Steering Committee for Technology Assessment

Ministry of Agriculture, Nature and Food Quality

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Phosphate – from surplus to shortage

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Policy memorandum of the
Steering Committee for Technology Assessment
of the Ministry of Agriculture, Nature and Food Quality

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This policy memorandum is based largely on the report *Phosphorus in agriculture: global resources, trends and development* by A.L. Smit, P.S. Bindraban, J.J. Schröder, J.G. Conijn and H.G. van der Meer of Plant Research International B.V., Wageningen, which was commissioned by the Steering Committee for Technology Assessment. Valuable commentary was provided by the Nutrient Flow Task Group and by members of the Steering Committee for Technology Assessment.

1. Introduction

This policy memorandum concerns an impending shortage of phosphate. Since the 1960s, phosphate in the Netherlands was primarily known as a problem of excess, a contamination problem in the form of overfertilization of water and soil. However, the present memorandum concerns the problem of *shortage*: the long-term depletion of mineral sources. If such a shortage occurs, this will have enormous consequences for agriculture and, consequently, the world food supply. This is because phosphorus is an essential nutrient for plants and animals; there is simply no alternative.

Until now, the discussion about global reserves of resources has focused primarily on the energy carriers, and increasingly on water. Although these problems are both serious, in a certain sense the threatening shortage of phosphorus is even more serious. Sustainable energy sources, such as sunlight, are abundant. It is primarily a matter of cost, although the supply of some metals can have a limiting effect because they are necessary for converting sunlight into electricity. By definition, water is part of a cycle, which as a whole is not decreasing in magnitude; as a result, there is not an absolute shortage of water, although signs of increasingly serious local or regional shortages are appearing. Theoretically, fresh water can also be extracted from salt water, although this requires energy and money. In contrast, phosphorus is a finite resource – in the sense that phosphate ores are becoming depleted – and after being used in agriculture, the mineral ultimately becomes unavailable for reuse, or can be reused only to a very limited extent. In short, once the phosphate is depleted, no more will be available, at least with current technology. Phosphate builds up in agricultural soils, it ends up in the sludge from water treatment plants – which is largely incinerated and thereby removed from the agricultural cycle – but mostly it is eroded, thereby ending up in the sediments of lakes, coastal seas and the ocean.

Besides an absolute shortage of phosphate, there is also the problem that a large proportion of the reserves are concentrated in only a few countries. Even before a physical shortage occurs, this concentration will lead to phosphate becoming a geopolitical topic, resulting in international tension and serious imbalances in availability.

This policy memorandum based largely on the report of Plant Research International B.V., Wageningen, which was commissioned by the Steering Committee for Technology Assessment of the Ministry of Agriculture, Nature and Food Quality, and which will be published simultaneously with this policy memorandum. For substantiation of the content of the present memorandum, please refer to the above report. In this memorandum, the following topics will be addressed:

- the demand for phosphate
- the supply of phosphate
- the depletion of phosphate reserves
- possibilities to avoid the coming scarcity
- the relationship with environmental and nature policy
- proposals for research and policy.

2. The demand for phosphate

Phosphorus (P), as an element in phosphate compounds, is an essential nutrient for all life on Earth, from micro-organisms and plants to animals and people. It is “essential” in the sense that there is no alternative. It is essential for the energy system in the cell and for building bones, membranes and genetic material (DNA and RNA).

The body of an adult human contains approximately 650 g of phosphorus. Every day, people need to consume approximately 0.7 g of phosphorus, while the consumption in Western countries is estimated at 1.7 g of phosphorus per day and in developing countries at 1.2 g. The phosphorus level in the human diet is therefore adequate. However, the core of the problem is the availability of phosphate for agriculture. The natural level of phosphate in the soil is very low and is limiting to plant growth. Before the industrial revolution, a phosphate concentration that was necessary for a good harvest could be obtained, for example, through sedimentation caused by flooding, by using the manure from grazing livestock and by recycling human excreta. Phosphate was a limiting factor nearly everywhere on Earth.

A breakthrough occurred in the 19^{th} century by means of the external application of phosphate as a fertilizer, where the mineral originated outside the area to be fertilized. Around 1850 the first phosphate-rich fertilizer was used in the form of guano from South America. This was quickly followed by the use of Thomas slag or phosphatic slag, a waste product of the steel industry, and finally by mined phosphate rock, known at the time as “mineral fertilizer”. As a result of this external source, the local phosphate cycles were broken; at the same time, this created the basis for a potential shortage in the future.

This external application of phosphate (and other fertilizers) from external sources was one of the preconditions for the increase in the world population from approximately 1 billion people in 1850 to the current population of 6.8 billion. This factor was much more important than the increase in agricultural production area.

Worldwide, 17.8 Megatons (= 1 million tonnes, or Mt) of phosphorus is used every year as a fertilizer, with large differences in usage between various countries. China is responsible for approximately 30% of global phosphorus consumption, India 15%, the USA 11%, while the EU-15 used 7% (figures from 2004), which indicates a greater correlation with the size of the population than with the size of the economy. For that matter, phosphorus is also used in other sectors besides agriculture: worldwide, 11-12% goes to industry, especially for the production of detergents.

