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The Story of Phosphorus: 8 reasons why we need to rethink the management of phosphorus resources in the global food system

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'the sustainability implications of global phosphorus scarcity for food security'

1. Phosphorus equals food

Phosphorus is essential for all living matter, including bacteria, plants and animals. We get our phosphorus from the food we eat, which in turn comes from the phosphate fertilizers we apply to crops. P fertilizer is essential for modern food production and is the limiting factor in crop yields. P is a critical global resource, along side water and energy resources.[1,2,3]

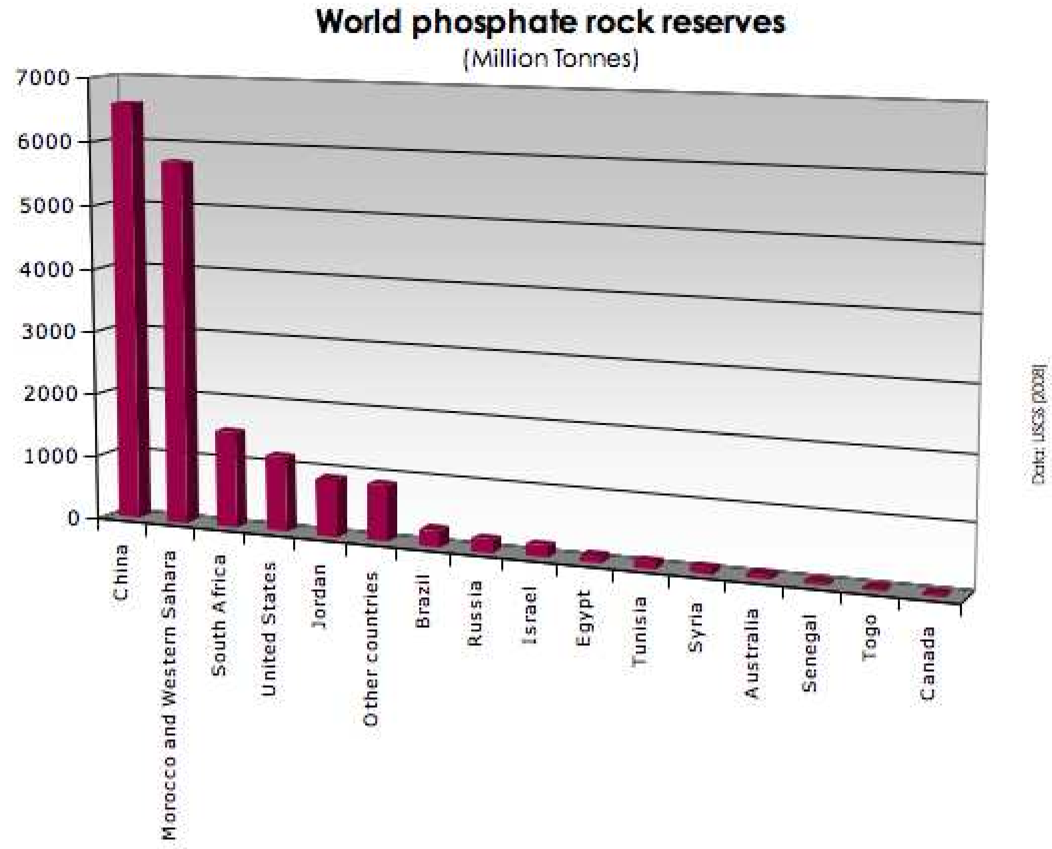
Around 90% of the phosphate rock extracted globally is for food production (the remainder is for industrial applications like detergents).[4,5]

2. A key non-renewable resource

The majority of the world's agricultural fields today rely on fertilizers derived from inorganic minerals, such as phosphate rock. Phosphate rock is a non-renewable resource that takes 10-15 million years to form from seabed to uplift and weathering, and current known reserves are likely to be depletedin 50-100 years.[4,5]

