Executive summary

Key Messages

Unsustainable phosphorus use is at the heart of many societal challenges. Unsustainable phosphorus use affects food and water security, freshwater biodiversity and human health. Increasing demand for food to support a growing global population continues to drive increases in phosphorus inputs to the food–system, as well as losses from land-based sources to freshwater and coastal ecosystems. These losses cause ecological degradation through the proliferation of harmful algal blooms in fresh waters, contributing to alarmingly high rates of biodiversity decline, economic losses associated with clean-up, and large-scale human health risks from contaminated drinking water supplies. The pace of species extinction, climate change and the growing number of extreme weather events, combined with population growth and the economic impact of COVID-19, have further strengthened the need to invest in phosphorus sustainability.

Challenges

The global anthropogenic phosphorus cycle is unsustainable. Phosphate rock is a non-substitutable, non-renewable natural resource, essential for fertilisers and animal feeds, and so for global food security. Phosphorus is also important in smaller quantities in industrial applications. Phosphorus emissions throughout agriculture, food and sewage systems are predicted to increase under global business-as-usual scenarios. The sources of emissions differ significantly between regions. Whilst agricultural systems vary, poor phosphorus management is widespread. Estimated losses of phosphorus from agriculture to surface waters account for about 34% of global fertiliser use (~5 Mt phosphorus year^{-1}) representing 56% of all terrestrial inputs to surface waters (see Section 5.5). In some regions, including parts of Africa and India, wastewaters are the dominant source of phosphorus emissions with wastes often discharged directly to rivers with no treatment. Globally, ~80% of all wastewaters are discharged without treatment (in low-income countries ~8% are treated, in high-income countries ~70% are treated) (see Section 5.5).

Affordable access to sustainable phosphorus sources is imperative to ensure food provision for all and to protect the livelihoods of smallholder and marginal farmers. Currently, 1 in 7 farmers cannot afford sufficient fertilisers to maintain fertile soils, impacting their ability to produce food (see Section 3.3). Without change, insufficient phosphorus fertiliser use in many parts of Africa will likely lead to crop yield reductions of nearly 30% by 2050 (see Section 3.3). Phosphorus additions to increase aquaculture yield are a growing and direct pollution threat to this food system and the freshwater and coastal ecosystems it relies upon. Almost half of the world's population rely on fish for 20% of their protein intake making aquaculture a critical global industry, with an annual turnover of US$ 160 billion (see Section 5.5). Significant improvements in phosphorus use efficiency can be made across these critical food provision sectors.

High dependency on imported phosphate rock and/or mineral phosphorus fertilisers can contribute to national food system vulnerability. Agriculture is entrenched in its reliance on mineral phosphorus fertiliser; 85% of phosphates produced for the market are processed to make mineral fertilisers and 10% are used to make animal feed supplements (see Section 2.1). Five countries hold 85% of known phosphate rock reserves, with 70% found within Morocco and Western Sahara. Geological depletion of phosphate rock is not an immediate threat, with a current global estimate of over 300 years of phosphate reserves (see Section 2.1). However, geopolitical, institutional and economic factors can impact phosphorus access domestically. Improving the efficient use of phosphorus in agriculture (see Section 4.6) and shifting reliance away from mined phosphorus sources by increasing phosphorus recycling (see Sections 6.4 and 7.4) could help to reduce supply risk, at least at a national scale.

Aquatic ecosystems are under severe stress from phosphorus pollution. The rate of biodiversity loss in fresh waters is higher than in any other planetary domain, and nutrient pollution is a key stressor (see Section 5.1). Globally, phosphorus losses from land to fresh waters have doubled in the last century and continue to increase, contributing to toxic algal blooms, biodiversity loss, and threatening human and environmental health. Climate change is expected to increase the severity of these impacts, whilst the release of greenhouse gases from phosphorus enriched lakes exacerbates climate change (see Section 5.4.2). Reducing nutrient emissions to fresh waters has been listed as a priority for most countries to redress water quality degradation, in line with the United Nations Sustainable Development Goal (SDG) 6.3.2.

Restoring ecosystems is notoriously difficult and carries unacceptable clean-up costs. The data required to assess the money spent to address the impacts of unsustainable phosphorus use remains limited. Of the few studies published, it has been estimated that eutrophication costs the US economy US$2.2 billion annually (see Section 5.5). In the UK, similar assessments indicate losses will increase from around £173 million ($220 million) in 2018 to over £400 million (>US$500 million) by 2080 as a result of climate warming alone (see Section 5.5). The present report estimates the global cost to implement catchment management to intercept phosphorus losses to fresh waters from anthropogenic sources could reach about US$265 billion year^{-1} (see Section 5.5). Despite this estimate, global baseline data on phosphorus emissions and impacts are limited. It is important to raise awareness of ecosystems under threat and to work across governments to ensure long-term ecosystem integrity through preventative management programmes.

