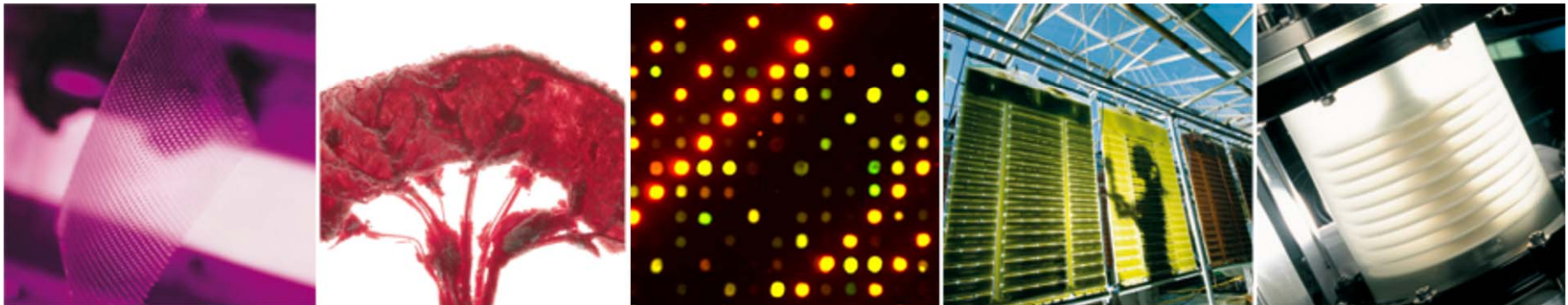

Life without Phosphorus?

Jennifer Bilbao, M.Sc
Department of Physical Process Technology

Green Bug Lectures
Stuttgart, November 2, 2010



Seite 1

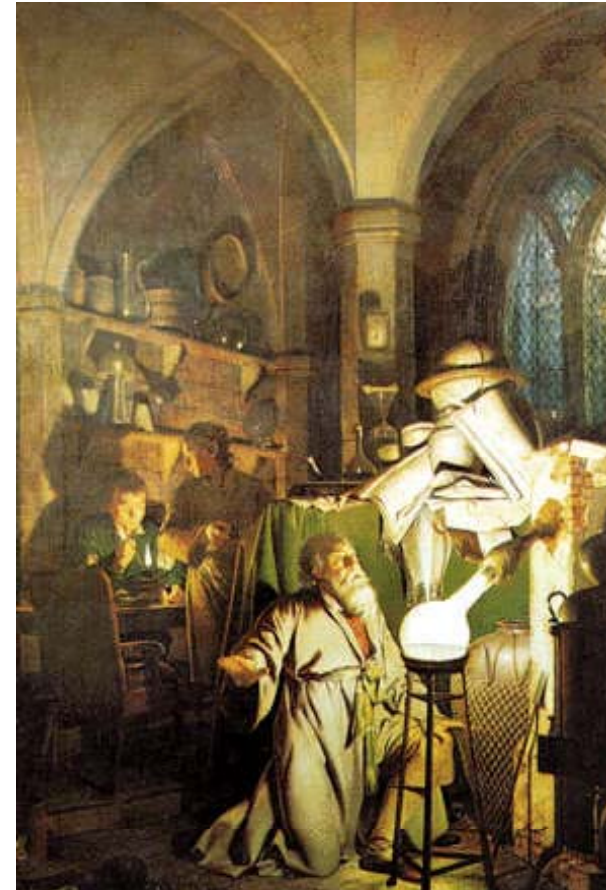
What is Phosphorus (P)?

- P is a chemical element
- P was discovered by Hennig Brand in 1669
- gr (*phosphoros*) "light-bringer"

Periodensystem der Elemente

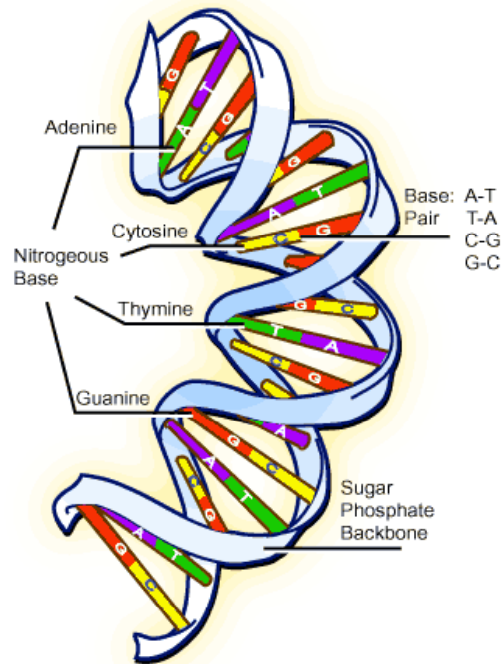
1	2	13	14	15	16	17	18
1 H Wasserstoff 1.01							2 He Helium 4.00
3 Li Lithium 6.94	4 Be Beryllium 9.01						
5 B Bor 10.81		6 C Kohlenstoff 12.01	7 N Stickstoff 14.01	8 O Sauerstoff 15.999	9 F Fluor 18.998	10 Ne Neon 20.18	
11 Na Natrium 22.99	12 Mg Magnesium 24.31		13 Al Aluminium 26.98	14 Si Silicium 28.09	15 P Phosphor 30.97	16 S Schwefel 32.07	17 Cl Chlor 35.45
19 K Kalium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titan 47.88	23 V Vanadium 50.94	24 Cr Chrom 52.00	25 Mn Mangan 54.94	26 Fe Eisen 55.85
27 Co Cobalt 58.93	28 Ni Nickel 58.70	29 Cu Kupfer 63.55	30 Zn Zink 65.41	31 Ga Gallium 69.72	32 Ge Germanium 72.64	33 As Arsen 74.92	34 Se Selen 78.96
35 Br Brom 79.90	36 Kr Krypton 83.80						
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirkon 91.22	41 Nb Niobium 92.91	42 Mo Molybdän 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07
45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silber 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Zinn 118.71	51 Sb Antimon 121.76	52 Te Tellur 127.60
53 I Jod 126.90	54 Xe Xenon 131.29						
55 Cs Cäsium 132.91	56 Ba Baryum 137.33	57 La-Lu Lanthan-Lutetium	58 Ce Cer 140.12	59 Pr Praseodym 140.91	60 Nd Neodym 144.24	61 Pm Promethium (147)	62 Sm Samarium 150.36
63 Eu Europium 151.97	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04
71 Lu Lutetium 174.97							
72 Hf Hafnium 178.49	73 Ta Tantal 180.95	74 W Wolfram 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platin 195.08	79 Au Gold 196.97
80 Hg Quecksilber 200.59	81 Tl Thallium 204.38	82 Pb Blei 207.2	83 Bi Bismut 208.98	84 Po Polonium (209)	85 At Astat (210)	86 Rn Radon (222)	
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac-Lr Actin-Lutetium	90 Th Thorium (232.04)	91 Pa Protactinium (231.04)	92 U Uran (238.03)	93 Np Neptunium (237)	94 Pu Plutonium (244)
95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)
103 Lr Lawrencium (262)							

