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Marine plastic: The solution is bigger than removal

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Despite the increase in the documentation on, and interest in marine debris, there remains a gap between the analytic information available and the recommendations developed by policy and decision makers that could reduce this pollutant. Our paper summarizes some successful initiatives across policy, industry, infrastructure and education; and where they sit in the value chain of plastic products. We suggest that a multidisciplinary approach is required to most effectively address the marine plastic litter problem. This approach should emphasize (1) minimizing plastic production and consumption (where possible), and waste leakage; by (2) improving waste management (taking into consideration the informal sector) rather than focussing on clean-up activities. We then suggest some steps that once addressed would assist policy professionals, and a wide variety of entities and individuals with decision-making to reduce marine plastic litter. We suggest the creation of a user-friendly framework (tool) would facilitate transparency and democratization of the decision-making process across stakeholders and the wider community. This tool would be most useful if it comprised information on (i) defining appropriate metrics for quantifying plastic waste for the study/work case; (ii) providing a list of possible interventions with their key associated enabling and disabling factors, (iii) identifying the main influential factors specific to the situation/region; (iv) recognizing the risks associated with the selected interventions and the consequences of these interventions on the most influential factors; (v) objectively ranking solutions using the information gathered (metrics, targets, risks, factors) based on the regional, national, and/or international context. This tool then provides an opportunity for user groups to explore different suites of options for tackling marine plastic pollution and co-create a suite that is optimum for them.

KEYWORDS

marine plastic, solutions, pollution, litter, debris

1. Introduction

Marine debris is an escalating challenge that is recognized globally (Lau et al., 2020). Plastic is often the largest proportion of this observed debris (Galgani et al., 2015) and has been found across the planet in some of the most remote locations. This is primarily because plastic is a durable, light and inexpensive material, and its manufacture is increasing annually (OECD, 2022). Thus, plastic debris is a global issue that continues to grow.

Marine plastic debris causes a wide variety of ecological and socio-economic problems (Beaumont et al., 2019). The proven and suspected impacts on marine organisms and ecosystems are far-reaching such as: entanglement of individuals, smothering and community change (as an invasive species vector) to ecosystems (Galloway et al., 2017; Koelmans et al., 2017). Plastic debris also results in income losses and increased costs for ocean users and coastal communities (Watkins, 2017; Schuyler et al., 2018). In recognition

of these wide-ranging effects, efforts to decrease plastic use, waste and pollution have surged in the past decade (Karasik et al., 2020) and targets increasingly made (e.g., UN Sustainable Development Goal 14.1).

To decide where to focus interventions that minimize ocean and coastal plastic debris, the source, pathway, type, amount, and location of accumulations must be considered. Plastic debris is mostly leaked into the ocean from populated land (Jambeck et al., 2015) and some types of debris (e.g., fishing gear) are deposited directly into the marine environment (Browne, 2015; Galgani et al., 2015). A recent study based on analysis of litter collection databases (Morales-Caselles et al., 2021) presents a conceptual model of the most likely pathways of the most frequent litter items. However, the exact pathways taken by plastic debris into the ocean, its degradation and fate are diverse and currently poorly understood, making it hard to predict patterns and amounts of marine debris. Although, we do know that rivers are the major conduit for plastic debris (González-Fernández et al., 2021). Indeed, plastic abundance estimates, calculated from different source data diverge greatly. For instance, estimates in surface waters vary between 0.27 million tons (Eriksen et al., 2014) and 0.09–0.24 million tons (Van Sebille et al., 2015) and this is likely to be just a portion of the total extent of existing plastic pollution. A mismatch between these estimates and that of plastic leakage from land (estimated at 4.3–12 million tons per year; Jambeck et al., 2015) still exists. Differences between estimates could occur because there is no clarity on the magnitude of plastic in reservoirs such as seabed sediment (Martin et al., 2022), ice (Obbard et al., 2014) organisms (Kvale et al., 2020) and the water column (Choy et al., 2019). Recently some (Weiss et al., 2021; Mai et al., 2022; Weiss and Ludwig, 2022) have argued that there is no or much less of a mismatch between estimates of plastic pollution being leaked vs. found in the ocean. Nevertheless, more work will be required to truly understand the residence times of plastic pollution within reservoirs.

