

## REVIEW ARTICLE

# Redefining plastic terminology: The urgent need for standardised definitions in science and policy

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**Abstract:** Plastic pollution is a pervasive global threat, yet efforts to mitigate it are hindered by inconsistent terminology across scientific, industrial, and policy domains. Key terms, such as “polymer,” “plastic,” and “macromolecule” are often used interchangeably despite distinct meanings. This semantic confusion undermines research integrity, muddles regulatory frameworks, and impedes effective environmental management. Without universally accepted definitions or a clear classification system, data comparability, policy implementation, and interdisciplinary collaboration are significantly compromised. This study systematically examines the scope and impact of terminological inconsistencies in plastics discourse. We conducted a structured review of recent (2020 – 2025) peer-reviewed literature spanning polymer science and environmental policy to assess how definitional ambiguity affects research outcomes and decision-making. The findings reveal that ambiguous usage of fundamental terms has led to misinterpretations in scientific studies, inconsistent policy decisions, and fragmented mitigation strategies. In response, we propose a standardization framework guided by the International Union of Pure and Applied Chemistry principles, delineating clear criteria to distinguish polymers, plastics, and macromolecules. We recommend embedding these standardized definitions across academic publications, industry standards, and environmental policies to improve communication, ensure regulatory clarity, and support sustainable management practices. By establishing a coherent global terminology for plastics, this work underscores an urgent call for collective action. Standardizing the language of plastics will not only enhance data comparability and strengthen international policy initiatives, but also ensure that scientists, policymakers, and industry leaders can collaboratively craft effective, evidence-based solutions to plastic pollution.

**Keywords:** Plastics; Polymers; Environmental policy; Terminology standardization; Sustainability

## 1. Introduction

Plastic pollution has emerged as one of the most critical environmental challenges of the 21<sup>st</sup> century, with far-reaching consequences for ecosystems, biodiversity, and human health.<sup>1-3</sup> The extensive production and

widespread use of synthetic polymers have intensified concerns over their persistence in the environment, leading to severe ecological and socio-economic impacts.<sup>2,3</sup> However, the effectiveness of research and policy interventions aimed at mitigating plastic pollution is often undermined by inconsistent terminology in

scientific, industrial, and regulatory discourse. For example, the interchangeable use of terms, such as “plastics,” “polymers,” and “macromolecules” has contributed to ambiguity in understanding the scope of plastic pollution, its classification, and the implications for policy formulation.<sup>4-8</sup> This is critical because we live in a language-driven world where the usage of words and their symbolic representations shapes thoughts, influences interpretations, and ultimately defines approaches to conventional issues.<sup>1,9</sup> Therefore, in scientific discourse, precise definitions play a crucial role in shaping policies, guiding societal perceptions, and determining responses to environmental challenges.<sup>1</sup> It is unarguable that establishing clear, accurate, and well-founded definitions that authentically reflect the subject matter is essential for effective communication and informed decision-making.

The advent of synthetic polymer production has ushered in a pervasive environmental challenge in the form of plastic pollution.<sup>2,3,10-12</sup> This issue has garnered increasing attention over the decades, as evidenced by the vast literature that varies in scope, scientific rigor, and tone.<sup>2,13-20</sup> For example, a search in Google Scholar using the term “plastic pollution” yields an enormous collection of literature on this subject. Given this significant volume of reports, vital questions emerge. For instance, “Why has the scientific discourse on plastic pollution persisted over the years?” “Are we addressing polymer or plastic pollution?” “Are there comprehensive solutions to address this challenge?” This paper critically examines the persistent issue of terminological inconsistencies in plastic pollution discourse. By systematically reviewing the literature from 2020 to 2025, we assess the extent to which terminology variations influence scientific research and policy frameworks. Unlike previous reviews that primarily discuss plastic pollution from an environmental or technological perspective, this study highlights the definitional challenges that hinder effective communication and problem-solving in the field.

To address this challenge, we propose a standardization framework aligned with the International Union of Pure and Applied Chemistry (IUPAC) principles. This framework provides clear distinctions between plastics, polymers, and macromolecules, thereby ensuring greater precision in academic research, industrial applications, and policy-making. The study advocates the integration of standardized terminology into the scientific literature, environmental policies, and industrial regulations to enhance clarity, improve data harmonization, and support evidence-based decision-making.

