The Future of Phosphorus Use in Agriculture

By Michael J. McLaughlin

Given the well-known fact that P is an essential component of many biomolecules in our body, and the fact that the human population will continue to grow, at least for the next five decades (United Nations, 2017), the future use of P in agriculture will continue to increase for some time. Most agricultural systems are, by definition, not closed systems due to the export of P in produce to feed this growing population, and hence there will always be a need to replace that exported P with P in farm inputs, as rates of soil weathering are too slow to match agricultural rates of P removal (Chadwick et al., 1999).

Perhaps a bigger change in the future might be the source of P used in agriculture in some countries—the source of the P used as farm inputs in agriculture has changed over the last 5,000 years (Ashley et al., 2011)—from the exclusive use of human and animal manures (which is essentially horizontal transfer of P in the biosphere), to the processing and use of igneous and sedimentary rock phosphates, which is essentially a vertical and horizontal movement of P from the geosphere to the biosphere. Now, at least in some developed countries, we have seen a move back to the recovery and use of P from human and animal waste streams for reuse in agriculture (Desmidt et al., 2015). Large-scale adoption of these technologies has been slow however, as the cost per unit P is still higher than mined P. Cost alone however does

SUMMARY

Securing the nutritional needs for our increasing population will continue to drive a healthy demand for P. Innovation will continue to broaden our viable choices for P, which combined with social drivers, will continue to generate momentum towards a more closed P cycle. Further advances in plant breeding, agronomy, and fertilizer technology are required for today's agricultural systems on soils with high P sorption capacity.

KEYWORDS:

food security; recycling; recovery; use efficiency; fertilizer technology; cycling

ABBREVIATIONS AND NOTES:

P = phosphorus; N = nitrogen

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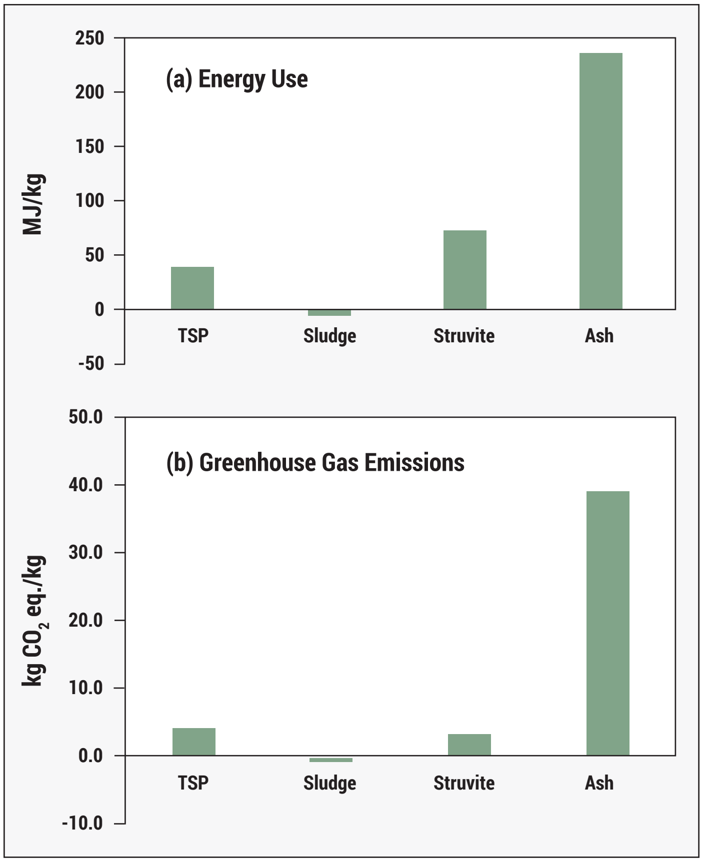

Figure 1. Energy use (a) and emissions of greenhouse gases (b) per kg P for four sources of P used in Swedish agriculture [redrawn from Linderholm et al. (2012)]. The negative values for sludge are due to credits for the N content in the material.

not take into account the externalities of energy consumption and greenhouse gas (GHG) emissions during manufacture and transport. A complete life-cycle comparison of use of P from triple superphosphate (TSP), struvite, sewage sludge and P recovered from sewage ash found that P use from sewage sludge application to farmland had the least energy consumption and lowest emissions of GHGs, but is compromised by the co-contaminants in the material (e.g., cadmium or persistent organic chemicals; Linderholm et al., 2012). Use of P recovered from sewage ash had higher energy requirements and emissions of GHGs than use of mined P (TSP) and struvite, with mined P having the lowest energy requirements (**Figure 1**). Furthermore, an important point to note with use of technologies to recover P from wastes is that the efficiency of recovery will seldom be close to 100% (Linderholm et al., 2012). Hence, there will always be some "leakage" of P to the environment (predominantly to fresh and marine waters and sediments; White, 1980).

Closing the P cycle is an aspirational goal and there is certainly room for improvement in the efficiency of use of mined P. The efficiency of P use in agriculture, and the efficiency of P transfer and capture through mined material to food to wastes has been the subject of much study and debate, as discussed earlier in this edition (Scholz and Wellmer, 2019). However, until the economic, legislative, and social drivers are aligned and favorable, global use of recycled P in agriculture will remain a small percentage of the total P use (Linderholm et al., 2012). The efficiency of P use in agriculture is also often erroneously stated to be low, when this is not the case once soil P fertility has been built up and retention or "fixation" of P is saturated; then rates of P used by farmers reduce to "maintenance" levels and the P balance efficiency nears 100% (Syers et al., 2008; Barrow et al., 2018). In those soils where the soil P status is low and P retention still strong, or where P retention mechanisms are not saturable (e.g., calcareous soils), efficiency of P use is low and it is for these situations that improvements in P use efficiency are needed through plant breeding, agronomic means, or new fertilizer formulations (McLaughlin et al., 2011). Bringing soils closer to a P balance efficiency of 100% at a lower total loading of "legacy" P is the goal, as this has both agronomic and environmental benefits (Sharpley et al., 2018).

Concluding Thoughts

While the history of P according to mankind started 350 years ago, the geochemical history of P started billions of years ago. Indeed, the origin of P on Earth has recently been questioned with a suggestion that P oxoacids were first synthesized from interstellar phosphine and delivered to the Earth on meteorites or comets (Turner et al., 2018). No matter the origin of P on Earth, mankind has been blessed that this essential element is abundant in the Earth's crust now. It is critical we use this resource wisely, to maximize crop production and quality, and minimize the environmental consequences of inefficiencies in the P cycle. **BC**

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