

Phosphorus



SUMMARY

1. Introduction

1. Why do we talk about phosphorus ?
2. How was phosphorus discovered?
3. What is phosphorus ?
4. Where is phosphorus ?
5. Why and how humans use phosphorus ?

2. Phosphorus cycle

1. The cycle

3. Anthropogenic phosphorus input

1. Why phosphorus became toxic ?
2. Why is it important ?
3. Current phosphorus dependency
4. Prospective of phosphorus demand
5. A new war on phosphorus ?
6. How can we ensure the safety of phosphate supplies?
7. Sustainable management of phosphorus

1. Introduction

1.1. Why do we talk about phosphorus ?

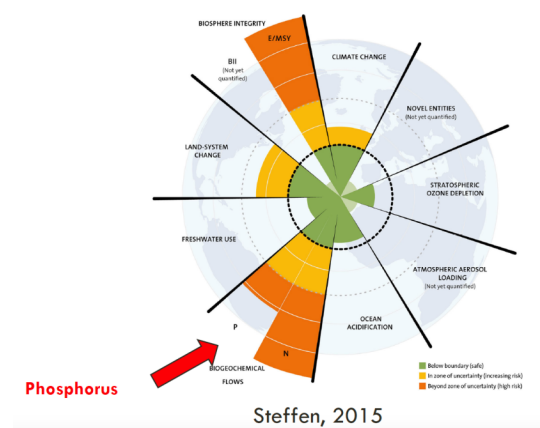
1 of the 9 planetary limits

1 of the 3 planetary limits exceeded

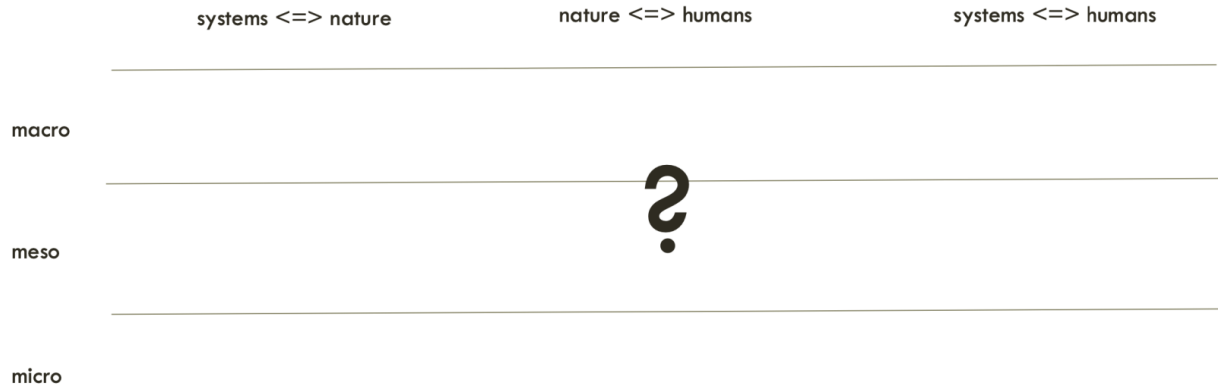
What is phosphorus ?

What is its cycle ?

In which human activities is it used ? How to return to a "normal" situation ?



During the course, think about the different interactions between humans, nature and systems involving phosphorus.



1.2. How was phosphorus discovered ?

According to you, how did humans discovered phosphorus ?

A. By looking for the Philosopher's Stone

B. By doing caving (spéléologie)

C. By observing a carp population in a lake

A - Complete answer :

By looking for the Philosopher's Stone AND analyzing urine. Yes.

Who ? Hennig Brand

When ? 1669

Why ? By looking for the Philosopher's Stone

How ? By analyzing large quantities of urine

Properties :

- it is phosphorescent
- it ignites spontaneously on contact with air

1769 : Scheele discovery

(Gervy, 1970)

(Joseph Wright, 1771)

1.3. What is phosphorus ?

According to you, where can we find phosphorus ?

