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环境中微塑料的迁移分布、生物效应及分析方法的研究进展

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摘要 微塑料由于其粒径小、光降解能力弱等特点，被视为一种潜在持久性有机污染物，是近年来研究的热点．在微塑料的来源、迁移分布、生物效应和分析方法方面，国内外已有大量的研究，但是缺乏对已有近期研究成果的比较系统、全面的综述．因此，本文对近几年来微塑料在自然环境(陆地、淡水和海洋)中迁移分布、生物效应和分析方法方面的研究进展进行了归纳总结：环境中微塑料的来源分为初级微塑料的直接排放和环境中大块塑料的降解；微塑料在环境中迁移主要通过淡水环境在陆地和海洋环境之间双向迁移；当前，微塑料在环境中的分布研究主要集中在海洋环境中，研究证实微塑料通过洋流作用分布于整个海洋；微塑料的生物效应主要分为摄入效应和与有机污染物结合的复合效应，微塑料对生物的潜在健康风险被初步证实；微塑料的分析方法是微塑料相关研究的基础，很多仪器方法(如显微镜检、光谱质谱分析)已经应用到微塑料的分析鉴定之中，一些新的仪器联用技术(如扫描电子显微镜与能谱仪联用、热吸附解吸与气相色谱质谱联用)也被开发出来．今后应加强对陆地和淡水环境中微塑料的分布、生物效应以及对人体健康影响的研究，并发展更为准确的微塑料定性定量分析方法．本文为微塑料的污染防治提供了较为系统的参考资料，也为该领域的研究、发展提供了可借鉴的思路．

关键词 微塑料，迁移分布，生物效应，分析方法

塑料一般通过油、气或者煤衍生的单体聚合产生，是一种高分子量的有机聚合物[1,2]．全球范围内，塑料的产量已达311亿吨，然而只有69.2%的塑料通过原料回收和能源回收被再次利用(http://www.plasticseurope.org/Document/plastics-the-facts-2015.aspx)，全球每年约2.8亿吨的塑料被当成废品进行处置[2]．由于塑料垃圾自然降解性差[3]，其在自然环境中，包括淡水、海洋、陆地环境的积累逐渐引起社会各界的重视[4~6]．

较大的塑料会通过某种形式的降解与分裂，形成小片段塑料[7,8]．暴露在阳光下的塑料，会在紫外辐射的条件下进行光氧化降解[5]．任何的降解过程都不可避免地弱化塑料，使之变得脆弱，直至分解成粉状的碎片[8]．风沙吹扫和海浪侵蚀等机械磨损也可使大块的塑料变小[9]．这些小块的塑料，被称为次生微塑料[10]．另外，合成纤维材质的衣物在制造、洗涤的过程中，进入自然环境的合成纤维碎片也被称为次生微塑料[1,10]．相对于次生微塑料，还有一种微塑料叫做初级微塑料，即按一定的目的进行设计和生产的微塑料[11]，日常使用的牙膏、面部磨砂膏中就广泛含有初级微塑料．微塑料(microplastics, MPs)是一种人工合成的尺度在0.001~5 mm的有机聚合物[12]．相

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较于大块塑料，微塑料光降解能力减弱，导致其在沉积物、土壤等介质中不断富集[13]，可在环境中持续存在数百年甚至上千年[14]．因此，微塑料作为一种持久性有机污染物，已引起人们关注．为了更好地认识微塑料对自然环境和人类健康的影响，人们对微塑料的迁移分布、生物效应和分析方法等进行了一些研究．

