et al. (2017) developed enzymatic digestion protocol using proteinase K with a 97% recovery of spiked plastic particles and no degradation eﬀects on the plastics in subsequent Raman analysis was observed. In another study by Cole et al. (2014), two enzymes and was used for biotic material removal, while retaining anthropogenic and inorganic mate- rial. They found that the optimized enzymatic protocol digested > 97% of the material present in plankton-rich seawater samples with no de- stroying in MPs debris.*Proteinase K cellulase*

文本框: LocationLo and Chan (2018) found slower growth rate during their larval stage of . once receiving continuous MPs for 65 days. As stated by Santos et al. (2015), debris ingestion by marine turtles may cause of death due to blockage of gastrointestinal tract by debris. In addition, MPs concentration was 47.5 items per turtle which*Juvenile Conyx juvenile*

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Table 4

MPs pollution in fresh waters (recent studies since 2013).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Location | Sample type | Detection method | MP range/average | MPs concentration | Type/size/color of MPs | Remarks | Reference |
| Laurentian Great Lakes | Microbeads from consumer | SEM/EDS | Size classes particles | 0.043 particles/m3 | Color variation among | 20% of particles | (Eriksen et al., 2013) |
|  | products |  | 0.355–0.999 mm  consisted of 81% of total |  | particles < 1 mm but majority were blue, white | were < 1 mm. |  |
| Tamar Estuary, Southwest | 82% of the debris and | Sieving and FTIR | The 1–3 mm size | 0.028 particles/m3 | and gold color.  Colors were black and yellow. | Signiﬁcant diﬀerence in size | (Sadri and Thompson, |
| England    Lake Hovsgol, Mongolia | fragments includes PE by 40%, PE by 25% and PP by 19%.  Fragments and ﬁlms were the | Sieving and light | category was the most abundant size.    Wide range of size from | 0.20 particles m3 | PP was present only in 1–3 and 3–5 mm and nylon only in < 1 and 1–3 mm Majority were blue and | frequency distribution between the spring and neap tides was observed.  There was decreasing trend | [2014](#_bookmark147))    (Free et al., 2014) |
|  | most abundant MPS | microscope | 0.333 to 5.00 mm |  | white. | for MPs density with distance |  |
|  |  |  |  |  |  | from the southwestern shore. |  |
| Yangtze Estuary System, | Microﬁbers | Floatation and | MPs had maximum size | 4137.3 ± 2461.5 and | Transparent and colored MPs | The unique design of spatial | (Zhao et al., 2014) |
| China |  | stereomicroscope | of 12.46 mm, and MPs | 0.167 ± 0.138 n/m3 | were the majority of MPs | scales provided good insights |  |
|  |  | method | (0.5–5 mm)  constituted > 90% by |  | with small fractions of white and black. | into MP source and fate. |  |
|  |  |  | number. |  |  |  |  |
| Pearl River Estuary, Hong | Expanded PS | Sieve and Visual | The highest abundance | Median number was | – | The amounts of large plastic | (Fok and Cheung, |
| Kong |  | sorting | size was 258,408 items/ | 520 ± 688 highest |  | and MP debris of the same | [2015](#_bookmark64)) |

Urban estuaries, China PP and PE Agitation, ﬁltration and micro-Raman spectroscopy

m2

Majority size was ranged

0.05 to 1.0 mm

2098 ± 1705 and lowest

94 ± 44 items/m2. Ranged from 10.6% to 119.8%

Colored MPs were the Majority followed by transparent, black and white

types were positively correlated.

The concentrations of suspended MPs proved their bioavailability to low trophic organisms.

(Zhao et al., 2015)

Tibet plateau lake, China PP, PE, PS and polyvinyl

chloride

Taihu Lake, China Cellophane, followed by PE, PS and PP

Sieving, Raman and SEM

μ-FT-IR and SEM/ EDS

The size of 1–5 mm was the most abundance

MPs were dominated by ﬁbers 48–84% in size of 100–1000 μm

8 ± 14 to

563 ± 1219 items/m2.

3.4–25.8 items/L in surface water and 11.0–234.6 items/ kg sediment

White, transparent, yellow and blue

White and transparent items were more common ranging from 29% to 44%

MPs pollution can be problem in inland waters in remote areas which have lack of waste management strategy. This study proved Taihu Lake was the most MPs polluted freshwater lakes worldwide.