Furthermore, this work challenges present perceptions and misconceptions surrounding plastic pollution, urging researchers and policymakers to adopt contextually appropriate definitions that reflect the material properties, environmental impacts, and regulatory requirements. By refining the language used in plastic pollution discourse, this study seeks to promote a more accurate, informed, and unified approach to addressing one of the most pressing environmental issues of our time.

## 2. Methodology

To systematically assess the inconsistencies in polymer-related terminology and propose a standardization framework, this study employed a structured literature review. The methodology was designed to ensure a rigorous, transparent, and reproducible analysis of the definitions and classifications of plastics, polymers, and macromolecules within scientific, industrial, and policy contexts.

A comprehensive review of peer-reviewed literature was conducted by searching databases, such as Scopus, Web of Science, and ScienceDirect, focusing on publications from 2020 to 2025 to capture recent advancements and policy discussions. Selection criteria prioritized studies that directly addressed terminological inconsistencies, environmental implications of misclassification, and the role of standardized definitions in regulatory frameworks. Key data points were extracted to identify patterns of inconsistencies, assess their impact on scientific discourse and policy, and evaluate existing classification models. The findings informed the development of a standardization framework aligned with the IUPAC principles, ensuring scientific accuracy and practical applicability. A summary of the methodological approach is presented in [Table 1](#).

## 3. Terminology ambiguity of plastic

Macromolecules are fundamental to life and technology. From DNA and proteins to advanced synthetic materials, they underpin biological structures and industrial innovations alike.<sup>5,21-28</sup> The evolution of polymer science has enabled the development of countless materials with tailored properties, propelling progress across multiple domains.<sup>5,29</sup> Despite their centrality, the terms “macromolecule” and “polymer” are frequently used interchangeably in the literature, often without clarification, leading to scientific ambiguity. While common, this conflation deviates

**Table 1. Overview of a structured methodology for terminology standardization in plastic pollution discourse**

Component	Description
Research approach	Structured literature review
Objective	To analyze terminological inconsistencies in polymer science and plastic pollution discourse and propose a standardization framework
Data sources	Scopus, Web of Science, and ScienceDirect
Timeframe of literature	2020 – 2025 (to ensure relevance and alignment with recent scientific and policy developments)
Selection criteria	- Peer-reviewed articles, reports, and policy papers related to plastic pollution and polymer terminology - Publications address definitional inconsistencies and their impact on scientific discourse and policymaking.
Data extraction	- Identification of commonly used definitions for plastics, polymers, and macromolecules - Analysis of inconsistencies in terminology usage across disciplines - Assessment of policy implications and recommendations.
Framework development	- Alignment with International Union of Pure and Applied Chemistry principles for standardization - Classification of plastics based on composition, function, and environmental impact - Proposal of terminology standardization model for academic, industrial, and policy applications.
Expected contribution	- Improved clarity and consistency in polymer science terminology - Enhanced communication between researchers, policymakers, and industry stakeholders - A foundation for more effective regulatory and environmental management strategies.

from precision. As Hartmann *et al.*<sup>4</sup> noted, the lack of internationally harmonized definitions contributes to terminological confusion across research, legislation, and public discourse. Similarly, the report of Zhu and Wang.<sup>30</sup> highlights the inconsistent usage of “polymer,” “plastic,” and “material” when discussing biodegradable alternatives. As summarized in Table 2, even reports in reputable journals employ these terms synonymously, often without differentiating between raw resins, compounded products, and processed articles.

According to Figge *et al.*,<sup>33</sup> a valid definition must include a definiendum (the term being defined) and a definiens (its conceptual boundaries). Good definitions are inclusive yet specific and free of counterexamples. Existing definitions of macromolecule (i.e., large molecules composed of repeating chemical units) and polymer (i.e., composed of macromolecules) do not always meet this standard. For instance, proteins, such as hemoglobin and nucleic acids, such as DNA are classified as macromolecules, despite lacking strictly repeating monomeric sequences.<sup>34-37</sup> In contrast, materials, such as polythene and polystyrene are composed of chemically identical repeating units (e.g., ethylene or styrene), meeting the formal criterion for polymers.<sup>5,21,29</sup> Hence, while all polymers are composed of macromolecules, not all macromolecules are polymers.<sup>21,29</sup> This distinction is illustrated in

