Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in
Green and Sustainable Chemistry

Green strategies for microplastics reduction

Mónica Calero, Verónica Godoy, Lucía Quesada and María Ángeles Martín-Lara

Currently, one of the biggest challenges is to reduce plastics contamination worldwide. In this scenario, some political, economic and social factors play a very important role in implementing efficient processes to control the plastic waste problem. In this work, some of the most recent advances in this field are presented. The eco-design of plastic products, the improvement of legislation for the manufacture, recycling and use of alternative materials, as well as for the intentional addition of microplastics to products, the development and research in biodegradable plastic and bioplastics, and the improvement of wastewater treatment facilities are important tools to reduce microplastic contamination and promote the circular economy.

Addresses
Department of Chemical Engineering University of Granada, 18071, Granada, Spain

Corresponding author: Calero, Mónica (mcaleroh@ugr.es)

Current Opinion in Green and Sustainable Chemistry 2021, **28:**100442

This review comes from a themed issue on **Microplastics (2021)**

Edited by **Teresa Rocha-Santos** and **Catherine Mounyrac**

Available online 6 January 2021

For complete overview of the section, please refer the article collection - Microplastics (2021)

https://doi.org/10.1016/j.cogsc.2020.100442

Targeting the problem of plastic waste in the environment

Plastic wastes represent an important fraction of municipal solid waste in most developed countries in the world. Every year, 29.1 million tonnes of plastics are introduced annually into the municipal waste stream in the EU, of which approximately 25% is still deposited in landfills [1]. Also, 8 million tonnes of mismanaged plastic waste are dumped into the ocean, which can degrade via foto-oxidation and thermo-oxidation into microplastics [2]. These particles are defined as synthetic in composition, nondegradable, insoluble in water and smaller than 5 mm [3].

Primary MPs are those intentionally added to personal care products (PCPs), drilling fluids for oil and natural gas extraction, products used for abrasive cleaning or in detergents [4]. The quantities of primary MPs from the mentioned sources discharged by the EU in a year are between 2900 and 7400 tonnes, being microplastics from PCPs the most contaminant source. The group of secondary MPs includes the wear of synthetic textile garments, the wear of tires, the paints of ships or roads and the physical-chemical degradation of plastic waste [5]. The quantities of secondary MPs dumped every year in the EU are estimated between 1.5 and 1.6 Mt, being tire wear the major source of those MPs [6–8]. MPs often reach seas and oceans through the litter dropped in towns, cities and beaches, poorly managed waste discharges, sewage and effluents, or lost fishing and shipping stuffs [9].

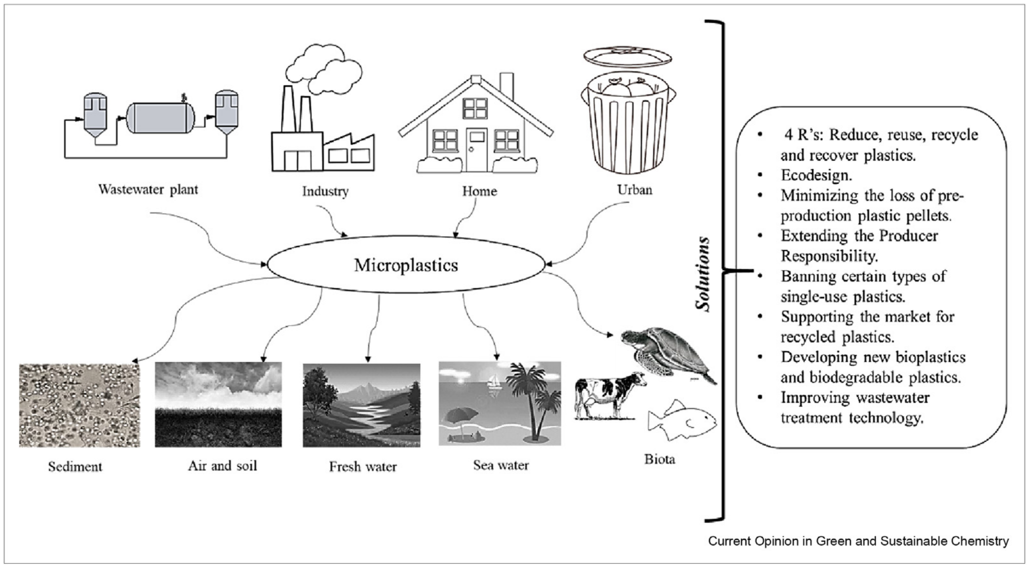
The main challenge to control and reduce the discharge of MPs comprises the development of strong and unitary legislation and the punishment of the countries that do not comply with them. The European regulation “Strategy for Plastics in the Circular Economy” [10] aims to restrict the intentional addition of MPs to products, to control the loss of pellets and to evaluate the Urban Wastewater Directive with regard to the effectiveness of the capture and disposal of microplastics. This regulation also considers carrying out actions for reducing the unintentional dumping of MPs by improving the tire design (abrasion and durability), extending product labeling and allocating more financial resources for ecodesign of plastic products and recycling. Also, there is still an intense debate around biodegradable plastics as part of the solution to solid waste accumulation. Dilkes-Hoffman et al. [11] consider that efficacy of biodegradable plastics should not be underestimated, but it depends on several factors such as the development of strong and unified legislation and the improvement of waste sorting and organic waste handling technologies. Finally, tools for monitoring marine debris and understand its spatial–temporal relationships need to be improved, as well as the development of activities and events to raise citizen awareness.