Solutions

Phosphorus emissions from land-based sources represent an opportunity to reduce global reliance on mined phosphate rock, whilst relieving stress on freshwater and coastal ecosystems. A move towards a circular phosphorus economy stands to increase the resilience of national scale food systems.

A global commitment to recycling nutrients in wastes and residues is needed. Recycling phosphorus-rich organic residues and manures is critical for phosphorus sustainability. Multiple strategies exist to improve the recycling of phosphorus in manures, abattoir residues, food processing and domestic wastes, sewage derived biosolids and wastewaters (see Sections 6.4 and 7.4). Beyond agronomic benefits, the win-wins are numerous, with benefits to society, environment, economy and business growth. Phosphorus recovery processes provide the opportunity to produce contaminant free, high purity phosphorus products that may substitute for mined phosphorus (see Section 7.4). To increase phosphorus recycling significantly, education, awareness-raising, investment in technology and infrastructure, and policy support are urgently needed. A goal for fertiliser products to contain a minimum of 20% recycled phosphorus by 2030, could set a benchmark that demonstrates green commitment across the fertiliser industry (see Section 2.6).

Reducing excessive consumption of animal products (e.g. meat, dairy, and eggs) and decreasing food waste will significantly reduce phosphorus losses from the food system (see Section 8.3). Consuming products grown with good on-farm nutrient management practices, including phosphorus recycling can further reduce losses. Over the last 60 years, 38% of the increased use of mineral phosphorus fertilisers can be attributed to global diet changes (see Section 8.1). This increase is predominantly related to increased consumption of animal products, especially in wealthier countries, where per-capita consumption is often higher than is recommended for healthy diets.

An international framework is needed to address the lack of accurate baseline data on many of the major phosphorus flows and stocks at national, regional, and global scales. Assessments are needed that quantify the extent of eutrophication, the costs of impacts and of necessary mitigation actions to accelerate efforts at ecosystem restoration and to prevent future damage.

Ten key actions

Ten key actions across sectors are proposed to improve sustainable phosphorus management globally (see Section 9.2). Among these actions, priorities and preferred solutions can be expected to differ nationally and between regions.

1. Increase the use of recycled phosphorus in fertiliser and other chemical industries, as an alternative or supplement to phosphate rock.
2. Optimise phosphorus inputs to agricultural soils and maximise crop uptake to minimise losses.
3. Optimise animal diets and the use of supplements to reduce phosphorus excretion.
4. Increase appropriate application of manures, other phosphorus-rich

residues, and recycled fertilisers to soils, to complement appropriate mineral fertiliser use.

5. Improve global reporting and assessments of phosphorus emissions and their impacts on freshwater and coastal ecosystems.
6. Implement integrated approaches for freshwater and coastal ecosystem restoration and protection at catchment, national and transboundary scales.
7. Implement national to global strategies to increase recovery and recycling of phosphorus from solid and liquid residue streams.
8. Ensure sufficient access to affordable phosphorus fertilisers (mineral, organic and recycled) for all farmers.
9. Promote a global shift to healthy and nutritious diets with low phosphorus footprints.
10. Reduce the amounts of phosphorus lost as food waste in food processing, retail, and domestic consumption.

Towards a Sustainable Phosphorus Future

Looking to the future, significant investment aligned with increased public awareness and political support is needed to implement the solutions outlined in this report. A decade has passed since the global anthropogenic flow of phosphorus was assessed as having crossed the planetary boundary.[i] Yet, despite clear opportunities to move towards more sustainable phosphorus use, there remains a lack of direction in relevant food and environmental policy to support such a transition. Intergovernmental coordination is urgently needed to address this issue (see Section 9.4). Multiple benefits are associated with sustainable phosphorus use, including:

- Improved sanitation, essential for health and the environment.
- Healthier diets for some individuals.
- New employment opportunities through the nutrient circular economy.
- Coherence with sustainable management of other nutrients including nitrogen, carbon and potassium.
- Return of organic carbon to soils, contributing to soil fertility and climate resilience.
- Reduction in greenhouse gas emissions including carbon dioxide and methane, and potential synergies with nitrous oxide.
- Reduced national dependency on the limited regions with phosphate rock reserves.
- Reduced mobilisation of contaminants contained in some phosphate rock reserves.
- Increased biodiversity and socioeconomic benefits associated with ecosystem recovery.

