European Commission

# Science for Environment Policy

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**Source:** Chen, M. & Graedel, T.E. (2016). A half-century of global phosphorus flows, stocks, production, consumption, recycling, and environmental impacts. *Global Environmental Change*, 36:139–152. DOI: 10.1016/j.gloenvcha.2015.12.005.

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## Sustainable phosphorus use — evaluating past patterns to inform future management

**Recycling waste from farming and mining could help improve the sustainable use of phosphorus, a recent study suggests.** The study traced the stocks and flows of phosphorus over a 50 year period to reveal changing patterns of global phosphorus use. The results can be used to develop the sustainable management of phosphorus — a finite and critical resource — in the future.

**Phosphorus is an element that is essential for all life.** It is a critical nutrient for plants and most of the global demand for phosphorus is for food production, where it is used as a fertiliser in agriculture. However, phosphorus in wastewater and excessive losses of phosphorus from agriculture reaching freshwater and marine environments also contribute to eutrophication, algal blooms and poor water quality, and damage ecosystem services.

The demand for phosphorus is likely to increase in the future to help feed the world's growing population. Its sustainable use is, therefore, essential, as most of the world's phosphorus is obtained from phosphate rock, which is a finite and non-renewable resource. Understanding past patterns of phosphorus use can help predict future use and develop sustainable management of phosphorus resources. This study thus evaluated the past global supply, demand and depletion of phosphorus resources.

The researchers modelled the global stocks and flows of phosphorus from 1961 to 2013 using data from a range of sources: previous studies, the US Geological Survey, the International Fertilizer Industry Association, the Food and Agriculture Organization, the International Plant Nutrition Institute, the US Department of Agriculture and the UK's Department for Environment, Food and Rural Affairs.

They calculated the flows of phosphorus between four areas of human activity associated with phosphorus: phosphate rock mining, industrial production, agricultural production and societal consumption. They considered the balance of phosphorus in the soil (including the natural deposition of phosphorus from the atmosphere), losses of phosphorus into water and the stock of phosphorus in waste generated from all these processes, and any phosphorus recovered from the waste.

Over the five decades, the amount of phosphorus extracted from phosphate rock rose by over four times, from 14.6 teragrams, or 14.6 million tonnes, of phosphorus (Tg P) in 1961 to 68.7 Tg P in 2013. Most of this increase is related to producing mineral phosphorus fertilisers.

Furthermore, as people become more affluent, dietary preferences have changed and more people are eating a greater amount of meat and dairy products, which require more phosphorus to produce than crops. The study found, for example, that demand for animal products increased at a higher rate than global demand for phosphorus over the study period.

The source of agricultural phosphorus has also changed. For instance, in 1961, 29% of phosphorus requirements for global croplands and grasslands came from mineral fertilisers, while 56% was derived organically, from manures, crop residues and human excrement. By 2013, 56% of agricultural phosphorus inputs came from mineral fertilisers, while 38% came from organic sources.

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## Sustainable phosphorus use — evaluating past patterns to inform future management *(continued)*

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Substantial variation exists in the magnitudes of phosphorus imbalances across regions. Excessive phosphorus fertilisation from mineral fertilisers and manure has resulted in a global surplus of phosphorus in cropland soils, although the study found that 30% of croplands are still deficient in phosphorus.

The researchers suggest changes to sustainably manage phosphorus resources. A return to recycling farm organic waste would significantly improve the sustainable use of phosphorus. Careful management would be needed to ensure only sufficient phosphorus is applied and retained, so that surplus phosphorus does not pollute water through run-off, leaching or soil erosion.

Improved soil conservation practices, particularly in Europe and the United States, have already resulted in a significant reduction in phosphorus reaching the water environment. In 1961, 90% of global phosphorus water pollution was from agricultural land. By 2013, this source accounted for 28.5% of phosphorus water pollution. Waste from agricultural production increased from 9.8 Tg P in 1961 to 20.7 Tg P in 2013, although its relative contribution dropped from 45.9% to 28.5%

Waste from mining phosphate rock contributed just 3% of phosphorus water pollution in 1961, and 62% in 2013. Mining waste was also responsible for 50% of phosphorus wastes from all sources in 2013. Recycling waste streams would improve the efficiency of phosphorus use, although the researchers point out that the number of impurities and low concentration of phosphorus in mining waste make its recovery more challenging.

Phosphorus losses from extraction to final consumption result in only about 22% of extracted phosphorus being consumed. Using phosphorus more efficiently, together with increasing the recovery and recycling of phosphorus from phosphorus-containing wastes, will help to address the problems of depleting phosphorus resources and the negative impact of phosphorus on the environment — despite its growing use — the researchers conclude.