



## Response to Comment on “Outside the Safe Operating Space of the Planetary Boundary for Novel Entities”

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## Response to Comment on “Outside the Safe Operating Space of the Planetary Boundary for Novel Entities”

Kunnas has written a comment<sup>1</sup> on our recently published policy analysis of whether humanity is currently outside the planetary boundary for novel entities<sup>2</sup>. We welcome continued scientific discussion, and we note that Kunnas supports our overall conclusion that the world is now outside the Safe Operating Space in terms of novel entities. We see support for our line of argument in Kunnas’ statement that there is a need to reduce the influx of new chemical substances and other novel entities, such as plastics, until societies can deal with the backlog of substances on the market that have not been subject to risk or safety assessment and consequent sound management.

Kunnas points out, and we agree, that we do not show *where* a quantitative boundary for novel entities is. In our view, quantifying a single boundary for the multitude and diversity of novel entities is an intractable problem. As such, we have as a first step rather characterized a multidimensional dynamic boundary. This characterization lets us evaluate several control variables that indicate that the planetary boundary has been crossed: the paper demonstrates how novel entities have resulted in many globally observed biological, chemical and geophysical changes that move the planet away from Holocene conditions. The characterization is precautionary (in both the lay and policy senses), recognizing that when threats are serious or irreversible, the fact that risks are uncertain and cannot be quantified should not mean that measures to prevent harm can be postponed. It is also pragmatically aligned with other principles of environmental responsibility and intergenerational equity, and plain old-fashioned prevention of large-scale environmental damage. With this characterization of the planetary boundary for novel entities, we recommend that operational guardrails for novel entities can and should be defined starting with the approaches available, as illustrated in our paper<sup>2</sup>, and evolve as scientific evidence increases and additional biophysical issues emerge.

We understand the wishes and needs by many to quantify the impacts of individual novel entities (and combinations), particularly under many current regulatory frameworks. Many approaches are being explored; for example, Kosnik et al.<sup>3</sup> explains that evaluating chemical pollution pressure on ecosystems and related capacities to cope with this pressure requires the consideration of appropriate spatiotemporal scales. Spatial units such as watersheds or catchments, come with their own (local) boundary where anthropogenic disturbance changes system functioning. This means that a simple spatial aggregation is not an appropriate way to derive a global boundary<sup>3</sup>. We agree with Kunnas that it is important to consider differences across novel entities in terms of their effects, environmental behavior and other properties, but we also clearly note the lack of data that currently prevents such a comprehensive analysis for most novel entities.

Kunnas also brings up the crucial point of what should be the minimum components of a risk assessment that takes the planetary boundary perspective into account, stating that “toxicity and persistence is not enough to rule out unintended consequences”. As we discuss in the paper, the planetary boundary framework recognizes that novel entities have the potential to create effects on endpoints that go beyond toxicity and direct human and ecosystem health impacts. Ozone layer thinning and ongoing climate change are both examples of endpoints in the realm of the geophysical processes of the planet with far-reaching consequences for humans and all other life on the planet. Therefore, chemical risk assessments need to include aspects of relevance for the planetary boundary threat they might cause, a planetary boundary profiling<sup>4,5</sup>.

Finally, we wish to respond to Kunnas' suggestion that "the long-run goal should be to eliminate the Novel entities category altogether". This may well be where the discussion shifts from defining a planetary boundary to a matter of societal self-constraint. In our paper, we are not calling for zero production of novel entities. As long as there is technologically enabled innovation, individual novel entities and combinations will arise, and a novel-entities category is likely to be a vitally important part of the planetary boundaries' framework to keep novel entities and their impacts under monitoring. When an issue becomes a "known known", as in the case of the role of CFCs in the breaching of the ozone depletion boundary, it shifts into the domain of management and harm mitigation. Until then, the novel-entities category provides an important call to action that recognizes the complex and dynamic planetary dimensions of chemical pollution.

In conclusion, we would like to again emphasize that the current rapidly increasing rate of production and releases of larger volumes and higher numbers of novel entities with diverse risk potentials far exceed societies' ability to conduct safety-related assessments as well as to monitor and soundly manage novel entities as a whole. Recognizing that the planet Earth has finite carrying capacities for novel entities and their diverse impacts, we again call on leaders of policymaking, business and civil societies to take urgent action to reduce the harm associated with exceeding the boundary by reducing the production and releases of novel entities.

- (1) Kunnas, J. Comment on "Outside the Safe Operating Space of the Planetary Boundary for Novel Entities." 2022.
- (2) Persson, L.; Carney Almroth, B. M.; Collins, C. D.; Cornell, S.; de Wit, C. A.; Diamond, M. L.; Fantke, P.; Hassellöv, M.; MacLeod, M.; Ryberg, M. W.; Sogaard Jørgensen, P.; Villarrubia-Gómez, P.; Wang, Z.; Hauschild, M. Z. Outside the Safe Operating Space of the Planetary Boundary for Novel Entities. *Environ. Sci. Technol.* **2022**, *56* (3), 1510–1521. <https://doi.org/10.1021/acs.est.1c04158>.
- (3) Kosnik, M. B.; Hauschild, M. Z.; Fantke, P. Toward Assessing Absolute Environmental Sustainability of Chemical Pollution. *Environ. Sci. Technol.* **2022**, *acs.est.1c06098*. <https://doi.org/10.1021/acs.est.1c06098>.
- (4) Reppas-Chrysovitsinos, E.; Sobek, A.; MacLeod, M. Screening-Level Exposure-Based Prioritization to Identify Potential POPs, VPvBs and Planetary Boundary Threats among Arctic Contaminants. *Emerg. Contam.* **2017**, *3* (2), 85–94. <https://doi.org/10.1016/j.emcon.2017.06.001>.
- (5) MacLeod, M.; Breitholtz, M.; Cousins, I. T.; Wit, C. A. de; Persson, L. M.; Rudén, C.; McLachlan, M. S. Identifying Chemicals That Are Planetary Boundary Threats. *Environ. Sci. Technol.* **2014**, *48* (19), 11057–11063. <https://doi.org/10.1021/es501893m>.