本文主要总结近年来微塑料的迁移分布、生物效应及分析方法的研究进展，一方面为微塑料的污染防治提供资料参考，另一方面探讨了今后微塑料的研究方向和重点．

1 微塑料的迁移分布

1.1 微塑料的源解析

微塑料一般分为两种，初级微塑料和次生微塑料．初级微塑料主要存在于个人护理品中，所以这些微塑料会随冲洗过程经家庭排水系统进入废水处理流[15]，进入到水环境中．尽管现存的污水处理系统对微塑料的最高去除率可达99.9%，仍有数量可观的微塑料进入到淡水环境[13,16]．次生微塑料按照来源主要包括大块塑料的破碎和衣服纤维的断裂．水环境中大块塑料的破碎主要和紫外辐射及水面波浪有关，但小型水域(如河流、湖泊)中的微塑料较大型水域(如海洋)暴露于紫外线中的可能性更高，而缺乏波浪提供的破碎力，这在岩石、潮汐地域的海洋中尤为明显[3]．陆地上的大块塑料，尤其是在土壤表面的，由于暴露在紫外线之下，破碎也是非常容易发生[8]．很多衣物的材质是合成纤维，这也是塑料的一种．研究表明，在洗涤期间每套成人衣服可以减少约1900根纤维[11]，这些次生微塑料会进入废水处理系统，进而进入水环境．

陆地环境中，微塑料的主要来源是含微塑料淡水[17]和污水处理厂污泥的施用．虽然污水处理系统有很好的微塑料去除率，但大部分的微塑料仍保留在污泥中[18]，这些含有微塑料的污泥会被用作农田肥料[19,20]，导致土壤中微塑料含量增加．研究表明，每年应用于陆地环境的微量塑料的质量可能会超过40万吨，这远高于海洋和淡水环境中微塑料含量的总和[21]．有研究发现，在最后一次污泥施用15年以后，仍能在土壤中检测到微塑料的存在[17]，表明微塑料可以在土壤中积累多年，对土壤的影响是长期的．

水环境中，微塑料的来源主要有包括含微塑料污水的直接排放、外界环境中的微塑料的引入和生物的排泄过程．其中，含微塑料污水的排放主要包括个人护理品的排放[22]、纺织厂和服装制造厂废水的排放[23]与污水处理厂污水污泥的排放[24]；外界环境中的微塑料的引入主要包括含微塑料的地表径流和地下径流的引入[9]、降雨暴风等极端恶劣天气对陆地或大气中微塑料的引入[23,25]和已引入的大块塑料的退化；生物排泄物的引入主要发生在海洋环境中，鱼类、贝壳类、鸟类、哺乳动物等海洋动物的体内都检测出了微塑料[26]，浮游生物的粪便中也检测出了微塑料[27]．

1.2 微塑料在自然环境中的迁移分布

微塑料能够在陆地环境、淡水环境和海洋环境之间进行迁移活动，主要的迁移路径如图1所示[16]．淡水环境被视为陆地环境和海洋环境微塑料迁移的桥梁[28,41]，研究表明，70%~80%的海洋微塑料都是通过淡水径流引入的[29]，因此淡水环境中的微塑料较陆地环境更加受到重视．一部分陆地环境中的微塑料会在重力作用和生物活动的影响下沉积到地下[42]，另一部分留在地表．地表上较轻的微塑料在风力的作用下进入淡水水体甚至海洋[30]，较重的微塑料随着地表径流冲刷或水土流失进入淡水系统，例如农业灌溉的排水沟、雨水冲刷等[16,31,32]，继而进入海洋环境．同样的，沉积到地下的微塑料也可能通过地下径流流入淡水系统．微塑料的迁移不仅仅是陆地到海洋的单一方向，在涨潮或洪水事件发生时，也会产生微塑料从海洋向陆地的迁移[33]．

微塑料的整体沉积、保留和运输的程度取决于许多因素，包括人类行为(如乱抛垃圾或回收)、颗粒特征(如密度、形状和尺寸)、天气(包括风、降雨和淹水)、以及环境地形和水文等，这些因素增加了预测迁移行为的困难[30]．微塑料在淡水河流运输的过程，一方面受到河流流速和深度的影响，较慢的流速和较深的深度会引起微塑料的沉积，而较快的流速和较浅的深度会引起已沉积的微塑料的运动[34]；另一方面，微塑料粒径的影响也不可忽略．研究表明由于微塑料的聚集沉积和斯托克斯沉降作用，中等粒径的微塑料更易运输，而较小或较大粒径的微塑料却易被保留下来[43]．