A. In our DNA

B. In our Smartphones

C. In our clothes

ELEMENTS OF A SMARTPHONE

ELEMENTS COLOUR KEY: ● ALKALI METAL ● ALKALINE EARTH METAL ● TRANSITION METAL ● GROUP 13 ● GROUP 14 ● GROUP 15 ● GROUP 16 ● HALOGEN ● LANTHANIDE

SCREEN

In Indium, **O** Oxygen, **Sn** Tin: Indium tin oxide is a mixture of indium oxide and tin oxide, used in a transparent film in the screen that conducts electricity. This allows the screen to function as a touch screen.

Al Aluminium, **Si** Silicon, **O** Oxygen, **K** Potassium: The glass used on the majority of smartphones is an aluminosilicate glass, composed of a mix of alumina (Al₂O₃) and silica (SiO₂). This glass also contains potassium ions, which help to strengthen it.

Y Yttrium, **La** Lanthanum, **Tb** Terbium, **Pr** Praseodymium, **Eu** Europium, **Dy** Dysprosium, **Gd** Gadolinium: A variety of Rare Earth Element compounds are used in small quantities to produce the colours in the smartphone's screen. Some compounds are also used to reduce UV light penetration into the phone.

BATTERY

Li Lithium, **Co** Cobalt, **O** Oxygen, **C** Carbon, **Al** Aluminium: The majority of phones use lithium ion batteries, which are composed of lithium cobalt oxide as a positive electrode and graphite (carbon) as the negative electrode. Some batteries use other metals, such as manganese, in place of cobalt. The battery's casing is made of aluminium.

Mg Magnesium, **O** Oxygen: Magnesium compounds are alloyed to make some phone cases, whilst many are made of plastics. Plastics will also include flame retardant compounds, some of which contain bromine, whilst nickel can be included to reduce electromagnetic interference.

ELECTRONICS

Cu Copper, **Ag** Silver, **Au** Gold, **Ta** Tantalum: Copper is used for wiring in the phone, whilst copper, gold and silver are the major metals from which microelectrical components are fashioned. Tantalum is the major component of micro-capacitors.

Ni Nickel, **Dy** Dysprosium, **Pr** Praseodymium, **Tb** Terbium, **Nd** Neodymium, **Gd** Gadolinium: Nickel is used in the microphone as well as for other electrical connections. Alloys including the elements praseodymium, gadolinium and neodymium are used in the magnets in the speaker and microphone. Neodymium, terbium and dysprosium are used in the vibration unit.

Si Silicon, **O** Oxygen, **Sb** Antimony, **As** Arsenic, **P** Phosphorus, **Ga** Gallium: Pure silicon is used to manufacture the chip in the phone. It is oxidised to produce non-conducting regions, then other elements are added in order to allow the chip to conduct electricity.

Sn Tin, **Pb** Lead: Tin & lead are used to solder electronics in the phone. Newer lead-free solders use a mix of tin, copper and silver.

CASING

C Carbon, **Mg** Magnesium, **Br** Bromine, **Ni** Nickel: The majority of phones use lithium ion batteries, which are composed of lithium cobalt oxide as a positive electrode and graphite (carbon) as the negative electrode. Some batteries use other metals, such as manganese, in place of cobalt. The battery's casing is made of aluminium.

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(Compound Interest, 2014)

Phosphorus

Pnictogen ←

atomic number: 15

symbol: P

electron configuration: [Ne]3s²3p³

name: phosphorus

atomic weight: 30.974

acid-base properties of higher-valence oxides: Weakly acidic

crystal structure: Cubic

physical state at 20 °C (68 °F): Solid

Other nonmetals

Solid

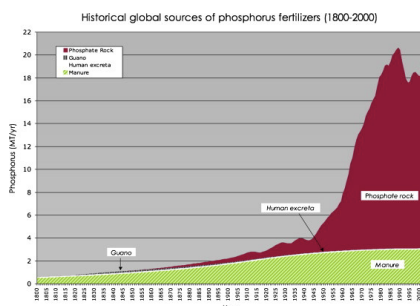
Cubic

Weakly acidic

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(Sanderson, 2018)