Additionally, there is little understanding and data on the flux/transportation between said reservoirs within the environment (Hoellein and Rochman, 2021). Although some accumulations do occur in offshore environments (e.g., ocean gyres), the relative size of these accumulations in proportion to overall plastic pollution, even if unknown, is likely smaller in comparison to nearshore areas. The uncertainty of plastic abundance in offshore environments is due to limited observations, the low resolution and the simplified assumptions of current modeling studies, and lack of in-depth knowledge of some key ocean processes (Van Sebille et al., 2020). Furthermore, the transboundary nature of marine plastic and its constant movement is reflected by features such as windrows (Ruiz et al., 2020; Andres et al., 2021). Together, these factors mean it is hard to estimate the size of the marine plastic debris problem, communicate about it and prioritize interventions to reduce it (Hartmann et al., 2019). This also indicates that it is hard to determine exactly where large accumulations of plastic debris might be located, and how they change. However, plastic debris is most likely to be located close to the main source of leakage e.g., at locations on or near land. As policy makers are currently operating in data-poor environments, applying the precautionary principle should prevail (Meidl, 2019) until a larger body of evidence regarding risk is built. Despite the extensive interest in the subject, the increased implementation of product specific policies (e.g., Adam et al., 2020) and business decisions to reduce plastic waste, it continues to be a "wicked" problem (Zijp et al., 2016; Stafford and Jones, 2019; Stoett and Vince, 2019) that needs multiple holistic solutions. Here, we briefly summarize key learnings from current marine plastic interventions and detail next steps that could assist decision makers with assessing and prioritizing future initiatives.

2. Measuring debris

Despite many national and regional initiatives and guidelines to assess plastic debris (e.g., OSPAR Indicator Assessments, descriptor 10 of the EU's Marine Strategy Framework Directive, NOAA's Marine microplastics database and many more), there remains patchy data on global, regional and local pattens of its accumulation. Considering the vastness of the marine environment, currently funded research and citizen scientists projects are unlikely to capture the full and evolving extent of marine debris in the sea surface and beaches. To address this, there have been recent innovations using aerial drones (e.g., Andriolo et al., 2022), other imaging technologies (JRC, 2016), and remote sensing options using satellite technologies (e.g., Maximenko et al., 2019; Topouzelis et al., 2019). Furthermore, automatic detection of debris is now permitting quicker estimation of abundance in some areas (e.g., Veerasingam et al., 2022). However, further innovation and community engagement are required to usefully utilize these technologies to support marine plastic minimization globally. To ensure these tools support the development of indicators and their long-term monitoring and assessment then a clear, standardized approach regarding metrics, targets and threshold levels should be implemented using a global standard. The opportunity to do this has arisen within the negotiations of a binding treaty on the life cycle of plastics, based on the recently approved UNEA 5.2 resolution.

3. Waste minimization

As plastic production keeps increasing, so does plastic waste (OECD, 2022). Curbing plastic production (e.g., non-essential items) would minimize the amount of plastic that could become mismanaged waste and end up in landfill or the environment. There is a long lead time to achieve this curbing, therefore other interventions should be considered. There has been growing public awareness and institutional responses regarding marine plastic waste globally. Interestingly, some public attitude surveys place government and industry at the heart of the responsibility for reduction in plastic waste (Dilkes-Hoffman et al., 2019) although these are only two sectors where change can occur. Globally, responses cover individual responsibility, corporate and industrial measures, government policy, education efforts, and take place at any point in the plastic life cycle and waste-stream. Thus, many different initiatives have been conceived and developed (Table 1). An extensive list of instruments and technology initiatives have been collated (Karasik et al., 2020) and numerous case studies assessed (Global Plastics Policy Centre, 2022) but because the exact

TABLE 1 Examples of responses and knowledge gaps to reducing marine plastic waste across its life cycle.