到目前为止，对于微塑料的分布研究主要集中在海洋环境．由于海洋的流动性，微塑料已经渗透了

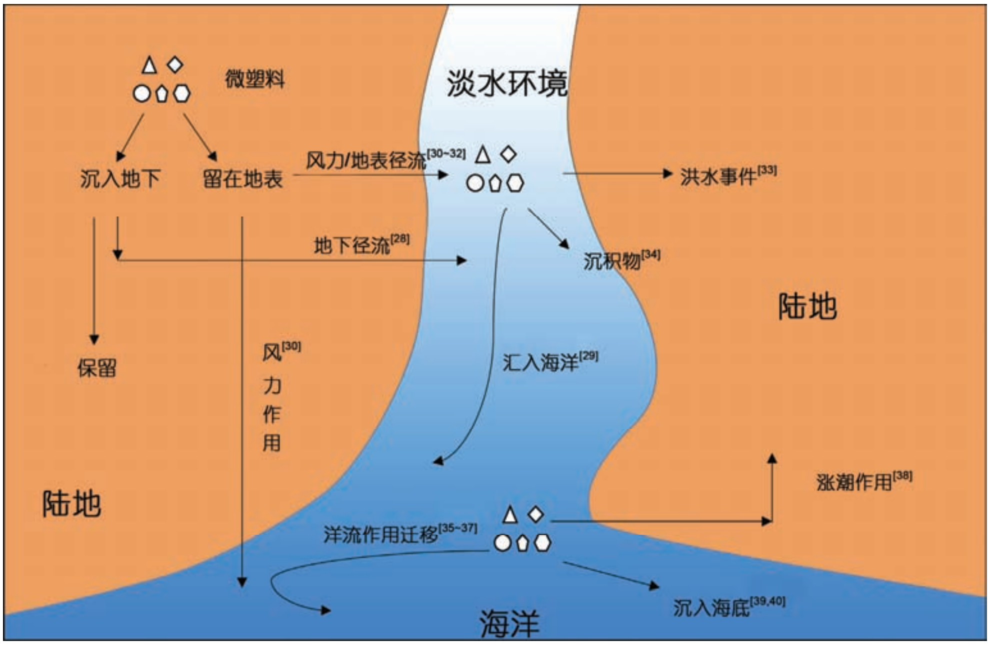

图 1 (网络版彩色)微塑料在自然环境中的迁移

Figure 1 (Color online) The migration of microplastics in the natural environment

整个海洋环境[9,44]，甚至在两极、中海岛和深海地区也发现了微塑料的存在[3,45]．尽管微塑料在海洋中普遍存在，但空间分布却非常不均匀[9]．虽然海洋中的微塑料有聚集于海洋环流的趋势[14,35~37]，但微塑料占海洋的范围和总量还不得而知．一些研究已经建立了模拟微塑料在海洋中分布的三维(3D)模型[46,47]，但已有的3D模型都没有考虑微塑料的粒径、形状、密度等因素的动态变化，比如微塑料会风化、与黏土结合或形成生物膜[48]．海洋中微塑料的归宿主要有两个：密度大于海水的微塑料会在重力作用下不断下沉，并在海洋沉积物中聚集[24]；密度小于海水的微塑料会漂浮在水面上[38]，并在波浪的作用下向海岸线迁移，或者在生物污染的作用下密度增大，最终密度大于海水而沉入海底[8,39,40]．海洋沉积物有积累微塑料的潜力[49]，研究发现，部分沉积物中微塑料的浓度很高，甚至能达到沉积物重量的3.3%[50]．因此，深海地区、海峡谷以及海岸线浅滩地区都是微塑料的聚集处[24,51]．

Wang等人[52]研究了中国中部最大城市武汉的淡水环境微塑料分布，发现人为因素对其分布的影响最大．Zhang等人[53]在中国西藏北部西陵盆地四湖的湖岸沉积物中也发现了微塑料的存在，这说明微塑料已经影响到人类活动非常有限的偏远地区．考虑到海洋及大气的长距离运输，微塑料污染可能是一个全球性问题．