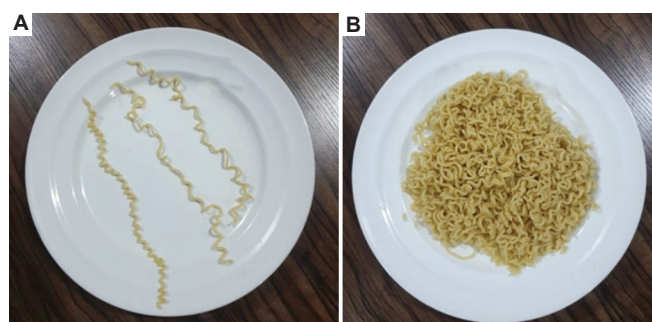
**Figure 1:** A macromolecule resembles a single strand of noodle, whereas a polymer is the entire bowl composed of multiple strands of noodles.

In essence, macromolecules can exist independently, but polymers cannot exist without comprising multiple macromolecules. A polymer’s bulk properties depend on the collective characteristics of its constituent macromolecules, such as molecular weight distribution, chain length, and polydispersity index.<sup>38-41</sup> Unlike small molecules with discrete melting points, polymers exhibit continuous properties, such as melting or glass transition ranges, because of variations among chains.<sup>21,22,29,42</sup> Further complicating matter is polymer memory, the phenomenon whereby the history of processing conditions (e.g., thermal or mechanical) can influence future behavior through residual stresses or orientation effects.<sup>42-44</sup> This means even polymers of identical chemical composition can behave differently based on processing, aging, and external stimuli.<sup>39,43,44</sup> Such variability defies one-size-fits-all modeling and reinforces that no two polymers are ever truly identical, even if synthesized from the same monomers.

Ambiguous terminology undermines scientific rigor and complicates environmental regulation, materials classification, and policy development.<sup>31,32,45</sup> Establishing clear distinctions between macromolecules and polymers is essential for academic precision

**Table 2. Examples of interchangeable use of “polymer,” “macromolecule,” and “plastic” across scientific journals**

Journal	Type	Title	Impact factor (2024)	Usage of terms	References
Macromolecules	Peer-reviewed	Plastic pollution: A material problem?	5.1	Refers to “plastics (generally used as a synonym for polymers)”	31
Nature Reviews Materials	Peer-reviewed	Reducing environmental plastic pollution by designing polymer materials for managed end-of-life	79.8	Describes plastics as “a ubiquitous class of synthetic polymer materials”	32
ACS Omega	Peer-reviewed	Plastic pollution: A perspective on matters arising	4.1	States that “plastics are polymeric systems (i.e., macromolecules)”	3



**Figure 1. Basic illustration of macromolecules and polymers. (A) Macromolecules; (B) Polymers. Image produced by First Author**

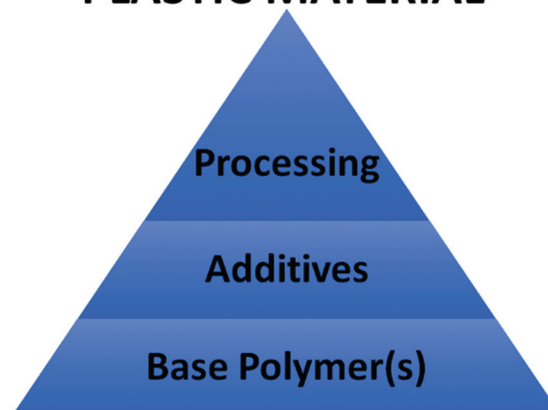
and harmonizing industrial standards and regulatory language.<sup>4</sup> As such, we strongly advocate for alignment with IUPAC definitions, which promote consistency across sectors and disciplines. Doing so will facilitate more effective stakeholder collaboration, enhance plastic pollution diagnostics, and support innovation in sustainable materials development.

#### 4. Distinction between polymers and plastics

Plastics represent one of the most transformative innovations in science and technology. However, for clarity in this discourse, we define plastics as synthetic or semi-synthetic composite materials composed primarily of polymers and additives, engineered for specific end-use applications. As illustrated in Figure 2, plastics are not merely polymers; they are functional materials tailored through compounding and physicochemical modification.

