Bioplastics and the Role of Institutions in the Design of Sustainable Post-Consumer Solutions

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Abstract

This article aims to understand the role of institutions, especially meso-institutions, in the construction of definitions that foster socio-technical changes, so that, through a single language with epistemic quality, it can be adopted by means of global governance in the solution of environmental problems arising from the plastic production chain. For this, through a narrative literature review and documentary research on European and Brazilian legislation, the article applies the theory to the case of the global definition of bioplastic. It appears that the creation of definitions matters to institutions and global governance, since they guarantee them the criteria of coherence, determination and epistemic quality, on the other hand, it is noted that obtaining these criteria is not the case of the definition of bioplastic, which suffers from a lack of global standardization. It is concluded, in this article, that the lack of a globally standardized definition of bioplastic promotes negative effects, such as Greenwashing. bioplastic and that, at the meso-institutional level, the function of transforming general rules into specific standards would make it possible to adapt the term "bioplastic" to operational norms in order to implement purposes of environmental preservation and sustainability.

1. Introduction

According to current data from the Organization for Economic Cooperation and Development - OECD (2022), global plastic production increased 230 times from 1950 to 2019 and reached a production level of 460 million tons. In addition, out of all this material produced, only 8% is circular plastic, which means that 92%, i.e., 423.2 million tons that cannot be reused or recycled. With regard to waste, in 2019, around 353 million tons of plastic were discarded worldwide, of which only 9% were recycled. In addition, it is estimated that, in 2019, 22 million tons of plastic waste leaked into the environment, which totals an accumulation of 109 million tons in rivers and 30 million tons in oceans.

This vast environmental pollution from plastics, particularly those based on petroleum derivatives, has led the scientific community to seek sustainable alternatives. Regarding this aspect, new materials obtained from partially or totally natural sources are being developed for application in the most varied sectors of the economy. From this socio-technical transformation, which aims to obtain new plastic materials with a sustainable purpose, numerous conceptual and practical doubts arise that have hindered the relationship between the different actors involved, directly or indirectly, in the production chain of plastics.

In this scenario, global governance is gaining more and more importance, as it is possible that it be exercised efficiently through the use of unified definitions about new technologies, such as bioplastics, by all actors (private and public) and in the various levels (from local to international). In this sense, the objective of this article is to understand the role of institutions, especially meso-institutions, in the construction of definitions that promote sociotechnical changes, in order to, by means of these definitions, achieve a unique language with epistemic quality that can be understood and officially adopted for environmental problems originating from the plastic production chain can be solved.

To this end, through a narrative literature review and documentary research on European and Brazilian legislation, the article is divided into three sections. The first aims to relate institutions to governance, in order to emphasize the indispensability of established definitions by the institutions so that the governance can be exercised efficiently. The second section aims to apply the theoretical contribution to the case of bioplastic, whose definition suffers from lack of definitions at a global level. Finally, the third section relates role of governance to the functions of meso-institutional intermediaries, when considering the effects that the global lack of definition of bioplastics has caused.

2. The relationship between governance and institutions and the importance of definitions

In this article, the governance is assumed from the perspective of André-Jean Arnaud (2014) as a form of management established from a shared authority with collective participation and at various levels (local, regional, national and global) in making of complex decisions. In order to relate governance to institutions, these are understood through the New Institutional Economics, divided into three layers.

At the top of the institutional environment are the macro-institutions through which rights are constituted, defined and allocated, there are the "rules of the game and the general conditions for their implementation". In the lowest layer, related to the organizations, there are the micro-institutions through which "transactions are organized and the allocation and usage of resources are shaped" (DAVIS, NORTH, 1971; NORTH, 1990; WILLIAMSON, 2000). In the middle layer, there are the meso-institutions that connect the macro-institutions to the micro institutions. It is noteworthy that through the meso-institutions the rules are transformed into specific technical norms for operators and users through devices and mechanisms. These can be private or public and take the form of regulatory agencies, certification bodies or professional organizations that define standards for a particular type of industry (MÉNARD, 2018; MÉNARD, 2022).