2 微塑料的生物效应

2.1 生物摄入效应

很多证据表明，微塑料广泛存在于自然环境中，包括陆地和水生环境[54~56]，因此生物与微塑料的接触是不可避免的．由于微塑料具有粒径小的特点，很多脊椎动物和无脊椎动物可能误食微塑料．自然界中，超过220个物种被发现能够摄入微塑料，以海洋生物为主，包括原生动物[57]、浮游动物[58,59]、鱼类[60,61]、龟类[62]、鸟类[63]、鲸类[54,64]等．目前对于淡水环境的研究较少，仅发现淡水鱼[65]和大型溞[66,67]能够摄入微塑料．有研究认为陆地生物对微塑料的摄入能力较差，但也有研究发现蚯蚓可以消耗石油中的微塑料颗粒[68]，秀丽隐杆线虫也被观察到能够摄入微塑料[69]．虽然大部分被摄入的微塑料能够通过排泄过程排出体外，但仍有少量微塑料存在于肠道中[70]，甚至穿过肠道壁进入生物的其他脏器中，造成进一步的影响[71,72]．

生物摄入微塑料的危害包括对自身的危害和对食物链(网)的危害．对自身的危害主要是亚致死效应

有关的生理影响, 包括减少繁殖、影响个体生长[73]、减弱适应性、内部损伤(如撕裂伤)和替代食物影响营养摄入等[71,74,75], 并涉及炎症反应、肝压力、氧化应激等等[1,76]. 由于微塑料能在生物体中积累, 食物链和食物网中低能级生物摄入微塑料后, 会对高能级的捕食者产生危害[58,71]. 正是因为越来越多的研究表明这种能级转移的存在, 人们开始关注人类摄入微塑料的健康风险.

2.2 微塑料中的增塑剂

为了使塑料具有一些特殊的物理性质(如弹性、刚性、紫外线稳定性、阻燃性、光泽等), 在生产的过程中常加入一些增塑剂[77~79]. 很多增塑剂具有毒性或是内分泌干扰物, 包括双酚A、邻苯二甲酸酯、多溴联苯醚等[78~83]. 这些塑料添加剂并不与聚合分子结合、或者是一种弱束缚, 因此随着时间的推移, 这些物质很可能从微塑料中释放出来[16], 对环境和生物造成危害. 微塑料增塑剂的释放主要发生在微塑料聚集且分散受限、紫外线充足且温度较高的区域[8], 因此, 垃圾填埋场及垃圾渗漏液中往往含有大量的增塑剂有毒物质[84]. 有学者已经发现了增塑剂对大型溞存在毒性影响[78], 但不同种类的微塑料释放的增塑剂区别很大, 因此毒性影响也非常复杂.

陆地土壤环境中也有大量的增塑剂被检出. Zeng等人[85]对中国广州的土壤进行了广泛研究, 检测出16种邻苯二甲酸酯化合物, 浓度为 0.195~33.5 mg/kg干土. Kong等人[86]对中国天津的耕地土壤样品进行了广泛的收集、检测, 得出了相似的结论. 在这些研究的基础上, Wang等人[87]对中国南京的蔬菜种植农田中的邻苯二甲酸酯化合物进行了分析鉴定, 发现高浓度的位置主要集中在塑料薄膜和塑料大棚使用的地方.

2.3 微塑料与有机污染物结合

研究证明, 环境中的微塑料能与疏水性有机污染物结合[88,89], 常见的疏水性有机污染物包括有机农药、多氯联苯、多溴联苯醚、多环芳烃以及二噁英等[88,90,91]. 微塑料与疏水性有机污染物的结合多发生在陆地及淡水环境, 主要因为人类活动带来的有机污染物的释放使得这两个环境中有机污染物的浓度高于海洋环境中有机物浓度[4]. 疏水性有机污染物由于其高疏水性, 因此很容易吸附水中、土壤中及沉积物中悬浮的有机颗粒. 很多因素都影响着疏水性有机污染物对微塑料的吸附, 包括微塑料的类型、大小、风化程度等[79,89,92,93]. 在海洋环境中, 海水的温度、盐度和pH也是不可忽略的影响因素[94,95].

人类可能通过两条途径接触到微塑料中的疏水性有机污染物. 第一条就是直接摄入, 包括食入含微塑料的双壳类、扇贝等海产品和海盐. 双壳类、扇贝都是通过摄食摄入了吸附有机污染物的微塑料但无法排出体外而在体内积累[96]. Yang等人[97]研究了中国超市中15个品牌的海盐, 均检测出了微塑料的存在. 尽管如此, 至今并没有研究显示, 人类能够通过直接接触微塑料而暴露于疏水性有机污染物[98]. 第二条途径就是通过食用摄入过含疏水性有机污染物微塑料的鸟类、鱼类等所导致的二次暴露, 这些鸟类、鱼类虽然能将大部分微塑料排除体外, 但部分有机污染物却能在体内累积[98]. 因此, 微塑料对人类健康的影响亟待学者们去深入研究.

