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Key actions for a sustainable chemicals policy

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ABSTRACT

Chemicals policies have spawned a wide range of regulations aimed at limiting damage to the environment and human health. Most instruments are reactive and fragmented. We propose a simple underpinning philosophy, “Do no harm”, to ensure a more sustainable, safe “chemical environment” for the future.

1. Introduction

We live in environments laden with low levels of complex chemical mixtures released by human activities (Bernhardt et al., 2017). Since 1950, global chemical production has risen 50-fold to keep pace with the demands of a growing human population (currently 7.7 billion). By 2050 production is forecast to triple again (EEA, 2016). Synthetic chemicals, entirely new to nature, are being created. Together with natural inorganic and organic substances and compounds, they are accidentally or intentionally released into ecosystems, with little opportunity for organisms, including humans, to adapt or avoid harmful effects. Scientific and media reports continue to heighten public concerns. For instance, UN/WHO highlighted 12.6 million deaths per year from environmental chemical pollution (Prüss-Ustün et al., 2016). We recognise, nevertheless, that chemicals have provided immense benefits to human societies. The challenge is to continue to benefit without the threat of increasing harm. Here we propose a set of actions, within a new chemicals policy, which would help to achieve this goal (see Fig. 1 and Table 1).

Chemicals management and regulation must be guided by an underpinning principle. In this we can learn from another field—medicine—where the guiding principle is “do no harm”, while achieving good health. Practitioners accept that, taken literally, this aim is unattainable, but pursue it nonetheless. In moving towards a safe “chemical environment” a similar approach is needed, even if some chemicals inevitably cause harm in performing their function. Pesticides kill, for example, but we strive nonetheless to avoid harm to non-target species.

The development of a better chemicals strategy would benefit from careful attention to duties and rights, which are familiar features of important ethical frameworks. The philosopher Onora O’Neill, for example, makes the case for a fundamental obligation (with counterpart rights) to ‘reject the principle of injury’; this would entail refraining from ‘systematic or gratuitous injury’ to others, including indirect effects arising from environmental damage (O'Neill, 1997; O'Neill, O. Towards, 1996). Depledge and Carlarne make some similar connections in their claim that ‘upholding the human right to health is inextricably linked to the quality of the natural environment’ (Depledge and Carlarne, 2008). The issues are complex, but two important points are worth emphasising. The first is that obligations and rights constrain human action and provide a strong case for environmental protection as a matter of justice (O'Neill, 1997; O'Neill, O. Towards, 1996). Second, in non-utilitarian frameworks such as that constructed by O’Neill, a weighing up of costs and benefits (even if all could be measured in a meaningful way) provides an insufficient guide to action: if harm to others breaches a fundamental obligation, it cannot simply be justified on the grounds that it maximises utility or preference satisfaction.

Many would agree with O’Neill that utilitarianism and environmental protection are ‘uneasy allies’ (O'Neill, 1997). We draw here on an act-centred approach with an emphasis on obligations, whilst acknowledging that the merits of different ethical theories have generated

