Consistently inconsistent: the false promise of 'sustainable' plastics

Justine Ammendolia[a,b], *Tony R. Walker*[b] *

[a]*Faculty of Graduate Studies, Interdisciplinary Studies, Dalhousie University, Halifax, NS, B3H 4R2, Canada*

[b]*School for Resource and Environmental Studies, Dalhousie University, Halifax, NS, B3H 4R2, Canada*

* Corresponding authors: Tony R. Walker (trwalker@dal.ca)

Justine Ammendolia https://orcid.org/0000-0001-5750-1103

Tony R. Walker https://orcid.org/0000-0001-9008-0697

This peer-reviewed article has been accepted for publication but not yet copyedited or typeset, and so may be subject to change during the production process. The article is considered published and may be cited using its DOI.
10.1017/plc.2024.9

Abstract

This Perspective explains why the lack of regulation around bioplastics remains a hurdle for the successful development and implementation of a legally binding agreement (the Global Plastics Treaty) by the United Nations (UN) Environment Assembly to curb plastic pollution by 2024. For example, bioplastics have been marketed to consumers as the panacea solution to our plastic waste crisis. Of the >400 million tonnes of plastics produced each year, <1% are bioplastics, but market value of bioplastics is expected to grow. The rapid growth of the environmentally 'sustainable' plastic market has resulted in an overwhelming variety of products with different properties and labels which has led to widespread public confusion, particularly about disposal guidelines. The umbrella term of 'bioplastics' describes plastics that can be fully or partially sourced from biological matter unlike conventional petroleum-based plastics. Within this family of plastics, products can be 'biodegradable', 'oxo-biodegradable' and 'compostable' depending on their chemical composition and external conditions required at disposal (end-of-life). However, cases of petroleum-based biodegradable plastics have been referred to as bioplastics which is inaccurate. Overall, this lack of regulation remains a hurdle for the successful development and implementation of the Global Plastics Treaty.

Keywords: Plastic pollution, Bioplastics, Bio-based plastics, Biodegradable plastics, Global Plastics Treaty.

https://doi.org/10.1017/plc.2024.9 Published online by Cambridge University Press

Impact statement

Unsustainable plastic production, overconsumption and mismanagement has resulted in increased global plastic pollution in the environment threatening sustainability. Most plastics (99%) are produced from fossil-based sources (i.e., conventional fossil-based plastics) and only 1% are derived from bioplastics. For an effective development and implementation of a legally binding agreement (the Global Plastics Treaty) by the United Nations (UN) Environment Assembly to curb plastic pollution by 2024 careful consideration should be given to switching to alternatives to conventional fossil-based plastics to avoid unintended consequences. For example, alternatives to conventional fossil-based plastics include plastics that are composed of renewable or fossil-based carbon sources or combinations of both, which can undergo biodegradation and are marketed as “biodegradable plastics”. However, biodegradable plastics undergo biodegradation only under specific conditions. Other alternatives to conventional fossil-based plastics include those that are derived from renewable resources (“biobased plastics”). These alternatives to conventional fossil-based plastics are often described as being sustainable compared to conventional plastics, yet they cause widespread consumer confusion, are unregulated and have unintended environmental consequences. Simply substituting these alternatives to conventional fossil-based plastics may not be a realistic solution to combat global plastic pollution as they pose hazards to organisms and human health. Increased consumer use of biobased and of biodegradable plastics must not distract from calls to reduce global plastic production to curb plastic pollution. The Global Plastics Treaty must carefully consider potential advantages and disadvantages of biobased plastics and biodegradable plastics compared to conventional fossil-based plastics.

https://doi.org/10.1017/plc.2024.9 Published online by Cambridge University Press

Introduction

Bioplastics have been marketed to consumers as the panacea solution to our plastic waste crisis (Rosenboom et al., 2022). Of the >400 million tonnes of plastics produced each year, <1% are bioplastics, but market value of bioplastics is expected to grow (Geyer, 2020; Silva et al., 2020). The rapid growth of the environmentally 'sustainable' plastic market has resulted in an overwhelming variety of products with different properties and labels which has led to widespread public confusion, particularly related to recycling or disposal guidelines (Purkiss et al., 2022; Charlebois et al. 2022; Walker, 2023). The umbrella term of 'bioplastics' describes plastics that can be fully or partially sourced from biological matter unlike conventional petroleum-based plastics. Within this family of plastics, products can be 'biodegradable', 'oxo-biodegradable' and 'compostable' depending on their chemical composition and external conditions required at disposal (end-of-life) (Mateos–Cárdenas, 2022). However, cases of petroleum-based biodegradable plastics have been referred to as bioplastics which is inaccurate (Burrows et al., 2022).

