ESPP Phosphorus Fact Sheet (v21_4_2019)

Reminder of units:

1 tP = 3.07 tPO₄ = 2.29 tP₂O₅

World phosphate production

World phosphate rock production:

USGS data (2017) indicates 263 million tonnes of “beneficiated phosphate rock” (marketable rock after washing, sieving, flotation) mined per year (2017). The tonnage of rock extracted in the mine will be higher than this figure, which corresponds to the tonnage or rock which is traded.

IFA data (2016) gives a somewhat lower figure of around 200 million tonnes of commercially sold rock.


Beneficiated phosphate rock contains 15-41% P₂O₅ (7-18% P).

This mined rock worldwide contains a total of 17-24 MtP/y phosphorus (P) equivalent to 35-50 MtP₂O₅/y.

World phosphate rock reserves and resources

Estimates for world reserves and resources of phosphate rock vary widely and can change with different assumptions about economic viability, technologies for access and extraction and with new exploration data.

One recent estimate is USGS 2018: >300 billion tonnes of rock (total world resources including reserves) but the indications above should be taken into account.

Prices of phosphate rock and fertiliser

For phosphate rock world market prices see https://www.indexmundi.com/commodities/?commodity=rock-phosphate&months=240

For fertiliser end-user prices see https://www.agrarmarkt-nrw.de/duengermarkt.shtm

The world market for phosphate fertilizers is around 50-70 billion US$/year.

https://www.grandviewresearch.com/industry-analysis/phosphate-fertilizers-market and https://www.marketsandmarkets.com/Market-Reports/phosphates-market-237175254.html However, part of this indicated value may be attributable to the nitrogen content of MAP or DAP fertilisers and the value will depend on whether it is based on price paid by farmers or on sale price from fertiliser producer (before distributor margin). The total world fertilisers market is estimated at around 200 billion US$, of which 75% is nitrogen fertilisers https://markets.businessinsider.com/news/stocks/the-fertilizers-market-is-expected-to-reach-over-245-billion-in-2020-1002227055

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Uses of phosphorus:

Overall distribution of uses

Based on CRU Phosphates 2012 (figures for 2011):
- A. Jung: fertilisers 87% (88% including speciality fertilisers see below), animal feed = 7%, industrial & food = 6%
- A. Sinh: within the 6% : 34% detergents & cleaners (= 2% of total), 21% = food & beverage = 1%, 11% = speciality fertilisers (=0.6% to add to fertilisers above) and other = metal treatment, water treatment, toothpaste and miscellaneous = 34% = 2%

P in flame retardants

- World flame retardant market (2017) = 2.25 million tonnes
- Around 20% of flame retardants are P-based
- P content of P based FRs estimate that P <10% on average by molecular weight
= c. 50 000 tP/y worldwide

P in fire extinguishers:
= c. 50 000 tP/y worldwide

Potential phosphorus demand for batteries

World demand for lithium in batteries in 2025 = 215 000 tonnes lithium carbonate equivalent = approx. 20 000 tonnes Li (based on molecular weight). Assuming lithium fluoro phosphate electrolyte = 1:1 Li-P this would be very approximately
= c. 90 000 tonnes P worldwide in 2025
Potential phosphorus sources for recycling

For Europe EU27
- 1 700 tP/year in animal manures
- 300 000 tP/year in sewage sludge
- 310 000 tP/year in animal by products
- 130 000 tP/year in food waste
- 75 000 tP/y in food industry by-products and wastes (other than those going to animal feed)

Compared to annual mineral phosphate fertiliser use = 1 500 tP/y

Phosphorus in fertilisers and in agriculture

EU market for fertilising products (this is much wider than phosphorus):
20 – 25 billion €/year:
- 80% mineral fertilisers
- 7% organic and organo-mineral fertilisers
- 6% growing media
- others = soil improvers, biostimulants, liming materials, agronomic additives

The phosphorus “surplus” in European agriculture was estimated to have decreased 50% from 2000 to 2013

Phosphorus inputs to agriculture in Europe, in ktP/year, are estimated at:
- 2 400 tP/y fed to livestock, of which around 9% in inorganic phosphate feed additives
- 3 300 tP/y to land (crops plus grassland), of which
  - Manure 53% (9.2 kgP/ha/y EU average)
  - 42% mineral fertiliser (7.3 kgP/ha/y)
  - 4% sewage biosolids (0.7 kgP/ha/y)
  - 1% other: compost, animal by-products other than manure, pesticides, seeds …

Phosphorus in diet

EFSA (European Food Safety Agency) indicates that human diet P intake is usually 1 – 1.8 gP/day. The mean daily intake of phosphorus for the US was (in 1994, persons > 9 years old) 1.5 gP/day for males and 1 gP/day for females.