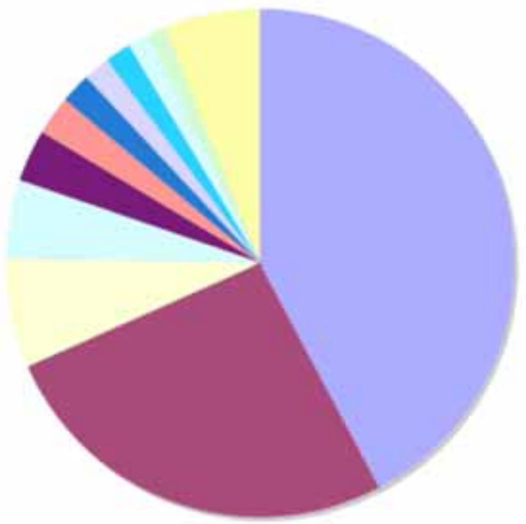
The worldwide use in agriculture corresponds with an average application rate of approximately 13 kg P/ha of arable land per year. However such a global average says little; in fact there is a split in consumption between industrialized and developing countries. In industrialized countries the fertilization level is high; for example in Europe, approximately 25 kg/ha of arable land per year is applied. The aim is to maximize the harvest, for which a significant overfertilization with phosphate is often used. Partly due to a surplus of animal manure, phosphate is building up in the soil and is largely fixed in a form which is no longer directly available to plants: phosphates of iron, calcium and aluminium. In developing countries, on the other hand, the level of fertilization is much lower. In Africa, for example, the average is only 2 kg/ha of arable land per year. Especially in sub-Saharan Africa, little phosphate is available. Moreover, a large proportion of the phosphate that is applied is lost to water erosion or wind erosion. The worldwide loss as a result of erosion is estimated at 20-30 Mt P per year, which ends up in the sediments of rivers, lakes, coastal seas and oceans.

The worldwide use of phosphate doubled during the period 1965-1990. After this, the use remained relatively constant until 2005, but in recent years there has been another increase (see the points in Fig. 4). The increase is therefore not proceeding gradually. Besides population growth, other factors apparently play an important role as well. For example, the reuse of human excreta has declined sharply in China in recent decades, especially in urbanized regions.

3. The supply of phosphate

Phosphorus is not part of a global ecological cycle, but it is part of a geochemical cycle. Besides recycling within natural ecosystems, at the global level there is limited recycling via fisheries and seabirds, where phosphate (altogether 0.3 Mt P per year) is returned from freshwater or salt water to the land. But in general terms, this concerns a one-way flow from the reserves in the mines and from erosion of arable land to the sentiments of lakes (including water reservoirs), coastal seas and the oceans, and via industrial processes and power plants to combustion ash and slag, and from there into cement. In specific regions, such as the Netherlands and parts of the USA, phosphate is building up in agricultural soils. This phosphate build-up can eventually become so great that leaching will occur. Recycling from ocean sediments takes place during a period of tens of millions of years by means of volcanism and the rise of ocean floors, followed by weathering (tectonic lift). It also takes place via the upwelling of ocean water, such as that off the coast of Peru.

The geographical distribution of the most important reservoirs of phosphate ore is shown in Figures 1a and 1b. These figures show the sum of the immediately extractable quantities and the reserves that are potentially extractable with higher prices and improved technology. The immediately extractable quantity is approximately one-third of the total reserve. Depending on the price level and the development of technology, new reserves will continue to become extractable.



	Extractable	Potential	Total	Total %
Morocco en W. Sahara	760	2.040	2.800	43
China	880	853	1.733	27
United States	160	293	453	7
South Africa	200	133	333	5
Jordan	120	107	227	3
Australia	10	150	160	2
Russia	27	107	133	2
Syria	13	93	107	2
Israel	24	83	107	2
Egypt	13	88	101	2
Tunisia	13	67	80	1
Other countries	119	175	293	4

Figure 1a. Total phosphorous reserves per country (the sum of the immediately extractable quantity [total 2,400Mt] plus the potentially extractable quantity [total 4,200 Mt]). Source: Jasinski 2008 (see report).

At this time, there are no prospects of new discoveries. However, there are possibilities for new technologies to extract phosphate from the “potentially extractable reserve”. As part of phosphate mining, quality aspects are also very important; the level of contamination of the