(Zhang et al., 2016)

(Su et al., 2016)

Lagoon-Channel of Bizerte (Northern Tunisia)

Fibers and fragments, without plastic pellets

Sediment sample The average MP size for

ﬁbers was

1.39 ± 0.27 mm and for fragments

0.51 ± 0.19 mm

3000–18,000 items/kg dry Sediment

Colors were clear, green white, black blue and red.

Due to high level of MPs pollution, this site considered as a hotspot.

(Abidli et al., 2017)

Hudson River, USA Microﬁbers as 43% cotton,

22% PET, 22% ﬂuoro- polymer/Teﬂon 7% PP and 7% nitrocellulose/clay

FTIR The size range of ﬁbers were 1.24 ± 0.14 mm with a length of 0.33 to

3.59 mm

0.625 to 2.45 ﬁbers L Dominant ﬁber and color was−1

blue followed by black, transparent and red

No signiﬁcant increase or decrease in the abundance of microﬁbers from river source to sea was observed.

(Miller et al., 2017)

River Thames, UK Secondary MPs which had 91% fragments

Sieving, visual inspection and Raman

Majority had size from 1 to 4 mm

33.2 ± 16.1 particles/100 g sediment

Dominant colors were red and yellow.

At all sites MPs were observed which originated from diﬀerent sources.

(Horton et al., 2017)

Urban surface waters of Wuhan, China

PE and PP were the dominant polymer

Stereoscopic micro- scope, SEM and FTIR

> 80% of MPs had a size of > 2 mm

1660.0 ± 639.1 to

8925 ± 1591 n/m3

Colored particles were the major type, accounting for 50.4% to 86.9%,

transparentpart24.7%

Residents and industries along the river shores can result in an increase in densities of MP particles.

(W. Wang et al., 2017)

Beijiang River Pp and PE Flotation, SEM, FTIR – 178 ± 69 to

544 ± 107 items/kg sediment

Dominant colors were brown and blue

Majority of heavy metals carried by MPs were derived from inherent load.

(J. Wang et al., 2017)

Vembanad Lake, Kerala, India

Low density PE was the dominant polymer type

Sieving, wet peroxide oxidation and Raman

MPs in sediment was 96–496 particles m−2

Mean abundance of

252.80 ± 25.76 parti- cles m.−2

Transparent and white were the dominant colors.

Film and foam were the dominant types of MPs.

(Sruthy and Ramasamy, 2017)

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|  |  | 文本框: S. REZANIA et AL. |  |
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|  | 文本框: MArinePollutionBulletin133(2018)191–208 | | |

文本框: 199

*S. Rezania et al.                                                                                                                                                                                                                                         MarinePollutionBulletin133(2018)191–208*

# 文本框: (Matsuguma et al., 2017)文本框: (Di and Wang, 2018)文本框: (Gray et al., 2018)文本框: (T. Wang et al., 2018)文本框: (Sighicelli et al., 2018)文本框: (Peng et al., 2018)accumulated in gastrointestinal system of green turtles (). In study by Van Cauwenberghe et al. (2015b) at six locations along the French–Belgian–Dutch coastline with a plastic body of*Chelonia mydas*

文本框: Reference文本框: MPs abundance in sediment increased from the deeper to surface layers.文本框: No signiﬁcant correlation between MPs concentrations in each sampling site was observed.
Big variation in MPs concentration was due to the diﬀerences in currents, winds, and point sources.
MPs distribution in the local region aﬀected by hydrodynamic eﬀect based on human activities.
Fragments were dominant by 73.7%.
Spheres shape consisted of ﬁber and fragments were dominant.
1.2 ± 2.8 particles g, lugworms had a plastic retention eﬃciency ranging from 0.59% to 1.78% over a 2–6 year lifespan. As conclusion, marine invertebrates such as and had on average 0.2 ± 0.3 and 1.2 ± 2.8 particles per gram of tissue, re- spectively. Table 6 shows the ingested MPs by diﬀerent types of biota throughout the world.−1*Mytilus edulis Arenicola marina*