3 微塑料的分析方法

对环境中微塑料的分析主要包括提取、分离、分析和定量四个步骤, 其中分析鉴定是最重要的一步. 微塑料的分析鉴定方法主要分为物理表征方法和化学表征方法. 现有的分析检测方法及其优缺点如表1所示.

3.1 物理表征

(ⅰ) 目视法. 目视法一般用于鉴定大型微塑料, 即粒径在1~5 mm的微塑料, 通常使用镊子和肉眼同时进行分类和鉴定. 当微塑料尺寸小于1 mm或者存在有机、无机颗粒干扰的情况下, 目视法将不再适用[99]. 总而言之, 在合适的条件下, 目视法是一种简单、快捷的分析鉴定微塑料的方法[100].

(ⅱ) 显微镜检. 显微镜检主要用于鉴别尺寸在几百微米的微塑料, 是应用非常广泛的初步鉴定微塑料的方法[101,102]. 在微塑料的尺寸小于100 μm时, 普通的显微镜很难进行分析鉴定[102], 研究证明普通显微镜的出错率甚至超过20%[103]. 正是因为这些不足, 能够提供更大更清晰图像的扫描电子显微镜(SEM)被应用到微塑料的显微镜检中. SEM可以提供清晰的微塑料表面纹理图像[104], 微塑料的颜色在这里无法作为鉴定的依据.

(ⅲ) 光谱分析. 傅利叶红外(FTIR)分析方法主

表 1 微塑料分析方法及优缺点

Table 1 The analytical methods for microplastics and their advantages and disadvantages

分析方法			优点	缺点
物理表征	目视法		简单、快捷[100]	存在有机、无机颗粒干扰的情况不适用[99]
	显微镜检		提供清晰的微塑料表面纹理图像[104]	出错率高、无法分析颜色信息[102,103]
	光谱分析	FTIR	提供微塑料的组成结构和丰度信息[108,109]	耗时长、成本高
		拉曼光谱	检测粒径小于1 μm的微塑料[66]	对微塑料中的添加剂和颜料化学品很敏感[105,111]
化学表征	DSC		应用广泛	只适用于初级微塑料[113]
	Pyro-GC/MS		能分析微塑料的降解产物[49]	不适用于大量样品的分析[105]
新方法	SEM-EDS		检测微塑料中无机添加剂的成分[115,117]	方法不成熟
	TDS-GC/MS		受杂质影响小, 分析时间相对较短[118]	要求的微塑料含量在1%以上[118]
	新型显微镜	TEM	能分析更小尺寸微塑料[120]	方法不成熟
		AFM	具有高成像分辨率, 能进行液体分析[121]	方法不成熟

要是提供微塑料成分的化学键信息, 不同的键结构会产生不同的峰型, 可以将微塑料和其他有机物、无机物区分开[105]. 透射、反射和衰减全反射都是傅利叶红外常用于微塑料鉴定的方法[106,107], 其中衰减全反射能提供最为稳定的表面光谱信息. FTIR分析不仅能提供微塑料的组成结构和丰度信息[108], 还能提供微塑料风化或氧化的一些信息[109], 这对研究判断微塑料的来源和输入途径十分有帮助[103]. 然而这种方法也存在着一些缺点, 例如每一个微塑料微粒都要逐一在探针下进行分析, 耗时长、成本高.

拉曼光谱分析是一种和傅利叶红外分析十分类似又互补的方法, 广泛应用于微塑料的分析鉴定中[38,110]. 与傅利叶红外相比, 拉曼光谱使用单色激光源, 因此拉曼光谱的激光束可以检测粒径更小, 甚至在1 μm以下的微塑料[66]. 然而, 拉曼光谱检测也存在一些缺点, 一是拉曼光谱对微塑料中的添加剂和颜料化学品很敏感, 这会干扰对聚合物类型的鉴定[111], 另外微塑料中的一些光敏物质会被激光束激发, 无法检测到反射信号[105].