© Peter Wich - Experimentalchemie.de - Chemie erleben!

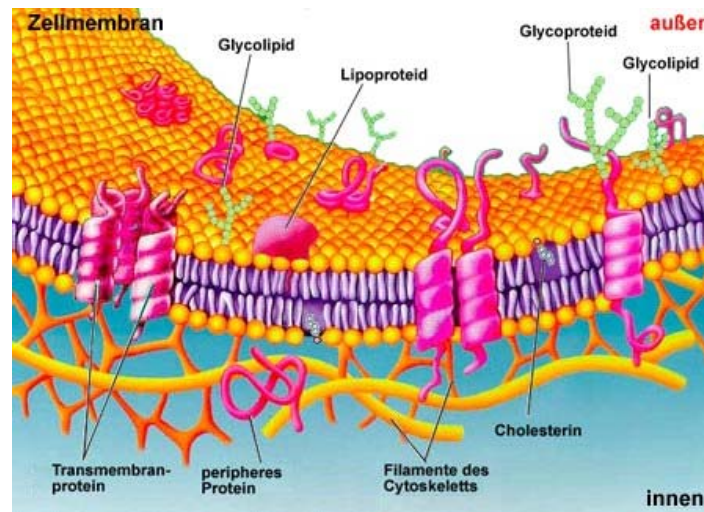


Why is P so important?

