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Achieving sustainable production and consumption of virgin plastic polymers

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The United Nations Environment Assembly (UNEA) recently adopted a resolution with a mandate to negotiate a new international legally binding instrument (a treaty) on plastic pollution. The mandate includes the need to 'prevent' as well as 'reduce' and 'eliminate' plastic pollution through a 'comprehensive approach that addresses the full life cycle of plastic'. Unsustainable production and consumption of virgin (primary) plastic polymers represents the single greatest threat to preventing plastic pollution and risks undermining the incoming treaty. However, current discussions on a global plastics treaty overlook upstream measures that address virgin plastic production and consumption, focusing instead on midstream and downstream measures on product design and waste management. This article presents the justification for and benefits of a stepwise approach for controlling virgin plastic production and consumption internationally, inspired by the Montreal Protocol on Substances that Deplete the Ozone Layer;

KEYWORDS

plastics, treaty, virgin, production, montreal protocol, prevention, pollution

1 Introduction

Virgin - also referred to as primary -plastic production and consumption are increasingly recognised as having reached unsustainable levels (Lau et al., 2020; Cabernard et al., 2022; Ford et al., 2022; Bergmann et al., 2022). Countries are inundated by an acute overabundance of inexpensive virgin plastics, undermining secondary markets for recycled material and investments in collection and recycling infrastructure (Bauer et al., 2020; Simon et al., 2021). As pressure mounts on the oil and gas industry in the context of a serious climate change response, fossil fuel companies are relying on plastics as the major growth industry (International Energy Agency, 2018; Yale Environment 360, 2019).

The petrochemicals used to produce virgin plastic polymers and other products account for 8% and 14% of total primary demand for gas and oil, respectively, and will soon become the world's biggest driver of oil demand, ahead of trucks, aviation and shipping (International Energy Agency, 2018). The result is a system where inexpensive virgin plastic is used freely and inefficiently, with unfavourable economics for most recycling, leading to a stark discrepancy between how much plastic is produced and how much is recycled. At the end of 2017, of all plastic waste ever produced, only 10% has been recycled; 14% was incinerated and a further 76% ended up in landfills or the natural environment (Geyer, 2020).

Policymakers increasingly draw the connection between eliminating plastic pollution and promoting a circular economy for plastics (European Commission, 2018). The two are inextricably linked. The recent adoption of UNEA Resolution 5/14 entitled *'End Plastic Pollution: Towards an international legally binding instrument'* will convene an Intergovernmental Negotiating Committee (INC) to negotiate a new legally binding instrument to end plastic pollution in all environments (herein termed 'the treaty'). The resolution expressly recognises the need for 'circular economy approaches', taking a 'comprehensive approach that addresses the full life cycle of plastic', in persuit of 'sustainable production and consumption of plastics' (United Nations Environment Assembly [UNEA], 2022). Yet current trends in virgin plastic production and consumption are forecast to overwhelm all efforts to improve waste management, widening the discrepancy even further (Organization for Economic Cooperation and Development [OECD], 2022b). Based on a 2016 baseline, annual virgin plastic production is set to double by 2040 and increase to 1.1 billion tonnes in 2050 (Lau et al., 2020; Geyer, 2020). Already, production of virgin plastic polymers and their conversion from fossil fuels are responsible for 90% of the plastic life cycle's carbon footprint (Organization for Economic Cooperation and Development [OECD], 2022a).

Because virgin plastic polymers are raw materials, products, and pollutants with a few hundred companies dominating production (Charles et al., 2021), a situation similar to ozone-depleting substances (ODS), there are clear learnings for the global community seeking to end plastic pollution in the approach taken by the Montreal Protocol on Substances that Deplete the Ozone Layer (Raubenheimer and McIlgorm, 2017; Andersen et al., 2021). The Protocol is widely considered to be the most successful multilateral environmental agreement (MEA) of all time (Gonzalez et al., 2015; Liu et al. 2016).

This paper reviews how measures under the Montreal Protocol could be adapted to virgin plastic polymers and, in so doing, provides an upstream global regulatory framework that addresses plastic pollution.

2 Policy considerations

2.1 Defining the lifecycle – where should intervention begin?

The need for a 'full life cycle approach' is explicitly mentioned in both preambular and operative sections in UNEA Resolution 5/14. However, no commonly agreed definition of the plastics life cycle exists. While it is obvious that the life cycle ends with plastic waste or its presence in the environment as pollution, it is less clear where it should begin. This presents policymakers with the challenge of defining it for the purpose of the treaty.