6.   Future prospects

文本框: Type/size/color of MPs文本框: Remarks文本框: From 100 to 1900 pieces/kg- dry sediment.文本框: White 57%, followed by brown 17% and black 14%, were the dominant colors文本框: In surface water ranged from 1597 to 12,611 n/m3 and in the sediments form 25  to 300 n/kg wet weight
In sediments of Charleston Harbor (413.8 ± 76.7) and
Winyah Bay, (221.0 ± 25.6) particles/m2.
0.330 ± 0.278 items/m3 in the surface water and
2.58 ± 1.14 items/g (dry) in the sediment
4000 to 57,000 particles/km2
文本框: The dominant color was transparent, and small-sized particles were predominant.文本框: Dominant colors were black, blue, colorless (translucent), gray, green, red, and white文本框: Colored, black and transparent-colored文本框: –文本框: 80.2 ± 59.4 items 100 g−1 dry weight文本框: Blue, transparent, white and redFor future studies, several aspects should be considered. As the most researchers studied the level of pollution, source and fate of MPs, the solution for these issue is still unclear. Hence, MPs recovery is almost impossible from natural water streams, identiﬁcation of upstream sources to reduce pollution mitigation is recommended. In this content, policy makers has important role to regulate some roles for the in- dustries to reduce MPs pollution which is threaten the human health as well as biota (Sharma and Chatterjee, 2017; Eriksen et al., 2018; Anbumani and Kakkar, 2018). If the toxic eﬀects of MPs in biota can be evaluated comprehensively, the possibility of same eﬀect to human health can be reduced (Rainieri et al., 2018). In addition, the estimation of polymer products fate and their released materials is necessary to evaluate their eﬀect on environment in the short and long term (Hahladakis et al., 2018).

文本框: Detection method文本框: MP range/average文本框: MPs concentration文本框: Density separation and FTIR文本框: MPs ranged  between 315 μm and 5 mm, while majority         ranged 315 μm−1 mm
MPs < 1 mm accounted for 79.8% of total
文本框: Raman and FTIR文本框: Sieving, H2O2 treatment, SEM and FTIR文本框: MPs size in both Charleston Harbor and Winyah            Bay was > 63 μm
Size ranged from
0.05 mm to 5 mm
文本框: Sieving, density separation and μ- FTIR文本框: –文本框: Density separation, microscope and μ- FT-IR文本框: 62.15% particles were between 100 and 500 μmAs plastic production is in direct relation with MPs generation, the possible solution for reduction of MPs impact in beaches are to scale down the plastic materials usage as well as applying smart recycling methods (Retama et al., 2016). Lusher et al. (2017) recommend further assessment of MPs impacts to predict the extent of the eﬀects on eco- systems, ecological processes and biodiversity. For this issue, to de- termine the type of harmful MPs, the comparison of uptake and re- tention of the diﬀerent categories and shapes of MPs is vital. For example, the behavior of ﬁlms and ﬁbers in marine environment is still unknown, comprehensive laboratory experiments to determine quan- titative characteristics of diﬀerent shapes of MPs in sedimentation process is required (Zobkov and Esiukova, 2017). Although, the role of MP ﬁlms and ﬁbers in marine environment is still unknown, it is re- quired to continue laboratory experiments to determine quantitative characteristics for sedimentation and suspension processes of diﬀerent shapes of MPs. As reported by Peng et al. (2018), future research should directed to the impact of exposure experiments on high-dose and short- term exposure as there are many related to ﬁeld investigation of MPs pollution.

文本框: Sample type文本框: PE, PP, PS, PET, PVC, acrylics and polyamides文本框: PS was the most common type by 38.5% followed PP by 29.4% and PE by 21%.文本框: Fragments were dominants by 76.2% in Charleston Harbor and 77.5% in Winyah Bay
Fiber was dominant by 75.3% in water and 68.7% in sediment
文本框: PE 45%, PS 18% and PP 15%文本框: Water文本框: PP was the most polymerThe investigations should be carried out to understand the real impact of these emerging micro-contaminants fundamentally that are present in aqueous environment and biota (Barboza and Gimenez, 2015). For instance, the diﬀerences between ﬁeld and exposure ex- periments showed that using MPs in laboratory are diﬀerent from the real conditions in term of relationship between exposure of MPs in mussels and water (Qu et al., 2018). As reported by Van der Hal et al. (2017), the ratio between MPs abundances and their abundances in biota in the same size is expected to be high and may induce even higher ingestion by marine biota.