1.4. Where is phosphorus ?



(Cordell, 2009)

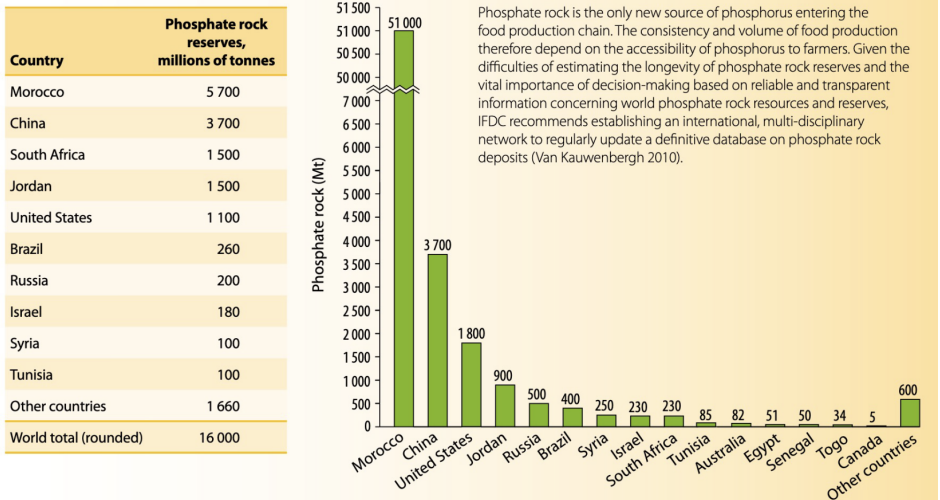


Figure 3: Recent estimates of the distribution of world phosphate rock reserves, as reported by the United States Geological Survey (left) and the International Fertilizer Development Center (right). Most potentially viable phosphate rock reserves are concentrated in a few countries. Sources: Jasinski (2010) and Van Kauwenbergh (2010)

Note: The United States Geological Survey's Mineral Commodity Summaries 2011, published on 21 January 2011, revised the USGS estimate of world phosphate rock reserves to 65 billion tonnes. Its revised estimate of Moroccan reserves is 50 billion tonnes, based on information from the Moroccan producer and IFDC. The top ten countries in the 2011 report are Morocco, China (3 700 Mt), Algeria (2 200 Mt), Syria (1 800 Mt), Jordan (1 500 Mt), South Africa (1 500 Mt), the United States (1 400 Mt), Russia (1 300 Mt), Brazil (340 Mt) and Israel (180 Mt). Source: Jasinski (2011)

(Syers, 2011)

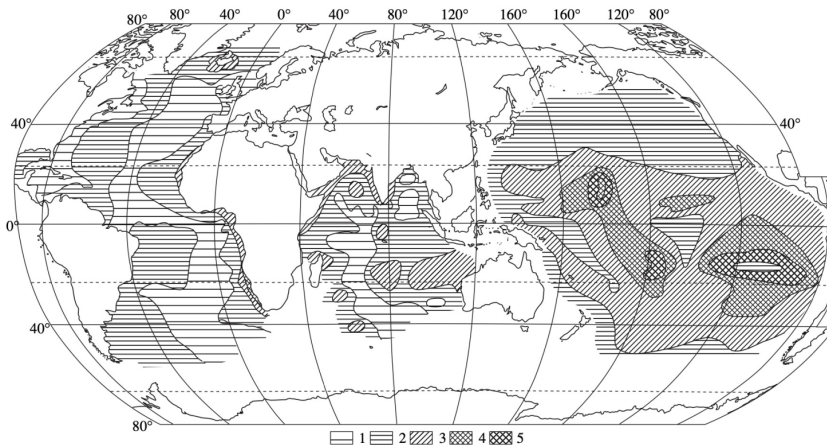


Fig. 1. Phosphorus distribution (%) in the upper sediment layer of the World Ocean, based on data from (Baturin, 1988; Baturin and Sevast'yanova, 1986; Baturin et al., 1995; Emel'yanov and Romankevich, 1979). (1) <0.05%; (2) 0.05-0.1%; (3) 0.1-0.2%; (4) 0.2-0.3%; (5) >0.3% (for the Indian ocean: (2) 0.05-0.08%; (3) >0.08%).