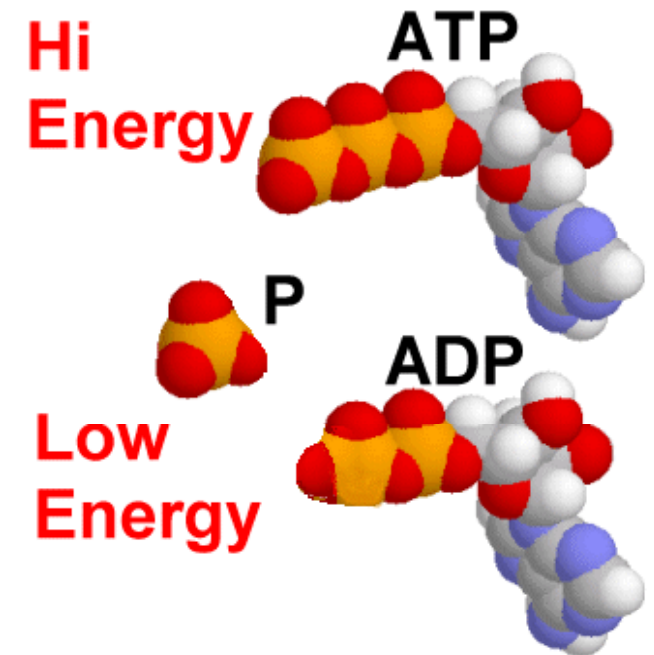
DNA



Cell membrane Phospholipides



Energy metabolism



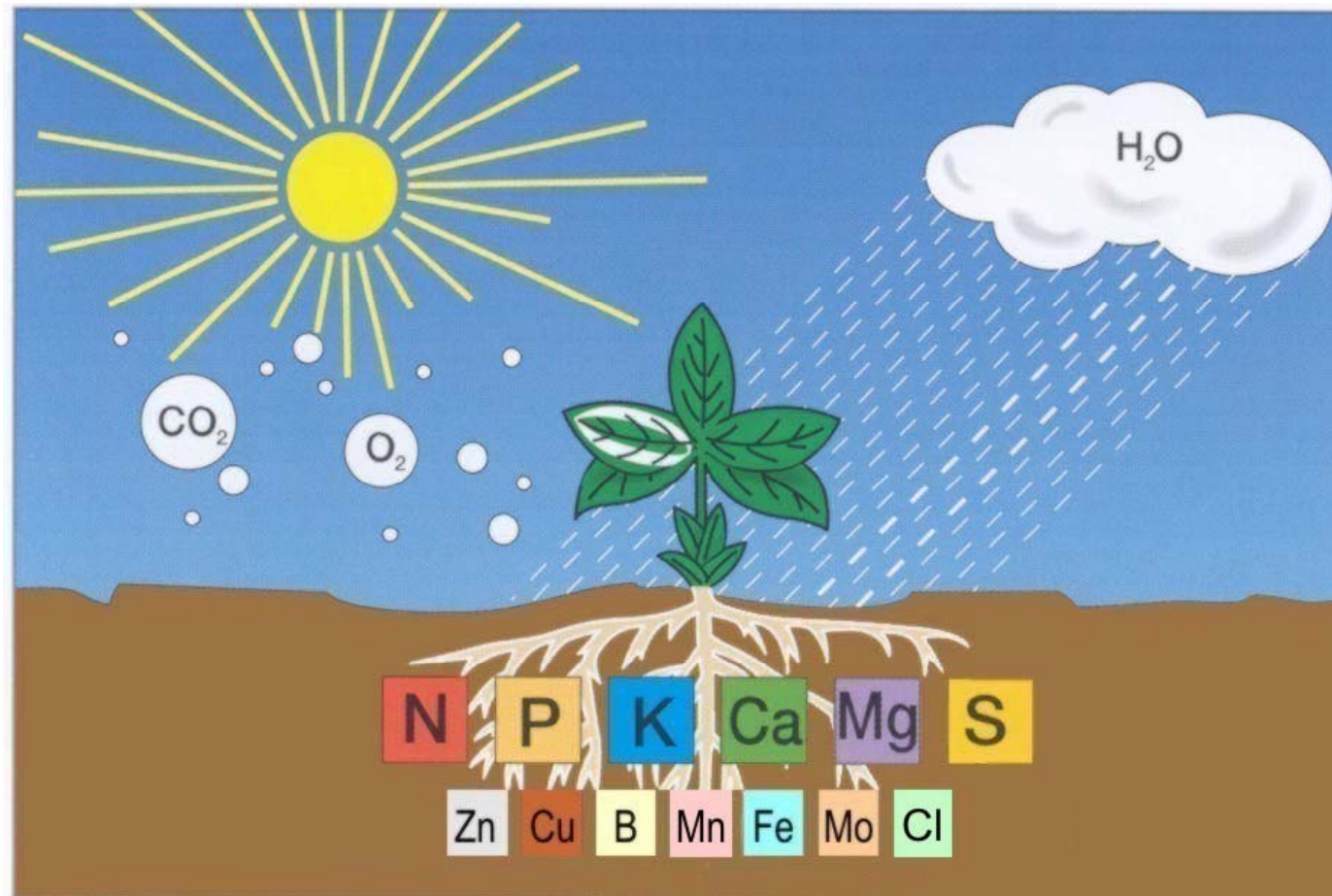
Uses of Phosphorus

10% explosives, plastics, detergents, pesticides

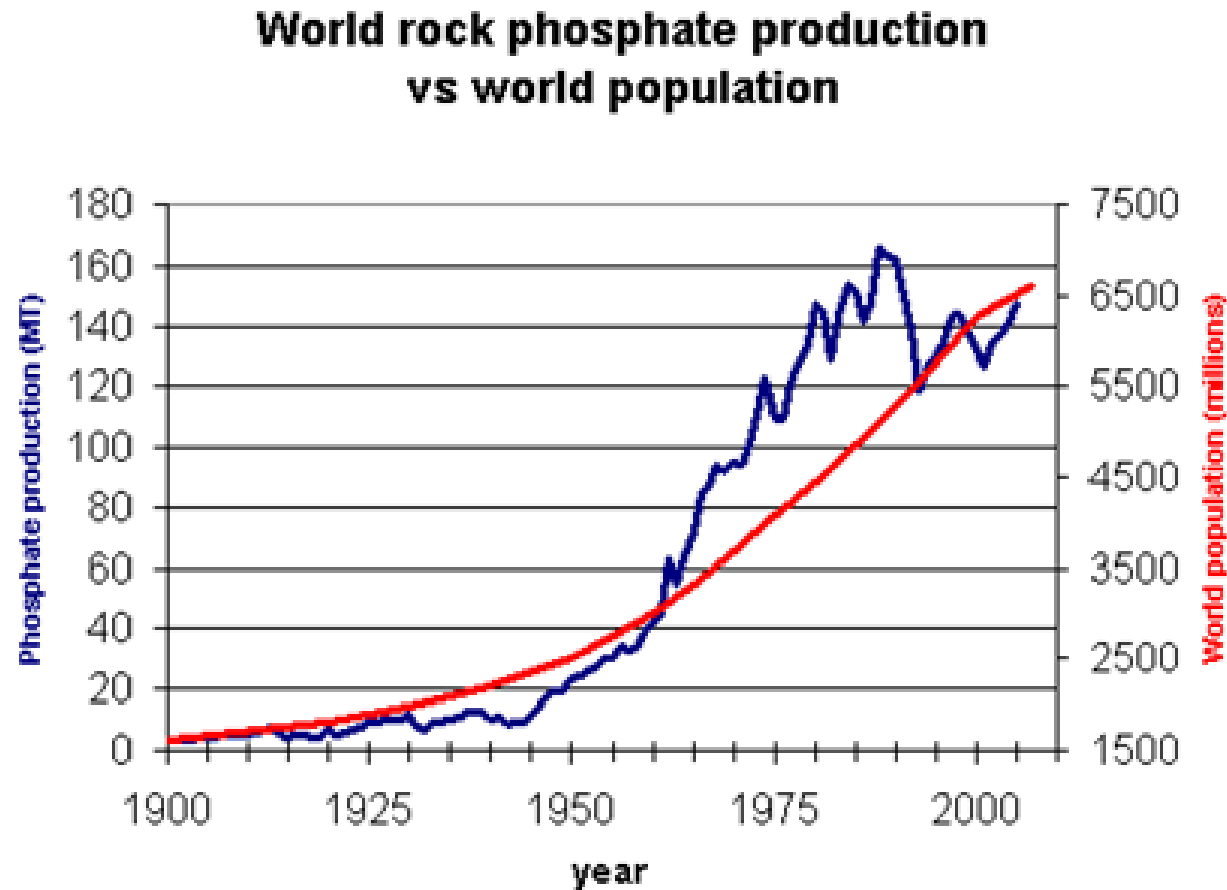