文本框: Table 4 (continued)文本框: Location文本框: Japan, Thailand, Malaysia, and South Africa文本框: Three Gorges Reservoir, China文本框: South Carolina Estuaries文本框: Wind Farm, Yellow Sea, China文本框: Italian Subalpine Lakes文本框: Shanghai, ChinaFor better understanding about environmental fate and ecological impacts of MPs future studies should focus on the development of new modelling approaches to assess transport of MPs in soil, sediments, and water (Lambert and Wagner, 2018). Maybe suitable solution can be detection and elimination of MPs sources and pathways to control in- ventories of materials or using novel equipment and technologies (Browne, 2015). Mai et al. (2018) suggested that for sediment sampling, location and depth should be speciﬁed and standardized while a certain food web of samples should be collected for sampling of biota.

In addition, future investigations can rely on suﬃcient validation of the MPs analysis, to improve the determination of MPs. Hence there are

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Table 5

MPs pollution in WWTPs (recent studies since 2016).

Location Sample type MP range/average Type/size/color of MPs MPs concentration Eﬃciency Remarks Reference Los Angeles (USA) Primary, secondary and tertiary MPs were between 90 and 300 μm in width and 100–600 μm in length More than 90% of these MPs were irregularly shaped blue polyethylene fragments. Around 90 particle/L 95–99% The majority of MPs was similar to the blue PE particles present in toothpaste. (Carr et al., 2016) Raritan River (USA) Primary and In downstream of WWTP, The Upstream (white) and downstream 27.8 to 43.9 particle/ – A moderate correlation between MPs and (Estahbanadi and secondary

concentration of MPs was 125–250 with 250–500 μm size.

(gray). Secondary MPs was the dominant m3 in size (66–88%)

distance downstream was observed.

Fahrenfeld, 2016)

US Tertiary Fibers were the most common type of particle 59% followed by fragments 33%. Mostly black and gray.

0.004 to

0.195 particle/L

– Average 4.4 × 106 particles were released per facility per day

(Mason et al., 2016)

Scotland Secondary Flakes 67.3%, ﬁbers 18.5%, ﬁlm 9.9%,

beads 3.0%, and foam 1.3%

PA, PE and PP were the most dominant types.

0.25 to 15.70 particle/ L

98% Signiﬁcant diﬀerence in the amount of MPS between the four sampling sites was found.

(Murphy et al., 2016)

Netherlands Particle sizes between 10 and 5000 μm Sewage sludges at three of the WWTPs had high number MPs of 650 particles kg wet weight−1

9 to 91 particles L 72% All the inﬂuents and eﬄuents of all−1

WWTPs had MPs and MPs entering to the surface water systems.

(Leslie et al., 2017)

Australia Primary, secondary and tertiary

Size range of 25–500 μm PE was highest in secondary and primary and PET in tertiary

0.28 particles/L 92–99% Synthetic ﬁbers from clothing needs more

attention rather than microbeads form personal care.

(Ziajahromi et al., 2017)

Oldenburg-East- Frisian, Germany

Primary, secondary and tertiary

MPs ranging from 0 to 5 × 101 m MP > 500 μm and 1 × 101 to−3

9× 103 m MP < 500 μm.−3

Black/blue, red, transparent were dominant.

1 to 10 particles/L 97% There was no correlations between MP

numbers, sizes or polymers and population.

(Mintenig et al., 2017)

Ljubljana, Slovenia PE microbeads Size of 37 to 95 μm Average concentration in body and facial

scrubs was 4.82 g/100 mL and 0.74 g/ 100 mL, respectively.

21 particles/m3 87% Even the low concentrations of MPs was

concern for the environment due to their persistency.

(Kalčíková et al., 2017)

Viikinmäki, Helsinki Region, Finland

Primary and secondary

Size ranged from 100 to < 300 μm Pre-treatment had the greatest eﬀect on

size distribution

380 to 686.7 particles/ L−1

99% MPs consisted of PE fragment which usually found in some widely used cleansing scrubs.

(Talvitie et al., 2017)

Mikkeli, Finland Primary and secondary

64% of MPs were smaller than 1 mm Fibers accounted for 96.3% of total MPs

while PE was the most abundant polymer by 63.9%.