Careful consideration by regulatory agencies should be given to switching to alternatives, such as bioplastics away from conventional fossil-based plastics to avoid unintended consequences. Aside from widespread consumer confusion related to bioplastics, governments and regulatory agencies need to properly understand that the use of biobased and of biodegradable plastics must not simply replace conventional fossil-based plastics as they have some advantages, but many disadvantages (SCEPT, 2023). Instead, we argue that bioplastics and biodegradable plastics need to be carefully regulated, clearly defined within the ongoing Global Plastics Treaty, and like conventional fossil-based plastics, there is an urgent need to reduce production of all plastics (Bergmann et al., 2022).

Overall, the lack of regulation remains a hurdle for the successful development and implementation of a legally binding agreement (the Global Plastics Treaty) by the United Nations Environment Assembly (UNEA-5) to curb plastic pollution by 2024 (Ammendolia and Walker, 2022; Bergmann et al., 2022; Dey et al., 2022; SCEPT, 2023). On March 2, 2022, the Heads of State, Ministers of environment and other representatives from UN Member States

https://doi.org/10.1017/plc.2024.9 Published online by Cambridge University Press

endorsed a historic resolution at the UNEA-5 in Nairobi, Kenya to end plastic pollution and forge an international legally binding agreement by 2024 (the Global Plastics Treaty). The resolution addresses the full lifecycle of plastic, including its production, design, and disposal (UNEA, 2022).

Bioplastics are not silver bullets to curb plastic pollution

Bioplastics are chemically diverse. Bioplastics are derived from plant-based materials like cellulose (e.g., 'biobased') and can occur in different blends with other plastic materials. In other words, 'biobased' only indicates that the carbon atoms used in the molecule chains are derived from nature (i.e. they are of "bio" origin) (SAPEA, 2020). The most popular 'biobased' materials which consist of ~60% of bioplastic production includes polylactic acid (PLA), which is a thermoplastic monomer derived from renewable, organic sources such as corn starch or sugar cane and poly-3-hydroxybutyrate (P3HB), which is a polymer belonging to the polyester class of bioplastics (Balla et al., 2021). PLA bioplastics are both biobased and biodegradable (but only under industrial composting conditions, usually at a high temperature) (Naser et al., 2021). Unlike PLAs, P3HBs are compostable and biodegradable in natural environments and toted as being non-toxic (Naser et al., 2021). Another example of a widely marketed 'biobased' bioplastic that is not biodegradable, is biopolyethylene (BioPE). Whilst BioPEs can be obtained from sugar cane and possesses similar characteristics to conventional petroleum-based polyethylene, it is not biodegradable which means that it does not mineralize into natural substances such as water, carbon dioxide or compost making their end-of-life claims and disposal in natural environments highly problematic.

Despite the widely used name, blended 'bioplastic' products often include petroleum-based plastics such as polypropylene in various proportions (Mateos–Cárdenas, 2022). 'Biodegradable' and 'oxo-biodegradable' labelled plastic products include additives that catalyse degradation of larger polymers. However, these plastics are not truly biodegradable or composable because they produce plastic fragments that generate microplastics and leach harmful chemicals presenting hazards to organisms and human health (Zimmermann et al., 2020; Venâncio et al., 2022;

https://doi.org/10.1017/plc.2024.9 Published online by Cambridge University Press

SCEPT, 2023). ‘Compostable’ plastics need to chemically breakdown by 90% in 180 days, but this process often requires industrial processing with high heat conditions which is often lacking in most municipal waste management facilities, which means these ‘compostable’ plastics either contaminate the waste stream or must be diverted to landfill (Purkiss et al., 2022). Thus, the lack of standardization of these labels is problematic because it assumes waste management facilities and infrastructure are geographically uniform and can process this specialized waste under ideal conditions.

Lack of consistency in labelling causes confusion

Currently, there are no international harmonized standards for the labelling of ‘compostable’ or ‘biodegradable’ plastics (Purkiss et al., 2022). However, these labels can be used based on regional and national standards (where they exist) where these products are commercially available (Napper and Thompson, 2019). Examples of regional and national standards have been established by the International Organization for Standardization (ISO), European Norm (EN) and the American Society for Testing and Materials (ASTM) (Napper and Thompson, 2019). For instance, products that are labeled ‘compostable’ in Europe must adhere to the EN13432 standard which indicates the ability to be processed in the industrial composting system in Europe (European Bioplastics, 2015). However, few municipal waste management facilities are capable of processing these ‘compostable’ or ‘biodegradable’ plastics making these misleading labels confusing for consumers and problematic at the end-of-life. To use these labels claiming ‘compostable’ or ‘biodegradable’ on products, the producers must adopt independent certification systems that adhere to ISO, EN or ASTM standards until international regulations are developed.