Adopted in 2013, the Minamata Convention on Mercury 'addresses mercury throughout its life cycle from its mining to its management as waste' (United Nations Environment Programme [UNEP], 2013). This approach identifies the full life cycle as beginning at the resource extraction phase. However, no other global policy instrument regulates any aspect of the mercury life cycle, and while related, the situation with plastics is much more nuanced. For instance, 99% of plastics are derived from fossil fuels (Nielsen et al., 2020), meaning the juristiction and competencies of the UN Framework Convention on Climate Change (UNFCCC) must also be considered alongside the possibility of a future fossil fuel non-proliferation treaty (Newell and Simms, 2020). As such, the life cycle of plastic needs to consider the life cycle of oil and gas to identify the minimum point at which intervention must begin.[1]

The lifecycle of oil and gas is typically divided into three stages based on functions and operations: upstream, midstream and downstream. Upstream involves the extraction and gathering of fossil resources; midstream involves the transportation of the fossil resources, including through pipelines, and downstream includes processing into petrochemicals (Al-Janabi, 2020). In this context, plastic does not yet exist.

As a material, plastic comes into existence upon polymerisation - a process of reacting monomers (e.g. ethylene) together to form polymer chains (see Figure 1). For this reason, while consideration should also be given to how best to address issues associated with the extraction of raw materials and sourcing of feedstocks for plastic production, including linkages to other conventions, polymerisation is squarely within the scope of the treaty. This is the beginning of plastic as a material – with the lifecycle thereafter divided into four stages:

i. upstream, *i.e.* production of virgin plastic polymers;
ii. midstream, *i.e.* product design and use;
iii. downstream, *i.e.* plastic waste management and treatment (De Silva et al., 2021);
iv. leakage, *i.e.* plastic in the environment.

Such an approach also ensures scope at least covers plastics when they come into existence as materials, and coincides with

1 This article focusses on fossil-based plastics that comprise ~99% of virgin production. However, the ~1% synthesised from bio-based feedstock (so-called 'bioplastics') also require inclusion within the scope of upstream controls.

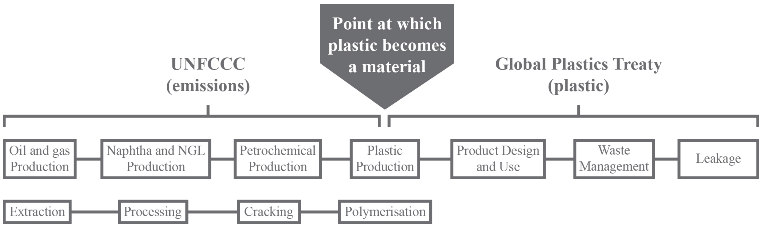

FIGURE 1
A diagram displaying the life cycle of fossil fuels (oil, gas, and coal) in relation to the life cycle of plastics. Polymerisation is the point at which plastics become materials and the minimum stage at which intervention under the incoming treaty needs to begin. However, this should not preclude negotiators from considering measures associated with the extraction of raw materials and sourcing of feedstocks for plastic production and its interlinkages to other conventions.

when plastic first enters the environment as a pollutant in the form of spilled pellets, flakes and powders (Karlsson et al., 2018). Using this definition also follows the approach taken in the Montreal Protocol, whose control measures begin at the point at which ODS are produced (De Sombre, 2000).

It also clearly delineates the scope of measures to be taken in relation to the UNFCCC, which addresses greenhouse gas emissions associated with the oil and gas industry and is mandated to address the negative externalities related to climate change (see Figure 1), though this should not preclude negotiators considering measures further upstream.

2.2 Policy to prevent pollution

UNEA Resolution 5/14 mentions the need to 'prevent' as well as 'reduce' and 'eliminate' plastic pollution (United Nations Environment Assembly [UNEA], 2022), which will not be achieved with mid- and downstream measures alone (Simon et al., 2021). Around 90% of all plastic waste ever produced was used just once (Geyer, 2020), demonstrating the necessity of upstream controls on virgin production to support mid- and downstream measures.