Plastics include thermoplastics, materials that can be melted and reshaped, and thermosets, which irreversibly

### PLASTIC MATERIAL



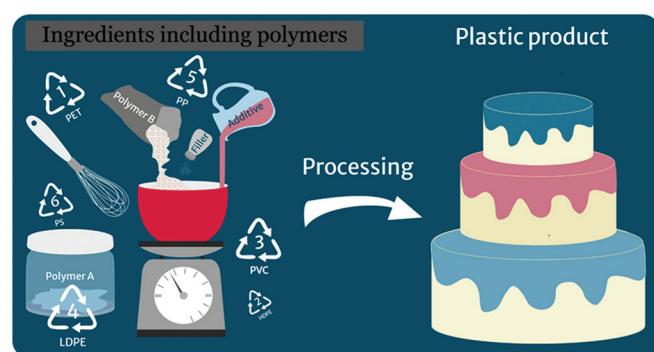
**Figure 2. Representation of a plastic material. Image produced by the authors. Created with MS PowerPoint and <https://pixlr.com/express/>; 2025; Austine Ofondu Chinomso Iroegbu**

harden upon curing. A pure polymer resin without additives or structural modification is not plastic.<sup>41,43,44</sup> Instead, plastics comprise formulated systems, where the polymer serves as the matrix and is integrated with additives, such as plasticizers, stabilizers, fillers, or colorants.<sup>41,43,46</sup> These additives impart critical properties, such as flexibility, durability, or ultraviolet (UV) resistance, enabling applications ranging from packaging films and fibers to foams, laminates, and molded components. Semi-synthetic materials, such as rayon and cellulose acetate, derived from natural polymers, are classified as plastics due to their engineered modification.<sup>41,43,46</sup> Similarly, elastomers like styrene-butadiene rubber become plastics when compounded, cast, and vulcanized into end products, such as automotive tires.<sup>41,43,46-48</sup> In contrast, in their

raw form, unprocessed styrene or butadiene polymers remain polymers, not plastics. The same logic applies to materials, such as polyurethane, used in mattresses and footwear: Only when processed with additives and cured do they qualify as plastics.<sup>49-51</sup> Once plastics are cured through heat, UV exposure, or ambient conditions, reprocessing becomes impractical as they transition into composites.<sup>52</sup>

Furthermore, coatings and paints (e.g., on vehicles, ships, and buildings) are classified as plastics due to their polymer-based formulations (e.g., alkyds, acrylics, epoxies, and polyvinylidene fluorides) and the inclusion of additives. These materials undergo crosslinking and adhere to substrates, contributing to plastic pollution in terrestrial, atmospheric, and aquatic environments.<sup>2,41,43,46,53</sup> Similarly, textiles, wigs, synthetic eyelashes, footwear, and similar consumer products, often formulated from polymer-based fibers with functional additives, are effectively plastics.<sup>3</sup>

Despite their widespread utility and contributions to modern life,<sup>3</sup> plastics are now at the center of environmental concern due to their persistent pollution and complex degradation behaviour.<sup>2,3,54</sup> An accessible analogy can be drawn from cake baking (Figure 3): Flour serves as the base (analogous to polymers), while ingredients, such as eggs, fat, and sugar (additives) determine the structure, texture, and taste.<sup>55,56</sup> Similarly, polymers are the base material in plastics, and additives define performance, form, and application.<sup>41,57,58</sup> The intricacy of cake chemistry reflects the multifactorial nature of plastic formulation: Different combinations



**Figure 3. Cake illustration correlating the complex nature of plastics**

Abbreviations: HDPE: High-density polyethylene; LDPE: Low-density polyethylene; PET: Polyethylene terephthalate; PP: Polypropylene; PS: Polystyrene; PVC: Polyvinyl chloride. Image produced by the authors. Created with <https://pixlr.com/express/> and MS PowerPoint; 2025; Austine Ofondu Chinomso Ireogbu

of polymers, additives, and processing methods result in vastly different materials and environmental behaviors.<sup>41,41,52,59-64</sup>

This understanding positions plastics as engineered composites, not simply as polymers. Recognizing this complexity is essential for advancing accurate classifications, improving pollution diagnostics, and developing targeted mitigation strategies.

In conclusion, the continued misuse and oversimplification of the term “plastic” undermine sustainable solutions. Existing definitions often fail to reflect the scientific complexity of modern plastic materials, either by being too narrow to capture emerging formulations or too broad to be practically applicable. Addressing this ambiguity is essential for refining scientific discourse, guiding environmental policy, and supporting more effective communication and innovation in sustainability research.