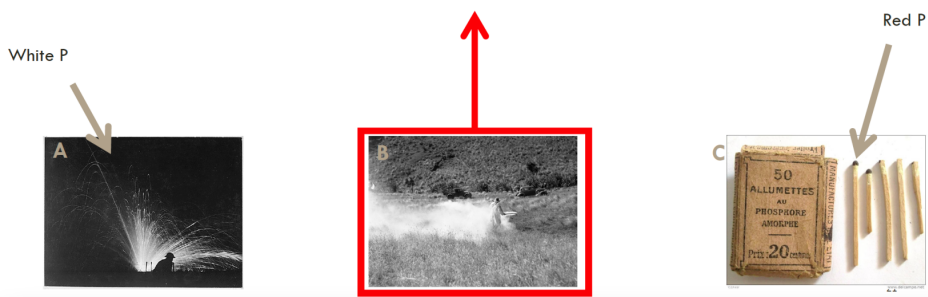
(Baturin, 2003)

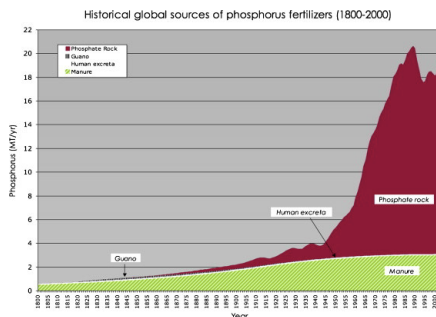
1.5. Why and how humans use phosphorus ?

According to you, why do we use phosphorus ?

- A. To create bombs
- B. To create fertilizers
- C. To create match scrapers (grattoirs pour allumettes)

90% of global demand for phosphorus is for food production





(Cordell, 2009)

And HOW ?

Use of phosphates before their discovery :

1. Use of bones
2. Use of guano

According to you, what is guano ?

- A. A plant that can be smoked
- B. A typical Latin American outfit

C. A pile of excrement

Seabirds and bats dropping are full of phosphorus !

2 reasons to use guano :

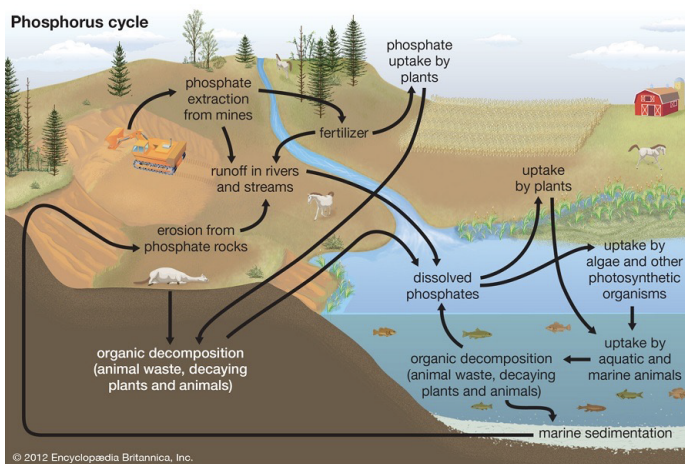
- Both live in large colonies
- High concentration of phosphorus

2. Phosphorus cycle

2.1. The cycle

According to you, what is not involved in the phosphorus cycle ?

