Title:
Technology cannot fix this: To stay within planetary boundaries, plastic growth must be tackled.

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Abstract

In this Matters Arising, we respond to a recent article by Bachmann et al.[1] We argue that dealing with plastics pollution as a novel entity within the planetary boundaries framework needs to consider the entirety of the plastics life cycle, from resource extraction to impacts on

earth system processes. Singling out LCA quantifications to set a boundary for recycling plastics is not only an unviable myth but may be a dangerous approach. Bachmann et al.[1] argue that it is possible to maintain business as usual and move the economy 'towards circular plastics' while staying within planetary boundaries. The authors' solutions rest on poorly operationalized terms and unrealistic estimates, which over-state what technological solutions can achieve and risk locking the world into an even more plastic-intensive future. We see major flaws in their baseline assumptions and aim to better define and contextualize plastics pollution within Earth systems.

Misrepresentation of the planetary boundaries framework

Bachmann et al.[1] apply a narrow understanding of the planetary boundaries framework, failing to conceptualize plastics' complexity as both a novel entity and a destabilizing factor affecting the boundaries for biodiversity and climate stability. Novel entities include new chemicals, engineered materials, organisms, or anthropogenically-mobilized natural elements. The impact of production, use, and release of today's diverse and complex groups of chemicals and plastics exceeds the safe operating space (SOS) for humanity[2]. The authors[1] claim to be able to 'determine absolute sustainability thresholds', mis-referencing Rockström et al.[3] They define the SOS for plastics using economic models, assuming that 'the market share of the plastics industry and, therefore, its share of SOS remains unchanged despite the increasing production volume of plastics". This is misleading.

The quantifications of individual planetary boundaries are neither fixed resource limits nor targets for maximizing human usage of the SOS. Together, the nine biogeophysical-defined processes provide a framework that alerts to the risks of reaching the limits of scientific prediction by characterizing anthropogenic shifts from Holocene-like conditions of the Earth system. These can be quantified because Earth's history provides evidence about system-wide interactions, feedbacks, stability, and change. Bachmann et al.[1] do not reflect the complex and interconnected impacts that plastics and their proposed 'solutions' will cause in Earth system processes, which could increase both climate change impacts and biodiversity loss. Disregarding absolute volumes of plastics and their biophysical effects while reifying economic markets is a departure from the scientific basis of the planetary boundary framework.

Unsound and Unclear definitions

The authors[1] also do not define central terms, including 'plastics' and 'plastics pollution', and refer to 'pure plastics', disregarding plastics' real-world chemical complexity and how associated chemicals degrade both human health and the environment. Plastics are diverse, consisting of >13,000 chemicals and substances, including monomers, additives, residues, and sorbed contaminants[4]. Some plastic-associated chemicals are toxic, hazardous, bioaccumulative, and persistent, and threaten environmental[2] and human and community health[4]. In failing to acknowledge these hazards, they undermine many of their proposed solutions, since recycling alone would merely transfer and intensify chemical toxicity[5] from product to product, and place to place, creating environmental injustices in the process.

Bachmann et al.[1] perform a Life Cycle Assessment 'from production to end-of-life', narrowly framing the plastics problem as a downstream waste problem. A sustainable approach to the plastics life cycle includes, rather than externalizes, upstream production.

The authors[1] assume that recycling is a sustainable solution without considering the feasibility. They assume plastics can be infinitely recycled, as with aluminum and glass. However, plastics recyclability is limited to a few rounds through mechanical recycling, compromising true circularity[6]. Moreover, they assume recycling is leak-proof and waste-free and fail to acknowledge the chemical hazards and the microplastic footprint of mechanical recycling[7].

Bachmann et al.[1] also misrepresent the state of recycling globally. Most collected plastic waste is not recycled but landfilled, incinerated, or traded to countries with low capacity[8], often resulting in poor waste management and leakage into the environment. Current mechanical recycling systems cannot technically or economically handle the vast majority of plastic produced, including products and packaging that contain additives, multiple polymers, non-plastic materials, and contaminants[9]. These limitations cannot be addressed without plastics being designed for ease of reclamation and recovery, which includes radically narrowing the range of plastics produced, i.e. chemical transparency and simplification[10].