## 5. Real-world repercussions of terminology inconsistency: Complexity in plastic pollution classification

Inconsistent terminology surrounding polymers, macromolecules, and plastics presents substantial environmental, regulatory, and ethical challenges. Plastics, which are engineered polymer-based materials, are integral to modern society, with applications ranging from electronics and electrical insulation to medical devices, such as syringes and catheters. However, their widespread use is paralleled by their pervasive environmental footprint, including macro-, micro-, and nano-plastics that pose a growing threat to global ecosystems and sustainability efforts.<sup>3,65-68</sup> Since 1950, plastic production has exceeded seven billion metric tons,<sup>3</sup> spurring movements to ban single-use plastics, promote bio-based alternatives, and accelerate circular economy strategies.<sup>69-75</sup>

Plastic pollution encompasses the intentional or unintentional release of plastic debris, often laden with additives, into ecosystems, where it interacts with environmental components to cause harm.<sup>2,3</sup> However, quantifying this pollution remains difficult. For instance, textile fibers, both synthetic (e.g., polyester, nylon) and natural (e.g., cotton, silk), release countless microfibers during wearing and washing, yet the environmental impact of these emissions remains largely unmeasured due to the absence of comprehensive data on clothing production.<sup>3,76,77</sup> In addition, the export of unwanted garments and electronics, often labeled as second-hand

goods, from developed to developing nations perpetuates environmental degradation and ethical inequities.<sup>3,78,79</sup>

Biodegradable polymers also present challenges when converted into plastics. For example, cellulose, though naturally biodegradable, becomes a persistent pollutant when processed into products, such as cigarette filters.<sup>80-82</sup> One discarded filter can contaminate up to 1,000 L of water due to leached toxins, such as pesticides, heavy metals, and organic pollutants. Similarly, tires, which comprise diverse and confidential chemical formulations, contribute 5 – 10% of marine plastic pollution, excluding terrestrial pollution, where accumulation may be even greater.<sup>83-92</sup> The tire industries' lack of compositional transparency and technological heterogeneity poses significant challenges for regulation and pollution mitigation.<sup>3,85-87</sup>

Electronic waste (e-waste), including discarded computers, phones, and televisions, is a significant source of plastic pollution.<sup>93-95</sup> Its dynamic and poorly characterized composition increases its environmental risk. Projections estimate that by 2030, global e-waste will exceed 70 million metric tons, excluding the growing reliance on plastics in solar panels, electric vehicles, and robotic systems.<sup>96-99</sup>

The emergence of bioplastics, such as polylactic acid (PLA), reflects the drive toward more sustainable materials. PLA, derived from renewable resources, is used in packaging, electronics, and medical applications.<sup>93,94,100</sup> However, despite its bio-based origin, PLA remains plastic and contributes to pollution if it does not fully degrade in natural environments.<sup>93,101-104</sup> Its biodegradation is often conditional, requiring specific composting conditions, and may not result in complete mineralization.<sup>3,105,106</sup> Moreover, the environmental promise of biopolymers is frequently compromised by their need for performance-enhancing additives that may not be biodegradable.<sup>30,107,108</sup>

The terms “green” and “biodegradable plastics” are thus misleading. Truly sustainable materials must demonstrate full environmental compatibility, meaning that all components, polymers, additives, and by-products are inherently and rapidly biodegradable under natural conditions.<sup>1,3,93,109</sup> In addition, they should exhibit biocompatibility, ensuring they are non-toxic to living organisms.<sup>1,3,93,109</sup> Unfortunately, present bioplastics often fall short of these criteria. Their performance is influenced by numerous variables, including polymer structure, environmental pH, temperature, and the nature of degradation by-products.<sup>1,3,107,110,111</sup>

In summary, inconsistent definitions of “plastic,” “polymer,” and “macromolecule” obscure our

understanding of pollution sources, hinder effective policy, and perpetuate misconceptions, such as the infallibility of biodegradable alternatives. Until universally accepted definitions are adopted, efforts to address plastic pollution will remain fragmented and less effective.