Type of response	Prevention (upstream)			Removal (downstream)
	Policy	Industry and infrastructure Reducing/ recycling/ Waste management	Education (engagement, motivation, mindset)	Collection
Actors	At individual/ corporate/ institutional/ government/ international.	At corporate/ academic/ institutional/ government international.	At individual/ corporate/ academic/ institutional/ government/ international.	At individual/ academic/ institutional/ government/ international.
Actions (Order of priority)	- Promote policies that support a circular economy - Policy **engaging with industry** (producer responsibility). - **Regulating** production, use & full **life-cycle** of the product (recycling and waste management).	- Foster and promote **circular economy** principles in industry (product full life cycle & producer responsibility). - Refuse, reduce, reuse, recycle, recover, redesign.	- Seek **agents of change** (such as children). - Encourage being "**plastic sensible**".	**Requirements** Long-term real solution; **minimize unintended** consequences on the environment & ecosystem (precautionary principle). Have a **framework** - include all factors and prioritize.
	Follow the **precautionary principle** when drafting policy (scientific evidence takes time to build, it is needed as a basis for policy).	- Being "**plastic sensible**" (reducing plastic consumption, single and non-single use). - Take precautionary principle into account.	- Raise **awareness** (consequences & costs, circular economy). - Change **behavior** (reducing consumption). - Closing the loop: refuse-reduce-reuse-recycle-recover-redesign.	**Size dependent** - Focus could be macro or microplastics. - Passive or active methods? - Technological or human focused?
	Regulate and enforce policies to ensure consequences (economic, ecosystem/environmental, emotional, ethical, local consequences). - **Enforce** and advise monitoring. - Use **economic incentives*** (deposit schemes).	**Waste** - Improve waste management pathways and waste collection; (emphasis on developing countries). - Improve waste-water treatment (emphasis on developing countries).	**Clean-ups*** multi-purpose (actual removal; ocean literacy; environ-mental awareness). - **Education programmes** (school; high-schools; institutions; monitoring & citizen science; youth engagement; NGOs).	**Locations** Rivers & water courses. Coast & ports/marinas. Beach clean-ups. Open ocean.
	Taxing* production/packaging/-single-use plastic/plastic bags. Policies for **specific items***: - fishing gear; (fishing for litter programmes, size of vessel => costs); - plastic blasting in shipyards.	**Innovation** - Investigate new ways of recycling plastic polymers. - Find alternatives to plastic packaging.	**Citizen science + outreach***. - Educational videos/on-line courses/MOOCs.	What is the future of waste collection?

*Indicates interventions with shorter time frames (e.g., 0.5–3 years). The bold texts indicate keywords.

nature of interventions and their outcomes are context specific, prioritization of actions is still complex.

Prevention initiatives aim at reducing the amount of plastic produced and circulating in the waste stream, and also the amount of waste leaked into the environment. These initiatives include actions, such as developing alternative materials or re-design using circular economy concepts, taxes and levies for plastic goods (Powell, 2018), continued education, recycling programmes and technological developments. Policy opportunities focus on a holistic approach that considers a circular economy, providing additional benefits such as more cost-effective processes which incentivise change. However, more regulatory and punitive approaches maybe needed to support behavior change (European Commission Directorate-General for Environment, 2018a,b). Industry measures should mirror policy opportunities with consideration of their global footprint and innovation. Educational initiatives, both formal and informal, are best targeted at specific groups and operated alongside other programmes to maximize the impact of both (Table 1).

Removal interventions can vary from small, focused and community led (e.g., beach clean ups) through to large-scale infrastructure projects. In addition to the reduction of plastic, the most successful of these projects also include an educational and public awareness component (Rayon-Vina et al., 2019) to also minimize the leakage and connect people to their local environment. Effective removal projects require specific consideration of target debris and location, so bespoke solutions are often best, but as there are very few evaluations of success that include the entire procedure all the way through to processing of collected waste, there are little data to help inform decision-making. To support long-term positive change, projects should have a "planned legacy" and be carefully assessed for their risk (e.g., environmental and socio-economic) as well as their opportunities.