90% fertilizers



Minerals for plants



Phosphate production and world population

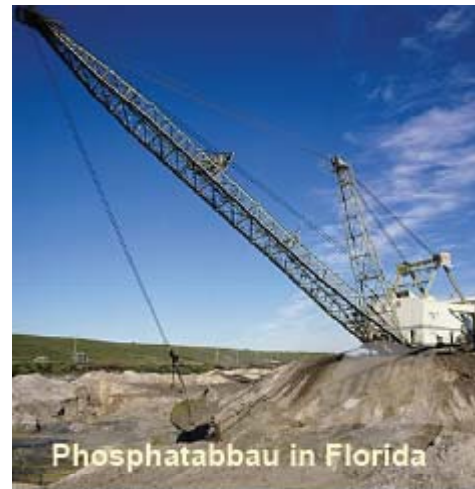


Where does P come from?

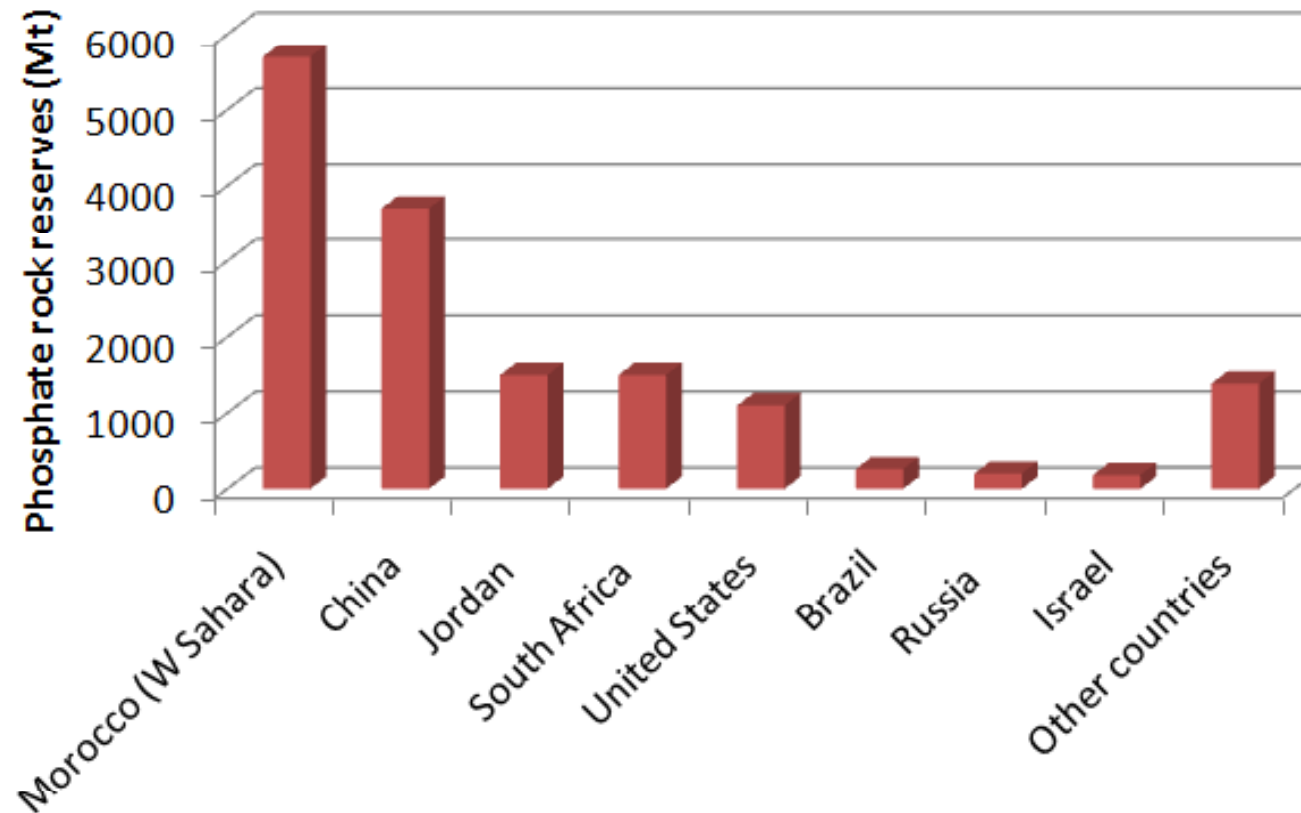
Guano -> bird excrements

Rock -> calcium phosphate (apatite)