3.2 化学表征

微塑料的化学表征主要是通过检测微塑料的化学成分来进行分析鉴定的. 检测与塑料相关的化学物质的方法可分为直接(或非破坏性)和间接(或破坏性)两种[99]. 以下介绍的差示扫描量热法就属于直接检测法, 而热分解气相色谱质谱联用属于间接检测法.

(ⅰ) 差示扫描量热法(DSC). 该方法是通过检测微塑料聚合物的热性能来进行分析检测的[112], 这种方法在微塑料的分析检测中比较常用[113,114]. DSC主要用于初级微塑料的检测, 如聚乙烯等[113].

(ⅱ) 热分解气相色谱质谱联用(Pyro-GC/MS). Pyro-GC/MS是通过分析微塑料的降解产物来判断它的化学组成的[115]. 通过分析比对微塑料中聚合物燃烧产物的热图谱与已知的特征热谱图, 来判断聚合物的种类[49]. 尽管如此, Pyro-GC/MS也有一些缺点: 必须人工将微塑料放入热解管中, 这不但耗时耗力, 还限制了微塑料的粒径; 一次只能分析一个微塑料颗粒, 不适用于大量样品的分析[105].

3.3 新方法探索

上述的分析方法虽然已经被更多的研究学者应用, 但仍存在着缺点和局限性, 也没有形成统一的方法学. 因此, 上述方法的改进以及新方法的开发、新仪器的使用及联用, 是十分必要的.

(ⅰ) 扫描电子显微镜能谱仪联用(SEM-EDS). 虽然SEM已经广泛应用于微塑料的分析鉴定中了, 但扫描电子显微镜能谱仪联用是在最近几年才开始应用的[100,116]. 扫描电子显微镜能谱仪联用主要是通过检测微塑料中无机添加剂的成分来进行分析鉴定的[115,117].

(ⅱ) 热吸附解吸与气相色谱质谱联用(TDS-GC/MS). Dümichen等人[118]最近提出的分析鉴定微塑料的新方法, 主要是通过热吸附解析去除有机杂质再进行质谱分析. 这种方法要求的微塑料含量在1%以上, 在实际应用中可能需要样品浓缩; 但受杂质的影响较小, 且分析时间相对较短.

(ⅲ) 透射电子显微镜(TEM)和原子力显微镜(AFM). TEM和AFM都是纳米材料表征分析的重要手段. Vignal等人[119]使用AFM绘制了微塑料表面应力场的3D图, 这为AFM用于微塑料的分析检测提供了一个新思路. AFM具有高成像分辨率和能进行液体分析的优点, 因此这项技术的开发利用也非常有价值[120]. 最近有学者将低电压透射电子显微镜技术应用于纳米塑料的分析[121], 这为我们在分析更小尺寸微塑料时提供了一个新方法.

4 展望

综上所述, 我们已经初步了解了自然环境中微塑料的来源分布、生物效应和掌握了一些基本的分析检测方法, 但是仍存在一些认识的不足和研究的空白. 因此, 为了使我们更好地应对微塑料广泛暴露于自然环境的健康风险, 应在以后的科研活动中加强以下几方面的研究: (1) 陆地环境和淡水环境中微塑料的分布及其交互作用研究. 目前, 微塑料的分布研究主要集中在海洋环境, 而鲜有对陆地和淡水环境的分布研究. 例如, 陆地环境中不同地形, 城市或农村, 工业、居住或商业用地等不同陆地环境的微塑料分布特点, 以及河流上中下游、河口支流等不同淡水环境的微塑料分布特点[122], 以及它们之间的交互作用. (2) 微塑料的生物效应研究大多是在实验室内通过受控实验进行的[123], 而在自然环境中的研究还十分缺乏, 特别是基因、细胞、组织、个体等水平上的系统的机理研究还几乎是空白[124], 亟待研究和探索. (3) 更加简单快捷的微塑料分析方法的研究. 虽然一些微塑料的分析方法已被较多采用, 但仍存在着不足和局限性, 还没有被国际上所广泛接受的统一方法学. 在今后的研究中, 一方面要改进这些方法的不足, 另一方面还要不断尝试新的方法, 找到更加准确、便捷的分析方法, 实现方法学的统一和标准化, 以便有效对比来自不同实验室的数据与结果. (4) 微塑料的污染防治、处理技术与相关政策法规研究. 越来越多的研究认识到微塑料的普遍性和不良生物效应, 而对于微塑料的污染防治和处理技术方面的研究却很少. 在今后的工作中, 应突出场地污染的防控技术研发和相关政策法规的制定. (5) 纳米塑料的研究. 虽然对自然环境中纳米塑料的研究要少于对微塑料的研究, 但由于纳米塑料具有高比表面积和高生化活性, 对生态环境及人体健康的影响不容忽视, 今后应加强对纳米塑料来源分布、生态影响以及分析鉴定的研究.