Certainly, meso-institutions contribute to the manifestation of governance, either through the development of regulatory agencies, or through the interference of a normalizations arising from standards (ARNAUD, 2014). In this way, they include the technical standards. These, in turn, are defined as a document that is: 1) consensual; 2) approved by a recognized organization; 3) endowed with rules, guidelines or characteristics for activities or their results; 4) common and repetitive use; 5) to obtain an optimal degree of ordering in a given context. It should also be noted that its contents should be based on "consolidated results of science, technology and accumulated experience aimed at optimizing benefits for the community", as well as being available to the public (ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS, 2006; ZIBETTI, et al., 2018).

This social purpose of technical norms, which contributes to the collective character of governance, was acquired by considering that technology inevitably results from the interaction of human actions in a given social context, with no way of disconnecting technical and social relations (VALADÃO, et al., 2014). Given this, technical norms are now considered sociotechnical norms, while by transforming general rules into specific standards they should aim to reduce social impacts in the discipline of best technological practice.

Concurrently, an attempt is made to relate institutions to the theory of sustainable sociotechnical transition, which defines the phases, as well as describes the intermediaries of these changes. In this context, the intermediaries presented are: a) macro-institutional, which determine the rules and regimes, as well as allocate rights; b) meso-institutional, which implement the rules and regimes, through the translation of macro-institutions, monitoring, enforcement and feedback; c) micro-institutional, which develop strategies and establish organizational arrangements (MAROTTI, et al, 2022).

The functions of the meso-institutional intermediaries are especially important and are essential for sociotechnical change to be achieved. The meso-institutional intermediaries implement the objectives and rules of macro-institutional directives and could also transfer the requirements and motivations of the micro-institutional intermediaries to the macro-institutional intermediaries, so it serves as a functional intermediary between the higher and lower structural levels, in both directions. Further to this perspective, they are responsible for detailing and specifying the macro-institutional rules in operational norms, monitoring compliance with these norms, punishing non-compliance or rewarding compliance, as well as providing feedback to micro-institutional intermediaries on the application or formulation of the macro-institutions (MAROTTI, et al., 2022).

Therefore, governance encompasses several actors, and it is in this plurality of actors (public and private) and levels (local, national and international) that global environmental governance is established. However, this multiple coexistence in the same thematic area, characterized by fragmentation and the absence of a clear hierarchy, favors conflicts and generates a scenario of insecurity. To help resolve this diversity of uncertainties and interconnected governance, Robert Keohane and David Victor (2011) propose six criteria: 1) Coherence; 2) Accountability; 3) Effectiveness; 4) Determinacy; 5) Sustainability; 6) Epistemic Quality.

In linguistic terms, a concept is the compilation of true statements about a certain object that is fixed by a linguistic symbol so that the definition is the delimitation or fixation of the content of a concept (DAHLBERG, 1978). In this respect, definitions serve to the institutions and, consequently, to the global governance, since they guarantee the criteria of coherence, determinacy and epistemic quality. This facilitates the possibility to fill gaps and obtain a common goal by all the other actors, at the most varied levels.

However, the analysis and implementation of the adequate definition becomes a challenge to global governance and counts on sociotechnical assistance, particularly from

meso-institutional standardization intermediaries. It is in this context of governance that the institutional terminological difficulty of “bioplastic” is problematic, especially when one considers the constant and growing development of new plastic materials that are obtained from partially or totally natural sources and strategically designed to reduce environmental impacts.

3. The absence of a global definition of bioplastics

In order to apply the theory of the previous section to the concrete case of the definition of bioplastic, it is first necessary to define the terms polymer and plastic. According to the International Union of Pure and Applied Chemistry (IUPAC), the international non-governmental organization and world authority on chemical nomenclature and chemical terminology, a polymer is defined as a substance composed of molecules of large size and which is characterized by multiple repeating units (a single or group of atoms). These units are known as monomers or constitutional units and, in the case of polymers, are covalently linked to each other in sufficient quantity to provide a set of properties that do not vary substantially with the addition or removal of some constitutional units (VERT et al., 2012).

In turn, plastics are a special group of polymers with characteristics that differentiate them from other materials, such as fibers, rubbers, among others, which are also polymers. The main characteristic of plastics is their ability to flow and be shaped by the use of controlled heat and pressure. The plastic, by the action of heat and pressure, easily softens to fit the shape of a mold. During subsequent cooling, the plastic becomes solid again, retaining the shape of the mold. Some plastics, known as thermoplastics, are those that can be repeatedly subjected to heating, molding and cooling processes. Other plastics, called thermosets, can be formed only once, making it impossible to melt and flow repeatedly (OLIVATTO, et al., 2018; COSTA, 2018; HERNANDEZ, SELEK & CULTER, 2004).