The Montreal Protocol controls harmful chemicals through limits at the production level and on the amount of 'consumption' in products and equipment, rather than downstream post-consumption, which has been the most significant driver of the successful ODS phase-outs. This success inspired authors such as Raubenheimer and McIlgorm (2017) to propose the use of the Protocol as a model to regulate land-based sources of marine plastic debris, and Andersen et al. (2021) to propose narrowing the exemptions for feedstocks used to produce plastics, which they estimate has the potential to reduce up to around 6% of total plastics production. It therefore follows that upstream measures regulating the production and consumption of virgin plastic polymers are also needed to effectively prevent plastic pollution, with the Montreal Protocol representing an appropriate lens through which to design and conceptualise them (Simon et al, 2021; Bergmann et al., 2022).

Furthermore, the Montreal Protocol was designed from the beginning as a flexible and adaptable "start-and-strengthen" instrument (Gonzalez et al., 2015). At its inception, there were still many uncertainties and unknowns relating to both ODS pollution impact and alternatives, requiring policymakers to base precautionary policies on the information and alternatives that were available (De Sombre, 2000). While there are far fewer uncertainties in the context of plastic pollution, many remain, and enduring success is likely to be achieved through the gradual strengthening of controls over time as new information and alternatives become available (Kaniaru et al., 2007; Andersen et al., 2021; Simon et al., 2021). Such an approach would also provide an enabling environment for industry innovation that will take place as demand for alternatives rise.

Parties should therefore strongly consider tackling plastic pollution through controls on virgin plastic production and consumption, *via* a start-and-strengthen approach. Throughout the INC and beyond, this could be operationalised in two distinct phases - fact-finding and policymaking.

3 Recommended measures

3.1 Phase I – fact-finding

3.1.1 Controlled substances

Article 2 of the Montreal Protocol identifies the control measures to be imposed on the production and consumption of controlled substances, which are listed in Annexes A, B, C, E and F. In the context of plastics, Parties must first identify the substances (polymers) to be controlled. Plastic polymers can be broadly placed into two categories: thermosets, which cannot be remelted and remolded (~20%); and thermoplastics, which can be melted and remolded (~80%) (Shieh et al., 2020). Industry further classifies thermoplastics into three main categories: *(i)* standard, used in common applications (~90%

of total market share); *(ii)* engineering, which possess improved mechanical or thermal properties (~10% of total market share); and *(iii)* high-performance, used for exceptional end-use applications and niche products (<1% of total market share) (Manas et al., 2008). Parties should clearly set out the polymers to be controlled under the new agreement in an annex, which thereafter constitutes the "controlled substances" subject to all other measures. Updates to the annex to account for new polymers should be made possible *via* Decisions by the Parties without need for further ratification.

3.1.2 Reporting

Article 7 of the Montreal Protocol requires all Parties to provide statistical data about ODS to the Ozone Secretariat every year. The Ozone Secretariat uses the data to calculate annual ODS production and consumption for each Party on an ozone-depleting potential (ODP) basis. In the context of plastics, reporting obligations should also allow for the determination of annual production and consumption of virgin plastic polymers. Mirroring the Montreal Protocol approach, 'production' should refer to the amount of virgin plastic a country produces, with 'consumption' referring to the amount of virgin plastic a country consumes, calculated as production plus imports minus exports of virgin plastics (Brack, 2003). 'Use' would refer to the sector the polymers are used in, such as packaging, agriculture and fisheries, building and construction, automotive, electrical and electronic, household, textile, leisure and sports plus others, including medical and laboratory.

Four key data points should form the basis of reporting obligations for virgin plastic by polymer type: (i) production; (ii) imports; (iii) exports; (iv) use. Fortunately, reporting is greatly facilitated by the relatively few virgin polymer producers, approximately 300 worldwide in 2019, about 100 of which account for 90% of all single-use plastics (Charles et al., 2021). The Parties should work to ensure a harmonised approach toward reporting, premised on mandatory obligations and clear definitions and formats with technical and financial assistance made available for developing countries and economies in transition.

In addition to forming the basis for fact-finding, reporting has independent value. Virgin plastic production is a key indicator for understanding progress toward eliminating plastic pollution and promoting a circular economy for plastics that is protective of human health (Lau et al., 2020). In other words, scientists and policymakers are hamstrung in drawing conclusions on the evolution of plastic pollution in the environment and effectiveness of measures on product design, use and waste management and treatment without knowing the quantities and types of virgin plastic entering the global economy each year.