The US Daily Reference Intakes (DRI) for phosphorus for adults are:
- EAR (Estimated Average Requirements) = 0.58 gP/day
- RDA (Recommended Daily Allowance) = 0.7 gP/day.
  NOTE: these are levels considered sufficient to ensure health, they are not maximum recommended levels
- UL (Tolerable Upper Intake Level) = 4.0 gP/day (3.0 gP/day for children)
Phosphorus in sewage, sewage sludge, sewage sludge incineration ash

Phosphorus in raw sewage

Estimates of phosphorus in raw sewage in Europe\textsuperscript{xvi} include:

- Human urine/excreta = P in diet = \textit{in gP/person/day} around 1.5 – 1.6
- Food wastes\textsuperscript{xxii} 0.1 - 0.3
- Soil on laundry, bathwater 0.1 – 0.2
- Domestic detergents assumed zero\textsuperscript{xxiii}
- Toothpaste 0.02
- Drinking water treatment 0.13\textsuperscript{xxiv}

\textbf{Total} (without detergents) \textit{around 2}

- Storm water runoff variable, e.g. 0.2
- Small industry 1 – 2

See detailed discussion in SCOPE Newsletter n°s 71 and 103\textsuperscript{xxv}

Phosphorus in sewage sludge

Levels of phosphorus in sewage sludge will vary widely depending on P content of raw sewage, on the % of households connected to sewerage and leaks not reaching the sewage works, on industrial inputs to the sewerage system, and on sewage treatment (% P removal) and will be modified be e.g. anaerobic digestion\textsuperscript{xxvi}.

Phosphorus content of sewage biosolids (after dewatering, and after digestion, composting or lime stabilisation) are 0.3 – 0.5 %P (fresh weight basis) rising to 2.4% in thermally dried biosolids\textsuperscript{xxvii}

Phosphorus in sewage sludge incineration ash

Both bottom ash and fly ash from sewage sludge mono-incineration\textsuperscript{xxviii} can be used as raw materials for phosphorus recovery, and contain 7% - 11% phosphorus (P), depending in particular on whether or not the sewage works are operating P-removal.

For example, data from Germany (2014) indicates median P concentration of 9.1 %P in mono-incineration ash (median 7.9%P in all sludge incineration ashes, including mixed incineration ashes)\textsuperscript{xxix}.

Phosphorus “efficiency”

In crop production in Europe, an average of 70% of applied phosphorus is taken up by the crop\textsuperscript{xxx} but it is often stated that “<20% of P mined for fertiliser reaches the food products consumed”\textsuperscript{xxxxi}.
**Eutrophication impacts**

**Europe**

‘Diffuse’ pollution affects\textsuperscript{xxxi} 35% of surface water bodies in Europe, and 35% of groundwater areas.

Phosphorus concentrations in European rivers, in average, fell around 50% between 1980 and 1995. Discharge of phosphorus from urban wastewater treatment plants (North West Europe) was reduced by around 70% from 1987 to 1996\textsuperscript{xxxiii}

Despite these improvements, phosphorus emissions remain one of the main causes for water bodies to fail to achieve EU Water Framework Directive quality status objectives, for example “Phosphorus is the top reason for English water bodies not achieving good ecological status”.\textsuperscript{xxxiv}

**USA**

40% of US lakes (by number) were in the “most disturbed” condition, as compared to a reference set of lakes in 2012\textsuperscript{xxv}.

46% of US rivers and streams (by length) had “high” levels of phosphorus, as compared to a reference set of rivers and streams, in 2008-2009\textsuperscript{xxvi}.

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\textsuperscript{1} Specifying units correctly can avoid mistakes such as that of Comber et al. who confused tonnes of phosphorus (P) with tonnes of food additives, leading to an error in (peer-reviewed) study conclusions of a factor of four. See SCOPE Newsletter n°104 [www.phosphorusplatform.eu/Scope103](http://www.phosphorusplatform.eu/Scope103)


\textsuperscript{3} IFA (International Fertilizer Association) annual statistics “Phosphate Rock Stats Excel File” at [https://www.ifastat.org/supply/Phosphate%20Products/Phosphate%20Rock](https://www.ifastat.org/supply/Phosphate%20Products/Phosphate%20Rock)

\textsuperscript{4} IFA as above

\textsuperscript{5} based on 16-22 MtP/y world fertiliser use from Cordell 2014 and Hermann et al. 2018 in SCOPE Newsletter n°128


\textsuperscript{9} 18% of flame retardants on the world market are phosphorus based according to [https://ihsmarkit.com/products/chemical-flame-retardants-scup.html](https://ihsmarkit.com/products/chemical-flame-retardants-scup.html) but note some inorganic phosphate flame retardants may be classified under “other” in this study

\textsuperscript{10} In organic P flame retardants, although the objective is to deliver P within the polymer compound to contribute to fire resistant, it is necessary to include the P in an organic molecule to ensure compatibility with polymer processing. Phosphorus is also present in some mineral flame retardants, such as ammonium polyphosphates

\textsuperscript{11} M. Michelotti (Prophos) cited in SCOPE n°127: 100 000 t/y of (MAP + ammonium sulphate) in ABC fire extinguishers in Europe. Estimate = estimate 500 000 Mt/y world. P content of MAP = 25% so assuming 50/50 MAP/ammonium sulphate
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