3.1. Litter prevention

3.1.1. Policy and regulations

The MARPOL (73/78) convention was the first legislative instrument for plastic waste and sought to prevent dumping waste at sea. Since then, many international and multilateral policy initiatives have been implemented to deal with the protection of the marine environment from plastic polluting activities (Gold et al., 2014; Chen, 2015).

Prioritizing interventions to minimize marine plastic litter and the implementation timescales are key to the initial reduction of plastic items (e.g., Cristi et al., 2020) in the marine environment. For instance, single-use plastic item bans have been effective in specific contexts, and therefore are considered as a relatively quick way of reducing waste load if conditions are favorable, e.g., alternatives readily available at same cost level, etc., (Xanthos and Walker, 2017). While single item bans cannot solve all marine waste challenges, they do provide opportunities for relatively rapid and cost-effective removal of a significant source of plastic from the waste stream. They are therefore considered useful initial actions for a range of regions (e.g., Royle et al., 2022) and they are often a useful step toward more complex interventions requiring greater community and stakeholder involvement that may need longer timescales.

Global (e.g., Lau et al., 2020), regional (e.g., European Commission Executive Agency for Small Medium-sized Enterprises, 2020; Omeyer et al., 2022; South East Asia) and national (e.g., USA; Milibrandt et al., 2022) assessments and subsequent models (e.g., Zero Waste Europe, EU Green Deal) and tools (e.g., Breaking the Plastic Wave Pathways Tool, Plastic Drawdown) have provided clear pathways for waste evaluation and policy appraisal. However, prioritizing long-term investment of interventions can be challenging without aligning waste minimization with other policy objectives and global targets. With this in mind, the alignment of waste management with health and wellbeing policies that was conducted in a recent assessment (Farrelly et al., 2021) provided important insight about the interactions of complex issues, revealing the value of analysis across objectives and interventions toward the UN Sustainable Development Goals.

Many multinational programmes exist today to support national and regional policy development and implementation (e.g., Commonwealth Clean Ocean Alliance, the UN Decade of Ocean Science for Sustainable Development, GEO Blue Planet Marine Litter Working Group). Despite widespread interest there is still no binding policy that addresses land-based sources of plastic pollution. There is now an agreement for an international treaty on plastic pollution stemming from its trans-boundary nature (Borrelle et al., 2017; Silva Filho and Velis, 2022) and steps toward this have started with the first Intergovernmental Negotiating Committee meeting conducted at the end of 2022. However, it is still unclear as to whether this treaty will address the plastic pollution issue entirely, and by what means (e.g., by curbing its production, Bergmann et al., 2022). Due to the context-specific nature required in interventions, national and regional policies are generally developed individually through incentivising or prohibitive programmes (e.g., bottle deposit schemes), taxes and levies (e.g., plastic bag levy, Rethink Plastic- Zero Waste Europe) or bans (e.g., single-use plastic ban) (Abbott and Sumaila, 2019). For example, plastic bags, are a topic where the national governments have collectively made the most policies, and where prohibitive regulations were most commonly used (Karasik et al., 2020). In this case it is still not clear if these are an overall success for the environment, due to the potential impacts of some of the materials used to replace plastic (Gómez and Escobar, 2022). In conclusion, powerful vectors of change can come from national regulations that contribute to international behavior change, such as waste import and export bans (Brooks et al., 2018), although mechanisms to connect these are often still undeveloped.

3.1.2. Industry including waste management and innovation

As producers of plastic, consumers and recyclers of plastic products and waste, industry holds a key to the solution of plastic waste reduction. This is the logic behind the EU Extended Producer Responsibility policy (EPR, Lorang et al., 2022). In the context of the "Waste Framework Directive" (2008/98/EC), and the "Packaging and Packaging Waste Directive" (94/62/EC) the EPR is used as a policy tool so that the producer has a responsibility of the post-consumer phase of the product, i.e., when it becomes waste. Industry also has a major part to play in how plastic and product life cycles are considered in the future. Many waste reduction strategies make good economic sense and have been implemented across the sector (e.g., Operation Clean Sweep). Coupled with these, industry has the opportunity to deliver radically different products using the concepts of circular economy to improve product design and reduce plastic waste through extended producer responsibility schemes. The shift is already seen in some sectors and supported *via* networks such as the "*Circula El Plástico*"[1] (Chile).