It is in the scenario involving environmental impacts caused by synthetic plastics that the bioplastics emerge, a growing class of polymeric materials that have been promoted as an alternative to conventional synthetic plastics. Concomitantly, new questions are enunciated regarding the possible environmental impacts related to these materials and, consequently, in their governance.

However, there are still many doubts as to the proper definition of bioplastic. From this point of view, the IUPAC has not conceptualized bioplastics, rather it launched recommendations in 2012 focusing on terminologies that can be used in relation to the

bioplastics and implemented in the areas of medicine, surgery, pharmacology, agriculture, packaging, biotechnology, polymer waste management, among others. In this publication the importance of these terminologies in the context of human health and environmental sustainability was emphasized, considering that they are increasingly interdependent. The importance of these terminologies also was emphasized in the field of research and micro-institutions, which are still developed independently in each sector, and in the field of public use by non-specialized professionals such as journalists, politicians and partners from complementary disciplines (VERT et al. , 2012).

Although the IUPAC does not conceptualize bioplastic, it does conceptualize a bio-based polymer as: “derived from the biomass or issued from monomers derived from the biomass and which, at some stage in its processing into finished products, can be shaped by flow”. Furthermore, IUPAC makes three important notes: 1) “Bioplastic is generally used as the opposite of polymer derived from fossil resources”; 2) The term bioplastic “is misleading because it suggests that any polymer derived from the biomass is *environmentally friendly*”; 3) “The use of the term “bioplastic” is discouraged. Use the expression ‘biobased polymer’” (VERT et al., 2012).

In addition to IUPAC, another important international non-governmental organization that aims to develop global standards for the market is the International Organization for Standardization (ISO), based in Geneva, Switzerland. However, although the ISO has a wide global presence, it does not have a standardized definition regarding what is considered bioplastic. It is worth noting that ISO is made up of more than 800 technical committees and subcommittees, which include specialists appointed by the full members for the area of standardization. These specialists develop a draft standard from a market need within a specific area, for example plastics. The experts' draft is considered a standard to be followed only after voting by the full members. Therefore, there is a true marketing nature of the standards created by ISO, although an attempt is made to dialogue with consumers through the Consumer Policy Committee (ISO, 2023).

Although the ISO does not present the definition of bioplastic, it presents other accessory definitions relevant to environmental aspects, such as bio-based and biodegradability. With regard to the bio-base, one can mention the ISO 16620 series, which seeks to standardize the determination of the bio-based content of plastics and which was reflected by European Norms (EN) 16640, 16785-1, and 16785-2 (BIOPLASTICS, 2022b). With regard to biodegradability, there is an even more extensive list of standards, such as those

referring to: a) the inputs, outputs and potential environmental impacts of a product system throughout its life cycle : ISO 14040 and 14044, reflected in ENs 16760 and 16751; b) measuring the carbon footprint, or green footprint: ISO 14067 and 22526; c) anaerobic digestion and industrial composting: ISO 18606 and 17088, reflected in EN 13432 and 14995; d) the aerobic biodegradation of plastics under controlled composting conditions: ISO 14855; e) biodegradation in marine environments: ISO 18830, 19679, 22404, 22403, 22766; f) those that the biodegradability in soil: EN 17033, and g) more currently in 2022, the conditions or home composting of biodegradable plastics: CEN/TC 261 SC 4 WG 2. (BRITO, et al, 2011; BIOPLASTICS, 2022b).

It is clear from these standards that the bio-based materials are those that use biomass resources, organic materials available on a renewable or recurrent basis, such as crop residues, wood residues, grasses, and aquatic plants., or according to the IUPAC concept, “living systems and collection of organic substances produced by living systems that are exploitable as materials, including recent postmortem residues.” (VERT et al., 2012). The biodegradable ones are those that are degraded when subjected to the enzymatic action of microorganisms available in the environment, being converted into natural substances, such as water, carbon dioxide and inorganic compounds (BRITO, et al., 2011; VERT et al., 2012).