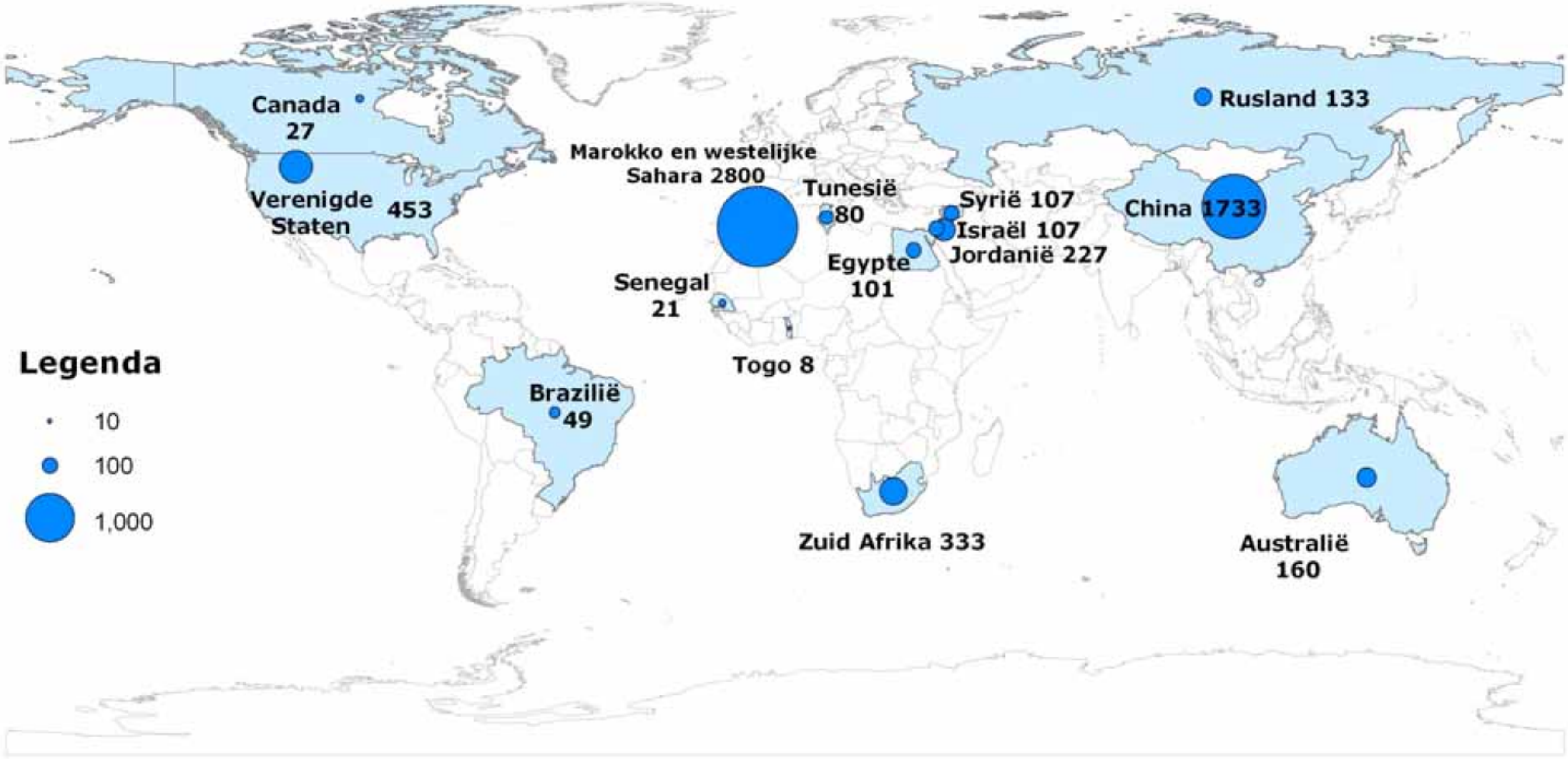


Figure 1b. Total phosphate reserves per country (total of the extractable quantity plus the potentially extractable quantity). Source: Jasinski 2008.

phosphate differs greatly between the locations at which it is found. Especially when sedimentary rock is used – the largest source of phosphate ore – there is significant contamination with organic material, clay, sand, iron, and various metals. Regarding metals, the toxic metal cadmium and the radioactive metal uranium are of the greatest concern. With increasing scarcity, it is expected that the quality of the phosphate will decline. Purification is technically possible, but will be expensive. An additional aspect is that in various countries, especially Morocco and the USA, the uranium that is present in rock phosphate appears to be economically feasible to extract. The quantities are even greater than the currently known uranium reserves.

Figure 1 shows that there are large differences in the presence of the ores between continents and within continents. The largest reserves are found in Morocco (including Western Sahara) and China, followed at a distance by South Africa, the United States and Jordan; in Europe, the only reserves are located in Russia and Finland. The largest producers at this time are (in order of magnitude) China, the USA, Morocco/Western Sahara and Russia.

The EU is almost entirely dependent on imports of phosphate; very little is mined in the EU. Import takes place in two forms: artificial fertilizer and animal feed. In total, 1.6 Mt P per year is imported, where the phosphate contained in animal feed ultimately ends up in animal manure. The total phosphorus import of the EU concerns nearly 10% of the entire world production of artificial phosphate fertilizer. It is important to note that the EU, other than is usually assumed, is not at all self-sufficient in food production due to this phosphate dependency.

4. The depletion of mineral phosphate reserves

The first signals of imminent scarcity can be seen in the recent price developments for phosphate (see Figure 2).