Additionally, for industry, gaps identified (Woodall and García-Hermosa, 2016) include opportunities to explore technological and novel material development (Cordier and Uehara, 2019) as well as to improve recycling and further development of polymer identification and sorting methods, improve knowledge on degradation and biofouling, and support more innovative ideas currently in the research phase (e.g., edible food packaging). Recycling, polymer identification/sorting, and degradation of marine plastic litter are interconnected subjects but the links, as yet, are not fully understood.

Global recycling levels are still low, some estimates from 2017 are as low as 9% (Nikiema and Asiedu, 2022) and cited as only 16% for the waste management industry, water treatment and associated sectors (Kaza et al., 2018). These low numbers reflect the many region-specific challenges including widespread lack of formal waste management collection systems in low-income countries, where the informal sector has bloomed. While the informal sector is vital in many low-income nations, it is rarely taken fully into account in budget calculations, partly because it is often hard to quantify. This exclusion overlooks the role of informal processes in the waste management industry. This lack of recognition and value can have negative impacts for the workers (with precarious

1 https://circulaelplastico.cl/en/ The Chilean Plastic Pact.

living conditions) who may lose their livelihood and fall deeper into poverty. When considering interventions in the waste management industry, integrating and coordinating these two sectors provides better outcomes, whilst improving the conditions for informal workers (e.g., Jenin Solid Waste and Environmental Management Project) is an important target globally (i.e., SDG 11).

3.1.3. Education leading to personal behavior change

Education is an important tool to reduce plastic waste (Thompson et al., 2009) and has proven to have a positive impact on the issue (Maddox et al., 2011). Additionally, education programmes can be targeted at specific ages or sectors of society; groups/communities; or focus on particular messages. Children are recognized as "agents for change" especially regarding environmental issues and thus many of these programmes include this age-group (Walker, 2017). The educational programme delivery is often successfully conducted (for all ages) alongside other marine plastic reduction initiatives (Löhr et al., 2017). To illustrate this, education is an important component of beach clean-ups (e.g., UK Marine Conservation Society) which do not solve marine waste in the long-term, although they do provide opportunities for data collection and awareness campaigns. Moreover, the topic of plastic pollution has an important role as a gateway to other global issues such as climate change, especially as it is so closely linked (Ford et al., 2022), and also has a trans-boundary component to it. There are currently a huge range of resources that can be used in education programmes on marine debris. These are pitched at different levels and different sectors of society [e.g., Green Indonesia, Massive Open Online Course (MOOC) on Marine Litter]. In addition, courses on marine biology, coastal management, marine pollution, ocean literacy and stewardship often present marine plastic impacts and how individual people can change their behavior to reduce them (SEPEA Science Advice for Policy by European Academies, 2019).

3.2. Removal: A small part of the solution

General consensus in the community considers that removal of plastic pollution from the environment is not optimal as a standalone action, as it is not a long-term solution (e.g., Nizzetto and Sinha, 2020), and it will only "solve" a fraction of the problem. Removal actions unsupported by other interventions (e.g., educational as in cleanoceanproject.org) should be considered as "quick and temporary fixes" and must be complemented with plastic waste minimization actions that stop plastic pollution entering the environment. These mean emphasizing life-cycle solutions at product conception, reducing or banning single-use unnecessary products and improving waste management. Indeed, some clean-up activities for macro litter, perform a joint function of educating and visualizing the plastic pollution problem for communities (e.g., beach clean-ups, fishing for litter activities and water wheels), as well as providing waste removal opportunities.