Figure 1 shows a summary of the main sources of microplastics, the pollution that is produced and the possible solutions that can be adopted to reduce the production and dumping of these particles.

Reduce, reuse, recycle and recover plastics

Waste management is based on the hierarchy of the four Rs, reduce, reuse, recycle and recover [12]. The best

Figure 1



Microplastics pollution in environments and some solutions to reduce this problem.

way to avoid the generation of microplastics is to reduce the amount of plastic waste. This can be achieved by reducing the production of plastic materials, using alternative materials such as glass, cardboard or other recycled or biodegradable products, as well as reusing discarded plastics by creating other products. One of the strategies that is proving to be quite successful is the return of containers in deposits, mainly due to the economic incentive for citizens [13]. Another alternative is recycling, which saves resources and energy, as well as reduces polluting emissions, thus benefiting society and the environment [14]. Finally, using plastics for energy production or for the production of new raw materials is the basis of the recovery process [15]. When it is not possible to reuse or recycle plastic products, the recovery of the energy stored into a residual material can be carried out through several mechanical, biological and caloric systems that convert, reprocess and break up plastic waste into new materials or energy.

Plastic waste reduction strategies at the industrial level

Currently, the plastics industry has a need of constant reinvention in the context of a circular economy, as the production should be linked with plastic waste reduction and their progress towards circularity [16].

The most important strategies for the reduction of plastic waste and progress towards circularity include (1) redesigning plastics for circularity, (2) minimizing the loss of preproduction plastic pellets, (3) extending the producer responsibility, (4) banning certain types of single-use plastics and (5) supporting the market for recycled plastics [17–22].

Redesigning plastics for circularity

In the last few decades, a series of standards and different environmental labels were published with the purpose of covering the environmental aspects of products. Among the set of standards is ISO 14006, which provides guidelines for the incorporation of ecodesign [23]. Ecodesign talks about activities taken at the development phase in order to reduce the environmental impact of the whole life cycle of the product [24,25].

In the case of plastics, eco-designing schemes should be applied to change the current way plastics are produced with the objective of reduction/prevention and reuse, and it requires a fine balance between regulations and incentives [26]. Other actions can be focused on the production of plastics free of toxic additives, the use of alternative materials or the production of long-life plastics [27].

Minimizing the loss of preproduction plastic pellets – initiative Operation Clean Sweep® (OCS)

The loss of pellets in the EU accounted for between 16,000 and 16,5000 tonnes every year [5]. Operation Clean Sweep® is one of the industry initiatives to mitigate this problem. Property of PLASTICS (Plastics Industry Association) and the American Chemical Council, it is a voluntary program designed to prevent pellets (pellets or primary microplastics) from ending up in the sea.