Experimental studies testing validity of the end-of-life claims by these labels are rare, yet a recent study revealed the complicated legacy of bioplastics (Mateos–Cárdenas, 2022). Mateos–Cárdenas (2022) demonstrated that popular consumer products using bioplastics are not always accurate to their definitions of being compostable or biodegradable. Eight different commercially popular biodegradable teabags sold in Ireland were tested and shown to not fully degrade in soil

https://doi.org/10.1017/plc.2024.9 Published online by Cambridge University Press

(Mateos–Cárdenas, 2022). While products containing non-synthetic plastic cellulose degraded into smaller fragments in a matter of weeks, the products made of the bioplastic PLA remained intact in the soil for one full year. Bioplastics that were blended with synthetic plastics were not able to fully biodegrade. Despite the so-called positive branding of environmentally sustainable options for such plastics, this study shows the current flaws in the branding and messaging behind these labels (Mateos–Cárdenas, 2022). Results from the Mateos–Cárdenas (2022) study help reinforce inconsistencies widely used in greenwashing labels in other consumer products.

Similarly, plastic disposable carrier bags that have been shown to behave inconsistently when placed in the natural environment (Napper and Thompson, 2019). Different products labelled as biodegradable, oxo-biodegradable and compostable did not deteriorate uniformly over a 3-year timeline while submersed in seawater, buried in soil, or left exposed in open-air conditions (Napper and Thompson, 2019). The functionality of these products after exposure to the elements under realistic environmental conditions demonstrates that bags still maintained their functionality and could carry groceries up to 6.8 kg (Napper and Thompson, 2019). Inconsistent labelling of other popular consumer products has been document by Walker (2023). For example, littering of pet waste bags may be occurring due to confusion by pet owners, who believe that these so called ‘biodegradable’ bags are compositable in the natural environment, which in the absence of industrial composting facilities, is untrue (Walker, 2023).

These studies have been critical to help demonstrate the consistent inconsistencies of bioplastics use, marketing and “greenwashing” labelling. As a result of these inconsistencies, there is an urgent need for international regulations under the Global Plastics Treaty to carefully consider potential advantages and disadvantages of biobased plastics and biodegradable plastics compared to conventional fossil-based plastics. Following detailed assessment, international standards must be applied to ensure bioplastics are properly labelled to avoid unintended consequences due to end-of-life mismanagement. The mislabelling of plastics has long been oversimplified and confuses the public with inaccurate information about the end-of-life potential of plastic waste and is a widely used form of “greenwashing”. Whilst bioplastics are often described as being sustainable alternatives to conventional plastics, it is only under restricted applications which

https://doi.org/10.1017/plc.2024.9 Published online by Cambridge University Press

may bring some advantages over conventional petroleum-based plastics (SAPEA, 2020; SCEPT, 2023).

Conclusion

The lack of standardized international frameworks to assess and measure and properly define bioplastics, other than regional and national standards (where they exist), are complicated by the absence of an international legally binding agreement. The revised Zero Draft text of the international legally binding instrument on plastic pollution released on December 28, 2023, already includes criteria to address biobased and biodegradable plastics (UNEP, 2023):

> *"Each Party shall ensure that alternative plastics and plastic products are safe, environmentally sound and sustainable, based on the minimum design and performance criteria and other related elements contained in part I of Annex C, including distinct sustainability criteria for: (i) bio-based plastics, (ii) biodegradable plastics and (iii) compostable plastics. The criteria shall build on a full life cycle analysis and take into account their potential for environmental, economic, social and human health impacts, including food security."*

However, with these ongoing discussions of the UN legally binding Global Plastics Treaty there are also other opportunities to discuss bioplastics to ensure that labelling is accurate and includes the chemical and physical diversity of materials used throughout the entire life cycle of these so called 'sustainable' plastics.

Author Contributions

J.A.: conceptualization, visualization, writing - original draft, writing - review and editing.
T.R.W.: conceptualization, visualization, writing - original draft, writing - review and editing.

Declaration of competing interest

https://doi.org/10.1017/plc.2024.9 Published online by Cambridge University Press

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. This perspective was also supported by the Natural Sciences and Engineering Research Council of Canada (NSERC), Grant/Award Number: RGPIN-2018-04119 to Tony R. Walker.

Data availability

No data was used for the research described in the article.

https://doi.org/10.1017/plc.2024.9 Published online by Cambridge University Press

References

Ammendolia, J and Walker, TR (2022). Global plastics treaty must be strict and binding. *Nature*, *611*(7935), 236.

Balla, E, Daniilidis, V, Karlioti, G, Kalamas, T, Stefanidou, M, Bikiaris, ND, Vlachopoulos, A, Koumentakou, I and Bikiaris, DN (2021). Poly (lactic Acid): A versatile biobased polymer for the future with multifunctional properties—From monomer synthesis, polymerization techniques and molecular weight increase to PLA applications. *Polymers*, *13*(11), 1822.