In addition to the terminological recommendations presented by IUPAC and the absence of a definition of bioplastic by ISO, one can find the concept used by European Bioplastics, which is used and disseminated worldwide (JONES, 2020; BIOPLASTICS, 2022a). This organization is a private association based in Berlin, Germany, and whose direction is given by representatives of member companies. These, in turn, are listed on the association's website, among which it is possible to observe large transnational companies in the industrial sector (BIOPLASTICS, 2022a). It should be noted that European Bioplastics, although it is recognized as a relevant association when the subject is bioplastics, but unlike ISO and IUPAC it does not have as its fundamental function the elaboration of international standards, and its concepts are followed by the market only as a reference.

In this regard, European Bioplastics (2022a) brings together the bio-based and biodegradability to formulate its concept of bioplastics. Thus, the concept of bioplastic has its conceptualization derived from these two initial concepts, which are notoriously complex. In this sense, it is notable to remember that there are several standards that seek to regulate the definition and measurement methods of the bio-based and biodegradability, among them are the standards issued by ISO, by the European Committee for Standardization (CEN) and the

American Society for Testing and Materials (ASTM); however, they do so without going into the definition of bioplastic itself.

Therefore, considering this current state of such norms and concepts, for a plastic material to be considered bioplastic, from the perspective of European Bioplastics (2022a), it must: either have a bio-based, even if partially; or be biodegradable; or both. Given this, the private association, European Bioplastic, has concluded that bioplastic can assume two major forms, as shown in Figure 1: a) all the plastic material that has biomass in its composition, whether or not it is biodegradable, b) all biodegradable plastic material, whether or not it contains biomass in its composition. In this regard, only conventional plastic is excluded from its concept of bioplastic; thus considered, it is a plastic material that does not contain biomass (fossil-based) in its composition and is non-biodegradable (BIOPLASTICS, 2022a).

The concept of European Bioplastics can therefore be considered as that of a generalist because it encompasses all plastic material other than not the conventional plastic. Besides that, the conceptualization of this association, while it does not delimit a minimum percentage of the bio-based to be used in the composition of the plastic material, it does make it possible that any material that presents even tiny percentages of biomass can be called bioplastic (JONES, 2020).

Further to this, Costa (2018) points out that the concept of biodegradability can be criticized for not defining criterion for time of degradability. This means that it could take years for the material to degrade and still be considered biodegradable. In this regard, Costa points out that the ideal concept for the preservation of the environment would be “compostable material” that completely biodegrades into neutral elements within a period of 45 to 90 days.

Another important factor that is subject to criticism in the concept of bioplastic of this European association is the fact that biodegradability is measured under specific laboratory conditions that are not always consistent with the destination of plastic material in day-to-day life. This means that, although a material may be considered biodegradable for testing purposes, it can take several years to degrade in uncontrolled environments, as well as generate secondary microplastics, whose impacts on the environment are as harmful as conventional plastic (JONES, 2020, SHRUTI, KUTRALAM-MUNIASAMY, 2019).

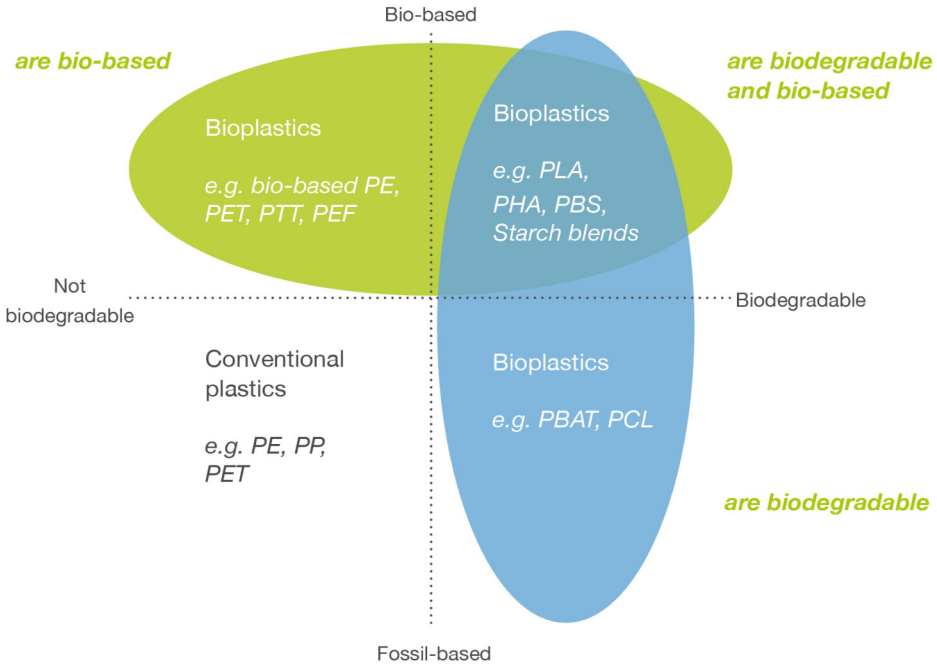

Figure 01. The Bioplastic concept of European Bioplastics.
Source: European Bioplastics (2022a).