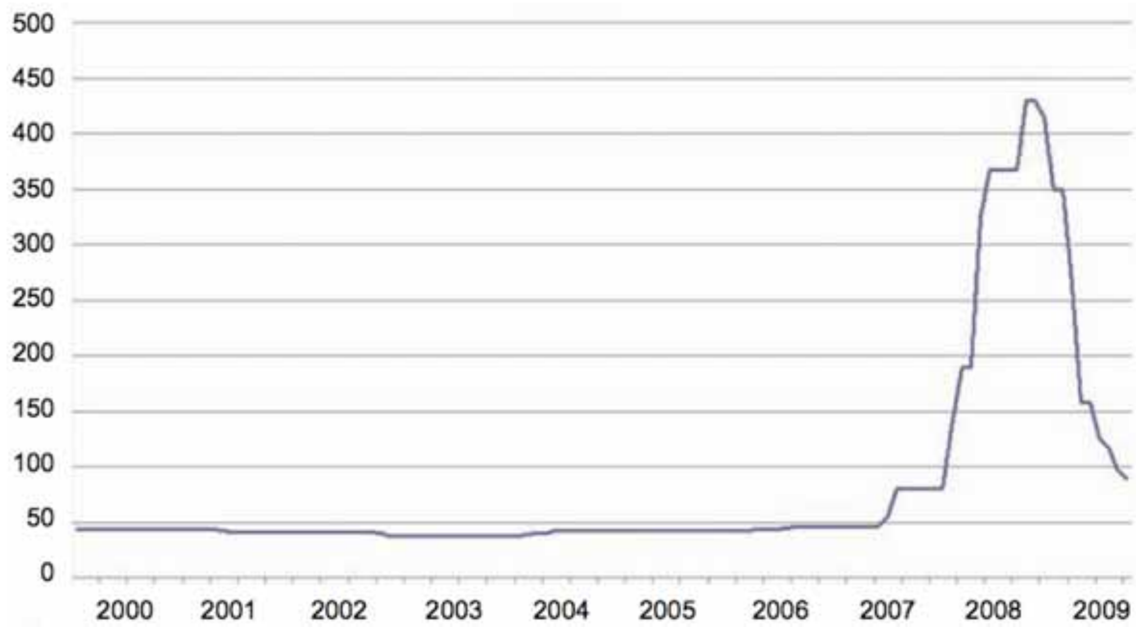


Figure 2. Development of the phosphate price, shown in $ per tonne of rock phosphate. Source: www.mongabay.com, using data about goods prices from the World Bank.

There is a tight market with rising demand and a limited increase in production capacity. Consequently, any sign of scarcity leads immediately to a sharp increase in price. During the recent price explosion, the temporary tariff imposed by China on phosphate exports possibly played a role, in addition to other factors such as increasing prices for energy and food.

In more fundamental terms, we can make a comparison with the *Peak Oil Theory* of King Hubbert (see Figure 3). This figure shows the actual cumulative development of oil production per country until 2004. The figure next to each country shows the year when the oil production in that country will began to decline. The curve as a whole indicates that the peak in world oil production should be reached right about now. The years to come will show whether this prediction was correct.

In a comparable fashion, we can refer to *Peak Phosphorus Theory*, which indicates a future peak in phosphate production (see Figure 4). However, this theory has not yet been worked out in detail; the figure contains only global data, and there is certainly no consensus about the continuation of the curve. However, this curve is reasonably consistent with the predictions that will be presented below.

For additional analysis of the future development, scenarios can be created that include different assumptions about consumption compared with reserves. We will briefly discuss two scenarios:

- a *constant consumption scenario*
- a *trend scenario.*

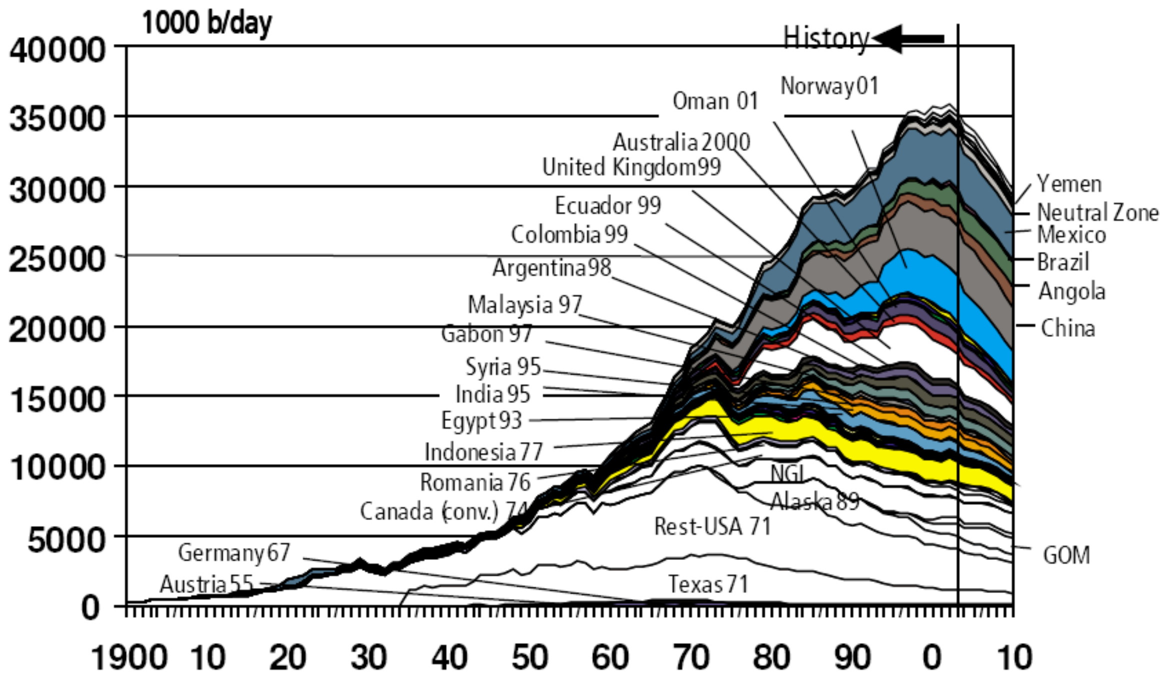


Figure 3. Peak Oil Theory according to King Hubbert. Source: Industry database, 2003 (IHS 2003), OGJ, 9 February 2004.

In the first scenario, there is a continuation of the current consumption level of 19.3 Mt P from rock phosphate per year. In this case, there are sufficient reserves for 125 years if we assume the currently extractable quantity, and 340 years if we also include the potentially extractable quantity. In the trend scenario, the following assumptions were made:

- increasing consumption of 0.7% per year until 2050, paralleling a population increase to 9.2 billion people during this same period;
- a stable population after 2050, with the additional assumption that the global food consumption pattern will move towards the Western diet, with larger quantities of meat;
- replacement of 10% of the fossil fuels used for transport with biofuels, for which phosphate is also required.

With these assumptions, depletion of currently extractable reserves will take place after 75 years, and total reserves will be depleted after 170 years. Losses during extraction, about which there is little clarity, can lead to even more pessimistic estimates.

The trend scenario provides more realistic points of departure than the constant consumption scenario, and is consistent with the consumption increase that has taken place during a longer period of history. Many observers therefore believe that depletion at 75 years is a more realistic scenario. This still seems to be a relatively long period. But with the existing production technology for phosphate and food, there will a shortage of food for the world population at some point, whether this shortage occurs after 50, 100 or 200 years. This concerns the actual ecological capacity of the Earth.

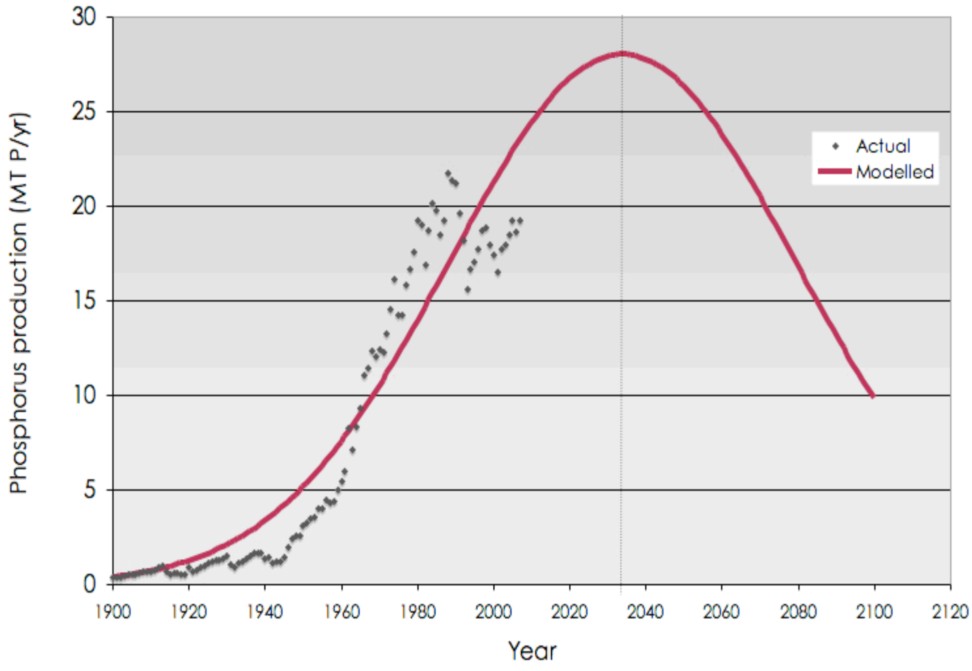


Figure 4. Hypothetical Peak Phosphorus Theory of Cordell et al., 2009; or the expected development of world phosphate production, linking up with the measured production through 2006. (see: http://phosphorusfutures.net/index.php?option=com_ content&task =view&id=16&Itemid=30).

The same applies to a number of micronutrients, such as zinc, molybdenum, manganese, copper, cobalt and boron (Keyzer et al., 2009).[1] In this memorandum we have focused on the macronutrient phosphorus because agriculture is almost the only user of this element in the Netherlands. With the micronutrients, there is also significant industrial consumption, for which alternatives can be sought if scarcity occurs

5. Geopolitics

Besides absolute scarcity, a second problem also threatens: the fact that regional scarcities will occur long before global scarcity due to the claims of wealthy – and militarily powerful – countries on the remaining phosphate reserves. This geopolitical problem cannot be solved by the market; wealthy countries will secure their supplies of resources by other means, as they have done previously with oil, gas and rare metals. Vulnerable countries or regions include India, Southeast Asia and sub-Saharan Africa, which have large or rapidly increasing populations and few phosphate reserves of their own.