Exaggeration of recycling capacities

The authors claim that 'recycling does not trigger any significant burden shifting in any scenario'. However, while chemical recycling is promoted as a complementary technology, it produces highly-contaminated and low-quality recyclates; and its outputs are typically burned as fuel rather than recycled into products[10]. The greenhouse gas impacts are, therefore, enormous – both through energy consumption and driving off high quantities of process CO_2. Bachmann et al.[1]'s assertions that chemical recycling "can be applied to all plastic fractions" and performs well on climate indicators seem to reflect industry messaging rather than independent assessment[11].

Historically, recycling rates have failed to scale or keep pace with increasing waste production. Particularly problematic is the 23% global recycling rate cited[1], based on modeling data from the 1950s to 2015[12]; in reality, this number is closer to 9%[13]. Bachmann et al.[1] call for recycling rates of 75% as soon as 2030, an 8-fold increase in recycling rates in 7 years. Plastics' chemical complexity further hinders its recyclability and yields plastics of lower material value and higher toxicity[9]. Both mechanical and chemical processes rely on blending recyclate with even greater quantities of virgin feedstock, further perpetuating production.

Bio-based plastics aren't a panacea

The authors claim that bio-based plastics comply with the assigned share of SOS for climate change as carbon taken up during the growth of biomass for feedstocks offsets the CO_2 emissions from plastic production and waste treatment. This is not a realistic view of the plastics' life cycle. Multiple studies show that bio-based plastics release twice as much CO2 during biodegradation in the marine environment compared with fossil-based plastics[14]. Additionally, bio-based plastics may have similar toxic concerns as conventional plastics[15].

Unrealistic narratives about plastics

In all, Bachmann et al.[1] present a misleading narrative that, intentionally or not, elevates technocratic and technological responses as the primary 'solutions' to the planetary plastics pollution crisis. They emphasize circular economy-based policies to improve mechanical and chemical recycling to an unrealistic level without taking externalities from these processes into consideration. Moreover, the authors' declared competing interests lead us to stress the importance of recognizing how such conflicts of interest can introduce bias into how research questions are framed and findings interpreted.

While the authors acknowledge the impossibility of achieving "sustainable plastics" by 2050, especially given the current growth trajectories of plastic materials, they downplay the necessity to first reduce total plastic production. To call for further investment in the recycling sector absent meaningful changes in the volume and toxicity of production assures lock-in of yet more plastics while delaying meaningful solutions to broad spectrum plastics pollution problems.

Simultaneously failing to address production also represents a missed opportunity to remove the practical barriers that would make recycling more successful in the future. The scenarios presented by Bachmann et al.[1] lack specifics on how to implement these new recycling technologies and who should bear their costs. The same holds for the authors' recommendations around carbon capture technology, which also remains largely unproven at scale.

Closing remarks

The world is at a critical moment as negotiations continue toward a Plastics Treaty to end plastic waste and pollution. The authors' focus on determining absolute thresholds, blinds them to the wider systems at play. Even they admit there is essentially no path to sustainable plastics by 2030. Decoupling the social and environmental impacts of plastics renders these solutions even more unrealistic. We cannot 'technology-fix' our way out of the plastics problem. Instead, what's required is a large-scale reduction in extraction and production and the safest possible design and use of only essential novel entities.

Conflict of interest

The authors declare no competing interest. However, the following authors would like to make a statement of transparency. Rebecca Altman serves on the Board of Directors for the Science and Environmental Health Network. Neil Tangri is employed by the Global Alliance for

Incinerator Alternatives. Mengjiao Wang is employed by Greenpeace Research Laboratories. Anja Krieger has worked as a freelance audio editor for a podcast series for the NGO Break Free From Plastic.

We define a COI as having incompatible outcomes, often driven by financial interests which can introduce unconscious biases or purposefully muddy waters, confuse narratives and delay action. This should not be confused with an 'interest' in which a party has a goal associated with a field of research, or scientific or environmental practice.

Author contributions statement:

All authors discussed the issues raised here, and contributed to the writing. P.V.G., B.C.A. and S.E.C. led the writing effort. All authors approved the final draft.

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