Another perception is that of oxo-biodegradable plastics. These, in turn, consist of polymers that are added to other chemical elements that accelerate their degradation through oxidation in the presence of light or heat. It is important to note that these additives are composed of transition metals: Iron, Nickel or Cobalt, whose leaching contributes considerably to environmental contamination (BRITO; et al, 2011; OLIVATTO, 2018). It is observed that this type of plastic cannot be considered bioplastic, according to the technical sheet presented by European Bioplastics (2022b), which can already be considered an advance for the purposes of preserving the environment.

4. The relationship between global governance and the roles of meso-institutional intermediaries in the case of bioplastic

In this scenario of growing and agile technological development and the search for sustainable sociotechnical transitions, the case of the definition of bioplastic is just one of the many uncertainties that present themselves today. Global governance in this regard is of vital importance as, through institutions and intermediaries, it has the function of internationally unify definitions for environmental protection.

For this purpose and as an example at the macro-institution, there is the Directive (EU) 2019/904 of the European Parliament and of the Council of June 5, 2019, which aims to "the reduction of the impact of certain plastic products on the environment". That Directive defines plastic as: "a material consisting of a polymer as defined in point 5 of Article 3 of Regulation (EC) No 1907/2006, to which additives or other substances may have been added, and which can function as a main structural component of final products, with the exception of natural polymers that have not been chemically modified" (EUROPEAN UNION, 2019). Therefore, the term includes not only fossil-based plastics, but all plastics that have been chemically modified, including bio-based plastics, biodegradable plastics and those that have both characteristics, such as polylactic acid (PLA), a plastic which contains lactic acid as a monomer and can be obtained from fermentation of natural sources, such as sugarcane bagasse.

In addition, this Directive, in order to achieve its objective of reducing environmental impacts, regulates "single-use plastic", i.e., plastic that is not conceived, designed or placed on the market to make multiple trips or rotations in its life cycle upon its return. Thus, the directive focuses on the circularity of the product only. For example, plastic cutlery, as per part B of the Annex to this Directive, will be restricted from being placed on the market as they are considered single-use plastics, even if it is made from biodegradable plastic, from biomass or both (EUROPEAN UNION, 2019).

In Brazil, however, there are still no macro-institutions that regulate plastic in the national territory. In this regard, the lack of a federal law that deals specifically with the use of conventional plastics stands out. What is observed is the action, when existing, at the states or municipalities through ordinary laws. This fact points to a deficiency in national and macro-institutional standardization on the subject in Brazil (SENADO FEDERAL, 2021).

As there is no globally standardized definition, such as through an ISO standard, the tendency is for macro-institutions interested in environmental protection to exclude any concept of bioplastic. In this way, macro-institutions prevent the negative effects of the absence of a definition from being perceived, and on one hand, its absence leaves room for the perpetuation of environmental impacts, while on the other, there is an extreme measure of exclusion of everything that could be considered bioplastic by macro-institutions.

The apparent impetus of this movement allows us to say that the definition of bioplastic is not in the interest of the organizations of technical standardization, such as the ISO, since they do not define it. However, with the total exclusion promoted by the European Directive, the opportunity to develop technologies that could be beneficial is lost, for example, the

cheapening of polylactic acid (PLA). In addition, exclusion individually does not remedy the lack of a global definition, thus protecting from negative effects only those States that have macro-institutional strength for bioplastics to be regulated, while in States with fragile macro-institutions the negative effects continue to exist, enabling the creation of a market of certifiers with different concepts or even the absence of certifiers due to this lack of definition.

Conversely, at the meso-institutional level, the transformation function of rules into specific sociotechnical norms would make it possible to adapt the term "bioplastic" to operational norms, so that meso-institutions, whether international or national, whether public or private, implement purposes of environmental preservation and sustainability. With this, through an internationally unified definition and with epistemic quality in favor of environmental protection, it is understood that it is possible to reduce the negative effects of the lack of definition, such as Greenwashing.