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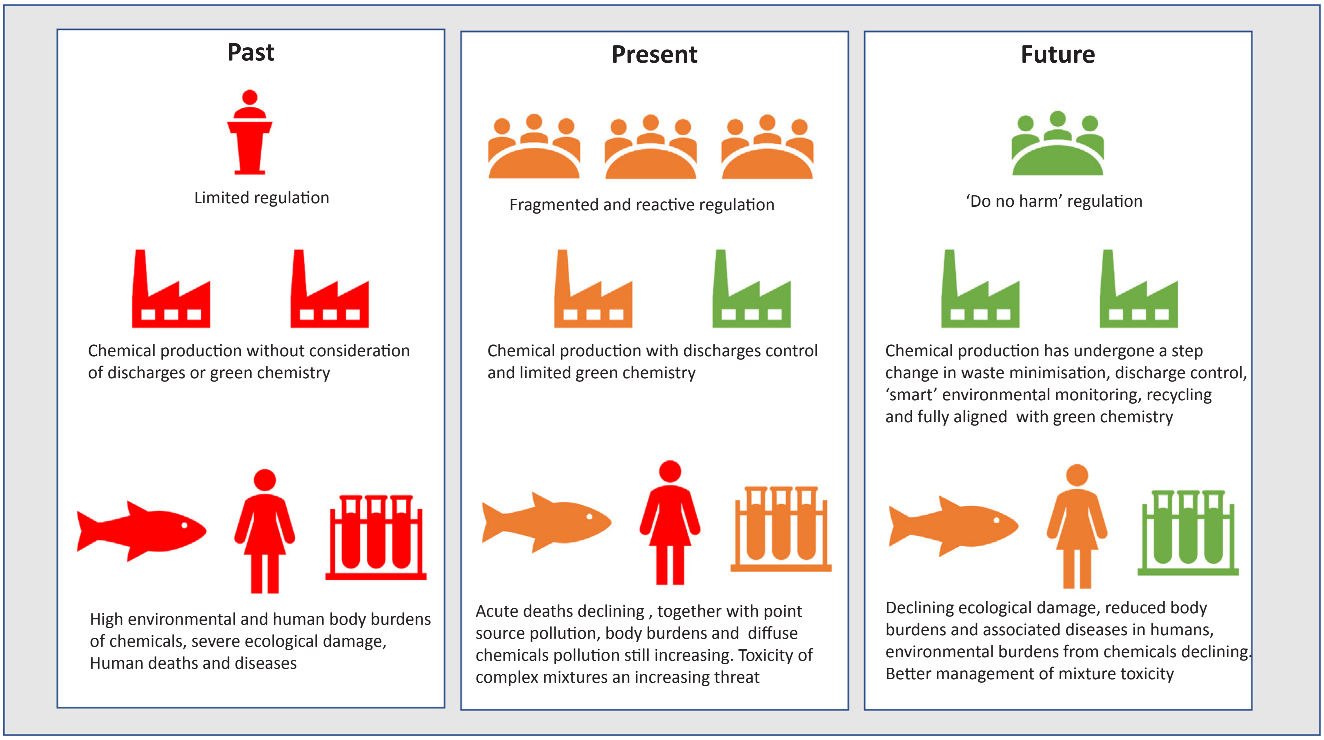

Fig. 1. Regulatory, production and enviornmental scenarios under past, present and future chemicals policy.

Table 1
Proposed actions, their justification and mechanisms for implementation.

Action	Why?	How
Reduce and minimise releases of chemicals into the environment.	Existing concentrations of chemicals are harming people, wildlife and ecosystems.	Change culture on use of chemicals. Make chemical use a last, not first, resort.
Remove from use chemicals that bioaccumulate	Chemicals that bioaccumulate may reach thresholds in target species where they become toxic. Additionally, future generations become responsible for pollution they did not discharge.	Use advances in chemical design and green chemistry to deliver active but non-accumulating chemicals.
A step change in recycling and reuse of chemicals.	Prevent further accumulation of chemicals and waste in the environment.	Allow sale only of products and chemicals that can be recycled. Investment in technological advances in processing waste.
Use more green chemistry to manufacture greener chemicals.	Advances will reduce threats to ecosystem and human health by reducing bioaccumulation and toxicity.	Ensure all chemicals in use are easily degradable OR fully recyclable and environmental impacts considered when chemicals are designed.
Commit to combined chemical and wildlife monitoring.	Give confidence to stakeholders that policy measures are having detectable and beneficial impacts	Commit to long-term integrated chemical and biological monitoring with the results made public.
Disincentivise pollution and penalise polluters	Anticipated pollution consequences of chemical use need to be discouraged. Unanticipated pollution damages need to be compensated.	Legal and financial deterrents should be aimed at pollution, and sanctions consistently imposed on polluters.

vigorous debate in environmental and other contexts (Foster, 1997; Goodin, 1995; Owens and Cowell, 2002). We note, too, that a fundamental obligation to refrain from systematic or gratuitous injury would have to be discharged through more specific (for example, institutional) obligations, policies and practices, which must themselves be debated and refined. The actions that we advocate below may be seen as examples of ways in which such an obligation might be discharged in the context of chemicals.