## 6. Implications of poorly defined terminology

The distinction between polymers and plastics is fundamental in environmental policies, yet ambiguities in their classification have led to inconsistent regulations that hinder effective strategies for mitigating plastic pollution. Policies often treat all plastics as the same, leading to overly broad or inaccurate bans and restrictions that fail to differentiate or identify the challenge.<sup>112</sup> For example, expanded polystyrene (styrofoam) was included in the latest European Union ban on single-use plastic. While styrofoam is a polymeric material, it does not meet the criteria for plastics for the following reasons: No additives or chemical modifications. Unlike plastics, styrofoam is made from pure polystyrene expanded with gas (e.g., pentane, carbon dioxide [CO<sub>2</sub>]). It does not contain plasticizers, stabilizers, or other chemical modifications that alter its base polymer properties. Styrofoam is created by expanding polystyrene beads, trapping air pockets within them. Distinct from plastics, which undergo chemical processing or additive incorporation. Thus, Styrofoam should be classified separately from traditional plastics in scientific discourse, environmental policy, and material science. Regulatory frameworks should recognize this distinction to ensure more precise classification and waste management strategies.

In another example, the United States Environmental Protection Agency (US EPA) clarifications on biodegradability, compostability, and bio-based plastics reveal several inconsistencies and gaps in the present regulatory framework, material classification, and environmental strategies.<sup>113</sup> For example, the EPA defines plastic as biodegradable if it fully decomposes within 1 year after disposal.<sup>113</sup> However, this does not ensure that the degradation process is environmentally benign, only that the material disappears from sight. The rate of degradation is prioritized over the nature of degradation, meaning that if a plastic breaks down into microplastics within a year, it can still be considered biodegradable. Biodegradability should not be defined based on time alone; it should ensure complete, harmless degradation in natural environments. If a material leaves harmful residues, persistent microplastics, or toxic

compounds, it should not be classified as biodegradable, regardless of how quickly it disappears. Closing the material loop should be the standard, ensuring that materials are purposefully designed to degrade into non-toxic, bioresorbable components that benefit the ecosystems.<sup>113</sup>

The EPA allows the plastic to be labeled as biodegradable, even if it requires industrial composting, incineration, or landfill conditions for degradation. Many biodegradable plastics, such as PLA, require high-temperature industrial composting facilities, but these facilities are not widely available. If these materials end up in landfills or marine environments, they persist as conventional plastics, even though they are marked as biodegradable. Biodegradable material should not require special environmental conditions; it should break down naturally where it is disposed of (e.g., soil, water, and marine ecosystems).<sup>113</sup> If plastic only degrades under industrial conditions but persists in oceans and soil, it should be classified as compostable but not biodegradable. Environmental adaptability must be a key criterion; biodegradable plastics should degrade effectively under diverse real-world conditions without human intervention.

The EPA's vague biodegradability definitions create loopholes for deception and allow marketers to market materials as environmentally friendly when they still cause long-term environmental harm. For example, some oxo-degradable plastics are labeled biodegradable because they break down into smaller fragments, but these fragments persist as microplastics in soil and marine environments.<sup>113</sup> EPA's definition does not distinguish between complete biodegradation and fragmentation, allowing misleading claims that mask ongoing plastic pollution.<sup>113</sup> We argue that biodegradability should require complete mineralization, meaning that plastics should fully degrade into natural compounds (CO<sub>2</sub>, water, and biomass) without persistent residues. If a material fragments into microplastics instead of fully degrading, it should not be classified as biodegradable.

The EPA only defines biodegradability based on decomposition but ignores the environmental effects of the breakdown process. Plastics that degrade into acidic byproducts, heavy metals, or toxic residues are still considered biodegradable under the EPA's criteria. There is no requirement for the degradation process to be neutral or beneficial to the environment. Biodegradable plastics should have a net-zero or positive environmental impact, meaning their degradation does not harm ecosystems and ideally enriches them. If plastic breakdown byproducts cause

soil contamination, water pollution, or harm to marine life, it should not be labeled biodegradable. Materials should be bioresorbable, ensuring they reintegrate into nature without disrupting ecosystems.

