Peak phosphorus!
Is it a threat?

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2008: Attention to phosphorus depletion takes off

Phosphorus depletion: the invisible crisis

Scientists warn of lack of vital phosphorus as biofuels raise demand

Some initial analyses with the Global Phosphorus Research Initiative estimate that there will not be sufficient supplies from mining to meet agricultural demand in 30 to 40 years.

Should we not have a look whether this is correct?
Motivation of behind peak phosphorus

Oil production USA

P, Nauru

P, USA

Oil production World

World liquids production: ultimate 2000 Gb conventional + 750 Gb non-conventional

World rock phosphate production

Netherlands Environmental Assessment Agency (PBL)
Resources and reserves

- Economic extractability
  - Not economic
  - Enhanced recovery
  - Sub-economic

Probability of being there

- Proved
- Probable
- Indicated
- Inferred
- Hypothetical
- Speculative

- Speculative unconventional
- Speculative conventional
- Unconventional
- Reserves

McKelsey diagram/ Rogner 1997

Netherlands Environmental Assessment Agency (PBL)
Resource estimates in the literature

USGS
1. For each region, we identify 8 resource categories. Model “eats” through these categories one-by-one

\[ Q_{j,q} = \min \left[ Q_{0,j,q}, \max \left[ 0, Q_{0,j,q} - \left( \int_{t=0}^{t} \text{Prod}_j - \int_{1}^{q-1} Q_{0,j,q} \right) \right] \right] \]

2. Each category is assigned a typical production costs. Costs rise linearly within each category. Regional production costs equal currently producing category.

\[ c_j = c_{0,j,q} + \frac{Q_{0,j,q} - Q_{j,q}}{Q_{0,j,q}} (c_{0,j,q+1} - c_{0,j,q}) \]

3. Each region can supply “P” in each other region. Market shares are assigned on the basis of productions and transport costs

\[ P_{ij} = D_i \frac{e^{\lambda (C_j + T_{ij})}}{\sum_j e^{\lambda (C_j + T_{ij})}} \]

4. Demand for phosphorus is determined for each region on the basis of population, agricultural production (exogenously to the model)
Current phosphorus flows
Use the 4 MA scenarios to create demand projections

<table>
<thead>
<tr>
<th></th>
<th>Global Coordination</th>
<th>Order from Strength</th>
<th>Technogarden</th>
<th>Adaptive Mosaic</th>
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<tbody>
<tr>
<td>Storyline</td>
<td>Rapid economic growth; focus on development; global cooperation</td>
<td>Divided world; focus on security issues; low economic growth in developing countries</td>
<td>Rapid technology development; focus on ensuring ecosystem services</td>
<td>Focus on regional development; protection of ecosystem services</td>
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<td>2100: 66460</td>
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<td>2100: 31420</td>
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<td>Agriculture</td>
<td>Rapid expansion of agricultural production, animal husbandry</td>
<td>Expansion of agricultural areas in developing countries</td>
<td>High yields compensate roughly the increase in agricultural demand</td>
<td>Slow expansion of agricultural areas in developing countries</td>
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Netherlands Environmental Assessment Agency (PBL)
Use the 4 MA scenarios to create P demand projections

2-3 times growth in P demand
Global P-rock production

Model performs (surprisingly 😊) well
Future production: Especially production in Africa, China…. USA, Middle East, FSU
Depletion of resources (global)

By the end of the century 40-90% of resources left. But certainty of resources being there decreases.
Depletion of resources (regional)

USA, SAm, ME, India, China, South-East Asia, Western Europe major importers (2050)

Northern Africa is likely to dominate production (much more oligopolistic market than oil)
Concentration of supply

Share of Africa increases to nearly 60% of all production. Focus on limiting inputs works only partly.
Options to reduce demand

Options for improvement:
1. Reducing food waste
2. Optimise (reduce) fertiliser use in developed countries
3. Reducing soil erosion
4. Recycling of manure, human excreta, crop losses, sewage waste
5. Reduce extraction losses
Policy scenarios

Measures could help, but in sustainable development scenarios avoiding soil depletion, more bio-energy production and hunger reduction could also increase production.
Conclusions

- Our analysis indicates that there are no signs of short-term to medium-term depletion.
- In the longer term, the depletion of low-cost and high-grade resources will have consequences for future production trends.
  - Optimistic viewpoint: lot of P left even at the end of century
  - Pessimistic viewpoint: Risk that less than 50% is left at end of the century. As there are no substitutes to P this is a serious threat.
- It is important to pay more attention to data on P resources.
  - Relatively little data (resources, consumption of different categories, ultimate fate)
- Phosphate rock depletion may lead to concentrating production to a few countries
- Major reductions in the use of fertiliser P can be achieved by improving plant nutrition management, better integrating of animal manure and recycling P content in human and/or animal excreta.
Calvin and Hobbes

Once you know things, you start seeing problems everywhere... and once you see problems, you feel like you ought to try to fix them...

And fixing problems always seems to require personal change...

...and change means doing things that aren't fun! I say Phooey to that!

But if you're willfully stupid, you don't know any better, so you can keep doing whatever you like!

The secret to happiness is short-term, stupid self-interest!

We're heading for that cliff.

I don't want to know about it.

I'm not sure I can stand so much bliss.

Careful! We don't want to learn anything from this.