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Introducing the EU project ZeroPM: zero pollution of persistent, mobile substances

Sarah E. Hale[1*], Olga I. Kalantzi[2] and Hans Peter H. Arp[1,3]

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The European Green Deal, launched by the European Commission in 2019, is a set of policies that will support the European Union (EU) on its journey of reaching climate neutrality by 2050. The accompanying Chemicals Strategy for Sustainability towards a toxic-free environment (referred to herein as the Chemicals Strategy for Sustainability [1]) shows how the EU proposes to reach its zero pollution goal outlined in the Green Deal. The bold action points presented in the Chemicals Strategy for Sustainability will provide better protection to human health, will strengthen industry's competitiveness, whilst at the same time supporting a toxic-free environment.

The Chemicals Strategy for Sustainability recognizes the need to address pollution from so-called persistent and mobile substances. The persistent nature of these substances means they do not sufficiently biodegrade in the environment and as such, contamination may become pervasive if they are emitted in substantial quantities. Mobile substances are defined as those that travel long distances with water, including groundwater, and can thus spread over large spatial and temporal scales. Because of this mobility, it can be difficult to relate the point of pollution release to the final point of contamination [2]. If continuously emitted into freshwater systems, and not removed, concentrations of persistent and mobile substances will gradually increase, and they will be detected in more areas. In addition, the vast majority of persistent and mobile substances are extremely difficult to remove from water resources meaning that exposure will also increase with continuing emissions. Examples of persistent and mobile substances that are attracting attention at the time of writing include melamine, benzotriazole, 1,4-dioxane and many per and polyfluoroalkyl substances (PFAS) [3].

These persistent and mobile substances are a threat to our planet's boundaries. In order to protect human health and the environment in the most effective way, preventative solutions should be used to reduce exposure and thus societal costs of persistent and mobile substance pollution. If a persistent and mobile substance is prevented from being used, then there is no exposure or removal costs. A holistic approach is needed whereby substances currently used in commerce are prioritized and strategies are then identified to prevent unnecessary exposure to these substances. A holistic approach includes not only an assessment of exposure, hazard and risk, but also requires reflection regarding product use scenarios, differentiating between 'essential-use' and non-essential use [4]. Preventative solutions can also come in the form of improved knowledge, guidance and support for companies as they transition away from persistent and mobile substances. Many companies are unaware of which of their products contain persistent and mobile substances. This means that significant financial and time resource investments are needed to identify, assess and implement safer and viable alternatives into production. However, barriers represented by a lack of knowledge, time and money can result in poorly informed decisions which may present themselves as regrettable substitutions. In such cases, one hazardous substance is replaced by another—equally, or more—hazardous that the first. One well-known example of this is when the PFAS substance PFOA was restricted because

*Correspondence: sarah.hale@ngi.no

[1] Norwegian Geotechnical Institute (NGI), Ullevål Stadion, P.O. Box 3930, 0806 Oslo, Norway
Full list of author information is available at the end of the article

of its persistence, bioaccumulation and toxic properties. One of the replacement chemicals that was used to take its place was GenX, which was then banned as a regrettable substitute because was persistent and mobile, as well as toxic [2]. Another example was the restriction of the endocrine disrupting substance bisphenol A, which was then replaced by a substance that was more persistent, mobile and similarly potent in its endocrine disruption potential, bisphenol S [5, 6]. These examples are now causing European regulators to work on problematic substance groups like PFAS and bisphenols, instead of dealing with one substance at a time.

A more holistic science-based evaluation considering the whole life cycle of the persistent and mobile substance can help improve substitution decisions by providing quantitative information regarding the relative impact of a chemical ingredient throughout manufacture, use and disposal. Prevention is also governed by perception and attitude as whilst persistent and mobile substances pose societal risks, they also provide benefits. The essential-use approach could be a powerful driver of change, if underpinned by a deep understanding of stakeholder concerns and attitudes. Encapsulating all elements of preventative solutions is a policy response built on integrative multidisciplinary research that tackles relevant barriers as well as harvests relevant synergies. It should build on the lessons learned from previous initiatives, using a set of instruments from regulatory approaches to market incentives and motivate voluntary change.