Phosphate rock reserves are highly geographically concentrated, and thus only exist under control of a small number of countries, including China, Morocco (who controls Western Sahara's reserves), and the US (see figure). The US has approximately 25 years of reserves remaining, while China has recently imposed a 135% export tariff to secure domestic fertilizer supply, which has halted most exports. Western Europe and India are totally dependent on imports.[4,5]

Importing Western Saharan P rock via Moroccan authorities is condemned by the UN and trading phosphate rock with Morocco has recently been boycotted by several Scandinavian firms.[6,7]



3. Peak P: no substitute?

Like oil and other natural resources, the rate of production of economically available phosphate reserves will eventually reach a peak, followed by a steep decline and subsequent ongoing decline of productivity. An analysis basedon industry data shows the global peak P is expected to occur around 2034 (see Peak Phosphorus).[8]

While oil and other non-renewable natural resources can be substituted with other sources when they peak (like wind, biomass or thermalenergy), phosphorus has no substitute in food production.[5]

4. Growing food demand

Demand for phosphorus is increasing globally, despite a downward trend in developed regions like Western Europe. This is due to an increasing per capita and overall demand for food in developing countries, from increasing population and global trends towards more meat- and dairy-based diets, which are significantly more P intensive.[9,10]

A balanced diet results in depletion of around 22.5kg/yr ofphosphate rock (or 3.2kg/yr P) per person based on current practice. This is 50 times greater than the 1.2 g/d/person recommended daily intake of P.[11]

Achieving the Millennium Development Goal of eradicating hunger,we must change the way we source and use phosphorus in global food production.The African continent is simultaneously the world's largest producer of phosphate rock (almost 30% of the global share) and the continent with the largest deficit in food security. [5,8]

5. Energy intensive

With growing concern about fossil fuel scarcity, we cannot afford to continue the energy intensive process of mining, processing and transporting phosphate rock and fertilizers across the global. Phosphate rock is one of the most highly traded commodities in the world.

Around 30% of energy use in agriculture in the US is fromfertilizer production and use.[12]

6. We've used up the good stuff

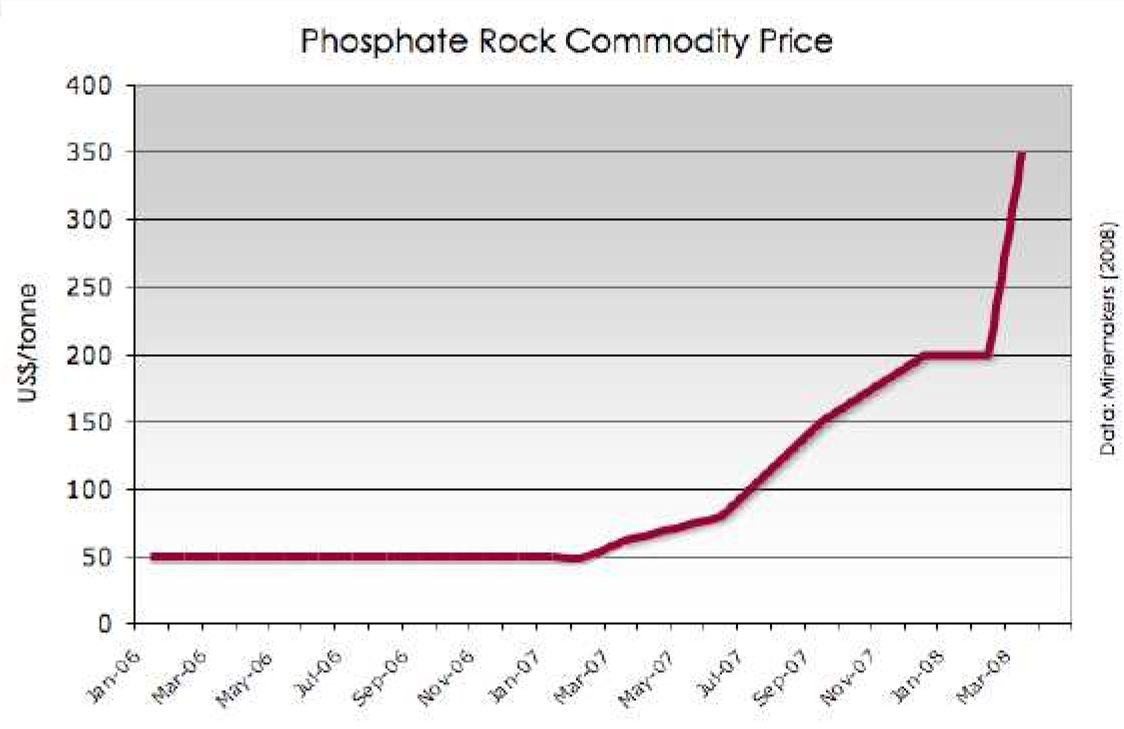
The quality of phosphate rock is declining for two reasons: the concentration of P_2O_5 in mined P rock is decreasing; and the concentration of associated heavy metals like Cadmium are increasing. The Cadmium content of phosphate rock can be very high. This is either considered a harmful concentration for application in agriculture, or, expensive and energy intensive to remove (maximum Cd concentrations for fertilizers exist in some regions, like Western Europe). [10,13,14,15]