3.1.3 Licensing systems

As supplies of chlorofluorocarbons (CFCs) and other ODS were significantly reduced under the Montreal Protocol phase-out schedules, the continued demand in some countries lead to a significant illegal trade in the controlled chemicals (Liu et al. 2016). By the mid-1990s, an estimated 20,000 tonnes of ODS were being traded illegally each year, equivalent to 20% of legitimate trade, and sophisticated smuggling networks had appeared (Environmental Investigation Agency [EIA], 2013). In response to this threat, the Parties agreed to establish cross-border licensing systems to monitor the flow of ODS and to prevent ODS from ending up on the black market. Licensing systems are regulatory schemes whereby a license is granted by authorities for a company to produce, export or import controlled substances, supported by a ban on unlicensed production, exports and imports. Many MEAs require licensing systems, including the Montreal Protocol as well as the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. The objectives for a licensing system for virgin plastics could be to: (i) assist the collection of information to facilitate compliance with reporting; (ii) facilitate notification and cross-checking of reported information; (iii) assist in preventing illegal trade (Montreal Protocol, 1997).

3.1.4 Baselines

The control measures under Article 2 of the Montreal Protocol establish a baseline for production and consumption from which the phase-out schedule is implemented. Such baselines will also be needed for virgin plastic production and consumption, by polymer, from which progress could be monitored. These should be based on average production and consumption by weight, over a multi-year period to compensate for annual fluctuations. The selection of the multi-year period that constitutes the baseline has important implications for virgin plastic production. A prospective baseline, for example 2025-27, would encourage expansion of virgin plastic production and consumption up to and through the baseline years, in direct contrast to the objectives of the treaty. This occurred prior to the adoption of the Montreal Protocol in 1987, which resulted in a net increase of aggregate world CFC production (Auffhammer et al., 2005). Similarly, multiple countries increased hydrochlorofluorocarbon (HCFC) consumption in the baseline calculation years prior to the start of the HCFC phase-out, resulting in artificially inflated baselines (Environmental Investigation Agency [EIA], 2016). On the other hand, a historical baseline such as 2019-21 would discourage expansion of virgin plastic production, serving as a soft freeze until additional controls can be adopted.

3.2 Phase II – policymaking

In accordance with UNEA resolution 5/14, the objective of policymaking should be to establish a set of controls to promote a circular economy, protective of human health, taking a comprehensive life cycle approach to achieve sustainable production and consumption of plastics (United Nations Environment Assembly [UNEA], 2022). Such decisions could be informed through thorough assessment by scientific and technical bodies, balancing environmental objectives and feasibility with societal and economic needs (Busch et al., 2021).

3.2.1 Freezes, phase-downs and phase-outs

Following the Montreal Protocol model, Parties should adopt restrictions on annual production and consumption of controlled substances (*i.e.* virgin plastic polymers). This would likely entail a cap on production and consumption ("freeze") at a certain level, such as 100% of an established baseline, followed by a series of reduction steps ("phase-down") to lower aggregate levels of production and consumption over time. Consideration should be given to schedules for different categories or types of virgin plastic polymers, as did the Montreal Protocol by first targeting five particularly potent and widely used CFCs and halons. For example, less necessary plastics that harbour higher toxicity and are used widely in applications that tend to end up as pollution could be targeted first (for example, polyvinyl chloride), with those used in engineering and high-performance applications accounted for in the tail of allowable production and consumption.

Parties should also target for immediate freeze and phase-out of particularly problematic virgin plastic polymers that are difficult to recycle, have high concentrations of toxic chemicals and for which alternatives are readily available, such as polyvinyl chloride (PVC), polystyrene (PS), polyurethane (PUR) and polycarbonate (PC), which collectively comprise 30% of total market share (Rochman et al., 2013). A similar phase-out schedule should also be considered for chemical families used as additives, catalysts, or polymerisation aids in plastic production that are known to be harmful to human health. This could support the Stockholm Convention on Persistent Organic Pollutants while also preventing repetitive cycles of hazardous chemical use (Sharkey et al., 2020; OECD 2018).

