

## **Key aspects of fertilizers and fertilization for closing the anthropogenic and agricultural phosphorus cycle**

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Phosphorus (P) is an essential plant nutrient and a sufficient P supply is required in order to maintain a high level of crop productivity. P has an eminent and well-known relevance as an ecological contaminant, too. Thus it is vital for sustainable crop production to develop strategies and measures which maintain crop productivity without detrimental environmental impact. This can only be achieved if the agricultural and anthropogenic P cycles are closed.

About 236,000 t P accrue annually with farmyard manure in Germany, an amount sufficient to satisfy the entire P demand of agriculture. In intensive agricultural livestock production manure is often treated as a waste problem rather than an organic fertilizer and source of nutrients. Even if maximum loads will not exceed an upper limit of 170 kg/ha nitrogen, P rates outreach crop demand by far. It is necessary to limit upper P load to the average off-take of 22 kg/ha P by agricultural crops in order to avoid P accumulation in soils. In addition, recycling chains for excess manure need to be implemented.

With mineral P fertilizers about 110,000 tons P are applied in Germany each year. Sewage sludge ashes could provide approximately 66,000 tons P annually. Thus this P source might replace up to 60% of the mineral P fertilizer input if fully utilized. Urban mining of P and its beneficiation into a suitable fertilizer product will not only contribute to alleviate P supply bottlenecks and price volatility of mineral P fertilizers, but also to preserve natural phosphate rock deposits. Mono-incineration of sewage sludge combined with technical processing should deliver a product that contains P in completely plant available form and that will not yield accumulation of heavy metals in soils.

The concept of Phosphorus: 100% Zero summarizes the most important claims for a sustainable handling of the finite resource P: P in all fertilizers, mineral and recycled, must be completely (100%) plant available and without (zero) contamination of organic

xenobiotics and heavy metals. In case of heavy metals the loads should not exceed off-take by harvest products in order to avoid accumulation in soils. P fertilizer rates irrespective whether applied in mineral or organic form should match the off-take by harvest products on sufficiently with P supplied soils. Only then the input of P is truly balanced and P losses by erosion and surface run-off to water bodies will be reduced effectively.