EXPERT SEMINAR ON THE SUSTAINABILITY OF PHOSPHORUS RESOURCE

Supply picture

Recent studies contain diverging numbers for reserves – 60 – to over 80 GT. It seems most probable that the known reserves[1] are around 60GT – known resources[2] are perhaps five to ten times higher.

Production is mainly concentrated in Morocco, US, China and Russia, although some production in more than 35 countries. Reserves from Morocco make up a large part of the new reserves that have been documented in recent studies – it is not clear whether this is all economically producible at the present time or if part is more resource than reserve. In addition, there are numerous deposits in countries that are not currently counted in some of the studies on reserves although studies are ongoing and covering an increasing number of countries.

Discrepancies in recent global production figures are probably largely due to differences in Chinese statistics since only production from large mines were declared in official figures, and not the output from the numerous smaller mines.

The accumulated P in soil needs to be taken into account for the supply picture as it is a big bank of P in the future. In China, it has been estimated that 85 million tonnes has accumulated in the soil since 1985.

New exploration, limitations and costs of extraction, gains in efficiency notably in Chinese mining, resources in important areas of environmental concern, etc are modifying the picture on reserves and resources. Many new phosphate mining and fertilizer processing projects are due to come on stream in the next 15 years. In more general terms, reserves are dynamic – as the price and technologies evolve so do the reserves. Resources can become reserves with technology changes, increasing prices for phosphate rock and changing political and regulatory attitudes.

Information and monitoring

There is a need for more assessment of the supply and demand position on phosphate rock. The Technical University of Zurich with IFDC are planning a five year study encompassing this and other issues. FAO maintain statistics on fertilisers, but not on phosphate rock – open question as to whether monitoring on P rock needs to be 'institutionalised'.

More information is needed on **fertilisation practices**, to have a better picture of the reality of what is happening on the ground.

Wider issues (including environmental)

Divergences between countries and continents in terms of supply picture – parts of Africa are independent in terms of reserves. Other continents have the opposite picture –Europe, S Asia very dependent, and more are going that way. **Security of supply** concerns may well be an

[1] Supplies of phosphate rock that are available with today's technology and are currently economically producible
[2] Total supplies of phosphate rock, including in the oceans, that may be available in the future

issue with some countries if production were to decline significantly – political stability of the producing countries is an issue in some cases; including countries containing some of the largest mines producing quality phosphate rock. This is linked to agricultural production prices, and how public opinion deals with dependency on other countries for fertilisers and hence agricultural production.

There is an interest in extracting **uranium** which is present in some phosphate deposits – not clear how this might affect the supply position. In order to remove the U, the phosphate rock must be processed to phosphoric acid and eventually used to produce other products; U production is essentially coupled with downstream production and cannot be separated.

Competition for the low **cadmium** level reserves might also be an issue – for environmental, mainly food security reasons, European countries demand low cadmium products, and regulation of cadmium in fertilisers in Europe is in the process of tightening – will lead to higher processing costs for fertilizers that meet these standards. Cadmium can be removed via various techniques but the costs are significant.

Demand for **rare earths** and some metals is likely to increase and this might be a revenue stream for phosphate mines – but more of these components are found with igneous phosphate deposits – sedimentary deposits are more associated with less desirable impurities. Igneous are less abundant P sources than sedimentary.

Some resources (but not reserves at present) are in environmentally sensitive areas – Arctic, Southern US, offshore which for the moment are not considered to be available for mining. In some cases it might be necessary to delay projects until environmentally acceptable technologies are available. Overburden and waste are significant cost factors for phosphate mines as would eventually be mining from the seabed.

Demand

Demand for P rock has been only slowly growing over the past 20 yrs – but what impact will growing population, dietary shift and depleted soils, notably in Africa have? It is very likely that demand will rise, at least until 2040-2050 and then level off or even decline due to potential population stabilization and probable efficiency gains from that point.

Some previous theories that phosphate rock production peaked in 1988 - now demonstrated that the decline between 1988 and 1993 was caused by the severe collapse of P fertilizer demand in the former Soviet Union and a consequent massive reduction in phosphate rock production in Russia.

Two major contributors to the reduction in P rock production in the USA include a significant reduction in the export of P fertilizers (notably to China) and a slight structural reduction in P fertilizer demand in the United States. In China, the rapid increase in P rock production since 2000 was driven by a significant expansion of new capacity of P fertilizers, thus production that was implemented with the objective of reducing the China’s high import reliance. In effect, Chinese P fertilizers production doubled between 2000 and 2006. By 2006 China became self reliant in its P fertilizer requirements and has since emerged as a major exporter of P fertilizers. A diminution of exports and a lowering of P fertilizer consumption in China through soil build up and enhanced nutrient efficiency use would reduce China’s requirement for P rock.