Every tonne of P_2O_5 in phosphoric acidgenerates 5 tonnes of phosphogypsum, a toxic by-product of phosphate rock mining. Radium levels are typically unacceptably high for reuse or disposal, and thus it must be stockpiled.16

7. Cheap fertilizer – a thing of the past

The price of phosphate rock rose 700% in 14 months alone. While demand continues to increase, the cost of mining phosphate rock is increasing due to transport in addition to a decline in quality and greater expense of extraction, refinement and environmental management.[13,15]

In addition to increasing the demand and hence price of phosphate rock, biofuel demand is increasing fertilizer runoff from short-rooted energy crops to pollute waterways.[17,18]



8. Recirculating human excreta

Human excreta (urine and faeces) are renewable and readily available sources of phosphorus. Urine is essentially sterile and contains plant-available nutrients (P,N,K) in the correct ratio. Treatment and reuse is very simple and the World Health Organisation has published 'guidelines for the safe use of wastewater, excreta and greywater'.[19,20,21]

More that 50% of the worlds' population are now living in urban centres, and in the next 50 years 90% of the new population are expected toreside in urban slums. Urine is the largest single source of P emerging fromhuman settlements. [22,23]

According to some studies in Sweden and Zimbabwe, the nutrients in one person's urine are sufficient to produce 50-100% of the food requirements for another person. Combined with other organic sources like manure and food waste, the phosphorus value in urine and faeces can essentially replace the demand for phosphate rock. In 2000, the global population produced 3 million tonnes of phosphorus from urine and faeces alone.[21,24,25]

Unlike phosphate rock, which only exists in a handful of countries' control, urine and faeces are available from any community or city,and hence can contribute to 'phosphorus sovereignty' and food security.[8]

In material flow terms, human excreta represents a readily available 'exchange pool' of phosphorus, before it is 'lost' to the hydrosphere typically as treated or untreated effluent discharged to rivers and oceans. If urine is reused as a fertilizer, then less phosphorus (in urine) is entering waterways, reducing the potential to cause toxic algal blooms.[11]

Although preventing phosphorus point sources from entering water bodies is often necessary to prevent water pollution, removing high levels of phosphorus at the wastewater treatment plant is expensive and energy intensive. Capturing urine at source (at the toilet) can be much more energy efficient and cost-effective and does not contain heavy metals like Cadmium.[11,26]

The cost of ecological sanitation systems around the world could be offset by the commercial value of the phosphorus (and nitrogen) they yield in the future. Particularly in Africa where synthetic fertilizers typically cost 2-5 times more than in Europe. A community ecological sanitation toilet in Tamilnadu, India, now pays users, recognising the fertilizer value of their urine and faeces.[27,28,29]

References

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