The success of the physical removal of plastic pollution from the natural environment depends on multiple aspects such as: size, abundance and type of plastic, location, methodology, and type of environment (e.g., coastal waters, open-ocean, rivers). A good example of focused and specific marine litter removal with reasonable success are the "Fishing for litter" initiatives (https://fishingforlitter.org). Other relevant points to be considered are the proposed removal location, consequences of the impact of the removal, and subsequent actions required to get the plastic to waste management sites (Sherman and Van Sebille, 2016). Schemes targeting plastic waste removal are most beneficial when located near existing infrastructure (e.g., transport links, industrial reprocessing plants, etc.,) to minimize additional development requirements and fuel consumption needs. Furthermore, collection or removal schemes should be designed to minimize the chance of biological "by-catch" (unintended entanglement or capture of organisms) and should also be targeted near the source of the waste leakage and where accumulations are found (e.g., estuary mouths, coastal areas) (Haarr et al., 2019; Falk-Andersson et al., 2020). A recent study based on analysis of litter collection databases (Morales-Caselles et al., 2021) identified coastal areas for collecting plastic waste before it moves to deeper open ocean. Many different initiatives exist and have been reviewed. Microplastic and macro waste collection methods (Microplastic: Padervand et al., 2020; macro waste Schmaltz et al., 2020) exhibit differing challenges and levels of success. For instance, some successful and simple removal projects have targeted particular pathways and capture waste before it enters marine systems (e.g., storm drains, Baltimore wheel).

While microplastic removal is technically possible (Karasik et al., 2020; Padervand et al., 2020), just a few methods are currently available (at the scale that would be required to make significant changes in ocean locations) that would not result in large-scale changes to biological communities. However, on land, some waste-water treatment processes can remove >95% of microplastics from waste-water (e.g., Talvitie et al., 2017) preventing further spread of this pollutant, and so filtering and gravity methods, biological and binding methods, membranes and physical capture (Karasik et al., 2020) should be considered useful tools to reduce this type of pollutant. These types of removal methods are developing more widely and mostly focus on waste-water.

Underpinning any intervention is a cost-benefit analysis and include aspects such as costs to the environment and communities, as well as the financial outlay. The financial cost of an intervention to remove marine plastic is rarely in the public domain, although some examples do exist (e.g., Burt et al., 2020, for a small-scale approach) costs range widely depending on situation (Nikiema and Asiedu, 2022). All negative (including unintended) consequences of plastic removal interventions must be considered at the planning stage (as with any development and activity) and the precautionary principle ought to be applied. For example, the debate on the impacts of mechanical beach cleaning is still ongoing, an activity that has been going on for decades (Zielinski et al., 2019).

To recap, in the authors' opinion, removal interventions require an appropriate accompanying narrative and activities, as they can deflect messages of resource sustainability, personal responsibility and industry accountability.

4. Thoughts on strategies for reducing marine plastic debris

Plastic waste is not only a marine problem, it is also a global societal challenge (Jambeck et al., 2020). Debates about

which solution is best for marine plastic continue as there is a growing realization that not all plastic pollution is the same (having different components, sources and pathways into the environment). It will not be feasible or realistic to remove all plastic already in the environment, neither is it appropriate or possible to stop the immediate production of all plastic (Patterson, 2019). It is more realistic to radically reduce the waste leaking into the ocean (and reducing production of certain items) while developing alternative materials, and hence reduce the overall burden entering the environment. In specific situations removal interventions that are most beneficial to the environment and local communities may help.

Reviews comparing similar interventions across different nations, (e.g., plastic bag bans, Xanthos and Walker, 2017; Knoblauch et al., 2018; Nielsen et al., 2019) have been successful in elucidating the drivers that are enabling and inhibiting these policies. Together these studies and others (e.g., Rochman, 2016; Critchell et al., 2019; Godfrey, 2019) show that no "one" solution to the marine plastic pollution is perfect for all scenarios. Instead, solutions require a location and case-specific focused approach. The key to reducing marine plastics will have to be multifaceted, as the processes that originate it are numerous, complex and overlapping. These solutions will need to be enacted at multiple points in the life cycle and waste stream of the plastic objects, and will need, in some cases, multinational agreements. A better understanding of the flux, sinks, sources and reservoirs of plastic waste will also help target and prioritize appropriate interventions.