Role of biomass and biofuel

Biomass burning or bioethanol production may lead to unavailability of phosphate resource, but if the ash from biomass is used as a soil amendment product or a fertilizer, or the by-product from the bioethanol is used in e.g. animal feed, then this is not necessarily so.

On the other hand, increasing the land area farmed due to biofuel production will likely lead to higher fertilizer needs to maintain or increase soil fertility on this land.

Consumption patterns

Greater **meat and dairy consumption** worldwide certainly an issue – but complex – some technology solutions are available (phytates etc) but will not resolve all demands. This is an issue of land use in that there is a maximum arable capacity due to topography, soil conditions, urbanization, rainfall limitations and other factors.

Overall balance between demand and supply – likely impact

Following recent updating of the figures, the number of total years of known available phosphate rock reserves is not the key aspect – it could be 200 (no increased efforts at recycling) or 400 (very considerable improvement), or much longer.

However, **factors outside the control of importing countries** (such as unavailability due to political instability) could upset that calculation. Linked to this, it is important to note that temporal distribution (how much is available when) is not the only factor – spatial distribution is very important – both in the sense of where the P is available and where it is used (urban vs rural) and geopolitically in terms of security of supply.

Depletion of low cost P rock in US and China within 50 yrs is a possibility and would have significant market effects – but optimising use and preventing export would delay this. Reasons for US/China depletion could be economically driven, but US limitations in production could be more politically or legally driven (land use, environment protection factors) as the US has vast resources of phosphate rock in several areas of the country.

The principal issue is that it is **unacceptable to waste P**, because as with most resources, the lost P brings with it pollution of other resources or increased demand for others (energy, water and so on) in its extraction and use cycle.

Need to take into account how manure and **recycling** of other sources affects and could affect overall balance. With social economic development (more meat eating worldwide), manure from animal husbandry should play an important role as a factor in modifying P balance. Phosphorus recycling from animal production to crop production will be a key option for sustainable grain production in the future although specialisation in livestock farming worldwide and transport costs for manure will make this difficult to achieve.

Also, need to take into account that putting in place recycling infrastructure could be slow work, so we should not bank on a rapid transformation to a P recycling society.

How could we have more recycling of P (in general)?

In theory, world could simply recycle all the P in circulation forever – P not that easy to lose as long as it doesn't go to the sea (but a lot currently does…)

There have so far been few **clear governmental or institutional statements** that P should be recycled – therefore not surprising that P has not been the focus of much recycling effort – no legislative or political pointers in that direction. Some initiatives now starting: The association of Waterboards in the Netherlands have recently put in their policy statement incentives to stimulate the recovery of phosphorus from municipal waste water. Sweden has an environmental goal decided by its parliament, to recycle 60 % of the phosphorus from wastewater as fertiliser, and half of these 60% back to agricultural land, at the latest in 2015.

Significant progress could be possible by 2050, but still barriers to this. One level of ambition could be to seek to arrive at **stability of mineral P inputs** by then – in other words, no need to increase the amount of P being mined, even taking into account regional P deficiencies.

To calculate the different potentials for P recycling, need to separate P from erosion, from landfilling of organic materials and P loss in sewerage systems, and filter out background losses (natural erosion). Very hard to put an overall figure on recycling potential. See comments above on more monitoring of fertiliser practices.

Factors affecting P recycling

Recycling possibilities are modified by trends in **urbanisation** – creates some difficulties (distance from water treatment plant to field) but also some opportunities – concentration of P source.

Energy needs for recycling (moving of water around in particular) might be comparable to moving P rock in some cases. Need perhaps an LCA[3] to compare some of these options.

Fertiliser prices have risen – and this should have a beneficial effect on economics of P recycling, and therefore on the mobilization and implementation of recycling efforts.

Concentrated and specialised livestock farming worldwide as well as Europe (eg, NL, DK, Brittany, Po valley) results in P soil saturation in some areas while in arable areas soil P is continuously depleted and needs replacing. Breaking this cycle is both financially very costly and structurally very difficult.

Need to make it clear that recycling of P is not a threat to producers – timescale is such that they can adapt to how this impacts on demand, particularly given likely rise in demand driven by population growth and need to generate soil fertility in parts of the world while in any event, some losses are inevitable.

Optimal solutions

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[3] Life Cycle Assessment

It might be best to focus on **use efficiency** as the major gains may be here. Notably, instruments that just affect the input side of the equation (e.g. blunt tax on fertilizer) would be less efficient than instruments that improve the use efficiency i.e. by stimulating practices that reduce the surplus (input minus output) per unit area and per unit product.

We should change from traditional approaches (P waste) to a P cycling and reuse concept through improved education and training programmes – especially for farmers.

In terms of solutions we should go with the scientific evidence, but take account of **cultural factors** – both public perception and the weight of past inappropriate use of some of this recycled material. This is especially relevant for P from sewage sludge, but also perhaps for some animal by-products. Resistance from farmers and consumers to some uses is clear.