Bergmann, M, Almroth, BC, Brander, SM, Dey, T, Green, DS, Gundogdu, S, Krieger, A, Wagner, M and Walker, TR (2022). A global plastic treaty must cap production. *Science*, *376*(6592), 469-470.

Burrows, SD, Ribeiro, F, O'brien, S, Okoffo, E, Toapanta, T, Charlton, N, Kaserzon, S, Lin, CY, Tang, C, Rauert, C and Wang. X (2022). The message on the bottle: Rethinking plastic labelling to better encourage sustainable use. *Environmental Science & Policy*, *132*, 109-118.

Charlebois, S, Walker, TR and Music, J (2022). Comment on the food industry's pandemic packaging dilemma. *Frontiers in Sustainability*, *3*, 812608.

Dey, T, Trasande, L, Altman, R, Wang, Z, Krieger, A, Bergmann, M, Allen, D, Allen, S, Walker, TR, Wagner, M and Syberg, K (2022). Global plastic treaty should address chemicals. *Science*, *378*(6622), 841-842.

European Bioplastics (2015). EN 13432 Certified bioplastics performance in industrial composting. https://docs.european-bioplastics.org/publications/bp/EUBP_BP_En_13432.pdf.

Geyer, R (2020). A brief history of plastics. *Mare plasticum-the plastic Sea: Combatting plastic pollution through science and art.* 31-47.

https://doi.org/10.1017/plc.2024.9 Published online by Cambridge University Press

Mateos–Cárdenas, A (2022). Fate of petroleum-based and plant-based teabags exposed to environmental soil conditions for one year. *Frontiers in Bioengineering and Biotechnology*, *10*, 966685.

Napper, I and Thompson, RC (2019). Environmental deterioration of biodegradable, oxo-biodegradable, compostable, and conventional plastic carrier bags in the sea, soil, and open-air over a 3-year period. *Environmental Science & Technology*, *53*(9), 4775-4783.

Naser, AZ, Deiab, I and Darras, BM (2021). Poly (lactic acid)(PLA) and polyhydroxyalkanoates (PHAs), green alternatives to petroleum-based plastics: a review. *RSC Advances*, *11*(28), 17151-17196.

Purkiss, D, Allison, AL, Lorencatto, F, Michie, S and Miodownik, M (2022). The Big Compost Experiment: Using citizen science to assess the impact and effectiveness of biodegradable and compostable plastics in UK home composting. *Frontiers in Sustainability*, 3, 942724.

Rosenboom, JG, Langer, R and Traverso, G (2022). Bioplastics for a circular economy. *Nature Reviews Materials*, *7*(2), 117-137.

SAPEA (Science Advice for Policy by European Academies) (2020). Biodegradability of plastics in the open environment. Science Advice for Policy by European Academies, Berlin. 231.

SCEPT (Scientists' Coalition for an Effective Plastics Treaty) (2023). Policy Brief: The global plastics treaty: What is the role of bio-based plastic, biodegradable plastic and bioplastic? (possible core obligation 8). 10.5281/zenodo.10021063

Silva, AL, Prata, JC, Walker TR, Campos, D, Duarte, AC, Soares, AM, Barcelò, D and Rocha-Santos, T (2020). Rethinking and optimising plastic waste management under COVID-19

https://doi.org/10.1017/plc.2024.9 Published online by Cambridge University Press

pandemic: policy solutions based on redesign and reduction of single-use plastics and personal protective equipment. *Science of the Total Environment*, *742*, 140565.

UNEA (2022). Draft Resolution: End Plastic Pollution: Towards an International Legally Binding Instrument. https://wedocs.unep.org/bitstream/handle/20.500.11822/38522/k2200647_-_unep-ea-5-l-23-rev-1_-_advance.pdf?sequence=1&isAllowed=y

UNEP (United Nations Environment Programme) (2023). Revised draft text of the international legally binding instrument on plastic pollution, including in the marine environment (UNEP/PP/INC.4/3). https://wedocs.unep.org/bitstream/handle/20.500.11822/44526/RevisedZeroDraftText.pdf

Venâncio, C, Lopes, I and Oliveira, M (2022). Bioplastics: known effects and potential consequences to marine and estuarine ecosystem services. *Chemosphere*, 136810.

Walker, TR (2023). What not to do with dog poop. *Science of The Total Environment*, *896*, 165332.

Zimmermann, L, Dombrowski, A, Völker, C and Wagner, M (2020). Are bioplastics and plant-based materials safer than conventional plastics? In vitro toxicity and chemical composition. *Environment International*, *145*, 106066.

https://doi.org/10.1017/plc.2024.9 Published online by Cambridge University Press