The Operation Clean Sweep® (OCS) scheme consists of promoting the use of good cleaning practices and pellet control in all operations in which plastic pellets are handled to minimize leakage to the environment. Some of the most relevant measures are easily applied, and they include (1) the use of sieves in drains to prevent spilled pellets from entering the sewage system, (2) the use of higher resistance bags or change from smaller package forms into bulk loading e.g. silos and the use of a liner with sleeves when filling containers to prevent pellet loss during loading and transportation, (3) the use of a more efficient cleaning by using vacuum unit to remove powder spillages or (4) the publication of the best practices for internal and external audiences to create good working procedures and specific instructions to achieve zero pellet loss goals.

Extending the producer responsibility

Another tool that can be used to decrease the release of plastic waste is the Extended Producer Responsibility Principle (EPR), in which the responsibility of the producer is extended to the postconsumer stage of the product. In the EU, the implementation of the EPR has shown some difficulties, including the lack of mandatory instruments with concrete measures and the lack of incentives for innovation. Consequently, the EPR needs to be readjusted to be effective in the reduction of plastic waste [28]. For example, in order to achieve a consistent approach, this tool should be based on actual data, reflecting the real costs of waste management and assigning fees and support on a reasonable basis. Also, if producers are only required to fund up to a specific target, they could pull away in areas where costs of service may be higher. Moreover, restrictions on additives constituents that are problematic for later waste management should be harmonized.

Banning certain types of single-use plastics

Several world's governments have banned some single-use plastics for relieving plastic marine pollution [29]. Single-use plastics include bags, food packaging, bottles or containers that are used only once before turning into waste.

In the European Union, the single-use plastics directive that prohibits, from 2021, the sale of single-use plastics is yet underway. However, unfortunately, coronavirus pandemic has contributed to the stop of prohibitions on single-use plastics in some other countries [30,31].

Supporting the market for recycled plastics

Currently, recycled plastic production is not economically competitive. Some possible actions to support the market for recycled plastics can be focused on (1) set taxes on the use of virgin plastics; (2) introduce campaigns concerning the environmental benefits of the use of recycled plastics or (3) incentive the production of recycled plastics [32].

Developing new bioplastics and biodegradable plastics

The increasing demand of society for environmentally sustainable products, as well as the need to reduce the carbon footprint and the accumulation of plastics and microplastic in the environment, has driven in recent years the development of new bioplastic materials that have the same requirements as those used so far but with less impact on the environment [33]. The term 'bioplastic' refers to the plastic generated from renewable biomass sources [34].

The use of bioplastics comprises some environmental advantages, such as increasing resource efficiency by using biomass as raw material, saving fossil-fuel resources, reduction of greenhouse gas emissions and carbon footprint and reduction in the overall cost of manufacturing products [35,36]. Bioplastic materials also have important technical advantages. For example, polyethylene furanoate (PEF) represents a better barrier against oxygen, CO_2 and water steam compared to polyethylene terephthalate (PET) [37].

However, there are some confusing concepts that make it difficult to understand bioplastics. Bio-based plastics or bioplastics are those that come from renewable sources independently of their biodegradability [38]. Biodegradation of plastics does not depend on the raw material but is rather linked to its chemical structure. There are bio-based and biodegradable plastics (starch and corn blends such as polylactic acid (PLA), polyhydroxyalkanoate (PHA) or polybutylene succinate (PBS)) and also bio-based and nonbiodegradable plastics (usually commodity and thermosets plastics that are made from renewable resources (commonly bioethanol)) [38−40].

Bioplastics have been widely applied as the packaging of pharmaceutical materials, drug capsules and in agricultural industries [40,41]. Other sectors that are increasingly demanding bioplastics are single-use bags, the manufacture of household appliances (mainly for the bathroom) and bioplastics for quilting in agriculture.