- A. Atmosphere
- B. Oceans
- C. Lacks



3. Anthropogenic phosphorus input

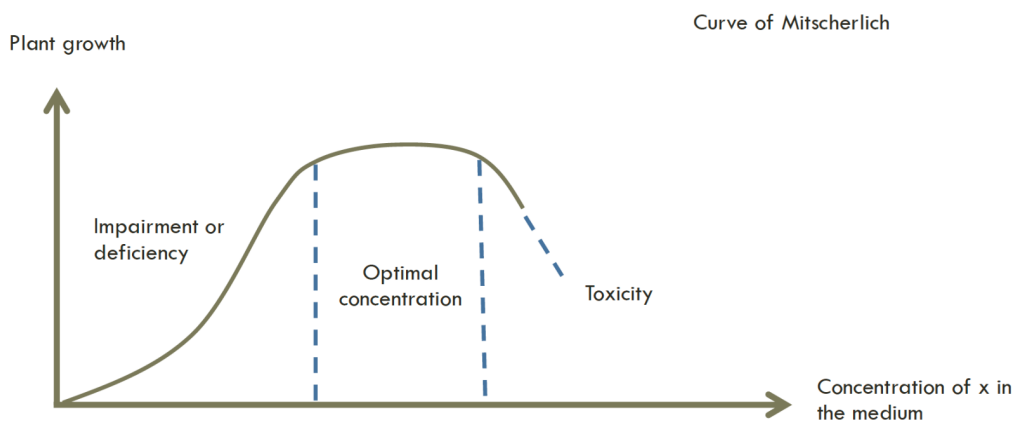
3.1. Why phosphorus became toxic ?

An ever increasing amount of phosphorus in ocean.

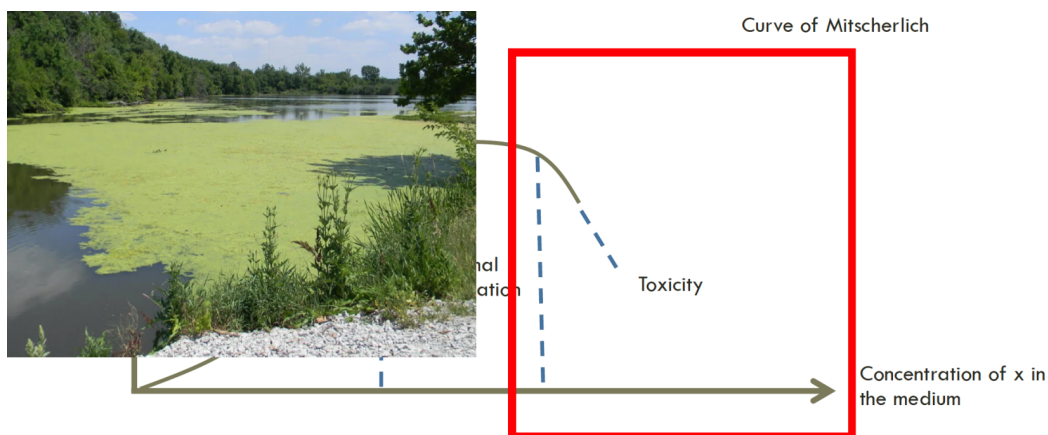
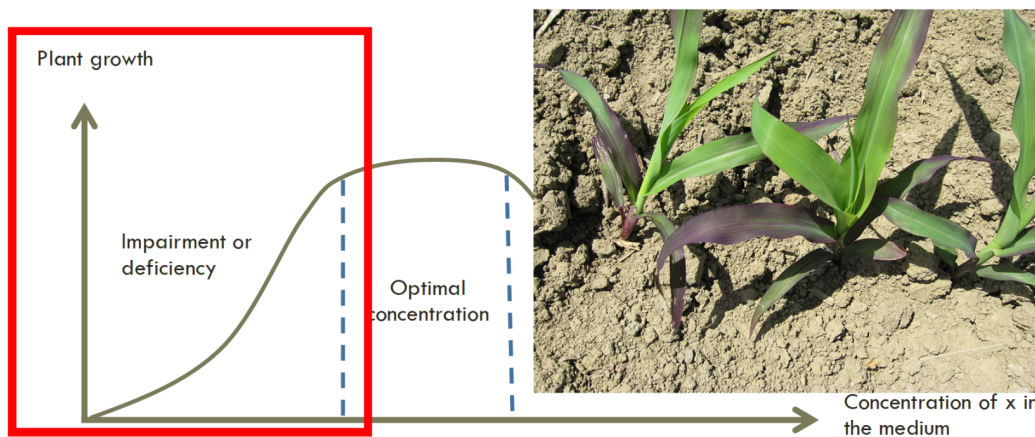
Table 2. Forms of present-day and preanthropogenic phosphorus supply into the World Ocean, Mt/yr (Compton *et al.*, 2000)