- fossil marine sediments
- volcanic deposits

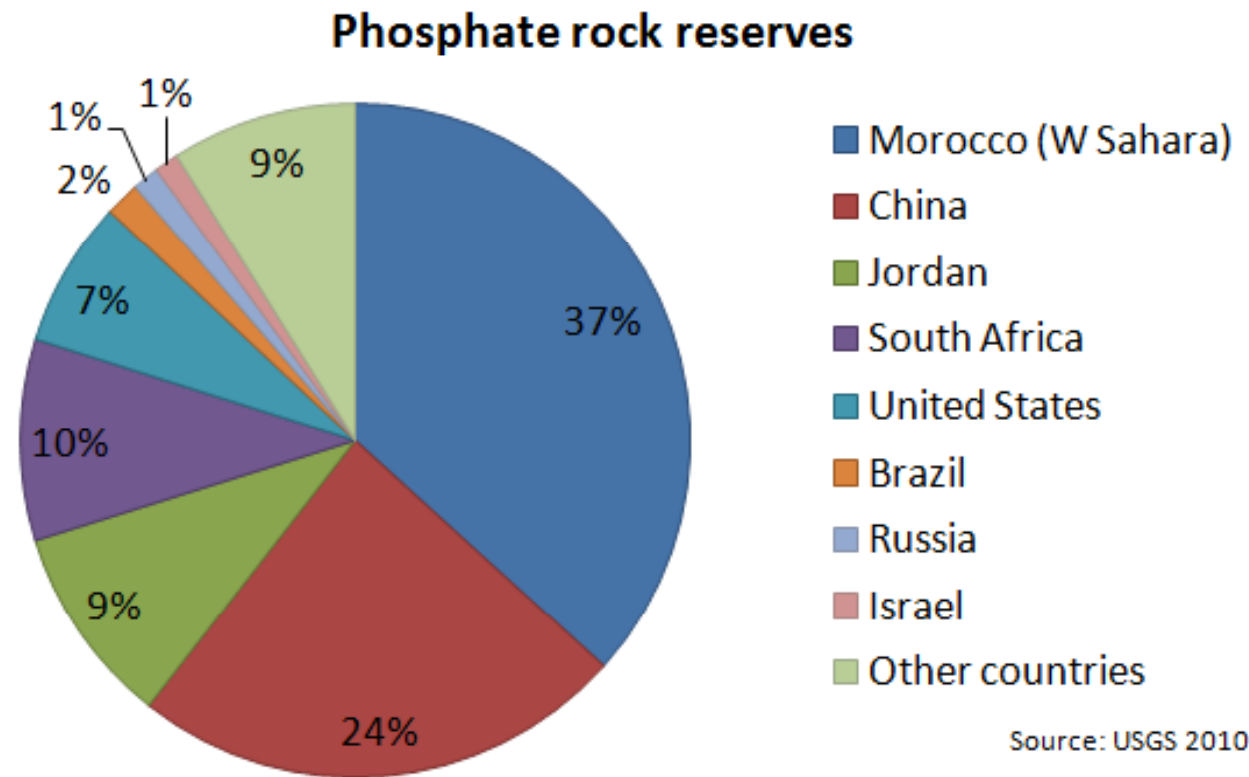


Where can P rock reserves be found?



Source: USGS 2010

Where can P rock reserves be found?



Peak Phosphorus

- Phosphorus rock is a **non** renewable resource
- US will deplete its reserves within 30 years*
- Global reserves will run out within **75–100 years!****
- Peak phosphorus 2030
demand will exceed supply



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Same scenario as crude oil?

Crude oil can be replaced!!!