Preventative approaches can also be maximized if they are focused on the most appropriate persistent and mobile substances. Screening and prioritizing chemicals used by industry by ranking them according to their exposure and hazard potential (which together quantify risk) is an efficient, transparent and robust path towards achieving zero pollution, as it identifies those persistent and mobile substances to focus efforts on first. The need for prioritization is clear as a recent survey showed there were 350 000 chemicals and mixtures of chemicals on the global chemical market [7]. The number of these chemicals that are persistent and mobile substances as well as their emissions, is unknown. To date, the most comprehensive assessment of persistent and mobile substances on the global market has been carried out for the entire REACH registered substance list of May 2017 [6]. The list consisted of a mere 22 400 chemical substances that were manufactured or imported into the EU at 1 tonne/year or more. The study concluded that 245 substances were of highest priority when considering toxicological hazards and potential likelihood for widespread exposure, based on production volumes, usage, or monitoring studies. Quantifying long-term chronic exposure to persistent and mobile substances in the environment are hampered by the inappropriateness of existing tools for chemical exposure assessments in regulatory guidelines. These tools rarely include key exposure pathways for persistent and mobile substances including groundwater extraction and bank filtration, they do they account for the intrinsic substance properties common to persistent and mobile substances (such as ionic interactions [8]), nor do they incorporate human-relevant methods to facilitate a refined understanding of the substance's mechanisms of toxicity. Applicability domains of existing fugacity models must be extended, and new approach methodologies (NAMs) should be used for effects testing combining human in vitro and in silico models to inform hazard assessments [9].

The need to prioritize persistent and mobile substances for prevention and removal, before exposure is too wide spread, or before risks are too great, is clear. Costs related to identification, screening and remediation of sites contaminated with PFAS across Europe is around €10–20 billion per annum, rising to €52–84 billion per annum when costs such as increased healthcare demands, ecological damage, property loss and impacts on the agricultural sector are included [10]. Removal of persistent and mobile substances from already polluted sites is difficult. Activated carbon filtration is an advanced remediation method often used in cases where more persistent substances are not amenable to advanced water treatment technologies such as ozonation. However, even activated carbon filtration has limitations and cannot remove the most mobile of the persistent and mobile substances [3]. It was recently estimated that spending between 0.8 and 1.5 billion Euro per annum in Germany to introduce AC filtration at water treatment facilities would only result in a partial removal of persistent and mobile substances [6]. Given that these costs represent only a partial removal and that the methods are resource intensive, there is an urgent need to identify sustainable treatment technologies able to remove persistent and mobile substances. Water used in drinking water production should be investigated as the consumption of water is one of the main mechanisms that increases the risk for human health from persistent and mobile substances. Sewage sludge is very often contaminated with persistent and mobile substances and this sludge is commonly applied to agricultural land, composted or sent to landfills. The use of sewage sludge thus represents direct environmental exposure pathways and one of the main emission sources of persistent and mobile substances to the environment. Mesophilic anaerobic digestion used for sludge stabilization or incineration is characterized by a lack of integrated knowledge about the fate of diverse persistent and mobile substances [11]. It is clear that technological advances are needed to be able to remove more persistent

and mobile substances from water and sludge. However, the choice of method should also be based on an evaluation of technical and economic costs and benefits, as well as net environmental effect. Persistent and mobile substances should be removed sustainably before emissions are widespread or they reach drinking water, whilst avoiding regrettable remediation. Regrettable remediation occurs when remediation efforts are put into place that are extremely costly, non-sustainable, or ineffective.

This collection of pieces focuses on the work that will be carried out in the recently started Horizon 2020 Research and Innovation Action project called "ZeroPM: Zero pollution of persistent, mobile substances". ZeroPM will interlink and synergize three strategies to protect the environment and human health from persistent, mobile substances: Prevent, Prioritize and Remove. To prevent pollution of persistent and mobile substances, ZeroPM will activate the momentum of the EU's Chemicals Strategy to support its implementation through the development of scientific, policy and market tools for the substitution and mitigation of prioritized, non-essential persistent and mobile substances to safer and sustainable alternatives. To choose the persistent and mobile substances for which this is most urgent, ZeroPM will prioritize persistent and mobile substances and substance groups through the development and application of robust screening and prioritization tools. These tools will identify all persistent and mobile substances on the global chemical market, taking into consideration their production, use, presence in the circular economy, exposure, hazards and risks. To remove, ZeroPM will focus on geographically impacted areas and prioritized groups of persistent and mobile substances, and develop next generation remediation methods to remove persistent and mobile substances from water resources, drinking water and sludge-derived products. ZeroPM will be the pathfinding project enabling the ambitions of the Chemicals Strategy to become an on-the-ground reality.

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Author details
[1]Norwegian Geotechnical Institute (NGI), Ullevål Stadion, P.O. Box 3930, 0806 Oslo, Norway. [2]Department of Environment, University of the Aegean, 81100 Mitilini, Greece. [3]Department of Chemistry, Norwegian University of Science and Technology (NTNU), N-7491, Vanløse, Trondheim, Norway.

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