Phosphorus sources and species	Preanthropogenic supply	Present-day supply
1. River runoff		
Dissolved P:		
inorganic	0.3–0.5	0.8–1.4
organic	0.2 (maximum)	0.2 (average)
Suspended P:		
organic	0.9 (maximum)	0.9 (average)
inorganic	1.5–3.0	1.3–7.4
detrital	6.9–12.2	14.5–20.5
2. Eolian	1.0 (including 20% of reactive P)	1.05 (including 20% of reactive P)
Total	10.8–17.8	18.7–31.4
Reactive	3.1–4.8	3.4–10.1

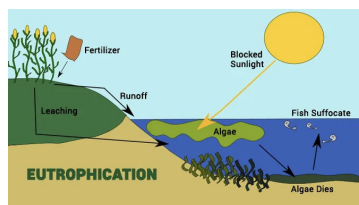
(Baturin, 2003)



(Gaujous, 1995)



Eutrophication phenomenon



(Pinay, 2018)

Social consequences :

- Crystalization of social tensions
- Agricultural world, local elected officials and environmental protection associations
- Different environment conceptions of public action, social responsibility and scientific knowledge

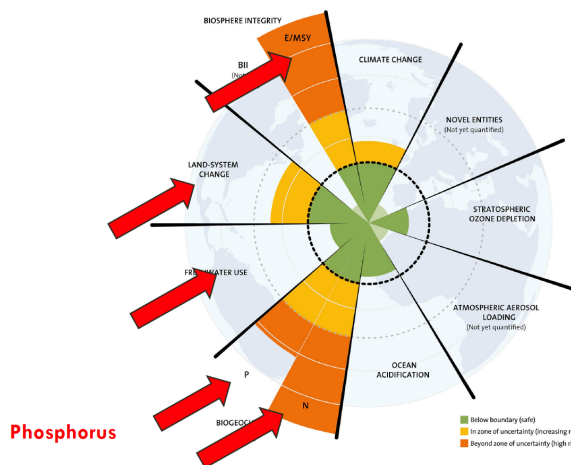
3.2. Why is it important ?

According to you, is this phenomenon really important ?

A. I guess, otherwise this course wouldn't exist

B. It is important but there are bigger issues

C. Not important, it is nothing in front of other issues



(Steffen, 2015)

Ocean Deoxygenation: Drivers and Consequences - Past - Present - Future - INTERNATIONAL CONFERENCE KIEL GERMANY 3 - 7 September 2018 SFB 754

Kiel Declaration on Ocean Deoxygenation
 Participants of the international conference "Ocean Deoxygenation: Drivers and Consequences - Past - Present - Future", 3 - 7 September 2018 in Kiel, Germany organized by: Kiel Collaborative Research Center SFB 754 and Global Ocean Oxygen Network (GO₂NE - IOC-UNESCO)

The ocean is losing its breath

Oxygen in the ocean supports the largest ecosystems on the planet. It is alarming that the ocean is losing oxygen, termed ocean deoxygenation, primarily due to global warming by greenhouse gas emissions, and pollution by nutrients and organic wastes particularly in coastal waters. We call on all nations, societal actors, scientists and the United Nations to:

- Raise global awareness about ocean deoxygenation through local, regional and global efforts, including interdisciplinary research, innovative outreach, and ocean education.
- Take immediate and decisive action to limit pollution and in particular excessive nutrient input to the ocean.
- Limit global warming by decisive climate change mitigation actions.