0.1 and 1 0.1 to

124.7 MPs/L

98% Due to high variation in MPs, several sampling should be conducted.

(Lares et al., 2018)

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Table 6

MPs pollution in biota (recent studies since 2013).

Halifax Harbor, Nova Scotia

wild and farmed blue mussels (),*Mytilus edulis*

Digestive tract Hydrogen peroxide

treatment

16–20 μm (33.3%).

Location Microorganism Accumulation part Detection method MP range/type MPs concentration Type/size/color of MPs Remarks Reference Ionian Sea (Eastern Deep water ﬁsh such as Gut Stereomicroscope, Fragments was the 1.3 pieces of litter per Dominant colors were The number of debris (Anastasopoulou et al., Mediterranean) P. violacea, G. highest by 56.0%, ﬁsh blue, brown, black, items per ﬁsh ranged 2013) melastomus, S. blainville, followed by plastic bag transparent and green. between 1 and 6 E. spinax and P. bogaraveo fragments 22.0%, Their size ranged from 5 (1.3 ± 0.2 of ingested fragments of ﬁshing to 60 mm. pieces). gears 19.0% and textile ﬁbers 3.0% English Channel Pelagic and demersal ﬁsh Gastrointestin- FT-IR Spectroscopy The size ranged from 1.90 ± 0.10 number of MPs were ﬁbers 68.3% PE by 35.6% and the (Lusher et al., 2013) al tracts 0.13 to 14.3 mm with the pieces per ﬁsh fragments by 16.1% and semi-synthetic cellulosic most common size of beads 11.5%. Black was material, rayon by 57.8% 1.0–2.0 mm. the most color by 45.4%. were most common types. Mussel farm in Two bivalves species: Gut Micro-Raman In M. edulis ranging from In mussels 0.36 ± 0.07 Dominant colors were The annual dietary for (Van Cauwenberghe Germany Mytilus edulis and spectrometer 5 to 10 μm (50.0%), and oyster 0.47 ± 0.16 red and blue. European shellﬁsh and Janssen, 2014) Crassostrea gigas while in C. gigas, particles per gram tissue consumers can be 11,000 11–15 μm (29.6%) and (ww). MPs per year. The average number in wild mussels was ∼170/ 5 mussels while in farmed mussels was

∼375/5 mussels.

170 and 375 per wild and farmed mussel

Colorful, transparent and black

Signiﬁcantly more MPs counted in farmed mussels compared to wild mussels.

(Mathalon and Hill, 2014)

Santos Bay The State of São Paulo, Brazil

*Lytechinus variegatus* Stomach Elutriate and

pellet–water interface assay

Larvae development varied from 17.2% to 53.3%, with a mean of 34.6%.

– Raw and beach-stranded

plastic pellets increased anomalous embryonic development by 58.1%

and 66.5%, respectively.

Plastic pellets act as a vector of pollutants, especially for plastic additives found on virgin particles.

(Nobre et al., 2015)

Northern Ireland Adult whales Digestive tract Microscope and FTIR Mean length of 2.16 mm

( ± 1.39, range 0.3–7 mm)

2.95 MPs per ﬁsh 29 particles (58% ﬁbers; 42% fragments) with a mean of 7.25 particles per compartment ( ± 2.63, range 5–11).

Marine mammals are exposed to MPs via trophic transfer from prey species

(Lusher et al., 2015)

China Bivalves Soft tissue H2O2 treatment, Floatation and ﬁltration, microscope observation, FTIR

Majority of MPs were fragments, ﬁbers and pellets.

4.3 to 57.2 items/ individual for bivalves

The main colors were black, blue, white, red, white and transparent.

250 mm was the most common size by 33% to 84% of the total MPs.

(Li et al., 2015)

Adriatic Sea, Italy Adriatic ﬁsh mullet Gastrointestin-

al tracts

Combination of density gradient separation and oxidant treatment, FTIR

Fragments 57%, followed

by lines 23%, ﬁlms 11%

and pellets 9%

1 to 1.78 items/ individual per ﬁsh

Size of 43% particles was 1–0.5 mm in sampled ﬁsh. The most common polymer was PE 65% followed by PET 19%.

Density gradient separation and oxidation treatment had a 90% yield.