- Solar energy
- Wind energy
- Hydroelectric power
- Biogas



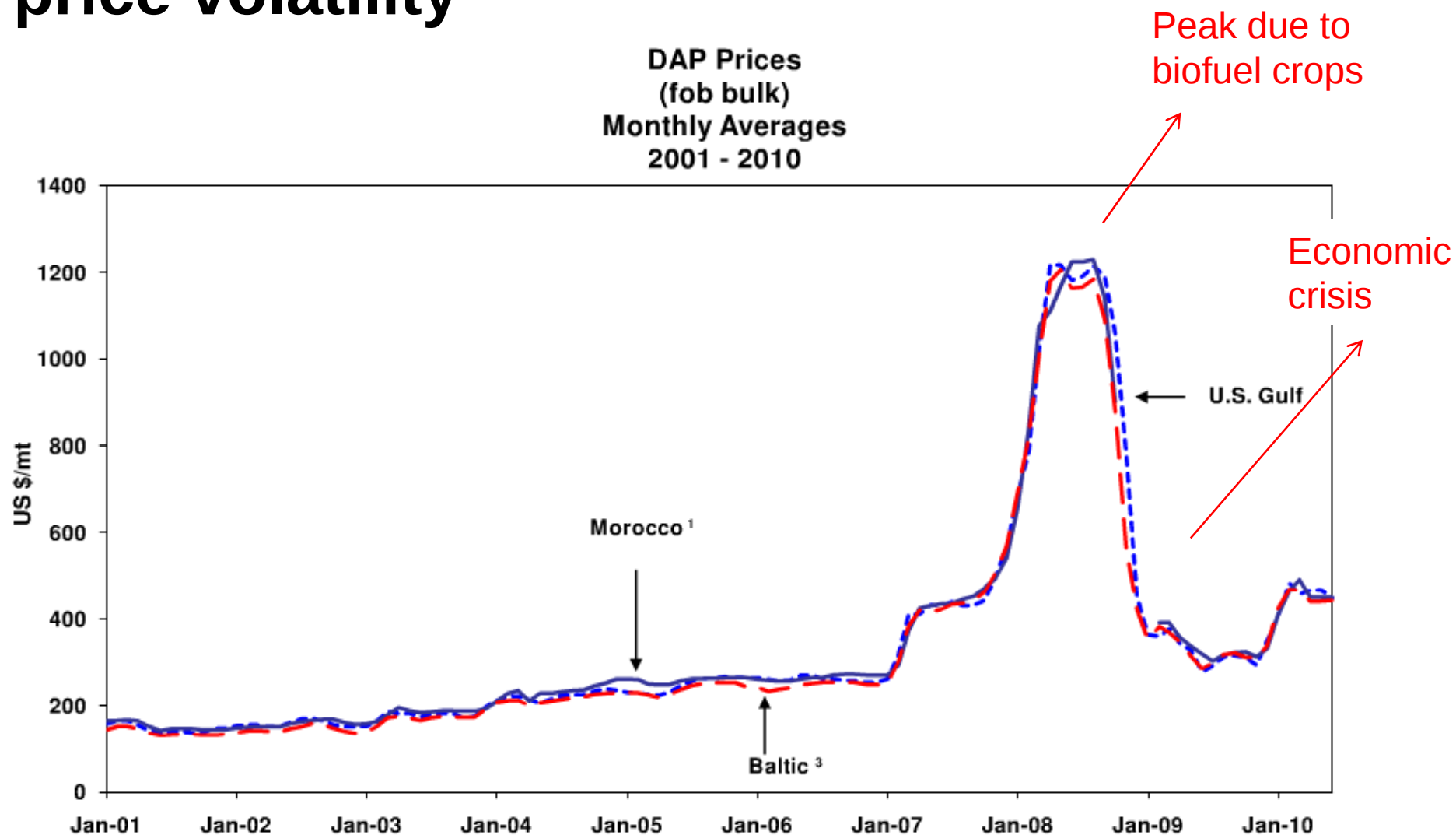
P cannot be replaced

P cannot be synthetically produced!

Consequences of P Scarcity

- farm output will decline
- higher fertilizer prices
 - higher food prices
 - food insecurity will increase
- global economic and social crisis
- Regional and global conflicts (wars?)

P price volatility



1. Derived from *Green Markets*. 2. Derived from *Fertilizer Week*. 3. Derived from *FMB Weekly Fertilizer Report*.



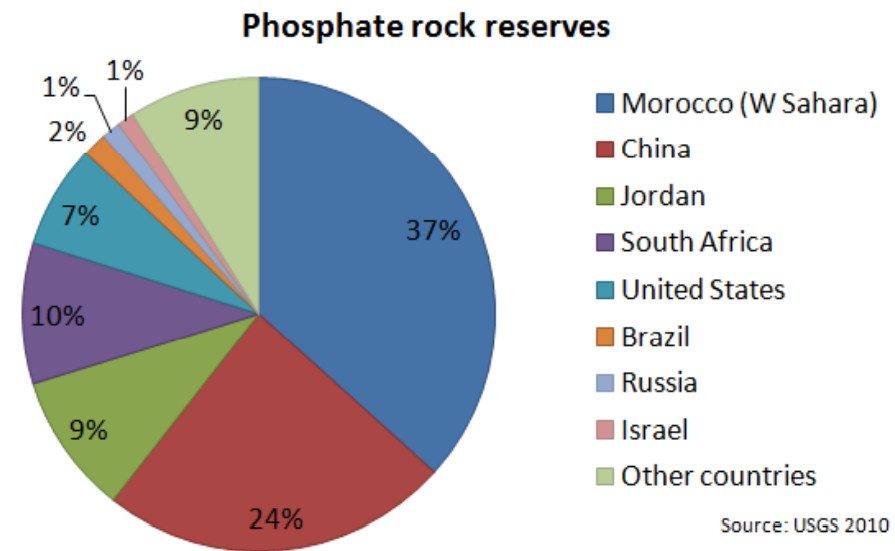
Graph by IFDC—An International Center for Soil Fertility and Agricultural Development

Consequences of P price volatility

- Price of food increased
- Conflicts in developing countries
- No changes in policy -> fertilizers nor agriculture
- UN -> Task Force on Global Food Security Crisis
 - Food security summits
 - Rome (2008)
 - Madrid (2009)

Geopolitical implications

- Five countries control 90% of the P reserves
- China 135% tariff on exports (2008)
- US extraction has now peaked -> dependent on imports
- Morocco next supplier