Both the Paris Agreement addressing Climate Change and the United Nations' 2030 Agenda for Sustainable Development demand conservation and sustainable use of the ocean, seas and marine resources in order to safeguard ocean ecosystems and their current and future societal benefits. These are severely threatened by ocean deoxygenation.

Conference Chair, Executive Board & Conveners
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 Prof. Eric Achterberg, GEOMAR & Kiel University, Kiel, Germany
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3.3. Current phosphorus dependency

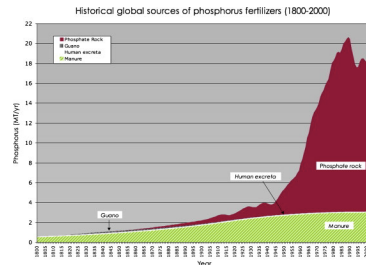
Rapid food demand to rapid population growth

Rectification of phosphorus deficiency of soils

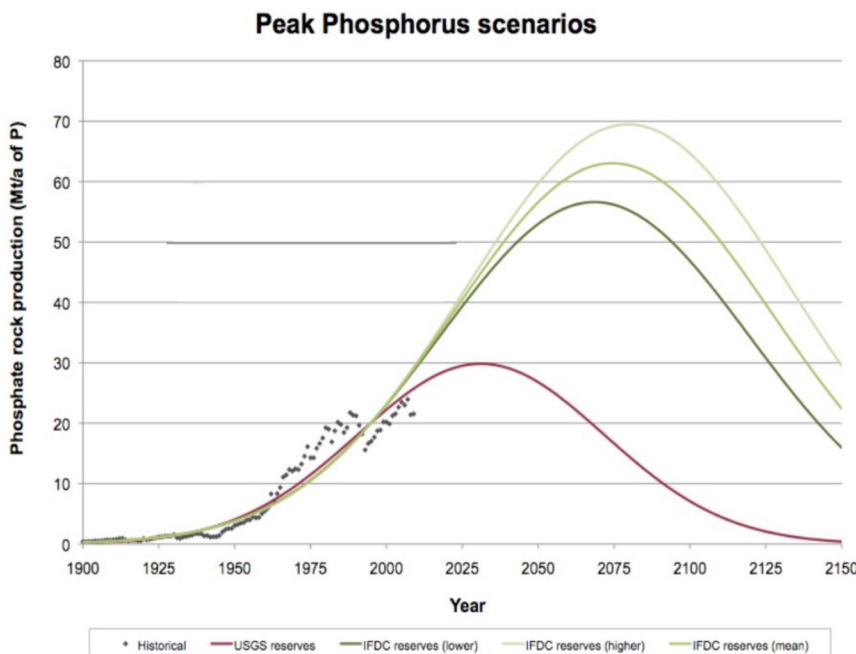
Saving people from starvation

« 90% of global demand for phosphorus is for food production, currently around 148 million tonnes of phosphate rock per year (Smil, 2000a, Smil, 2000b, Gunther, 2005) »

(Cordwell, 2009)



Phosphorus peak



Cordell et al, 2009; 2011

Figure 1. Peak phosphorus curve, indicating that production will eventually reach a maximum, after which it will decline. Red line indicates the original 2009 analysis based on USGS reserve data (Cordell, Drangert & White, 2009), while the green curves were updated with IFDC 2010 phosphate rock reserve data.

(White, s.d.)