(Avio et al., 2015)

Mediterranean Sea Large pelagic ﬁsh

(, and )*Xiphias gladiusThunnus thynnus Thunnus alalunga*

Stomach Stereomicroscope coupled with Axiovision digital image

Mesoplastics were more abundant in swordﬁsh stomachs by 44.4%, whereas albacore ingested more MPs about 75.0%.

4 to 16 number of plastic debris per ﬁsh

In diﬀerent shapes and color; transparent and white were in all top predators, while blue and yellowish were in blueﬁn tuna and swordﬁsh.

Positive correlation between the level of bioaccumulative and toxic compounds and alteration on the reproductive system.

(Romeo et al., 2015)

Spanish Atlantic and Mediterranean coasts

Demersal ﬁsh Stomach Visual identiﬁcation, alkaline digestion and stereoscopic microscope

Average of 1.56 ± 0.5 items per ﬁsh, and the size of MPs ranged from

0.38 to 3.1 mm.

1.56 ± 0.5 items per

ﬁsh

The dominant colors were black 51%, red 13%, gray 12.7%, blue

8.7% and brown 6.3%.

The highest abundance of MPs was 33.3% in red mullets followed by dogﬁsh by 20.8%.

(Bellas et al., 2016)

文本框: MArinePollutionBulletin133(2018)191–208文本框: S. REZANIA et AL.文本框: 202North and Baltic Sea Pelagic and demersal ﬁsh Gut Visual observation, FTIR

and ATR

Almost 40% of the particles were PE.

0.03 ± 0.18 plastic items

(Rummel et al., 2016)

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Table 6 ()*continued*

Location Microorganism Accumulation part

Detection method MP range/type MPs concentration Type/size/color of MPs Remarks Reference

Brazos River Basin, Central Texas, USA

Sunﬁsh bluegill () and longear ()*Lepomis macrochirusLepomis megalotis*

Stomach Stereomicroscope A signiﬁcant diﬀerence

for mean number of MPs per ﬁsh between the upstream and urban areas observed.

10.1–13.9 of plastic per

ﬁsh

Dominant colors were blue and black in the size range of 150 μm up to 3 mm length and 5–30 μm in diameter.

Dominant colors were gray and blue by 79.1% of the total sample.

No direct eﬀects of ingested MPs on the condition of ﬁsh could be determined.

Sunﬁsh ingested MPs during their normal feeding habits.

Peters and Bratton (2016)

Swedish West Coast Marine invertebrates and

ﬁsh

Stomach Digestion and extraction, light microscope and FTIR

Most common MPs were

ﬁbers.

1 and 3 particles per ﬁsh Dominant colors were

black 32%, blue 28%, red

9%, transparent 6%, and green < 1%

68% of analyzed individuals of brown trout had MPs.

(Karlsson et al., 2017)

Dutch river delta and Amsterdam canals

Common shore crab (); sand hopper (.); periwinkle (); blue mussel () and Paciﬁc oyster ().*Carcinus maenasGammarus sppLittorina littoreaMytilus edulisCrassostrea gigas*

Digestive gland

FTIR In body residues between 10 and 100 particles g dw were measured.−1

11 to 105 particles g dw−1

Colorless and black were the most colors and ﬁbers were the most one.

Suspended MPs in the water phase have the potential to be transported to the sea.

(Leslie et al., 2017)

Northeast Atlantic around Scotland

Demersal & pelagic ﬁsh Gastrointestin-

al tracts

Dissection microscope and FTIR

Plastics ranged in size between 0.1 and 15 mm.

1.8 ( ± 1.7) number per

ﬁsh

Dominants colors were black 43.0% followed by clear 21.9%, blue 13.2%,

red 11.4%, green 9.6%

and white 0.9%.

Ingestion was much higher in species found in shallower coastal waters than species in deeper further oﬀshore waters.

(Murphy et al., 2017)

Paciﬁc and Grays Harbor counties, Washington

Northern Fulmars () and Sooty Shearwaters ()*Fulmarus glacialisArdenna grisea*

Gastrointestin- al tracts

Zoom binocular Maximum dimension of a piece of hard plastic averaged 17 mm for Northern Fulmars and 22 mm for Sooty Shearwaters.

13.3 and 19.5 for fulmar and shearwaters respectively.