A transition towards more sustainable phosphorus use will help countries contribute to their commitments to multiple UN-SDGs, that include:

[i] A level of human interference in the global phosphorus cycle that results in potentially irreversible environmental damage (see Section 2.3).

SDG 1 – No poverty and SDG 2 – Zero Hunger, through the development of business growth within the circular economy, risk reduction to sectors (and employees) reliant on healthy aquatic ecosystems and reduction in poverty-related malnutrition through the protection and provision of livelihoods.

SDG 3 – Good Health and Well-Being, by reducing the risk of harmful algal blooms, and a reduction in illnesses from hazardous water pollution (e.g., cyanotoxins produced during harmful algal blooms).

SDG 6 – Clean Water and Sanitation, through a reduced risk to drinking water supplies resulting from improvement to water resources impacted by phosphorus pollution and the protection and restoration of aquatic ecosystems, and improved sanitation where phosphorus recovery drives infrastructure investment.

SDG 12 – Responsible consumption and production, through improved sustainable management and efficient use of natural phosphorus resources, and improving environmentally sound management of chemicals (e.g. fertilisers) and all wastes throughout their life cycle.

SDG 13 – Climate Action, through reduced contributions to greenhouse gas emissions from phosphorus polluted ecosystems.

SDG 14 – Life Below Water, through the sustainable management and protection of marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience.

SDG 17 – Partnerships, through improved sustainable phosphorus partnerships reliant on the development, transfer, dissemination, and diffusion of environmentally sound technologies to all countries.

An aspirational goal for phosphorus is proposed

The following goal is identified as an interim focus for 2050, which would together represent a major step on the pathway to a sustainable phosphorus future.

The OPF '50:50:50' Goal calls for a 50% reduction in global phosphorus pollution and a 50% increase in the recycling of phosphorus lost in residues and wastes, by 2050.

Globally achieving this target would deliver benefits across all seven of the OPF pillars. Key benefits of achieving the ‘50:50:50’ goal for each OPF pillar, are listed below (see Section 9.5).

Benefits to ‘Phosphorus Access’: Achieving the ‘50:50:50’ goal could return an additional 8.5 MT of recycled phosphorus to farms each year, supporting food production and food system resilience.

Benefits to ‘Food Security’: Achieving the ‘50:50:50’ goal could create a food system that would provide enough phosphorus to sustain over 4 times the current population.

Benefits to ‘Agriculture and food production’: Achieving the ‘50:50:50’ goal could save the global farming community almost $US4 billion in annual mineral phosphorus fertiliser costs needed to replace losses.

Benefits to ‘Water Quality’: Achieving the ‘50:50:50’ goal could significantly reduce the impacts of eutrophication, cutting the need for adaptation costs by over US$250 billion $year^{-1}$, with socio-economic benefits of restored ecosystems, including greater biodiversity and growth of ecotourism.

Benefits for 'Recycling': Achieving the '50:50:50' goal could support a transition to a circular economy for the phosphorus cycle; decoupling economic growth from the consumption of finite phosphate rock resources.

Benefits for 'Recovery': Achieving the '50:50:50' goal could develop sustainable business opportunities, accelerating and supporting new jobs through emerging green economy sectors.

Benefits to 'Sustainable Consumption': Achieving the '50:50:50' goal could provide consumers with better access to foods produced in phosphorus sustainable ways, allowing consumers to better support a transition to a sustainable phosphorus future, sustainable city living and post COVID-19 'Green Recovery'.

The '50:50:50' goal aligns with several aspirational goals that have also called for reductions in nutrient losses in recent years. These include:

- The United Nations Environment Programme (UNEP) Colombo Declaration which calls for the halving of nitrogen (N) waste by 2030.
- The working group of the Post-2020 Global Biodiversity Framework which proposed to reduce pollution from excess nutrients by 50% by 2030.
- The Farm to Fork strategy underpinning the European Green Deal, which calls for actions to reduce nutrient losses by at least 50% and to reduce fertiliser use by at least 20% by 2030 (see Section 9.5).

If the world is to meet climate change, biodiversity, and food security targets, and avoid building costs of predicted phosphorus impacts, positive action on phosphorus management is essential. The present report calls for the establishment of an intergovernmental coordination mechanism to catalyse integrated action on phosphorus sustainability (see Figure 9.1). This should be supported by an international framework to consolidate the collective knowledge, quantify the economic and societal benefits of improvements in phosphorus management and establish targets for time-bound improvements.

The report identifies a clear opportunity to raise awareness of the need for sustainable phosphorus management through the United Nations Environment Assembly (UNEA) and calls for a UNEA resolution on sustainable phosphorus management or an equivalent global commitment to act.