Bioplastics also present certain technical complexities that need to be solved. For example, many bioplastics derived from agricultural materials pose a challenge to food safety, as these materials do not fulfill the necessary physical requirements [42]. It is also necessary to improve the separate collection and sorting of biodegradable materials, as Directive 2018/851 of the European Parliament about waste sets the objective of separate collection and recycling of bio-waste in all European countries by 2023 [43]. Also, quality controls of the final compost to meet technical requirements and more facilities to accommodate the waste are needed [44,45]. In addition, legislation on bioplastics should be strengthened to avoid the incorrect management of their waste and further pollution of the environment, as well as improve the balance between the properties of the bioplastic during the use phase and its subsequent biodegradability. Also, a better understanding of the fate and potential impacts of MPs from bioplastics is important for progress in this field [46–48].

Improving wastewater treatment technology

One of the main routes of environmental pollution through microplastics is the wastewater treatment plants. This wastewater contains microplastics that come mainly from cosmetics, cleaners or synthetic clothing [49,50]. Currently, wastewater treatment plants can remove 90–98% of microplastics, yet the final effluent contains a large amount of microplastics, which are reintroduced into the environment [51,52]. Consequently, a large amount of microplastics is discharged into rivers and oceans [53]. Microplastics removed from wastewater during treatment processes are often washed away with the sludge, which is commonly used as organic fertilizer [54]. As an example, in the Vancouver (Canada) wastewater treatment plant, a water inflow with 1.76 billion microplastics is determined annually, of which 1.28 billion ends up in the primary sludge, 0.36 billion in secondary sludge and 0.03 billion are discharged to rivers and seas [55].

The improvement of wastewater treatment plant technologies (especially tertiary treatment) is neccesary in order to reduce the amount of microplastics in the final effluent that is released into the environment. Treatment technologies include disc filtration, rapid sand filtration, dissolved air flotation, and membrane bioreactor [51]. Improving tertiary wastewater treatment, particularly the filtration process, is the biggest challenge for pollution by microplastics.

Some of the alternatives proposed for effluent treatment are the use of ozone, rapid sand filtration, reverse osmosis, dissolved air flotation or membrane bioreactors [54,56]. In the case of sludge, oxidation and decomposition treatments are proposed with the aim of release the microplastics trapped inside [54]. Finally, Akiyama et al. [57] believe that 35% of microplastics found in the oceans come from clothing, so they propose an acoustic wave system to filter and eliminate microplastics in washing machines.

In the coming years, society will face the challenge of searching for new technologies in the treatment plants, to reduce the amount of microplastics both in the effluents and the sludge, as well as the revaluation of the recovered microplastics.

Conclusions

The reduction of MPs in the environment is linked to the hierarchy of the four Rs in the plastics sector in general: reduction at source, reuse of products and their subsequent collection and recycling. Based on this premise, the conclusions of this article could be summarized in the following points:

- The role of industries is to improve the design of plastic products (eco-design) to allow more reuse and better recycling, as well as investing in more sustainable products (avoiding single-use plastics).
- The economic measures should include more resources in the research and development of biodegradable plastics and bioplastics, as well as improvement of waste recycling facilities in general and composting facilities for biodegradable waste. This would help in promoting recycling and make it more economically viable.
- Finally, legislation on control in the production of plastics, waste management and use of alternative materials should be unified and reinforced.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Papers of particular interest, published within the period of review, have been highlighted as:

* * of outstanding interest

1. *PlasticsEurope, Plastics–The Facts. An analysis of European plastics production, demand and waste data*. 2019.
2. Jambeck JR, Geyer R, Wileox C, Siegler TR, Perryman M, Andrady A, Narayan R, Law KL: **Plastic waste inputs from land into the ocean**. *Science* 2015, **347**:768.
3. Leslie HA, Bradsma SH, van Velzen MJM, Vethaak AD: **Microplastics en route: field measurements in the Dutch river delta and Amsterdam canals, wastewater treatment plants, North Sea sediments and biota**. *Environ Int* 2017, **101**:133–142.
4. GESAMP: **Guidelines for the monitoring and assessment of plastic litter and microplastics in the ocean**. In Kershaw PJ, Turra A, Galgani F, Eds., *IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP/ISA joint group of experts on the scientific aspects of marine environmental protection*, vol. 99; 2019:130. Rep. Stud. GESAMP.
5. * * *Eunomia, Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products*. Final Report; 2018:335.