31% of fulmar intestines contained plastic with mean dimension

4.8 ± 0.3 mm and mass was 7.0 ± 1.4 mg while in Sooty Shearwaters, the incidence of plastic at 64% (16/25) was signiﬁcantly lower than in fulmars

The average mass in

*proventriculu*s was

65.6 ± 14.9 mg/piece, and in *ventriculus*

25.3 ± 4.0 mg/piece.

(Terepocki et al., 2017)

Texas Gulf Coast, USA Six marine ﬁsh species Stomach Stereomicroscope Fragments were the most

MPs.

0.45 to 1.38 of plastic per

ﬁsh

The majority of MPs ﬁbers were categorized as hue purple/blue by 35.5% and purple by 23.0%.

Foraging preferences and methods of prey capture inﬂuence MPs ingestion.

(Peters et al., 2017)

Malaysia Dried ﬁsh Edible tissues Raman spectroscopy and

EDX

Polymers 59.0% and

pigments 21.3%.

1 to 3 MPs per ﬁsh 29 MPs and 9 pigment

particles were isolated from the eviscerated ﬂesh.

The most abundant polymers were PP 47.2% followed by PE 41.6%, PS 5.56%, PET 2.77%, and

nylon-6 2.77%.

(Karami et al., 2017b)

French Atlantic coast Blue mussel (*Mytilus*

*edulis*) and Paciﬁc oyster ()*Crassostrea gigas*

Soft tissues μFT-IR MP size ranging from 50 to 100 μm was about 50% of MPs for both species

0.61 ± 0.56 per mussel and 2.10 ± 1.71 for oyster.

Majority fragments and ﬁlaments. MPs in the mussels were gray by 51%, black, red, green 23, 11, 8 and 7%

respectively.

Diﬀerent sampling sites and diﬀerent seasons, organism type had eﬀect on contamination.

(Phuong et al., 2017)

文本框: MArinePollutionBulletin133(2018)191–208文本框: S. REZANIA et AL.文本框: 203Fish larvae Digestive tract Microscope and FTIR 1.39 particles m (Steer et al., 2017)−3

### (continued on next page)

Location Microorganism Accumulation part Detection method MP range/type MPs concentration Type/size/color of MPs Remarks Reference Western English 66% of ingested MPs MPs in ﬁsh consisted of Ratio of waterborne MPs Channel, UK were blue ﬁbers, blue or red ﬁbers 83% to ﬁsh larvae ranged mirroring trend for and blue fragments 17%; from 27:1 nearest the waterborne MPs. fragments ranged from coast, to 1:1 at 35 km 50 to 100 μm in size, from the coast. 100 to 1100 μm in Great Barrier Reef Green sea turtles (Chelonia mydas) Foregut ATR-FTIR Particles ranging between 0.45 and – Most particles were transparent and dark Acid digestion followed by emulsiﬁcation (Caron et al., 2018) 4.5 mm green. resulted in no signiﬁcant change in the area of non-digested target polymers pieces. Persian Gulf Five littoral mollusk Whole body Microscope and FTIR Microﬁbres by 50% 0.2 to 21 particles per g MPs were microﬁbres The dietary exposure of (Naji et al., 2018) species followed fragments by of soft tissue and fragments and regional mollusk 26% were most common colored in black, white, consumers of MPs, they type. red, pink and green. have about 4800 MPs per Coastal waters of China Mussels (Mytilus edulis, Whole body Microscope The abundance of MPs in 1.52 to 5.36 items g−1 The most common type capita per year. Mussels were more likely (Qu et al., 2018) Perna viridis) mussels varied 0.77 to 8.22 items individual− 1 of MPs was ﬁber, followed by fragment to ingest smaller rather than larger MPs. and bead, PET, followed by rayon, PE, PVC and PP. PET was 74% in mussels Mondego estuary in Commercial ﬁsh Gastrointestin- Stereomicroscope and (μ- 30% of MPs had the 1.67 ± 0.27 item/ﬁsh. Fibers Fibers 96% Fish species from the (Bessa et al., 2018) Table 6 ()*continued*

with ﬁbers ranging from length.

Portugal

al tract

FTIR)

larger size class (4–5 mm),

followed by fragments 4%. Majority were blue 47%, followed by

transparent 30% and

black 11%.