The amount of published literature on marine plastic pollution has increased annually (Aretoulaki et al., 2020) as have the actions being implemented to reduce this problem. However, there remains limited scientific evidence as to which of these interventions should be prioritized, and the local conditions and national circumstances required for them to be most successful (see Global Plastics Policy Centre, 2022; Nikiema and Asiedu, 2022). Debate about what defines a successful intervention and its context continues as the body of scientific evidence slowly grows, and zero plastic waste pollution remains far from practical in most cases.

Based on the points discussed throughout the paper, we suggest some steps that could be useful to support stakeholders and the wider community in decision-making regarding plastic pollution interventions with measurable outcomes and action accountability. In addition, the information gaps and analyses suggested in the steps below would be useful in supporting negotiations of a global plastics treaty, and potentially useful in the implementation of actions required to achieve some of the agreed targets. We think it is necessary to:

1- Scope the issue by agreeing on the metrics to quantify the presence and type of plastic pollution to compare the situation before and after intervention or interventions. This would help define, *a priori*, what is to be considered a success and provide an indication of achievement over time.
2- Use a list of possible interventions (e.g., Karasik et al., 2020) and their context specific nature to identify the interventions suitable for the current situation/region/context. This short-listing process supports focused discussions for stakeholders.
3- Identify the main influential factors that are context specific to the situation/region (e.g., socio-economic, socio-cultural perspectives, behavioral, legal, infrastructure, timeline, value for money, perception of waste impacts, long-term additional benefits). Providing further opportunity for engagement between stakeholders and decision-makers.
4- Establish potential risks associated with the selected interventions, building on Schmaltz et al. (2020) and Nikiema and Asiedu (2022) and combining them with the most influential factors in the specific context/region of the situation. Taking into consideration the influence and consequences of those in the specific context (indicating sources of risk) for the success of each intervention.
5- Bringing together the interventions, metrics, targets, most influential factors and risks as an assessment tool to provide the opportunity for decision-makers to objectively rank (prioritize) and choose a suite of actions that are most likely to be successful, given their specific circumstances, location, and the challenges that may be faced at a regional, national and international context.

Based on the points above we suggest the relevance of creating a user-friendly tool. This means a tool that provides an interface for users to input and access information and options available, and to test their ideas in a simple manner.

Various modalities should be considered, to help ensure wide engagement of the tool across sectors. This could include platforms such as a website, a phone app and/or printed material. This would facilitate transparency and democratization of the decision-making process across stakeholders and the wider community and would comprise information from above points. Additionally, the global plastic treaty, that is under negotiation could be an invaluable opportunity to request the eventual signatory countries to report on current plastic debris and how they change overtime.

5. Concluding statements

Given the diversity and complexity of the marine environment and of the sources of marine litter, there is no one solution to this wicked problem. Instead, a portfolio approach of multiple actions that are specific to the local/regional context is required. The choice of interventions to minimize plastic items and waste (in general and their arrival in the marine environment) should be taking into consideration a host of pertinent factors, such as socio-economic, socio-cultural, behavioral, infrastructure, legal, timeline, value for money, local infrastructure, perception of waste impacts, unintended consequences, and long-term additional benefits. We therefore suggest a tool designed to facilitate transparency and democratization of methodologies by gathering pertinent information from diverse sources and sharing it across sectors. This tool would present the current problem and share a list of possible interventions that could be adopted by decision-makers. It would also provide understanding of possible challenges that may arise from interventions. Thereby, could be a useful mechanism to help choose, prioritize and optimize interventions.

Plastic waste is not an isolated challenge; it is highly linked to other global challenges such as climate change and resource over-exploitation. Decisions to minimize marine plastic debris should also consider a holistic view of the region/area/context and other challenges present when prescribing interventions. This addresses the fact that marine plastic debris is a trans-boundary issue and to best tackle it, therefore, requires cooperation across geographically close and distant countries. As solutions are diverse, they operate at an optimum over different set of geographical, sectorial and temporal scales. In conclusion, marine plastic pollution can only be reduced when interventions are part of a suite of well-designed actions that are diverse and take full account of the specific context.

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