It is important to remember that the term "greenwashing" was used for the first time by Jay Westerveld in 1986 and has been widely used since the 1990s by Non-Governmental Organizations (NGOs), including Greenpeace. These organizations popularized the term and began to denounce companies that falsely show themselves to be environmentally friendly (PEARSON, 2010; PAGOTTO, 2013; LYON, MONTGOMERY, 2015; DE FREITAS NETTO et al., 2020; BRITO, GONÇALVES -DAYS, 2021). Several authors and institutions sought its conceptualization, understanding it as a verbal or non-verbal, commissive or omissive communication, which masks real environmental problems of organizations or individuals (TERRACHOICE, 2010; LYON, MAXWELL, 2011; LYON, MONTGOMERY, 2015; BRITO, GONÇALVES-DIAS, 2021; OXFORD, 2022).

Moreover, even in the case of the EU, although the issue of definition is overcome, a problem is created in the roles of monitoring and enforcement. This because, macro-institutions, although they can regulate inter-individual relations, do not have the capacity to modify behaviors by themselves. In this regard, it is necessary to create, through meso-institutional intermediaries, a whole apparatus for monitoring the use of the term "bioplastic", as well as a means to punish non-compliance and compensate for compliance, when applicable. Moreover, it is necessary to create a feedback mechanism for micro-institutional intermediaries on the use of this product.

Essentially, it is understood that the complexity of global governance related to environmental problems is not solved only with the creation of the appropriate institutional definition, despite it being a possible limiting alternative of negative effects, such as

Greenwashing. The definition must also be accompanied by sociocultural reinforcements that aim at valuing the environment, not only at the individual level, but also at the political-collective level. Given this, it is necessary that institutional intermediaries act in order to achieve an international unity and, in particular, that meso-institutional intermediaries monitor, enforce and provide feedback on the use of bioplastics.

5. Final remarks

Some general lessons emerge. First, when identifying and analyzing the different concepts used by meso-institutions and macro-institutions, the contrast of institutional scenarios is confirmed, and this arises from the absence of efficient global definitions with epistemic quality, which consequently create diverse situations. Second, these conceptual differences raise the issue of different effects for private agents and consumers.

The basic message conveyed by our analysis is that meso-institutions are important, mainly, for the unification of concepts that are used by public policy makers, specifically the environmental area, as well as to reduce informational asymmetry, since the consumer has little or no information regarding the quality attributes of the products. In fact, it is also suggested that the lack of a dominant meso-institution leads to efficiency problems in global environmental governance and favors the practice of Greenwashing, in addition to creating disincentives to differentiate products, through certifications, from what actually can be considered bioplastic, situations that are experienced in Brazil.

In this scenario, Greenwashing is a negative effect of the diffuse and sometimes generalist conceptualization of bioplastic insofar as the prefix "bio" is used by various agents in an opportunistic way. This symbolic imposition generated by the improper use of the prefix. “bio” conveys to consumers an environmentally positive image of the product, which masks its negative environmental implications. Furthermore, the misuse of the prefix on the product also misleads the consumer about the organization that sells it, or that earns credit for its use, since it conveys the erroneous appearance of being an environmentally friendly organization.

Still, there is more to learn from the situations herein identified. In Brazil, given the absence of a macro-institutional definition for bioplastic, there is inhibition of an environment that promotes the development of sustainable productive activity and the incorporation of sociotechnical changes. Another point worth mentioning is that the absence of pressure to change the rules and clarify the relevant definitions benefits a group of companies, which are

probably those that do not actually work effectively with an environmentally suitable plastic, fully bio-based and, simultaneously, biodegradable.

On the other hand, in Europe, the absence of a definition of bioplastic at the macro-institutional level, with the consequent favoring of Greenwashing, causes its total exclusion by Directive (EU) 2019/904. Although this measure aims to reduce environmental impacts, it only considers plastics that fit the idea of circularity, even if these plastics are of fossil-based or non-biodegradable. In another way, biodegradable and bio-based plastics, when they are created for the purpose of single use, are discouraged by this Directive, even though they simultaneously have the bio-based and biodegradability characteristics and present less environmental impacts than conventional plastics.

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