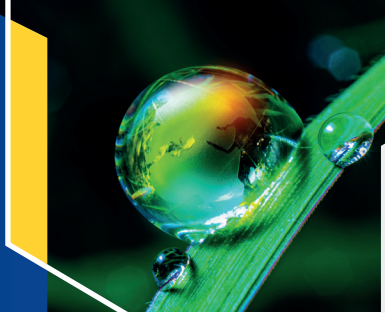
CAS INSIGHTS™

R&D TRENDS: REDUCING FERTILIZER WASTE IN AGRICULTURE



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Overview

Conventional nitrogen fertilizer manufacturing involves energy-intensive fossil fuel operations, which contribute significantly to the 10.7 to 12.0 gigatonnes of annual CO_2 emissions. Additionally, sources of mined phosphorus and potassium are diminishing or experiencing supply chain disruptions.

Background: Annual agricultural emissions range between 10.7 and 12.0 gigatonnes of CO_2 equivalent. Fertilizer production represents a sizeable proportion of these emissions, and the most crucial macronutrients — nitrogen, phosphorus, and potassium — are vulnurable to future supply chain restrictions.

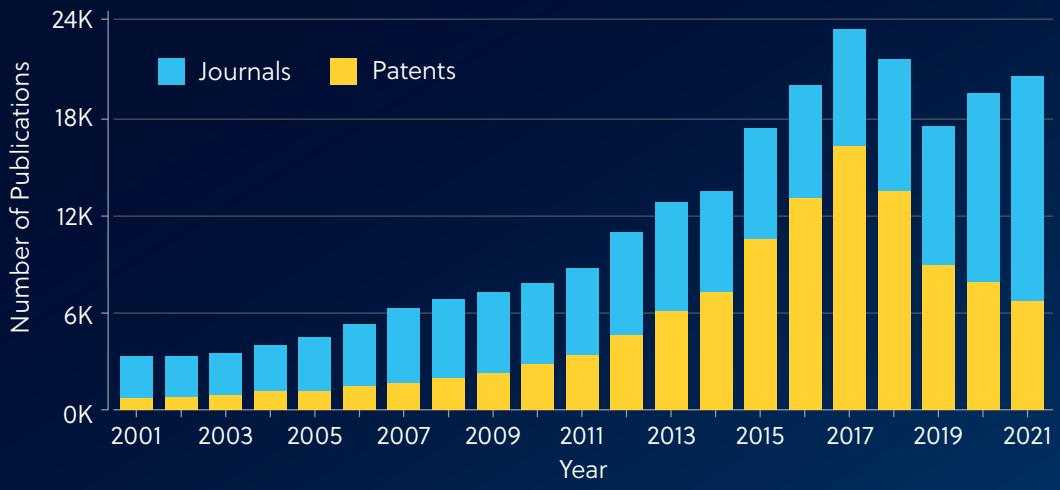
Market data: China is the leading fertilizer consumer worldwide, followed by India and the U.S. The global organic fertilizer market is expected to reach $19.88 billion by 2029, and fertilizer demand is far outweighing supply.

Opportunities: Alternative 'green' methods for fertilizer production include green ammonia synthesis and nutrient recovery from phosphorus- or nitrogen-containing wastes. Many such processes are now commercialized.

Key benefits: Utilizing liquid, solid and biosolid waste products for nutrient recovery reduces harmful emissions and accelerates the development of greener fertilizer production for a sustainable future in agriculture.

Trends in fertilizer research and nutrient recovery

Research activity focusing on fertilizer, sustainability, recycling, and recovery peaked around 2017, according to an analysis by CAS. However, the number of patents filed steadily declined since then, while publication outputs remained stable.



Rethinking modern agricultural methods

With global food shortages and finite fertilizer resources, a rethink of modern agricultural methods is vital, especially owing to the substantial carbon footprint. Alternative sustainable methods are leading the way in the future of farming and food production.

Biorefineries	Biochar (charcoal)	Green ammonia	Nanoscale and controlled-release fertilizers	Struvite
Combined production of sustainable energy, biofuels, food, chemicals, and nutrient-rich fertilizers that utilize renewable biomass as a feedstock	Anaerobic pyrolysis of organic matter, e.g., dead plants or leaf litter are clean and energy-efficient approaches to producing stable carbon	Producing 100% renewable and carbon-free ammonia using renewable energy, nitrogen, and water	Controlled-release formulations would increase the efficacy of nitrogen and phosphorus delivery while decreasing environmental nitrogen and phosphorus loss	Struvite ($MgNH_4PO_4$), a crystalline mineral composed of magnesium, ammonium, and phosphate, is a sustainable means for phosphorus recovery from wastewater and is used in fertilizer production

Industry innovation in nutrient recovery

Nutrient recovery processes are being commercialized to help streamline efficiencies, reduce costs, and minimize environmental impact. Some examples include:

1

Pearl® and WASSTRIP® technologies (Ostara Nutrient Recovery Technologies Inc., Canada)

are key processes for phosphorus removal used to produce Crystal Green®, a sustainably recovered slow-release fertilizer. The Root-Activated™ release optimizes uptake and protects local water resources while increasing yield.

4

The RecoPhos Project (The RecoPhos Consortium)

is a multidisciplinary project undertaken by academia, industry, and enterprise. The objective is to recover phosphorus from sewage, sludge, and ashes using an innovative reactor, to implement a fully operational bench scale reactor and design a pilot scale plant.

2

The Aqua2™N Process (Easymining Services, Sweden)

recovers nitrogen from sludge liquor. Nitrogen is adsorbed and harvested as crystals, which are then repurposed for fertilizer production.

5

AirPrex® (CNP CYCLES GmbH, Germany)

is a patented sludge optimization process that improves biological phosphate elimination. In the AirPrex® reactor, digested sludge is treated to to precipitate MAP or struvite.

3

AshDec® Thermochemical P-Recovery system (Metso Outotec, Finland)

improves plant availability and reduces heavy metal content through the recovery of phosphorus from sewage, sludge, and ash. The phosphorus product is citrate soluble, and phosphorus release is controlled.

Abbreviations: MAP = magnesium ammonium phosphate; WASSTRIP® = Waste Activated Sludge Stripping to Remove Internal Phosphorus.

The future of fertilizers

Comprehensive research highlights numerous innovations in nutrient waste and wastewater recovery, as well as environmentally friendly fertilizer production methods. Sustainable agriculture will be a key contributor toward minimizing energy consumption and protecting the finite nature of global phosphorus, nitrogen, and potassium reserves.

Learn more at cas.org/insights

More comprehensive information and references can be found at: cas.org/sustainable-ag-report

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