What might be the solutions (in more detail)?

Mining

Extraction now rather efficient in many mines, up to 95% of prospect estimates. But still potential to improve extraction technologies, digging techniques, benefication techniques, reuse of process water, use of by-products, processing of tailings in many cases. Deposits that are currently considered unworkable may be producible using new technology. Deposits that are considered unsuitable for conventional products may be suitable for unconventional products. Situation varies from mine to mine. Some by-products currently inexploitable for technological and economic reasons.

Some good economic drivers for improvement, but permit conditions, public pressure and economic sustainability can also be a driver.

Animal feed and other biotech

Phytase a partial solution but only for monogastrics. Even though Phytase largely accepted by the market, still room for technological improvement. The benefits of phytase are variable and depend on use of manure. If the manure is used well the benefit is small. If the manure is either not used or applied based on nitrogen content the benefits of phytase are bigger. Overall effect is limited as inorganic feed industry only accounts for 6% of yearly P consumption.

Biotechnology can offer solutions in a number of areas, for instance for improved up-take of P by use of microbial inoculants. It is not a magic bullet for general use, but it has potential for targeted applications and for integration with other agricultural practices.

Farm scale measures

Major gains at farm scale probably to be found in appropriate fertilisation practices (esp manure use - increasingly evident in EU) and erosion control. Numerous options available in terms of crop combinations and other agronomic approaches to tackle different soil P status situations, whilst using the minimum P necessary. Other soil conditions, such as compaction, and tackling soil erosion also part of the context. Catch crops, buffer zones all been tried for quite some time. More specific application techniques would definitely help – sub-surface placement or positioning.

Maintenance of soils phosphorus status is the key – should not over deplete or saturate in order to have efficient cropping. Once adequate phosphorus status in soil achieved, simply a question of replacing what the crop is taking although soil erosion can weaken this.

One option to look at is how to efficiently use or explore the accumulated P resources in soil by rhizosphere management i.e. by manipulating the chemistry and biology of the rhizosphere, the narrow layer of soil surrounding roots to increase P mobilization and acquisition.

Land tenure and short term outlook from users who don't own the land could be a limit to these approaches especially but not exclusively in the developing world. Specialisation in agriculture also not helpful, but impossible to turn back the clock to mixed farming. Hard to line up intensive livestock areas and intensive arable areas.

Fertiliser prices also likely to have a significant impact on manure use, and value attached to manure.

In intensive agriculture in China, too much P was used/applied in past 20 years, causing available soil P as Olsen P to increase from 7 ppm in 1980 to 20 ppm in 2006. In 1980, close to 80% of cropland in China contained less than 10 milligrams of phosphate available to plants per kilogram of soil — indicating a phosphate deficiency. Since then, the Chinese government has created a series of policies to encourage the production and use of phosphate fertilizer. But with phosphate use increasing at a rate of 5% per year, 85 million tonnes has accumulated in the soil. The average phosphate content in the soil has nearly tripled and only a quarter of cropland is deficient in this nutrient now. This process has greatly increased crop production, but has also led to eutrophication and similar problems – now looking to reach a balance.

Waste water and sewage sludge

Sewage infrastructure basically designed for public health reasons. Now currently focused on existing legal obligations – removing P in order to prevent eutrophication.

Legal, political and technological situation on sewage sludge varies widely throughout the EU. Some MS using 2/3 or more of their sludge in agriculture - around 41% of phosphorus from sewage sludge across the EU is currently recovered and reused in agriculture.

Economic incentives for phosphorus recovery can be positive where sewage sludge treatment is already relatively expensive. Phosphorus recovery can have a positive economic effect because of the reduction of the amount of sludge to be treated.

Struvite is one option for recovering the P from sewage sludge, where this is not too dilute or side stream treatment in combination with digestion of sewage sludge is applied.

For efficient P recycling and safe food production, P applied into soils from waste water should be plant available and recycled materials should not contain harmful elements. Handling such **contaminants** in water treatment facilities can be very expensive but source separation has been implemented in some Scandinavian countries, the Netherlands and other places. In order to avoid non-sustainable end-of-pipe solutions, unwanted contaminants must be avoided upstream, at source, before discharge of wastewater to the sewage system. A range of legal and technical measures exists to ensure this. The success of this policy is demonstrated by the substantial decrease in concentration of heavy metals in sewage sludge in Member States. There are limits to how often compost can be cycled without concentrating contaminants.

Direct use from sanitation systems can be part of the answer in developing countries – use of urea and excreta.

There are some possible policy actions that could represent low hanging fruit, for example improvement of some processes in removing P from waste water.

More research is needed to more precisely decide the plant-availability of recovered phosphorus, related to different treatment methods, soil conditions and crops.

Detergents

Only minor gains to be found in Europe, as industry works already to reduced P or P free detergents. Overall P use in detergent industry limited, but worldwide, P free detergent may play a part.