In terms of geopolitics, various developments are possible. It is conceivable that phosphate-rich countries, such as China and the USA, will ban exports. It is also conceivable that a phosphate cartel (PPEC) will be established, consisting of countries with large reserves. In addition, it can be foreseen that importing countries will attempt to negotiate long-term contracts with phosphate-rich countries. For example, for the EU there is the possibility to include phosphate imports in the existing association treaty with Morocco. A key aspect of the above is that securing one's own food supply must take place with the realization that phosphate is part of the *global commons*, and that no unnecessary shifting to other countries will occur.

6. How can the imminent scarcity be avoided?

The transition from surplus to shortage also has consequences for environmental policy. Current environmental policy on phosphate focuses primarily on counteracting eutrophication. Besides a limited stimulus for livestock farms to use phosphate more sparingly, the policy primarily aims a directing phosphate flows in a different direction, i.e. away from soil and water to waste. This "waste route" is advantageous in that it counteracts diffuse dispersion and significantly increases the opportunities for phosphate recovery. But to truly counteract phosphate scarcity, ecological restructuring will be required. This means reducing the total consumption of phosphate, while simultaneously increasing recycling.

In order to sketch out a picture of the magnitude of the losses and thereby the potential for improvement, we refer to the following figures. As discussed in Section 2, the annual loss to lakes and oceans is 20-30 Mt P. This is more than the total annual production from phosphate mines of 19.3 Mt P. This situation is obviously not sustainable. Another consideration is that six times as much phosphate is used in agriculture than is consumed by people in food.

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[1] M.A.Keyzer, W.C.M. van Veen, R.L.Voortman, J.Huang, H. Qiu, G.Fischer and T.Ermolieva: *Nutrient shortages and agricultural recycling options worldwide, with special reference to China, contributed paper at the 2009 EAERE conference (PDF).*

Below is a brief overview of the options for limiting phosphate consumption and reducing phosphate loss.

Mining

During mining, it is estimated that 30-50% of the mined phosphate is lost. This is such a large loss of phosphate – a portion of which is usable – that there are good opportunities here. However, it is difficult to obtain data on these losses. It is also possible to consider mining sediments from bodies of water. In shallow lakes (and certainly in reservoirs behind dams that are filling with sediment) this is perhaps an option. Mining marine sediments is not yet economically feasible, but with a high phosphate price, it could possibly become cost-effective to extract the reserves on the continental plate near the coasts of Mexico and Namibia. This will require a great deal of energy, however, and will therefore also depend on the price of energy.

Agriculture

The processes in agriculture are a key factor in the phosphate problem.

- First of all, the soil erosion of arable lands must be reduced; at the world level, more phosphate is lost by erosion (20-30 Mt P per year) than is taken up by arable crops.
- In addition, agriculture can pursue an improved fertilization strategy. An initial point with respect to fertilization strategy is the ongoing development of precision fertilization. A second point is the fact that additional phosphate fertilization does not lead to a corresponding increase in yield. Consequently, in many cases a significant reduction in phosphate fertilization would lead to only a small decline in yield. The same applies to the addition of phosphate to animal feed. The greatest benefit can be achieved by increasing production on fertile arable land that is already in use, which requires less phosphate per kilo of product.
- The choice of arable crops is also important. Crops with an extensive root system, such as oilseed rape, can take up phosphate from the soil more efficiently. When re-mobilizing the phosphates that are already fixed in the soil, mycorrhizae (fungi that have a symbiotic association with plant roots) play an important role. As a result, the decline in production mentioned above can be entirely or partially compensated.
- In addition, it is important that yield reductions are limited, especially in developing countries.
- Finally, there is the manure from intensive animal husbandry. Today, this manure is often not used productively due to the heavy concentration in livestock production areas. This is certainly a key aspect for the Netherlands, but also for countries such as China and the USA.

However, one development which is leading to increased phosphate consumption, at least temporarily, is the otherwise desirable "restoration" of degraded or even abandoned land, which at present comprises 30% of all arable land in the world.

Fisheries and aquaculture

As a result of the global fishery, approximately 0.3 Mt P is brought from the sea to the land, which is a relatively limited amount (approximately 1.7% of world phosphate consumption). In view of the fact that more than 70% of the popular fish species are overfished or nearly so, there is no capacity for additional phosphate recovery from this source. Perhaps there are possibilities in the capture of herbivorous sea animals, but this could be harmful to biodiversity. Aquaculture is another possibility, but this sector would then be unable to use phosphate fertilization for algae. Using fish oil for raising farmed fish also does not provide any benefit compared with wild fisheries. In seawater itself, the concentration of phosphorus is much too low for recovery, although there are possibilities in estuaries where phosphate is supplied by rivers.