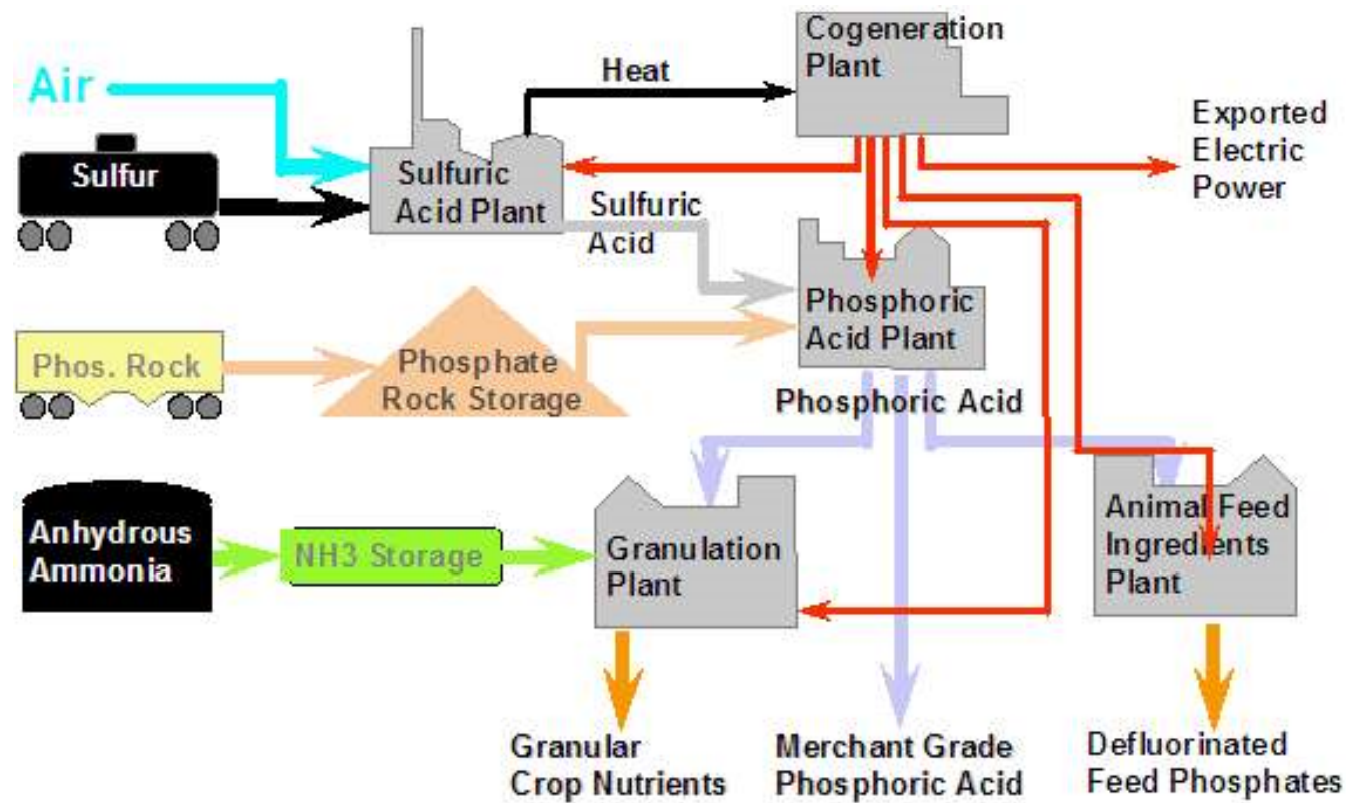
Geopolitical implications

- Morocco's P reserves -> W. Sahara
 - internationally recognized as a sovereign country
 - Since 1975 it's been occupied by Morocco
- In 2004 US signed a bilateral free trade agreement with Morocco -> long access to P



Geopolitical implications

Availability of sulfuric acid

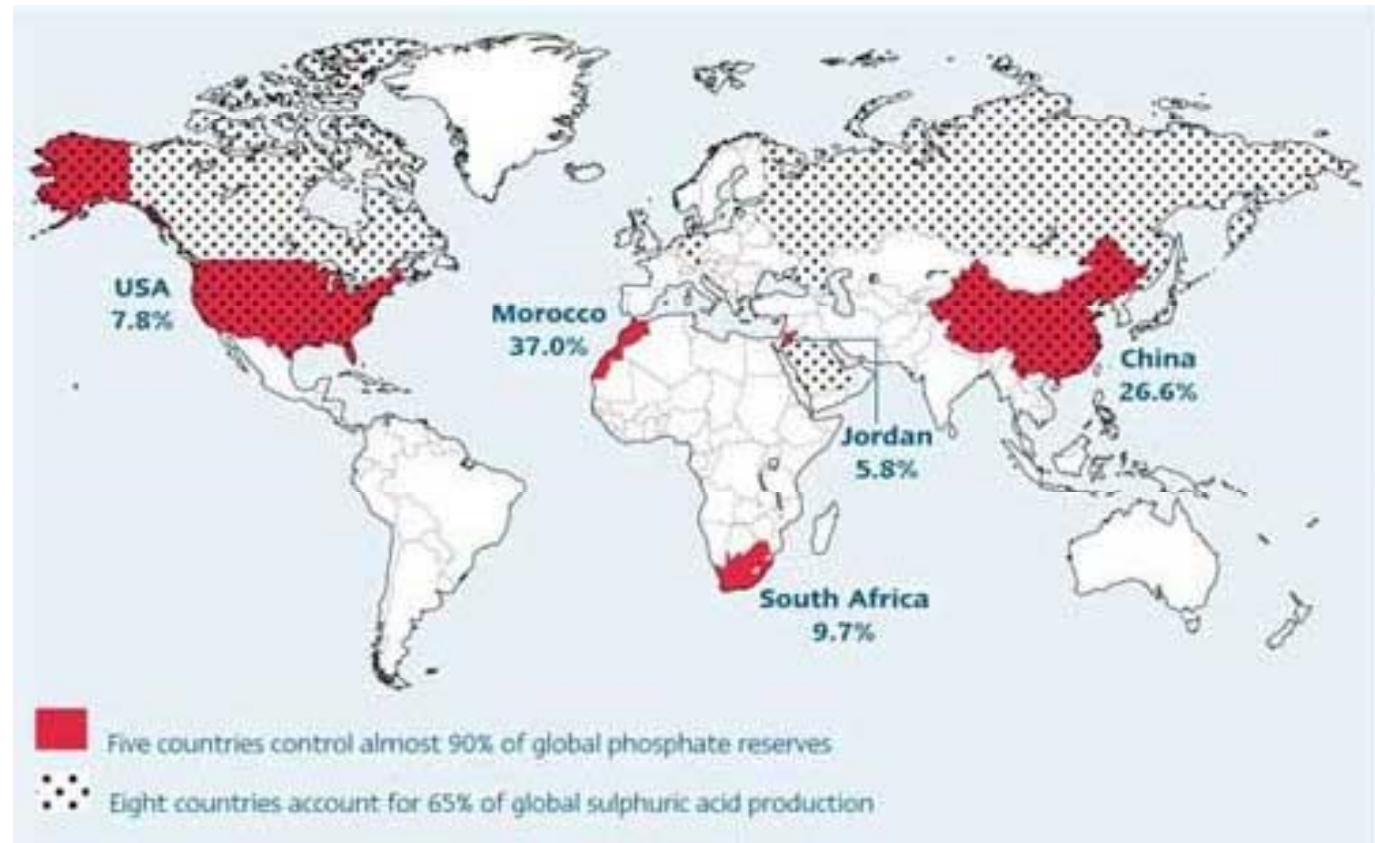


Geopolitical implications

Sulfuric acid

developed countries

- Control of supply and price
- Price control of P



*Rosemarin, A., Bruijne, G. d. & Caldwell, I. (2009)

Environmental implications

Phosphate rock contains naturally occurring radioactive materials

- Uranium (Radium) -> 20 to 300 ppm, or 7 to 100 pCi/g
- Thorium -> 1 to 5 ppm, or 0.1 to 0.6 pCi/g

By-product of phosphate fertilizer production

-> Calcium sulfate (phosphogypsum)

Only in Florida

- 1000 Mt of phosphogypsum (25 stacks)
- 30 new Mt are generated each year



What happened with P after fertilization?

