ESPP Phosphorus Fact Sheet *(v17/4/2022)*

http://www.phosphorusplatform.eu/factsheet

Reminder of units[i]:

1 tP = 3.07 tPO_4 = 2.29 tP_2O_5

World phosphate production

World phosphate rock production:

USGS data[ii] indicates 219 million tonnes of "beneficiated phosphate rock" (marketable rock after washing, sieving, flotation) mined per year (2020), down from 263 Mt in 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)[iii] gives a somewhat lower figure of around 200 million tonnes of commercially sold rock.

For comparison of different data sources, see B. Geissler et al., Science of the Total Environment 642 (2018) 250–263 https://doi.org/10.1016/j.scitotenv.2018.05.381 in SCOPE Newsletter n°128)

Beneficiated phosphate rock contains[iv] 15 - 41% P_2O_5 (7-18% P).

This mined rock worldwide contains[v] a total of 15 – 39 MtP/y phosphorus (P) equivalent to 33 - 89 MtP_2O_5/y.

For comparison, the FAO estimate for P use in fertilisers and the % of total P used in fertilisers (for both, see below) suggests a total global use of mined P of around 24 MtP/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)[vi] 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

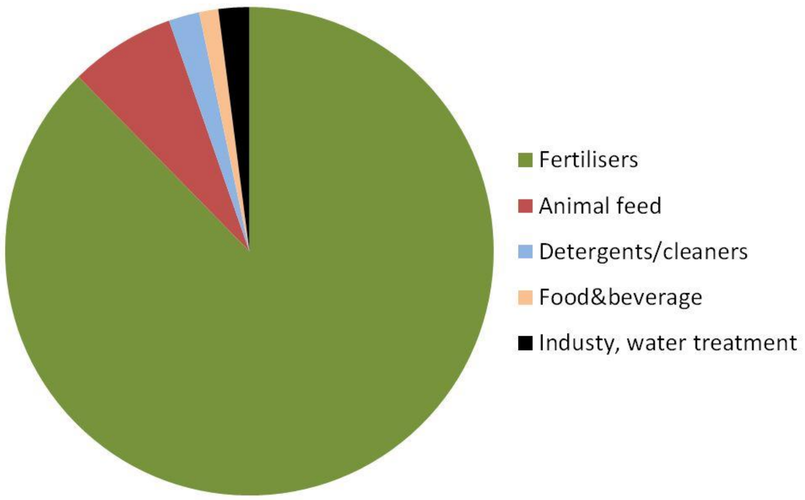
For fertiliser end-user prices see https://www.agrarmarkt-nrw.de/duengermarkt.shtm

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[vii] https://markets.businessinsider.com/news/stocks/the-fertilizers-market-is-expected-to-reach-over-245-billion-in-2020-1002227055

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[viii]
- Around 20% of flame retardants are P-based[ix]
- P content of P based FRs estimate that P <10% on average[x] by molecular weight

= c. 50 000 tP/y worldwide

P in fire extinguishers:

= c. 50 000 tP/y worldwide[xi]

Potential phosphorus demand for batteries

World demand for lithium in batteries in 2025 = 215 000 tonnes lithium carbonate equivalent[xii] = approx. 20 000 tonnes Li (based on molecular weight). Assuming lithium fluoro phosphate electrolyte = 1:1 Li-P this would be very approximately
= c. 100 000 tonnes P worldwide in 2025.

Spears et al. (2022[xiii]), based on Xu et al. (2020[xiv]), estimate that global demand for phosphorus for Lithium Iron Phosphate (LFP) batteries could, in a high scenario, reach 3 MtP/y by 2050

P in agrochemicals

The world use of glyphosate, which is the most widely used herbicide worldwide, is around 826 000 t product/year[xv] and P is 18% of glyphosate molecular formula:

- 150 000 tP/y used worldwide in glyphosate alone

This does not include use in other phosphorus containing herbicides, pesticides and fungicides.

P in phosphonates

Phosphonates are used in water treatment, water conditioning (e.g. cooling systems, osmosis and water clarification), oil recovery and drilling, medical, cosmetic and other applications. World consumption is around 60 000 t phosphonates/year[xvi] and phosphorus content is maybe <30%

- 20 000 tP/y

Potential phosphorus sources for recycling

For Europe EU27
- 1 700 000 tP/year in animal manures[xvii]
- 300 000 tP/year in sewage sludge [source as above]
- 310 000 tP/year in animal by products [source as above]
- 130 000 tP/year in food waste[xviii]

- 75 000 tP/y in food industry by-products and wastes (other than those going to animal feed)[source as above]

Compared to annual mineral phosphate fertiliser use = 1 500 000 tP/y [source as above]

Phosphorus in fertilisers and in agriculture

FAO estimates[xix] world phosphate fertiliser demand at c 21 MtP/y for 2022

EU market[xx] 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[xxi] to have decreased 50% from 2000 to 2013

Phosphorus inputs to agriculture in Europe, in ktP/year, are estimated[xxii] at:

- 2 400 ktP/y fed to livestock, of which around 9% in inorganic phosphate feed additives
- 3 300 ktP/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[xxiii] . 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[xxiv].