2. Achieving sustainable use of chemicals

We have identified the following key areas where further strong measures must be taken if our objectives of "doing no harm" and achieving "chemical sustainability" by 2050 are to be met:

2.1. Reduce and minimise releases of chemicals into the environment

A vital step will be to create a situation, through encouragement and, wherever necessary, strong regulation, in which fewer chemicals are released in smaller amounts. This will take time, but the challenge must not be shirked because it is 'too difficult'. Major reductions in the volume and variety of chemicals used in agriculture, by industry and in the home are imperative. We accept that use of chemicals cannot cease completely, but significant reductions are feasible. As one example, the Scottish Government provides direct advice to farmers to significantly reduce pollution. Measures include carefully planning of storage and handling arrangements for livestock, slurries and manures, animal feedstuffs, silage effluent, agricultural fuel oil, dirty water, fertilisers, veterinary medicines and pesticides on farms https://www.gov.scot/Publications/2005/03/20613/51368. Likewise, industrial and domestic wastewater discharges can be reduced along with amounts of solid waste (which releases chemicals as it decays), for example Switzerland is upgrading its wastewater treatment plants to severely curtail chemicals in effluents. This approach should be widely adopted. Innovative actions could limit other intended and unintended chemical releases by incentivising people and organisations to actively reduce chemical use, and to recycle much more of what they do use. Publicly identifying those responsible for excessive chemical discharges of all kinds helps to raise awareness of the need to act.

2.2. Remove from use chemicals that bioaccumulate

Rachel Carson, in her transformative book Silent Spring, described the loss of birdlife following the accumulation of DDT though food webs, with levels in fish-eating birds 10,000,000-fold greater than in lake waters (Carson, 2012). Bioaccumulation has now led to a wide range of chemicals accumulating in top predators globally, including perfluorooctanesulfonic acid (PFOS) in polar bears (Boisvert et al., 2019) and polychlorinated biphenyls (PCBs) in whales (Ross et al., 2000), as well as in humans (Wattigney et al., 2015). This process is a central concern when evaluating chemical threats. Within the US, Canada and the European Union chemicals are designated as bioaccumulative if the bioaccumulation factor in aquatic species is greater than 5000 L/kg wet weight or, in the absence of such data, that log K_{OW} (an indicator of solubility in water and fat [hydrophobicity]) is greater than 5. A lack of laboratory data ($<$ 4% of synthetic chemicals have been evaluated) has resulted in the log K_{OW} value being the default assessment criterion. Unfortunately, the K_{OW} does not take into account the metabolism of chemicals, so can potentially create false positives, nor is it only hydrophobic chemicals that bioaccumulate (Kelly et al., 2007). There has been no move to reduce the bioaccumulation value over recent years despite widespread damaging impacts. A key future goal for chemical design is to minimise bioaccumulative potential. Positive developments in computational and green chemistry have led to production of plant-based biodegradable plastics. A similar approach should be applied to fine chemicals. As progress is made, we should rapidly curtail the use of bioaccumulative substances.

2.3. A step change in recycling and reuse of chemicals

In an ideal world all chemicals would be recycled. In 'throwaway societies' recycling rates are low, or even non-existent in some countries. The European Union aims to achieve 50% recycling for household waste by 2020. The UK currently recycles 45.2%. We advocate 100% recycling of all solid waste, which, importantly, would permit the cessation of landfilling. Improved separation and processing of wastes will be required, facilitated by much stronger incentives and regulation to help achieve 100% separation at source. Where recycling is not possible (for example, during pesticide application), the chemicals employed must be designed to be easily degradable so that they do no harm in the wider ecosystem.

New technologies can help to recycle and reuse chemicals and waste economically. These range from extracting rare and very valuable metals from mobile phones and computers for reuse in new appliances, to incineration of organic waste at high temperatures involving depolymerisation, gasification, pyrolysis and plasma arc gasification to liberate large amounts of 'renewable' energy. Even food waste is used in this way in some countries https://tinyurl.com/yd29kttl.

2.4. Use more green chemistry to manufacture greener chemicals

The manufacture of chemicals using green chemistry principles, reliance on renewable resources and production based on a circular economy, have all significantly increased over the last two decades (Ragauskas, 2006; Clark, 2017). Successes have been achieved in several areas (pharmaceuticals, solvents, catalysis, renewables), with overall environmental footprint reductions of up to 50% demonstrated. New products such as bio-based polymers and plastics, biodegradable polymers and biocides demonstrate the potential of such changes, although the twin challenges of relative cost and systemic management of use/recovery/recycling/reprocessing remain.

These efforts have been commendable yet insufficient to protect ecosystems, wildlife and humans from damaging chemical exposures. Intensification of integrated R&D to replace chemical manufacturing routes dependent on unsustainable processes and raw materials is vital. Stable policies are essential to provide a secure economic, environmental and socially acceptable space for further innovation in chemicals manufacture and use. Strong regional and global agreements will continue to be necessary.