Industry
As noted in Section 2, between 11% and 12% of mined phosphate is used by industry, primarily for the production of detergents. In industrialized countries, phosphates in laundry detergents have been largely replaced by zeolites, but they are still used in dishwasher detergents. Other countries could also follow this replacement route. For that matter, detergent phosphates can be effectively recovered by wastewater purification, an option that may be applicable in the future to all phosphate contained in sewage sludge.

Households
Of course, there is also a role for households. The first priority would be to eat less meat. Although all phosphorus from livestock production and meat can theoretically be reused, phosphate is unavoidably lost during the production of animal feed. And because animal production requires much more land than plant production, the losses are larger. Theoretically, the phosphate in human excreta can also be entirely reused. But this is rarely done because sewage sludge is often heavily contaminated, among other reasons. However, incinerating the sludge and recovering the phosphate is a potentially feasible option (see below). In addition, reducing food waste is important in any case. In the Netherlands, households waste approximately 10% of their food consumption; across the entire food chain (*field-to-fork*) the total loss is estimated at 30% to 50%.

Waste processing
There are various promising possibilities in waste processing.

- First of all, there is wastewater processing. Worldwide, this amounts to 3-3.5 Mt P per year, which is approximately 40% of the phosphorus content of global agricultural production. Modern technologies, such as those being developed at the North Brabant sludge processing plant and Thermphos in Vlissingen (both in the Netherlands), make it possible to recycle virtually all the phosphate in sewage sludge.
- In addition, there are the organic waste streams from agriculture and industry. Crop residues are not always returned to the land. Especially with new developments, such as the production of biofuels, effective reuse of the phosphate in the residues should have priority. For example, phosphate can be recovered from combustion gases, or the residues can be used as animal feed.
- Slaughter waste, especially the bones, contains large amounts of phosphate, but due to sanitary considerations, bone meal can no longer be used as a fertilizer in the Netherlands and other European countries, and it cannot even be used in fish feed. There have been various initiatives for reusing the phosphate in bone meal, but the most effective option would be to allow bone meal to again be used in animal feed. The latter option would apply only to feed for *other* animal species, because using bone meal in feed for the same species leads to a risk of BSE.
- Reuse of animal manure was referred to previously. In cases where reuse is impossible, incineration of organic waste with phosphate recovery from the ash is now the most promising option. In the Netherlands, such waste streams are very large: more phosphate is contained in incineration residues than in the total quantity of fertilizer used! In addition, it is very important to prevent the phosphate in sewage sludge from disappearing into cement.

Generally speaking, in waste processing there are many opportunities for new technologies to recover phosphate. In this area especially, the Netherlands can become an innovative market leader and could export its expertise.

7. Relationship with environment environmental policy and nature policy

Measures such as those above will have consequences for the other environmental and nature policies, in both a positive and negative sense. Positive relationships include the following:

- Higher phosphate prices will lead to more efficient use and improved recycling. Eutrophication with phosphorus will consequently stop “by itself”.
- Measures to counteract erosion are not only beneficial for retaining phosphate, but also for conserving the production capacity and nutrient utilization of the arable land itself.
- Valorization of waste reduces the cost of waste processing.

But there are also objections and risks:

- There are indications that removing phosphates from detergents leads to declining fish populations in the sea.
- If the choice is made for maximum phosphate efficiency instead of maximum production, this will lead to lower production per hectare and consequently to an increase in the area of arable land. This will soon impinge on nature reserves. The priority must therefore be on more efficient utilization of soil phosphate, possibly by adding mycorrhizae.
- Reluctance to improve degraded arable land would lead to increased demand for arable land elsewhere, and consequently to increased pressure on forests and nature reserves.

There are important research questions here regarding the development of optimal strategies.

8. Research and policy at the national and international levels

The imminent depletion of phosphate is a worldwide problem; consequently, research must be conducted and policy must be established not only at the national level, but also at the European and global levels. The emphasis must be on national and international regulations and incentives that focus on closing the phosphorous cycles. Research in this area is beginning, but there are virtually no national or international policy bodies that are specifically concerned with phosphate scarcity. Until now, almost everything has been left up to the market, even though a phosphate shortage would cause serious problems; for example, it would impede the realization of the millennium development goals of United Nations.

At the national level, especially in the Netherlands, a strong emphasis must be placed on the further development of recycling technologies for sewage sludge, manure, slaughter waste and residues of biomass production. It is therefore important that the legislation for the use of waste streams for fertilization or animal feed is re-evaluated, in both the national and European context. In addition, it is advisable for the government to mandate the recovery of the phosphate in combustion ash from incinerated sewage sludge, which is already the case in Sweden and Denmark. Research into reducing phosphate fertilization, specifically on phosphate-saturated soils, must become another priority. In the future, the phosphorus in such saturated soils can possibly be “mined”. At the national level, the possibilities offered by development cooperation should also be addressed. The Netherlands has placed agriculture high on its policy agenda; as a result, the phosphate issue should also be given specific attention.