The US EPA does not mandate eco-design, meaning manufacturers are not required to design plastics with a sustainable end-of-life strategy. Many so-called biodegradable plastics are still made using fossil fuels, contain harmful additives, or require high-energy processing. If a plastic's production process contributes to environmental degradation, it should not be classified as biodegradable. Biodegradable plastics should be intentionally designed from the start with sustainability in mind. This means removing harmful additives, using bioresorbable materials, and ensuring complete reintegration into the environment. Closing the material loop should be a regulatory requirement, ensuring that materials are biodegradable and contribute to long-term sustainability. Eco-design should encompass responsible sourcing, energy-efficient production, and non-toxic degradation. Inconsistencies in definitions and terminologies result in policies that promote a one-size-fits-all approach.

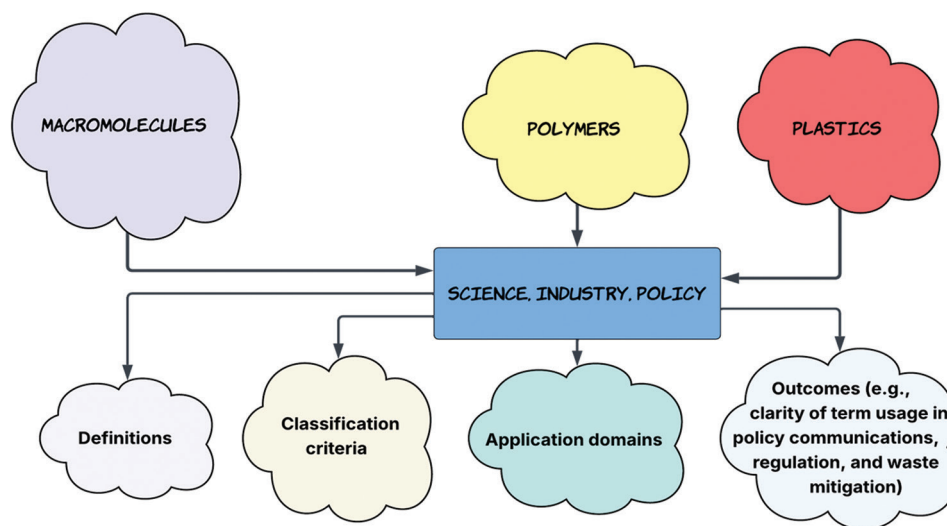
## 7. Implications and recommendations

Despite significant advancements in understanding plastic pollution, a definitive conclusion regarding the toxicity of plastic particles remains elusive due to the complexity of individual plastic materials. However, their ubiquitous environmental presence poses substantial risks to critical Earth systems, biodiversity, and ecosystem services. Addressing these concerns requires the continuous refinement of toxicological testing methods and the development of novel approaches to assess the long-term environmental and health impacts of plastic debris across different size categories. Given the complexity of plastic weathering, which involves continuous degradation and multiple simultaneous processes, an interdisciplinary approach is required to bridge research gaps and improve hazard assessments beyond conventional toxicological studies.

One critical yet underexplored aspect of plastic toxicity assessments is the role of plastic-associated chemicals, including additives, residual monomers, and degradation by-products. These compounds significantly contribute to the hazardous nature of plastics but remain poorly characterized due to their diverse chemical compositions and the need for advanced analytical techniques. Present plastic leachate

**Table 3. Proposed standardization framework for plastics and polymers**

Component	Description
Definition standardization	Establish universally accepted definitions for “plastics,” “polymers,” and “macromolecules” based on International Union of Pure and Applied Chemistry guidelines to prevent ambiguity and misinterpretations.
Material classification	Develop a classification system distinguishing plastics by composition (e.g., fossil-based, bio-based), processing methods (e.g., thermoplastics, thermosets), and degradation potential (e.g., biodegradable, non-biodegradable).
Terminology consistency	Ensure consistency in terminology across scientific disciplines, industry, and policy frameworks to prevent confusion in environmental assessments, product labeling, and regulatory documents.
Regulatory alignment	Align definitions and classifications with international regulatory standards (e.g., American Standards Testing and Materials and International Standard Organization) to harmonize global policy efforts and facilitate international trade.
Scientific and industrial integration	Integrate standardized definitions into industrial manufacturing standards, scientific research methodologies, and sustainability frameworks to improve cross-sector collaboration.
Environmental impact assessment	Incorporate life cycle assessments into plastic material classification to evaluate long-term sustainability, recyclability, and ecological footprint.
Education and public awareness	Develop educational programs and public awareness campaigns to ensure all stakeholders (scientists, policymakers, industry leaders, and consumers) understand and adopt standardized definitions.
Technological innovations	Encourage research into sustainable plastic alternatives, including enhanced biodegradable plastics, bio-based polymers, and closed-loop recycling technologies for a more sustainable future.
Implementation and policy recommendations	Propose policies that enforce standardized definitions in product labeling, waste management regulations, and international trade agreements to ensure global compliance and drive effective plastic pollution mitigation.