2.5. Commit to combined chemical and wildlife monitoring

US President Reagan once said, regarding arms control with the then Soviet Union, 'trust but verify'. Similarly, in chemicals management we need to 'verify' that we are indeed 'doing no harm'. A strong commitment to monitoring networks with a sampling programme sufficient to detect the presence of harmful chemicals and harm to wildlife and humans is vital (Johnson and Sumpter, 2016; Lindenmayer and Likens, 2010). Monitoring sites, whilst representing diverse national landscapes, should include locations where the greatest chemical discharges are known to occur. The sites should include negligibly to highly exposed environments and be monitored over decadal time-periods. To monitor hydrophobic chemicals, biota samples (including human fluids and tissue samples) can be extracted and also archived. Fluctuations in different wildlife populations or disease burdens can then be compared against changes in chemical and non-chemical stressors over time. Responsible bodies must commit to such long-term monitoring sites, avoid changing methods, monitor at appropriate frequencies (at least annually) and make all results public. In the field of human health, consistent biomonitoring is taking place within the NHANES project https://www.cdc.gov/nchs/nhanes/biospecimens/biospecimens.htm and in Europe a similar coordinated effort is also coming together https://www.hbm4eu.eu/the-project/. A good example of consistent wildlife and biomonitoring exists in Germany https://www.umweltprobenbank.de/en/documents. Combining wildlife monitoring with information on chemical exposure was able to show links between species decline and the use of the neonicotinoid insecticide (Woodcock et al., 2016). These programmes can be supported from pollution charges outlined below. It should be an aspiration of every country to commit to consistent combined long-term chemical monitoring of humans and wildlife. It is an essential part of all environmental management.

2.6. Ensure polluters bear the full costs of prevention, mitigation and clean up

The Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005) clarified the role of the natural environment in underpinning economic, environmental and social well-being. However, chemical use has had numerous damaging impacts on natural capital (for example, through nitrates leaching into groundwater), as well as on human health and well-being (through increasing body burdens of pollutants and associated toxicity). Such harms need to be disincentivised and ameliorated in accordance with the 'polluter pays principle' (PPP), which means that the costs associated with pollution should be borne by the polluters rather than the community at large (Defra, 2018).

The PPP can be difficult to implement for institutional and political reasons (as attempts to increase domestic fuel prices amply demonstrate) and because 'the polluter' is not always easily identified (either in terms of specific sources or in the broader sense of who, exactly, is responsible – producers or consumers, for example?). Further, the PPP may not fully address the issues of individual contributions when releases go beyond a tipping point, such as might be considered to have occurred with carbon emissions and climate change (Huseby, 2015). Nevertheless, the PPP can play a vital role in assigning responsibility for the costs of preventing and controlling pollution (whether by regulatory or fiscal means), and for those of clean up, remediation and compensation when pollution has already occurred (Academy, 2018). Its effectiveness in the former context is illustrated by the plastic bag charge, which has reduced use by 85% in the UK, and in the latter context by the considerable success of the USA's 'Superfund' program since 1980 (United States, 1980). Increasing analytical sophistication should also enable 'fingerprinting' to identify particular sources of pollutants while public reporting via phone apps could become influential (e.g. https://www.litterati.org/).

3. Conclusions

Currently a myriad of chemicals used by human societies are contaminating the environment. Many, perhaps most, probably do no harm, but some definitely do. Vivid examples include the deaths of tens of millions of vultures in Asia following the ingestion of the pharmaceutical diclofenac and the marked decline of pollinating insects as a likely consequence of their exposure to neonicotinoid and other pesticides. We think that the regulatory approaches utilized presently, involving risk assessments of each individual chemical, are wholly inadequate. Mixtures, for instance, have been largely ignored, despite their obvious relevance.

The actions we propose reflect an urgent need to transform and enhance the relevant institutions, policies and practices to reach a situation where we "do no harm" in the use and disposal of chemicals. Others are also worth considering, such as using machine learning statistical techniques to predict the toxicity of chemicals. The overarching goal must be to reduce very significantly the number of chemicals reaching the environment and to ensure that if any still do, they degrade rapidly to non-toxic intermediates prior to complete mineralisation. We recognise this will often require societal change, but specific examples such as plastic bag charges, smoking restrictions and the wearing of car seatbelts show that legislation can help to transform behaviours. It is surely time for a radical rethink of how societies use and then dispose of chemicals. Unless current practices change, chemicals will continue to do unanticipated harm to ecosystems and human health.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

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References

Bernhardt, E.S., Rosi, E.J., Gessner, M.O., 2017. Synthetic chemicals as agents of global change. Front. Ecol. Environ. 15, 84–90. https://doi.org/10.1002/fee.1450.