This report was prepared for the European Commission and includes a complete description of sources of secondary microplastics, emissions calculations and measures to reduce this kind of pollution.

6. Verschoor A, de Poorter L, Dröge R, Kuenen J, de Valk E: *Emission of microplastics and potential mitigation measures. Abrasive cleaning agents, paints and tyre wear*. 2016:76. RIVM Report 2016-0026.
7. * * *Amec foster wheeler environment & infrastructure UK limited, intentionally added microplastics in products*. 2017:220. Final Report.

This report was prepared for the European Commission and includes a complete description of the use of primary microplastics in products, emissions calculations and an environmental and human health risk assessment by proposing a Risk Management Option Analysis.

8. Baensch-Baltruschat B, Kocher B, Stock F, Reifferscheid G: **Tyre and road wear particles (TRWP) - a review of generation, properties, emissions, human health risk, ecotoxicity, and fate in the environment**. *Sci Total Environ* 2020, **733**:137823.
9. IUCN: *Solutions to plastics in the ocean – the baltic and beyond. Summary of a symposium 13-14 june 2019, arranged by the royal Swedish academy of sciences*. Final Report; 2019:32.

10. ** European Commission: *A European strategy for plastics in a circular economy. Communication from the commission to the European parliament, the Council, the European economic and social committee and the committee of the regions*. Brussels 16.1.2018. COM; 2018. final, (2018).

This communication is part of a European Action Plan for a circular economy with special emphasis on plastics, addressing the challenges posed by this material throughout the value chain and taking into account their entire life-cycle.

11. Dilkes-Hoffman LS, Pratt S, Lant PA, Laycock B: **The role of biodegradable plastic in solving plastic solid waste accumulation**. In *Plastics to energy*. Edited by Al-Salem SM, Ed, United Kingdom: Elsevier & William Andrew Applied Science Publishers; 2019:469–505.

12. Solis M, Silveira S: **Technologies for chemical recycling of household plastics – a technical review and TRL assessment**. *Waste Manag* 2020, **105**:128–138.

13. Eriksen M, Thiel M, Prindiville M, Kiessling T: **Microplastic: what are the solutions?** In *Freshwater microplastics. The handbook of environmental chemistry*. Edited by Wagner M, Lambert S, Eds, vol. 58. Cham: Springer; 2018.

14. ** Prata JC, Silva AL, da Costa JP, Mouneyrac C, Walker TR, Duarte AC, Rocha-Santos T: **Solutions and integrated strategies for the control and mitigations of plastic and microplastic pollution**. *Int J Environ Res Publ Health* 2019, **16**: 2411.

This article reviews the solutions that can be adopted to reduce pollution by plastics in the environment, improving both the life cycle and the management of this plastic waste.

15. Quesada L, Blázquez G, Calero M, Martín-Lara MA, Pérez A: **Characterization of fuel produced from pyrolysis of plastic waste**. *Energy* 2019, **186**:115874.

16. ** Jia L, Evans S, van der Linden S: **Motivating actions to mitigate plastic pollution**. *Nat Commun* 2019, **10**:4582.

This communication summarizes actions to mitigate plastic pollution and is of special interest for improving the information of the topic cover in our work.

17. Andreasi Bassi S, Boldrin A, Faraca G, Astrup TF: **Extended producer responsibility: how to unlock the environmental and economic potential of plastic packaging waste?** *Resour Conserv Recycl* 2020, **162**:105030.

18. Chen Y, Awasthi AK, Wei F, Tan Q, Li J: **Single-use plastics: production, usage, disposal, and adverse impacts**. *Sci Total Environ* 2021, **752**:141772.

19. Civancik-Uslu D, Puig R, Voigt S, Walter D, Fullana-i-Palmer P: **Improving the production chain with LCA and eco-design: application to cosmetic packaging**. *Resour Conserv Recycl* 2019, **151**:104475.

20. Czarnecka-Komorowska D, Wiszumirska K: **Sustainability design of plastic packaging for the Circular Economy**. *Polimery* 2020, **65**:8.

