

The Story of Phosphorus

Willem Schipper



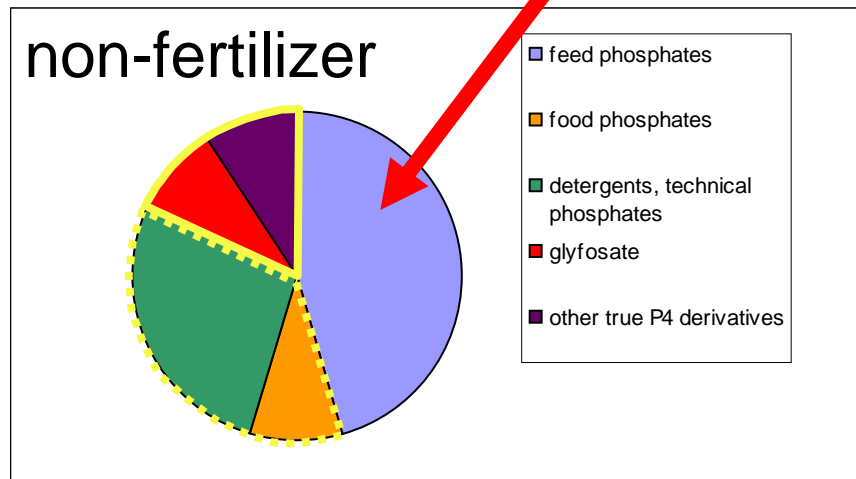
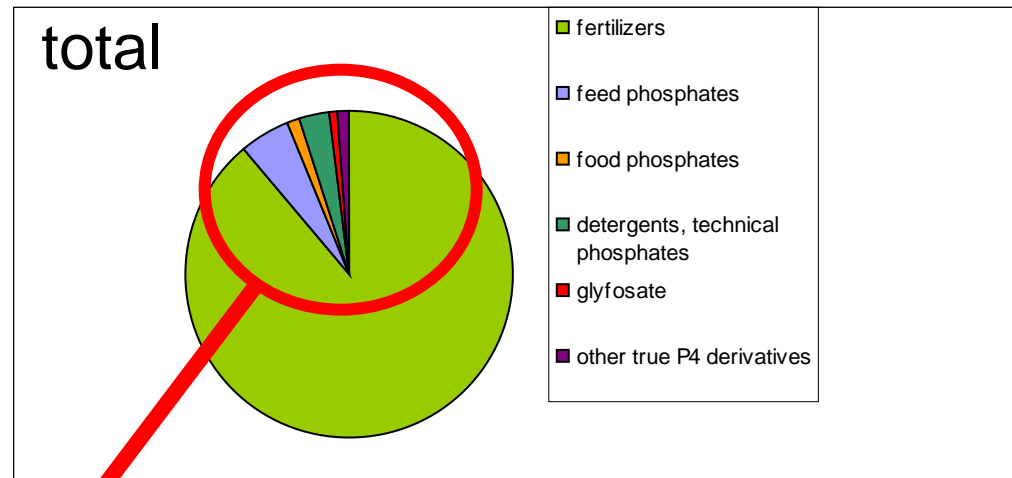
Consulting

why we care about P

- essential to life
- important industrial uses
- limited access for EU
- finite resources
- largely wasted in society
- element = suitable for recycling

world usage of phosphorus

Worldwide 21 Mt/y P



fertilizers

- via H_3PO_4 (phosphoric acid, MGA)
- with other crucial elements: NPK
- many varieties
- irreplaceable