3.4. Prospective of phosphorus demand

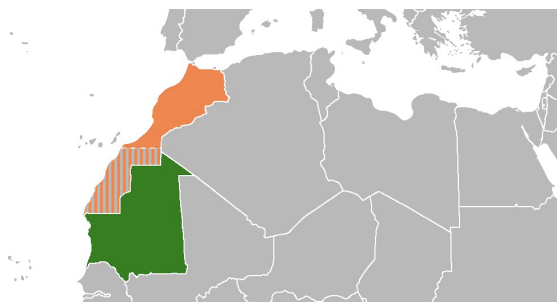
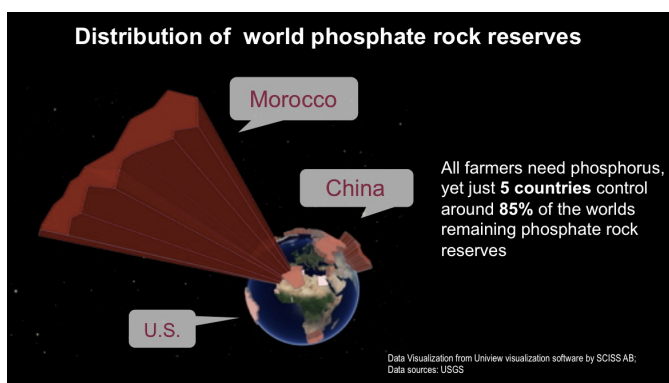
« Following more than half a century of generous application of inorganic high-grade phosphorus and nitrogen fertilizers, agricultural soils in Europe and North America are now said to have surpassed 'critical' phosphorus levels »

« Consequently, demand for phosphorus in these regions has stabilized or is decreasing. »

« However in developing and emerging economies the situation is different. Global demand for phosphorus is forecast to increase by around 3–4% annually until 2010/11 »

=> high demand and an approaching peak...

3.5. A new war on phosphorus ?

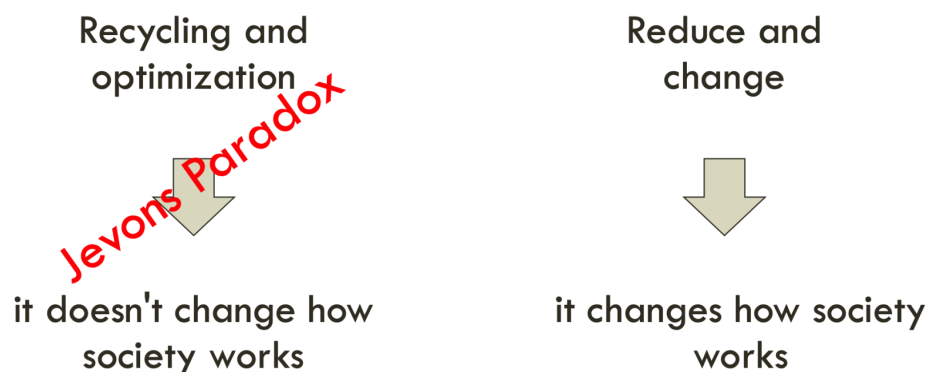


(Wikipedia, s.d.)

3.6. How can we ensure the safety of phosphate supplies?

Phosphorus security goals might therefore include:

1. "Increase number of people fed per tonne phosphorus input, or, reduce total phosphorus demand while maintaining food/agricultural output;
 2. Reduce dependence on phosphorus imports (to reduce vulnerability to geopolitical dynamics and thereby increasing long-term access to phosphorus);
 3. Ensure healthy soils (no phosphorus-deficiency, no phosphorus accumulation, balanced nutrition and presence of organic matter);
 4. Ensure farmers needs are met (e.g., maintaining or increasing productivity; ensuring access to phosphorus fertilisers);
 5. Reduce losses and wastage where avoidable;
 6. Reduce eutrophication and pollution by preventing phosphorus from the food system from entering waterways."
- 4/5 phosphorus mined for food production never actually reaches the food on our forks
 - Existence of a whole toolbox of phosphorus recycling and efficiency
 - Low tech and high tech phosphorus recovery in the sanitation sector to changing diets



3.7. Sustainable management of phosphorus

Possible solutions for the management of phosphate nutrition of tropical crops in the context of ecological intensification :

1. Making better use of the diversity of the plant world and genetic resources
2. Greater use of species assemblages in time and space
3. Make more efficient use of mineral and organic inputs
4. Assessing the potential of microbial inoculants and bio-effectors
5. Maintain and promote the activity of the soil's macrofauna
earthworms = ver de terre

(Hinsinger, 2015)

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