The US Daily Reference Intakes (DRI)[xxv] 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)

The human body contains around 700 g of phosphorus, that is around 1% of wet weight.

Phosphorus in sewage, sewage sludge, sewage sludge incineration ash

Phosphorus in raw sewage

Estimates of phosphorus in raw sewage in Europe[xxvi] include:

	in gP/person/day
- Human urine/excreta = P in diet =	around 1.5 – 1.6
- Food wastes[xxvii]	0.1 - 0.3
- Soil on laundry, bathwater	0.1 – 0.2
- Domestic detergents	assumed zero[xxviii]
- Toothpaste	0.02
- Drinking water treatment	0.13[xxix]
Total (without detergents)	**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[xxx]

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[xxxi].

Phosphorus content of sewage biosolids (after dewatering, and after digestion, composting or lime stabilisation) are 0.3 – 0.8 %P (fresh weight basis), that is 2 – 3 %P (% dry matter).[xxxii]

Phosphorus in sewage sludge incineration ash

Both bottom ash and fly ash from sewage sludge mono-incineration[xxxiii] 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)[xxxiv].

Phosphorus "efficiency"

In crop production in Europe, an average of 70% of applied phosphorus is taken up by the crop[xxxv] but it is often stated that "<20% of P mined for fertiliser reaches the food products consumed"[xxxvi].

Phosphorus losses from land to aquatic systems

Global annual losses of P from croplands to water are estimated at 0.6 (Mekonnen & Hokstra) or 3.7 MtP/y by (Lun et al.) and global discharge of P from rivers to oceans at 4 – 22 MtP/y by different authors (all secondary references in Huang 2021[xxxvii])

Eutrophication impacts

Europe

'Diffuse' pollution affects[xxxviii] 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[xxxix]

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".[xl]

USA

40% of US lakes (by number) were in the "most disturbed" condition, as compared to a reference set of lakes in 2012[xli].

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[xlii].

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[i] 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

[ii] https://www.usgs.gov/centers/nmic/commodity-statistics-and-information Numbers for "World mine production" are found in the annual Mineral Commodity Summary Phosphate Rock. Note that the most recent year indicated is an "estimate" and the this excludes smaller mines in China. By croos-referencing numbers to the publication "Marketable Phosphate Rock, Monthly" it is seen that the annual number is for "marketable" phosphate rock, not raw rock as mined.

[iii] IFA (International Fertilizer Association) annual statistics "Phosphate Rock Stats Excel File" at https://www.ifastat.org/supply/Phosphate%20Products/Phosphate%20Rock

[iv] IFA as above

[v] based on 16-22 MtP/y world fertiliser use from Cordell 2014 and Hermann et al. 2018 in SCOPE Newsletter n°128)

[vi] Jasinski, S.M., 2018. Phosphate Rock (Mineral Commodity Summaries). USGS: pp. 122–123 Retrieved from. https://minerals.usgs.gov/minerals/pubs/commodity/phosphate_rock/mcs-2018-phosp.pdf

[vii] Fertilizer Market Global Report 2017, The Business Research Company, Press Release PR Newswire 2 August 2017 https://markets.businessinsider.com/news/stocks/the-fertilizers-market-is-expected-to-reach-over-245-billion-in-2020-1002227055

[viii] https://ihsmarkit.com/products/chemical-flame-retardants-scup.html or 3 million tonnes https://www.sciencedirect.com/science/article/pii/S0306374715300464

[ix] 18% of flame retardants on the world market are phosphorus based according to https://ihsmarkit.com/products/chemical-flame-retardants-scup.html but note some inorganic phosphate flame retardants may be classified under "other" in this study

[x] 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

[xi] 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

[xii] Source: https://www.statista.com/statistics/452010/projected-demand-for-lithium-in-batteries-by-type-globally/ Another source says global lithium production 2016 = 35 000 t http://cleanenergytrust.org/enough-lithium-feed-current-battery-market-demand/

[xiii] "Concerns about global phosphorus demand for lithium-iron-phosphate batteries in the light electric vehicle sector", B. Spears, W. Brownlie, D. Cordell, L. Hermann, J. Mogollón, Communications Materials 2020:3-14, DOI.

[xiv] "Future material demand for automotive lithium-based batteries", C. Xu et al., Communications Materials 2020:1-99 (Nature), DOI.

[xv] Benbrook C. "Trends in glyphosate herbicide use in the United States and globally », 2016 https://dx.doi.org/10.1186%2Fs12302-016-0070-0

[xvi] In Nowack 2003 https://doi.org/10.1016/S0043-1354(03)00079-4 citing Davenport B. et al. CEH report: chelating agents. SRI Consulting, Menlo Park, CA, USA, 2000.