21. Nahman A: **Extended producer responsibility for packaging waste in South Africa: current approaches and lessons learned**. *Resour Conserv Recycl* 2010, **54**:155–162.

22. OECD, Improving Markets for Recycled Plastics: *Trends, prospects and policy responses*. Report of OECD; 2018. Available in: http://www.oecd.org/environment/improving-markets-for-recycled-plastics-9789264301016-en.htm.

23. *ISO 14006*. Geneva: Environmental Management Systems – Guidelines for Incorporating Ecodesign; 2011.

24. Johansson G: **Success factors for integration of ecodesign in product development: a review of state of the art**. *Environ Manag Health* 2002, **13**:98–107.

25. Pigosso DCA, Rozenfeld H, McAloone TC: **Ecodesign maturity model: a management framework to support ecodesign implementation into manufacturing companies**. *J Clean Prod* 2013, **59**:160–173.

26. Copello de Souza L: *SDG 12 Initiatives to reduce the production and consumption of plastics*: *Extract from the civil society report*. Spotlight on Sustainable Development; 2019:5. 2019.

27. Hahladakis JN, Velis CA, Weber R, Iacovidou E, Purnell P: **An overview of chemical additives present in plastics: migration, release, fate and environmental impact during their use, disposal and recycling**. *J Hazard Mater* 2018, **344**:179–199.

28. ** Leal Filho W, Saari U, Fedoruk M, Iital A, Moora H, Klöga M, Voronova V: **An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe**. *J Clean Prod* 2019, **214**:550–558.

This article discusses the role of the Extended Producer Responsibility principle on the mitigation of plastics waste.

29. Den Y, Zhang J, Zhang C, Ding Z, Hao C, An L: **Countermeasures on plastic and microplastic garbage management**. In *Microplastics in terrestrial environments. The handbook of environmental chemistry*. Edited by He D, Luo Y, Eds, Cham: Springer; 2020:95.

30. Prata JC, Silva ALP, Walker TR, Duarte AC, Rocha-Santos T: **COVID-19 pandemic repercussions on the use and management of plastics**. *Environ Sci Technol* 2020, **54**:7760–7765.

31. Vanapalli KR, Sharma HB, Ranjan VP, Samal B, Bhattacharya J, Dubey BK, Goel S: **Challenges and strategies for effective plastic waste management during and post COVID-19 pandemic**. *Sci Total Environ* 2021, **750**:141514.

32. Gu F, Wang J, Guo J, Fan Y: **Dynamic linkages between international oil price, plastic stock index and recycle plastic markets in China**. *Int Rev Econ Finance* 2020, **68**:167–179.

33. Calabrò PS, Grosso M: **Bioplastics and waste management**. *Waste Manag* 2018, **78**:800–801.

34. Karan H, Funk C, Grabert M, Oey M, Hankamer B: **Green bioplastics and part of a circular bioeconomy**. *Trends Plant Sci* 2019, **24**:237–249.

35. Marichelvam MK, Jawaid M, Asim M: **Corn and rice starch-based bio-plastics as alternative packaging materials**. *Fiber* 2019, **7**:32.

36. Mekonnen R Muthuraj T: **Recent progress in carbon dioxide (CO_2) as feedstock for sustainable materials development: Co-polymers and polymer blends**. *Polymer* 2018, **145**: 348–373.

37. Yadav B, Pandey A, Kumar LR, Tyagi RD: **Bioconversion of waste (water)/residues to bioplastics- A circular bioeconomy approach**. *Bioresour Technol* 2020, **298**:122584.

38. Poulopoulou N, Kasmi N, Siampani M, Terzopoulou ZN, Bikiaris DN, Achilias DS, Papageorgiou DG, Papageorgiou GZ: **Exploring next-generation engineering bioplastics: poly(-alkylene furanoate)/Poly(alkylene terephtalate) (PAF/PAT) blends**. *Polymers* 2019, **11**:556.

39. Walker S, Rothman R: **Life cycle assessment of bio-based and fossil-based plastic: a review**. *J Clean Prod* 2020, **261**:121158.

