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Micropollutant removal from wastewater: Facts and decision-making despite uncertainty

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The occurrence of a plethora of anthropogenic organic compounds in treated wastewater and hence in receiving water bodies is a well-established fact. It raises concerns about possible negative impacts on aquatic ecosystems and drinking water resources. In Switzerland, this has led to political decisions to mitigate the risk of adverse effects by upgrading the wastewater treatment plant (WWTP) infrastructure. These decisions have been recently criticized, first as being premature and second as being likely to drive receiving waters toward states that are not desired by society (1).

Given the current uncertainties and knowledge gaps, some aspects of this criticism warrant a broader discussion of the role of science in societal decision making. In this viewpoint, we would like to emphasize three aspects.

A well-informed decision by the Swiss government

Decisions on upgrading WWTP infrastructure should, of course, be based on reliable knowledge of costs, energy demand and societal acceptance. The decision made by the Swiss Parliament was, in fact, based on the results of many years of careful scientific research that examined removal efficiencies, costs, energy demand and the feasibility of implementing the recommended technologies at existing WWTPs. Experimental evidence was gathered in multiple pilot- to full-scale projects conducted since 2006. Parallel studies have been or are being performed in other countries like Germany and France, confirming key results (2). In the Swiss system of direct democracy, such legal decisions undergo a thorough societal consultation process in which all relevant stakeholders (authorities, industry, professionals in the field, fishermen, environmental NGOs, etc.) participate. This consultation is in addition to the discussion of every new law in Parliament before it is passed. Thoughtful criticism should take into account the published information on the Swiss decision process and its scientific basis (3,4).

Science is only one of many grounds for societal decision making

Decisions on environmental issues are often controversial, especially when they involve conflicting economic interests or social values. In some cases, questions about science may be used to distract attention from questions about the prioritization of desired objectives. This prioritization is a societal decision, which must be made by individuals, groups or an entire society and is legitimized by the democratic process. The case of micropollutant removal involves the fundamental question of the desired ecosystem state. Anthropogenic loading of bioavailable organic compounds (i.e., biological oxygen demand, BOD) and nutrients introduced with sewage effluents adversely affected natural community diversity in receiving water bodies. These effects were by and large mitigated with the reduction of BOD and nutrient loading with the conventional WWTP technologies. Micropollutant removal will further decrease the toxicity associated with sewage effluents, but the effects of this reduction on community diversity remain to be seen. Nonetheless, it is clear that the input of micropollutants into aquatic systems represents a departure from natural conditions. The Swiss law recognizes WWTPs as relevant point sources of micropollutants and requires that this loading be decreased to restore more natural conditions and to protect drinking water resources.

Similarly, European legislation defines the goal of achieving good ecological and chemical status of water bodies in accordance with the Water Framework Directive. It would also be possible to define the desired ecosystem state as one that supports abundance of fish species based on economic interests rather than the natural reference status. But this is a question of values, which cannot be answered by science.

Uncertainty is not an excuse for inaction

When societal decisions involve scientific issues, uncertainty is often seen as an impediment to decision making. It may be claimed that taking action would be premature since there is insufficient evidence that the societal gain will outweigh the costs. In the case of micropollutants, it has been suggested that, ideally, "removal treatments would emerge that precisely targeted the compounds of concern" (1). The call for this level of control is reminiscent of the deterministic view that if one "could comprehend all the forces by which nature is animated and the respective situation of the beings who compose it" then "nothing would be uncertain and the future, as the past, would be present to its *(the observing intelligence)* eyes." ascribed to Laplace's demon (5, page 4).

Such a deterministic view is completely at odds with our understanding of ecosystems and their evolutionary development. Dealing explicitly with uncertainty is a hallmark of science and it is incumbent upon scientists to communicate uncertainty clearly. The scientific basis for taking action may be better posed in probabilistic than in deterministic terms.

Yet societal decision making is rife with uncertainty in all arenas, not just when environmental issues are involved. We (as individuals, groups or societies) have to decide whether the expected gain from taking a specific action is larger than the potential loss if expectations are not met (i.e., due to a false prediction). At least in the case of decisions involving scientific questions, there are opportunities to reduce the uncertainty of our scientific knowledge. In the case of micropollutant removal, careful observation of full scale implementation will allow us to "identify which species would decline if we switched off the tap of organics in effluent" (1). We would also point out that the questions associated with a "no action" alternative (such as whether the probable loss of species diversity due to anthropogenic micropollutants is worth less than the costs for their removal) are difficult to answer with any degree of certainty.

All societal decisions are made despite uncertainty. When societal decisions involve scientific questions (e.g., decisions on environmental issues), this uncertainty is made explicit by scientists (as is consistent with the requirements of scientific integrity). Scientists should also strive to improve the knowledge base for societal decision making. In this context, the full-scale implementation of mitigation measures, based on sound scientific knowledge and democratic processes, offers opportunities to observe in the future how ecosystems respond to reductions in micropollutant loadings.

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