[xvii] Van Dijk et al. "Phosphorus flows and balances of the European Union Member States", 2016 http://dx.doi.org/10.1016/j.scitotenv.2015.08.048 updated by van Dijk for P-REX 2016

[xviii] ESPP estimate in SCOPE Newsletter n°122 www.phosphorusplatform.eu/Scope122

[xix] FAO « World fertilizer trends and outlook to 2022", ISBN 978-92-5-131894-2, FAO 2019 https://www.fao.org/3/ca6746en/ca6746en.pdf – page 15 : 49096 x 000t P_2O_5 in 2022 = (x 0.436) = 21 MtP/y.

[xx] Michał Wendołowski, Fetrtilizers Europe, ACI conference Amsterdam, 28 November 2018

[xxi] European Commission 2017 "CAP monitoring and evaluation indicators 2014-2020, CAP context indicators. Water quality https://ec.europa.eu/agriculture/cap-indicators/context_en or https://ec.europa.eu/agriculture/cap-indicators/context/2017/c40_en.pdf

[xxii] Derived from K. van Dijk et al., "Phosphorus flows and balances of the European Union Member States", Science of the Total Environment 2015 (estimates are for the year 2005) http://dx.doi.org/10.1016/j.scitotenv.2015.08.048 Based on 161 million hectares of agricultural land in Europe, in Van Dijk et al. cited from FAOSTAT-Land 2012

[xxiii] https://www.efsa.europa.eu/fr/efsajournal/pub/4185

[xxiv] USDA Continuing Survey of Food Intake of Individuals (CSFII) in 1994 cited in NAP 1997 below

[xxv] US National Institutes of Health (NIH) "Nutrient Recommendations: Dietary Reference Intakes (DRI)" https://ods.od.nih.gov/Health_Information/Dietary_Reference_Intakes.aspx see "Dietary Reference Intakes for Calcium and Related Nutrients" 1997

[xxvi] www.phosphorusplatform.eu/Scope071

[xxvii] The figure for food waste is higher in countries where sink grinders are widely used, e.g. Canada

[xxviii] Phosphates are banned in domestic laundry and domestic dishwasher detergents since

[xxix] Phosphates are dosed to drinking water supply to prevent plumbsolvency, so levels are variable depending on local use. The figure indicated is average for the UK.

[xxx] www.phosphorusplatform.eu/Scope071 and www.phosphorusplatform.eu/Scope103

[xxxi] Anaerobic digestion will decrease the organic carbon content of sewage sludge and will generally increase the proportion of phosphorus in soluble form, which is then 'lost' from sewage sludge in dewatering

[xxxii] UK official nutrient management guidance (AHDB) RB209 updated January 2019 http://adlib.everysite.co.uk/resources/000/279/483/RB209_Section2.pdf

[xxxiii] "mono-incineration" = incineration of sewage sludge separately, that is not mixed with other wastes with low levels of phosphorus (such as municipal solid waste, biomass or industrial sludges)

[xxxiv] BAM, Krüger & Adam, 2014, "Monitoring von Klärschlammmonoverbrennungsaschen hinsichtlich ihrer Zusammensetzung zur Ermittlung ihrer Rohstoffrückgewinnungspotentiale und zur Erstellung von Referenzmaterial für die Überwachungsanalytik" https://www.umweltbundesamt.de/publikationen/monitoring-von-klaerschlammmonoverbrennungsaschen

[xxxv] From Van Dijk et al. 2016 as above

[xxxvi] E.g. Jarvie et al. http://dx.doi.org/201510.2134/jeq2015.01.0030 Sharpley et al. 2018 https://dx.doi.org/10.2134/jeq2018.05.0170 and others, often based on Cordell et al. 2011 https://dx.doi.org/10.3390/su3102027

[xxxvii] Huang et al. 2021 "The shift of phosphorus transfers in global fisheries and aquaculture" https://doi.org/10.1038/s41467-019-14242-7

[xxxviii] European Environment Agency, EEA Report n° 7/2018 "European waters — Assessment of status and pressures 2018" https://www.eea.europa.eu/publications/state-of-water

[xxxix] European Environment Agency "Environmental Signals" (chapter 13 "Eutrophication") 2016 https://www.eea.europa.eu/publications/92-9167-205-X/page014.html

[xl] Environment Agency of England & Wales "The state of the environment: water quality", February 2018 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/709493/State_of_the_environment_water_quality_report.pdf

[xli] US EPA (2012). National Lakes Assessment 2012 Report, available here: https://www.epa.gov/national-aquatic-resource-surveys/national-results-and-regional-highlights-national-lakes-assessment

[xlii] US EPA (2009). National Rivers and Streams Assessment, 2008-2009, available here: https://www.epa.gov/national-aquatic-resource-surveys/nrsa