40. ** Shah S, Matkawala F, Garg S, Nighojkar S, Nighojkar A, Kumar A: **Emerging trend of bio-plastics and its impact on society**. *Biotechnol. J. Int.* 2020, **24**:1–10.

This review discusses the types of bio-plastics and differences with respect to fossil-based plastics, the utility of bio-plastics in different sectors and their future prospects.

41. Zhang C, Wang C, Cao G, Wang D, Ho S: **A sustainable solution to plastics pollution: an eco-friendly bioplastic film production from high-salt contained *Spirulina sp.* Residues**. *J Hazard Mater* 2020, **388**:121773.

42. Jiménez L, Mena MJ, Prendiz J, Salas L, Vega-Baudrit J: **Polylactic acid (PLA) as a bioplastic and its possible applications in the food industry**. *HSOA J. Food Sci. Nutr.* 2019, **5**. 048.

43. European Commission, Directive 2018/851 of the European parliament and of the Council of 30 may 2018, amending Directive 2008/98/EC on waste.

44. Zhao X, Cornish K, Vodovotz Y: **Narrowing the gap for bioplastic use in food packaging: an update**. *Environ Sci Technol* 2020, **54**:4712–4732.

45. Adekoyama O, Majozi T, Adedoyin S: **Bio-based and biodegradable plastic materials: life cycle assessment**. In *Handbook of nanomaterials and nanocomposites for energy and*

environmental applications. Edited by Kharissova OV, *et al*., Eds, Springer Nature Switzerland AG 2020; 2020.

46. Kawashima N, Yagi T, Kojima K: **How do bioplastics and fossil-based plastics play in a circular economy?** *Macromol Mater Eng* 2019, **304**:1900383.

47. Shruti VC, Kutralam-Muniasamy G: **Bioplastics: missing link in the era of microplastics**. *Sci Total Environ* 2019, **697**: 134139.

48. Haider TP, Völker C, Kramm J, Landfester K, Wurm FR: **Plastics of the future? The impact of biodegradable polymers on the environment and on society**. *Angew Chem Int Ed* 2019, **58**: 50–62.

49. Kay P, Hiscoe R, Moberley I, Bajic L, Mckenna N: **Wastewater treatment plants as a source of microplastics in river catchments**. *Environ Sci Pollut Res Int* 2018, **25**:20264–20267.

50. Rochman CM: **Microplastics research – from sink to source**. *Science* 2018, **360**:28–29.

51. Katyal D, Kong E, Villanueva J: **Microplastics in the environment: impact on human health and future mitigation strategies**. *Environ Health Rev* 2020, **63**:1.

52. Edo C, González-Pleiter M, Leganés F, Fernández-Piñas F, Rosal R: **Fate of microplastics in wastewater treatment plants and their environmental dispersion with effluent and sludge**. *Environ Pollut* 2020, **259**:113837.

53. Conley K, Clum A, Deepe J, Lane H, Beckingham B: **Wastewater treatment plants as a source of microplastics to an urban estuary: removal efficiencies and loading per capita over one year**. *Water Res X* 2019, **3**:100030.

54. ** Sol D, Laca A, Laca A, Días M: **Approaching the environmental problem of microplastics: importance of WWTP treatment**. *Sci Total Environ* 2020, **740**:140016.

This article deals with the discharge of microplastics into the environment through wastewater treatment plants. It aims to provide an overview of the processes available to remove microplastics from both water and sediment.

55. Gies EA, LeNoble JL, Noel M, Etemadifar A, Bishay F, Hall ER, Ross PS: **Retention of microplastic in a major secondary wastewater treatment plant in Vancouver, Canada**. *Mar Pollut Bull* 2018, **133**:553–561.

56. Zhang Z, Chen Y: **Effects of microplastics on wastewater and sewage sludge treatment and their removal: a review**. *Chem Eng J* 2020, **382**:122955.

57. Akiyama Y, Egawa T, Koyano K, Moriwaki H: **Acoustic focusing of microplastics in microchannels: a promising continuous collection approach**. *Sensor Actuator B Chem* 2020, **304**: 127328.