EEA. 2016. Chemicals in Europe: understanding impacts on human health and the environment. < https://www.eea.europa.eu/articles/chemicals-in-europe-understanding-impacts > .

Prüss-Ustün, A., Wolf, J., Corvalán, C., Bos, R., Neir, M., 2016. Preventing disease through healthy environments A global assessment of the burden of disease from environmental risks. WHO press.

O'Neill, O., 1997. Environmental values, anthropocentrism and speciesism. Environ. Values 6 (2), 127–142. https://doi.org/10.3197/096327197776679121.

O'Neill, O., 1996. Towards Justice and Virtue: A Constructive Account of Practical Reasoning. Cambridge University Press, Cambridge esp. ch 6.

Depledge, M.H., Carlarne, C.P., 2008. Environmental rights and wrongs. Environ. Sci. Technol. 42, 990–994. https://doi.org/10.1021/es087077o. p. 991.

Foster, J. (Ed.), 1997. Valuing Nature? Economics, Ethics and Environment. Routledge, London and New York.

Goodin, R., 1995. Utilitarianism as a Public Philosophy. Cambridge Univeristy Press, Cambridge.

Owens, S., Cowell, R., 2002. Land and Limits: Intepreting Sustainablility in the Planning Process, 2nd ed. Routledge, London and New York esp. ch 3.

Carson, R., 2012. Silent Spring - 50th Anniversary Edition. Penguin Classics.

Boisvert, G., Sonne, C., Rigét, F., Dietz, R., Letcher, R.J., 2019. Bioaccumulation and biomagnification of perfluoroalkyl acids and precursors in East Greenland polar bears and their ringed seal prey. Environ. Pollut. 252 (Part B), 1335–1343. https://doi.org/10.1016/j.envpol.2019.06.035.

Ross, P.S., Ellis, G.M., Ikonomou, M.G., Barrett-Lennard, L.G., Addison, R.F., 2000. High PCB concentrations in free-ranging Pacific killer whales, Orcinus orca: Effects of age, sex and dietary preference. Mar. Pollut. Bull. 40, 504–515. https://doi.org/10.1016/S0025-326X(99)00233–7.

Wattigney, W.A., Irvin-Barnwell, E., Pavuk, M., Ragin-Wilson, A., 2015,. Regional Variation in Human Exposure to Persistent Organic Pollutants in the United States, NHANES. J. Environ. Public Health 571839. https://doi.org/10.1155/2015/571839.

Kelly, B.C., Ikonomou, M.G., Blair, J.D., Morin, A.E., Gobas, F.A.P.C., 2007. Food Web-Specific Biomagnification of Persistent Organic Pollutants. Science 317, 236–239.

Ragauskas, A.J., et al., 2006. The Path Forward for Biofuels and Biomaterials. Science 311, 484–489. https://doi.org/10.1126/science.1114736.

Clark, J.H., 2017. From waste to wealth using green chemistry: The way to long term stability. Curr. Opin. Green Sustain. Chem. 8, 10–13. https://doi.org/10.1016/j.cogsc.2017.07.008.

Johnson, A.C., Sumpter, J.P., 2016. Are we going about chemical risk assessment for the aquatic environment the wrong way? Environ. Toxicol. Chem. 35, 1609–1616. https://doi.org/10.1002/etc.3441.

Lindenmayer, D.B., Likens, G.E., 2010. The science and application of ecological monitoring. Biol. Conserv. 143, 1317–1328. https://doi.org/10.1016/j.biocon.2010.02.013.

Woodcock, A., Isaac, N.J.B., Bullock, J.M., Roy, D.B., Garthwaite, D.G., Crowe, A., Pywell, R.F., 2016. Impacts of neonicotinoid use on long-term population changes in wild bees in England Ben. Nat. Commun. 7, 12459. https://doi.org/10.1038/ncomms12459.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Defra. Information Paper on the Policy Statement on Environmental Principles, 2018, pp. 13.

Huseby, R., 2015. Should the beneficiaries pay? Politics Philos. Econ. 14 (2), 209–225.

British Academy. Consultation Response: Environmental Principles and Governance after the United Kingdom leaves the European Union, August 2018, pp. 6.

United States. Comprehensive Environmental Response, Compensation, and Liability Act of 1980. 1980.