3.2.2 Exemptions

The Montreal Protocol has several categories of exemptions, including global exemptions for certain laboratory or analytical uses as well as critical-use and essential-use exemptions, which authorise a specific country to use a specific amount of a controlled substance for a certain time. Such an approach could be considered in the case of plastics to allow for continued use, for example the medical or automotive sectors, allowing time-limited use of controlled substances considered essential for society until alternatives are readily available and commercialised (Andersen et al., 2021). Such exemptions should also consider critical development issues with direct relevance to the 2030 Agenda for Sustainable Development, such as lack of access to safe drinking water (Sustainable Development Goal 6). While plastic pollution is often discussed in the context of SDG14 – life below water – it also traverses areas of relevance to SDG 3, 6, 11, 12, 13 and 15, amongst others. This is exemplified by the deletion of the word 'marine' in front of 'plastic pollution' in the final Resolution 5/14 text and inclusion of a reference to sustainable production and consumption of plastics (SDG12). As such, the new plastics treaty needs to be developed, implemented, and embedded within the broader sustainable development landscape.

3.2.3 Adjustments

Most multilateral environmental agreements allow for controls to be adjusted and strengthened over time. Under the Montreal Protocol, an "adjustment" of the phase-down schedule of any given controlled substance is possible without the need for a formal amendment, which requires ratification. It is therefore recommended that a mechanism responsive to the objectives of the agreement is established for plastics that enables controls to be gradually strengthened as new scientific, environmental, technical and economic information becomes available (Busch et al., 2021; Simon et al., 2021). This approach has worked exceptionally well in the case of the Montreal Protocol, which under Article 6 requires an assessment and review of control measures every four years (Andersen et al., 2021).

3.2.4 Non-party trade provisions

Provisions on trade by Parties with non-Parties should prohibit or restrict countries party to the agreement from trading in controlled substances with countries not party to the agreement. Article 4 of the Montreal Protocol requires that Parties ban the import and export of controlled substances from and to non-Parties. Such an approach has worked to maximise participation and facilitate compliance. In 2009, the Montreal Protocol was the first UN treaty to receive universal ratification, a key contributing factor being the existence of such controls (Gonzalez et al., 2015).

3.2.5 Assessment panels

Parties to the Protocol are required to base their decisions on current scientific, environmental, technical, and economic information. The Scientific Assessment Panel (SAP), Environmental Effects Assessment Panel (EEAP) and Technology and Economics Assessment Panel (TEAP) all assess information to inform and strengthen ODS policy. Since these are housed within the governing body, their work remains highly applicable and relevant to the agreement's objectives. Having such a high degree of responsiveness allows the Protocol to adapt quickly to new information in a rapid and responsive manner. A similar approach could be adopted in the context of plastics, whereby a dedicated scientific mechanism would be tied directly with the new instrument. Operative paragraph 3(f) of Resolution

5/14 explicitly mentions the need for considering such an approach during negotiations. If adopted, this would likely facilitate a start-and-strengthen approach as new information becomes available by ensuring relevance and responsiveness to the instrument's objectives. Such an approach is a necessary complement to independent science-policy panels, such as the one that will be established as a result of UNEA Resolution 5/8 for chemicals, waste and prevention of pollution.

4 Conclusions

UNEA Resolution 5/14 specifically calls for a 'full lifecycle approach' to achieve 'sustainable production and consumption of plastics.'. As production and consumption of virgin plastic polymers is widely understood to have reached unsustainable levels, there are clear lessons from the approach adopted by the Montreal Protocol.

Upstream (*i.e.* production) controls are a necessary precursor to achieving sustainable production and consumption of virgin plastic polymers, facilitating economic circularity and enabling the reduction and elimination of plastic pollution. While critical, midstream and downstream measures will be inadequate if instituted alone, meaning upstream controls are required as part of a holistic package of policies to address the plastic pollution crisis.

Effective upstream action will assist consumer goods companies and retailers to redesign packaging, transition to alternative product delivery systems such as refillable and reusable packaging and incentivise innovation in alternatives to plastics while avoiding regrettable substitutions. It will also support municipalities and the industry to manage waste in a responsible and environmentally sound manner through streamlining waste streams and relieving pressure on overwhelmed collection and management infrastructure. Such measures would also tackle up to 90% of the plastic value chain's life cycle greenhouse gas emissions, contributing significantly to global efforts to tackle climate change.

Author contributions

TGr conceived the article. TGr and TGa drafted the article. CP and CD contributed to content and structure. TGr, TGa, CD and CP reviewed and edited the article. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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