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Summary for "环境中微塑料的迁移分布、生物效应及分析方法的研究进展"

The research progress in migration, distribution, biological effects and analytical methods of microplastics

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Microplastics (MPs) are synthetic organic polymers. The particle sizes of MPs range from approximately 0.01 to 5 nm. The photodegradation of MPs is more difficult than that of bulk plastics. Therefore, MPs are regarded as potential persistent organic pollutants. Researches of MPs have become a hot spot, and lots of MPs studies were reported recently. Although there are a lot of studies on the migration, distribution, biological effects and analytical methods of MPs in natural environments, systematic and comprehensive review articles are emergent, especially for the recent literatures. The present work summarized the researches involving the migration, distribution, biological effects and analytical methods of MPs in recent years. MPs are generally divided into two types, primary MPs and secondary MPs. Primary MPs are intentionally designed and produced for certain purposes, while secondary MPs generate from the fragmentations of bulk plastics and the breakage of clothes fibers. Currently, researches of MPs distribution focus on in marine environments, and found that MPs distributed throughout the ocean, even in the north and south poles, driven by the flow of sea water. However, researches of on MPs distribution in fresh water and terrene are limited. Researches also showed that MPs could migrate among terrestrial, freshwater and marine environments, where freshwater environments affected the migration and interaction of MPs between terrene and marine environments. Studies of biological effects of MPs focus on two parts, ingestion effects and combined effects with organic contaminants. Ingestion of MPs damages living beings and then MPs transfer through food chains. The responses of living beings to MPs are mainly related to sublethal effects at environmental-relevant concentrations. The inhibition of individual growth and reproduction, disturbance of proteins and genes, and reduction of nutrition uptake were reported for specific physiological effects of MPs. Some researches proposed that MPs could be accumulated in living organisms. Therefore, humans, as a part of the food chains, will inevitably be affected by MPs. The organic contaminants combine with the MPs released from the plasticizers in the production of MPs and then are adsorbed in the natural environments. MPs have been found in seafood. As a result, MPs become one medium of human exposure to organic pollutants. The analysis and identification of MPs are critical to other researches, such as environmental behaviors and toxicity. In general, the analytical methods of plastic include physical and chemical characterizations. Physical characterizations involve visual, microscopy and spectroscopy methods. Chemical characterization methods, such as differential scanning calorimetry (DSC), gas chromatography mass spectrometry (GC-MS), scanning electron microscope and energy disperse spectroscopy (SEM-EDS), and thermal desorption gas chromatography mass spectrometry (TDS-GC-MS) are frequently used in chemical characterizations. Although lots of analytical methods were proposed by researchers, there are still some shortcomings and limitations, for example, the influence from environmental or biological matrices. It is necessary to develop effective and accurate methods for the analysis of MPs. Through many researches of MPs were reported recently, the information of source, migration, distribution, biological effects and analytical methods of MPs is not enough to scientifically evaluate their environmental and health risks. Consequently, the present review also proposes some perspectives for MPs researches. It is worth to study the distribution of MPs in terrestrial and freshwater environments, the biological effects at individual level, the prevention and control of MPs pollution and the environmental behavior of nanoplastics. Integrating the data of MPs source, distribution, behavior and toxicity is necessary to the scientific evaluations of MPs risks. This review provides insights in the control techniques and theoretical researches of MPs.

microplastics, migration and distribution, biological effect, analytical method

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