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Phosphorus flow severely affected by human activity in three large river basins

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Human activities have caused phosphorus to accumulate in soils and water bodies, creating a legacy that could last for decades, new research shows. A study of three major river basins highlights better sewage treatment facilities and reduced fertiliser use as key reasons for an overall decline in phosphorus levels in the Thames River basin, UK, since the late 1990s.

Phosphorus flows naturally through the environment. However, humans have disrupted its natural cycle, in particular by mining phosphate rocks on a huge scale to make the fertiliser that we depend on for food production. When large amounts of phosphorus leak into rivers from farmland, animal wastes and sewage, it can build up and cause eutrophication, a costly impairment of water quality arising from excessive growth of algae. This can lead to decreased biodiversity and changes in species composition and dominance and, in some circumstances, can have toxic effects.

This international study suggests that since pre-industrial times, human-driven changes to the phosphorus cycle have been large, and these may need to be considered alongside changes to the carbon and nitrogen cycles. The researchers focused on phosphorus from human activities in these three river basins:

- the **Thames River basin, UK**: a mixed urban-agricultural basin which includes parts of London and flows into the North Sea;
- the **Maumee River basin, USA**: a rural, cropland-dominated basin in Indiana, Ohio and Michigan, which flows into Lake Erie;
- the **Yangtze River basin, China**: an area which has undergone rapid population growth and economic development, which flows into the East China Sea.

The three basins were chosen because each has been subject to management, monitoring and research for several decades, leading to the availability of important data sets. The researchers gathered new and historical data dating back 70 years on factors which have influenced phosphorus flow in the river basins. This involved data on the flows in fertiliser and agricultural trade, rivers, food waste disposal and sewage infrastructure. Informed by the known properties of each basin, including setting, size and human population, they calculated, for each year and then across years, the net phosphorus input (including from mineral fertiliser and imported animal feed, and from imported food and household cleaners in the form of effluent from sewage treatment or sludge applied to soils) and net phosphorus output (including via food/feed trade, waste transport to landfill and transport by river).

In the UK, between 1940 and 1980, around 15 times more phosphorus from fertiliser alone entered the Thames basin than the total amount that exited it, on average each year. The phosphorus input from food/feed from farms was seven times greater than the total amount exported, four times greater for landfilled food waste and twice as much for phosphorus from sewage treatment works.

Total input to the Thames basin started to fall in the 1980s as a result of reduced fertiliser use, likely from a combination of factors such as greater awareness of crop nutrition, the cost savings possible with reduced fertiliser use and the associated water quality risks. Since the late 1990s, slightly more phosphorus leaves than enters it each year. During the 2000s, there was also drop in phosphorus entering the basin from sewage, thanks to better sewage treatment, which was partly motivated by the EU's Urban Waste Water Directive. The Thames is the only basin in the study to show clear signs of improvement.

Continued on next page.

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(continued)

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In the USA, total phosphorus input to the Maumee basin was up to around three times greater than output until the late 1990s. Since this point, however, input and output have been roughly equal. However, the researchers highlight that 200 000 metric tons of 'legacy' phosphorus remains. This legacy phosphorus built up in the basin mostly in the 1970s and 1980s, and will likely continue to be released into water bodies over the coming decades. This illustrates the complexity of phosphorus dynamics and the long-term effects of accumulation.

In contrast, phosphorus levels have been rising rapidly in the Yangtze basin since 1980. Although the researchers had less data for this basin than for the Thames and Maumee basins (e.g. no sewage input data), they estimate that the Yangtze basin accumulated a remarkable 1.7 teragrams (Tg) of phosphorus in 2010 (equivalent to 1 700 000 metric tons), largely due to fertiliser use. This 1.7 Tg per year is equivalent to around 8% of the annual global rate of phosphorus production from phosphate rock.

The researchers say that their study provides evidence that human-driven phosphorus flow 'massively' dominates natural flows, even for large basins. This is likely to be the case for many other agricultural and urban basins around the world, they suggest.

Strategies to reduce the impact of this accumulated 'legacy phosphorus' are needed, and it is important to create new technologies and policies that recycle phosphorus for re-use as fertiliser, rather than allowing it to escape or build up excessively in the landscape, the researchers conclude.

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