Normally soils are over fertilized

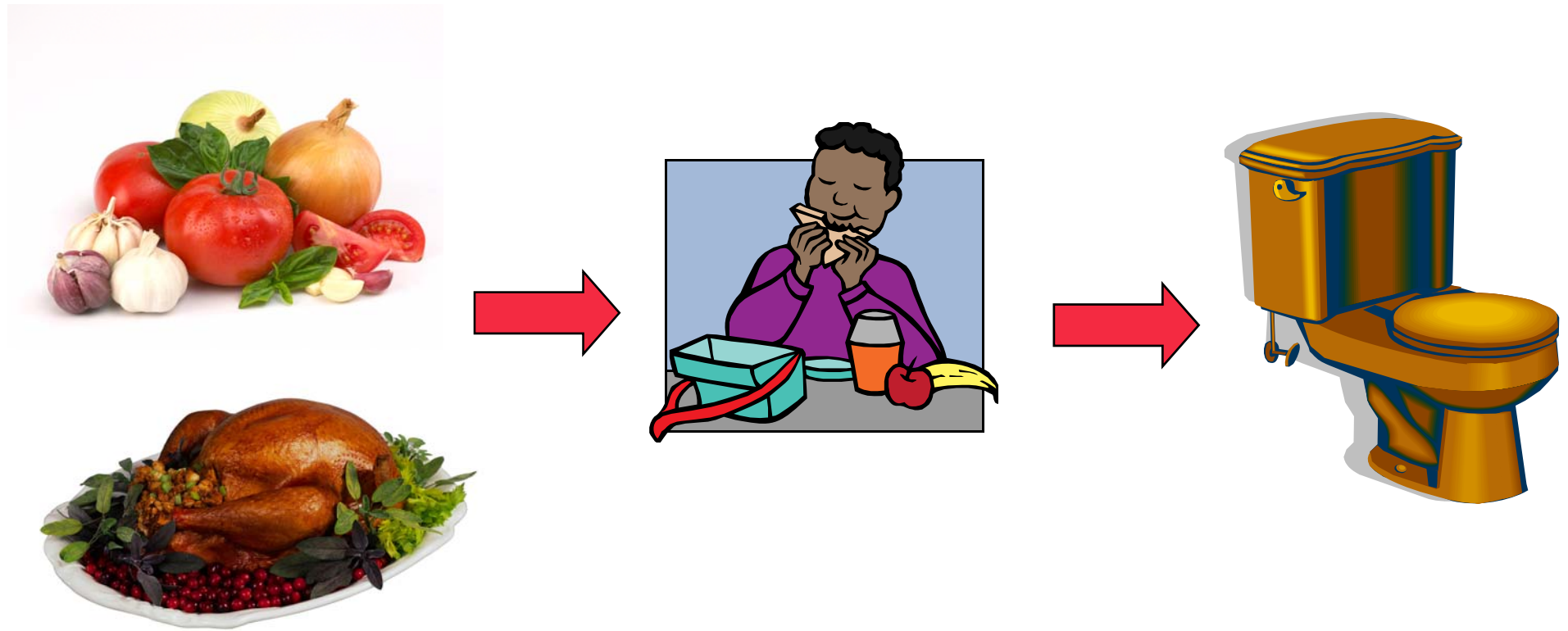
- N-based nutrient management in most EU-countries (except the Netherlands and Sweden)

Eutrophication

- Over-fertilization of lakes with nutrients
 - > Over-grow of water plants and algae



What happened with P after fertilization?



and after that?



Eutrophication

Or to the wastewater treatment plant..



State of Art in wastewater treatment plants

Chemical precipitation of phosphate

- Aluminium and iron salts are used
- They do not have a value as fertilizers
- They must be disposed in landfills

Potential P-Recycling in Germany

Demand in agriculture: 150 000 t P/a

Type of waste	t P/a
Sewage sludge	56700
Meat and bone meal	30277
Biowaste	15261
Paper	13500
Slaughterhouse	5460
Others	7499
Total (rounded)	130 000

What can be done?

There is no fast or a unique solution!

Sustainable P-Use

- Study phosphorus sustainability challenge
- Develop new technologies for P recycling
- More laws and regulations
 - Fertilizer production
 - Agriculture sustainability

New technologies for P-Recycling

- Wastewater and sewage sludge
 - Struvite precipitation (ammonium magnesium phosphate)
 - Calcium phosphate precipitation
- Ashes from sewage sludge incineration



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An unacknowledged problem in politics

- No response from governments, UN agencies or international NGOs
- USGS and IFA publish their own reports
- Little response from fertilizer companies
- Improve public awareness!



Summary

- P is a non renewable resource
 - Geopolitical conflicts could occurred
 - Policy makers do not recognize this as a problem
 - No structures for the sustainable use of P
-
- More public awareness is needed!

What can we do?

More Information

- Ecological sanitation

www.gtz.de/ecosan

- Global Phosphorus Research Initiative

<http://phosphorusfutures.net/>

- Global Phosphorus Forum

<http://www.phosphate-forum.org/>