At the European level, an important first step is to fundamentally acknowledge that the EU, other than is often assumed, is *not* self-sufficient in food production and probably never will be[2]. After all, self-sufficiency requires phosphate reserves that are sufficient to compensate the unavoidable losses. Therefore, a fundamental reconsideration of EU policy on food security is required. One of the strategic options that deserves consideration is a levy on phosphate. This could provide a stimulus to use phosphate more efficiently and to recycle more phosphate. This stimulus would become even greater if the revenue was used to promote more efficient phosphate use and recycling, and to encourage innovative recycling technology. It is also important that the EU Nitrates Directive is expanded to become a Nitrates and Phosphates Directive. Moreover, phosphate criteria should be included in the conditions that link the Common Agricultural Policy to farm supplements, i.e. *cross-compliance*.

At the global level, there is a need for *global governance* of the *global commons*, in this case, the global phosphate reserves. Phosphate scarcity should be placed on the agendas of the FAO, UNDP, the WHO, the World Bank, the WTO and the OECD. The OECD did this recently.

The World Health Organization (WHO) recently established guidelines for the safe reuse of wastewater, including sewage. These guidelines do not focus directly on the phosphate problem, but they can contribute to the solution. The World Trade Organization (WTO) can take a role in managing the geopolitics with respect to phosphate. Under the banner of the United Nations, the World Food and Agricultural Organization (FAO) should include the proper use of phosphate in its *Good Agricultural Practices* and should pay attention to monitoring phosphate reserves and phosphate flows. The United Nations Development Programme (UNDP) should focus especially on the availability of phosphate for developing countries that do not have any phosphate reserves themselves. Finally, the World Bank should provide loans to developing countries to fund programmes focusing on phosphate recycling.

There is also a great need for private initiatives. It is time for the large environmental protection organizations to place the imminent phosphate shortage on their agendas. Analogous to the World Water Forum, a World Phosphate Forum could also be established.

In the area of research, the Global Phosphorus Research Initiative (GPRI) (www.phosphorusfutures.net) has recently been launched. This is a joint initiative of a number of universities with the aim of conducting interdisciplinary research in the areas of phosphate security and food security, as well as promoting awareness of the phosphate problem. Regional studies will also be very important.

Realizing the necessary changes will take many years; to avoid a catastrophic shortage, it is therefore crucial to begin the above-mentioned initiatives as soon as possible.

[2] The EU can only become self-sufficient if Morocco and the Western Sahara also become members of the EU, but the chance of this happening is small for a number of reasons.

9. Recommendations to the Minister of Agriculture, Nature and Food Quality

In closing, the Steering Committee makes the following recommendations to the Minister of Agriculture, Nature and Food Quality (LNV), in coordination with the Ministers of Environment and Development Cooperation:

For the political agenda:
1. *Place the approaching phosphate shortage on the agendas of global forums and the European Union.*
2. *Develop ideas for an EU Phosphate Policy, including a possible special purpose levy on phosphate.*
3. *Reconsider the legislation on the use of waste streams for fertilization and animal feed.*
4. *Develop supplementary policy in the Netherlands for recycling phosphate in waste streams, especially animal manure, sewage sludge, slaughter waste, and ash and slag from industrial combustion processes.*
5. *Promote the reuse of residue products from the production of biofuels.*
6. *Mandate the reuse of phosphate from the combustion ash of sewage sludge as soon as possible.*
7. *Assign priority to phosphate scarcity in Development Cooperation policy, with special attention for Africa.*

For the R&D agenda:
1. *Promote innovation regarding the reuse of phosphate from waste streams.*
2. *Promote research and extension concerning high precision phosphate fertilization regimes.*
3. *Promote innovation to improve the utilization of phosphate already in the soil, for example by using mycorrhizae.*

The Steering Committee believes there are important opportunities in various areas for the Netherlands to take a leading role in solving the phosphate problem. There are also opportunities for the export of expertise and technology.

Appendix 1: Remit and membership of the Steering Committee for Technology Assessment

The work of the Steering Committee for Technology Assessment contributes to the expertise policy of the Ministry of Agriculture, Nature and Food Quality by:

1. Exploring the consequences of possible technological developments and considering alternatives and/or;
2. Exploring possible technological contributions to the solution of societal problems relevant to the policy fields of the Ministry and/or;
3. Exploring and making explicit the standards and values that are involved with specific developments, as well as the differences in standards and values between various groups in society.

The following people, all in an individual capacity, are members of the Steering Group:
Drs. W.J. (Wouter) van der Weijden, Chair (Centre for Agriculture and Environment)*
Mr E.J. (Evert-Jan) Aalpoel (dairy farmer)
Ir. G. (Ger) Roebeling (Management Development Foundation)
Prof. J.L.A. (Leo) Jansen (Emeritus Professor of Environmental Engineering, Delft University of Technology)*
Dr A.M.C. (Anne) Loeber (Researcher and Senior Lecturer, University of Amsterdam)
Prof. H.A. (Helias) Udo de Haes (Emeritus Professor of Environmental Sciences, CML, Leiden University)*
Drs. J.A.C. (Hans) Vink (General Manager Nutreco Aquaculture [Skretting] NW Europe)*
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* Member of the ‘Phosphorus’ project group, which prepared this advice.

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