**Figure 4. Visual synthesis of proposed terminology standardization framework. Image produced by the authors. Created with [https://lucid.app/documents/#!/home?folder\\_id=recent](https://lucid.app/documents/#!/home?folder_id=recent); 2025; Austine Ofondu Chinomso Iroegbu**

toxicity assessments lack standardized protocols, leading to inconsistencies in reported hazard levels. In addition, many hydrophobic plastic-associated

chemicals present challenges in aqueous toxicity testing due to their limited solubility, further complicating risk evaluations.

**Table 4. Overview of plastic-related terminological inconsistencies across major regulatory bodies and standard organizations**

Regulatory body/region	Present definition/term	Inconsistency	Implication
European Union Directive 2019/904	Plastic=polymer-based material	Omits additive requirement	Overbroad bans, e.g., on pure expanded polystyrene
United States Environmental Protection Agency	Biodegradable=breaks down in <1 year	Allows microplastic fragmentation	Mislabeled harmful materials as “eco-friendly”
International Union of Pure and Applied Chemistry	Polymer versus macromolecule versus plastic	Precise distinction	Not widely adopted in policy or industry
American Society for Testing and Materials/ISO	Varies by committee (e.g., D883, ISO 472)	Lack of harmonization	Conflicts in international trade and labeling

International Organization for Standardization

To effectively address these challenges and promote a harmonized understanding of plastic-related terminology, we propose a standardized framework that aligns with global scientific, industrial, and regulatory standards (Table 3 and Figure 4). This framework ensures that definitions and classifications are universally understood, preventing misinterpretations and facilitating more effective policymaking.

## 8. Conclusion

As illustrated in the summary Table 4, clear and precise terminology is far more than a semantic detail and is foundational for effective environmental science, policy, and management. Yet today, ambiguity in defining basic terms, such as “plastic” and “polymer” has fostered misaligned policies, inefficient resource allocation, and inconsistent mitigation efforts.

As plastic pollution escalates worldwide, the need to reassess how we define and classify plastics becomes increasingly urgent. For example, as research reveals new long-term health and ecological impacts of plastic debris, outdated definitions often fail to capture the full scope of these risks, resulting in regulations that lag behind scientific reality. Moreover, plastics are highly complex materials, frequently composites of multiple polymers, additives, and degradation byproducts, and simplistic definitions cannot account for this complexity. Such oversimplification hampers our ability to accurately assess environmental risks and devise targeted management strategies.

At the global level, a harmonized lexicon for plastics is essential to coordinate international efforts and enforce environmental agreements. Without alignment in terminology, countries maintain inconsistent plastic waste classifications, recycling practices, and regulatory

standards, undermining progress in combating plastic pollution.

Meanwhile, rapid innovation in material science, from novel biodegradable polymers to advanced composite plastics, demands that definitions and regulations keep pace with these advances. Meeting this challenge requires systemic change. We must overhaul how plastics are defined and categorized across scientific discourse and legal frameworks by grounding definitions in robust scientific consensus (such as IUPAC guidelines) and adopting them universally. This shift should extend beyond academia and government: Standardized language about plastics must permeate industry practices, educational curricula, and public discourse, ensuring a common understanding among all stakeholders.

By embracing clear, standardized definitions of plastics and plastic pollution, the global community can establish a shared foundation for action. A common language will facilitate more effective waste management and recycling initiatives, while also ensuring more coherent regulations worldwide. Ultimately, addressing terminological ambiguity is not just an academic exercise but a catalyst for stronger global stewardship. Embracing a common language empowers science-based policies, unifies international efforts, and bolsters our capacity to preserve environmental and human health for future generations.

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## Conflict of interest

The authors declare they have no competing interests.

## Author contributions

*Conceptualization:* Austine Ofondu Iroegbu

*Writing – original draft:* Austine Ofondu Iroegbu

*Writing – review & editing:* All authors

## Availability of data

Not applicable.

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