Mondego estuary are vulnerable to MPs contamination.

Northeast of Persian Gulf, Iran

Benthic and pelagic ﬁsh species

Fish muscles Microscope observation, SEM

MPs were identiﬁed as fragment, ﬁber, and pellet. The majority of the collected MPs were ﬁbrous in shape.

5.66 to 18.5 items/10 g

ﬁsh muscle

MPs were < 300 μm. And dominant colors were black, transparent and blue.

The relationship between metals (except Hg) and ﬁsh size is not clear and consistent.

(Akhbarizadeh et al., 2018)

Spanish Mediterranean coast

*Sardina pilchardus* and

*Engraulis encrasicolus*

Gastrointestin- al tract

Stereomicroscope and FTIR

Ingested ﬁbers was 83% and PET was dominant by 30%

0 to 3 items/ﬁsh Dominant colors were blue by 45.8% and transparent by 20.8%.

The relationship between MPs and natural ﬁber ingestion and sexual maturity was not signiﬁcant

(Compa et al., 2018)

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# many detection techniques but there is a need for establishment of comparability of obtained results with these methods (Klein et al., 2018). Beer et al. (2018) suggested that to better understand about the impact of the MPs levels in Baltic environment, more data on the plastic retention times and potential releases of chemicals from the plastic particles should be obtained.

7.   Conclusion

Acknowledgments

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This paper complied the comprehensive information about im- portance of study on MPs pollution as a critical environmentally issue. In this regard, the following topics were discussed: a) Source of MPs, b) Detection methods and their pros and cons, c) MPs pollution in aqueous environments (marine, fresh waters and WWTPs), d) MPs pollution in biota e) existing gaps and recommendation for future works.

From literature it can be concluded that the sampling and detection of MPs in majority of studies in marine environment performed in se- diment and some of them in water. In terms of color black, blue and white were dominant while PE, PP and ﬁbers were major types of MPs. The range of MPs was between 3 and 150 items per/kg and the con- centration of 2 to 100 MPs/kg of dry sediment. Mostly the researchers concluded that there was no signiﬁcance diﬀerence between variety, abundance, number and types of MPs.

Diﬀerent lakes and rivers had diﬀerent types and level of MPs pol- lution. Similar to marine environment, PE, PP and ﬁbers reported as major types of MPs in fresh waters while dominant colors were trans- parent, white and blue. In addition, variation in type and colors of MPs in freshwaters related to human activities. It can be concluded that the level of MPs pollution was high due to activity of residents and in- dustries those were located near to fresh waters.

In terms of MPs pollution in biota, the majority of ingested MPs were accumulated in gastrointestinal tracts and stomach of biota. The number of MPs in biota was in the range of 1 to 20 items in diﬀerent types of ﬁshes. The dominant color of ingested MPs by biota was black and blue which majority consisted of ﬁbers and fragments.

Based on the recent studies on MPs pollution in WWTPs, primary and secondary treatment can remove most MPs from wastewater, while tertiary treatment was not eﬀective. Additionally, the removal eﬃ- ciency ranged between 70% and 99%, while the remaining fraction is still a problem. Even after removing most of MPs, 0.25–1 MP m may be present in eﬄuent waters. Since large quantities of eﬄuents are released every day, it is conﬁrmed that eﬄuents are responsible for the contamination of ecosystems.−3

Based on these investigations, following conclusion can be drawn:

1.   Determination of particles by physical diﬀraction of the light as FTIR and Raman methods have limitation for small particle size.

2.   Regulate some rules to mitigate the generation of secondary pollu- tion which can be transferred to the marine as well as fresh waters.

3.   Source-reduction based on banning certain plastic applications, such as microbeads in cosmetics products.

4.   Substitution of some plastic products by biodegradable alternatives and improvement of worldwide waste management systems.

5.   Better understanding of MPs fate by evaluation the residence time of MPs within the stomach and gut of biota.

6.   Evaluation of MPs interaction with biota to prevent the associated problems which may threaten the future health.

7.   More attention should be considered for the treatment or prevention of MPs pollution in WWTPs as they are associated to human directly.

8.   Future studies should be directed towards prevention, awareness and reduction methods.

9.   Researchers have to focus to stablish treatment techniques as the MPs detection is developed in satisfactory level.

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