DNA
skeleton
ATP: energy



other uses of P



Lithium ion batteries



flame retardants



herbicides

food uses of P



solid acid for
baking powder



emulsifying
agent



moisture retention
in cooking



chelation

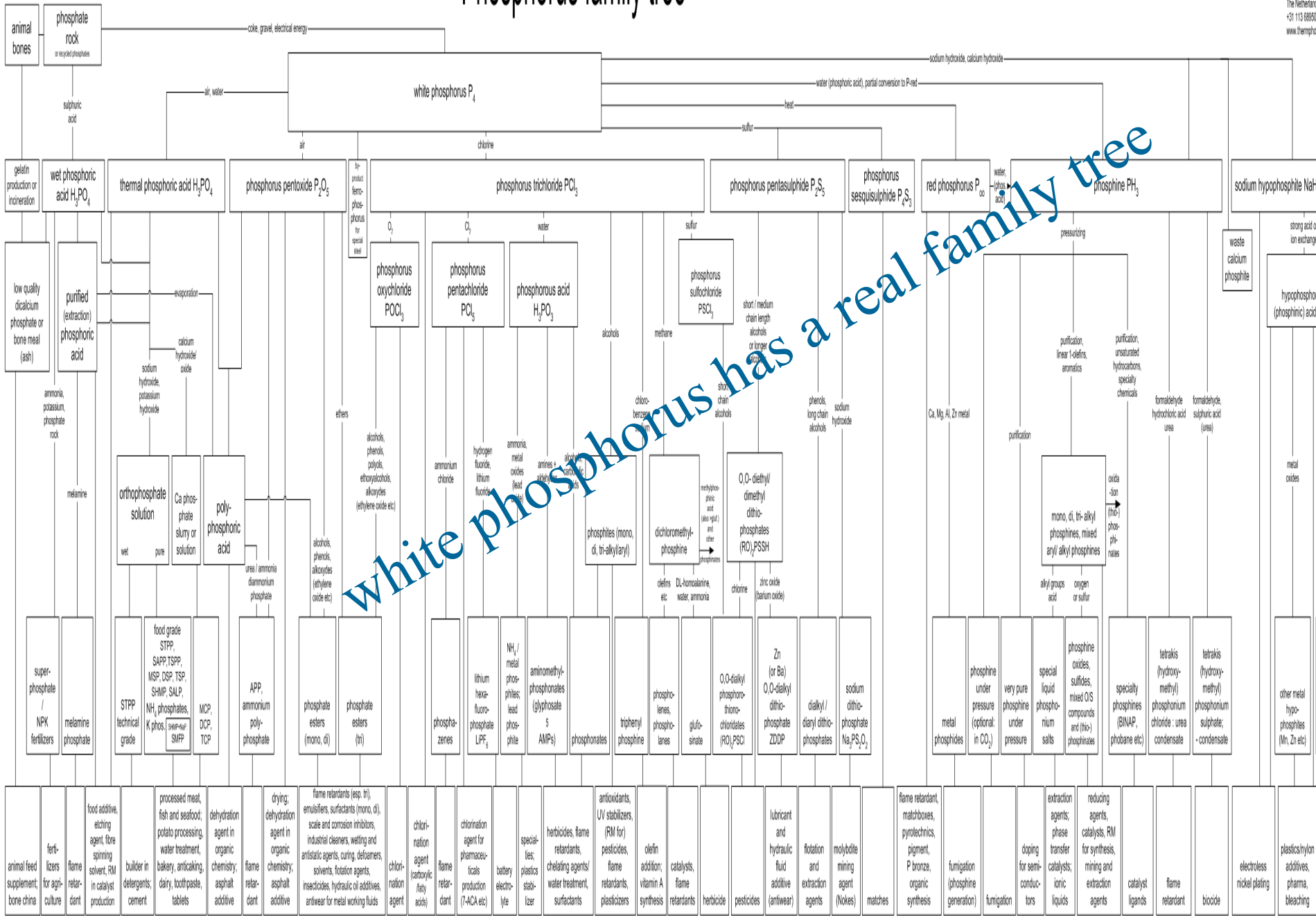


acidulation

Na, K, H-
orthophosphates
pyrophosphates
tripolyphosphates
blends

...

Phosphorus family tree

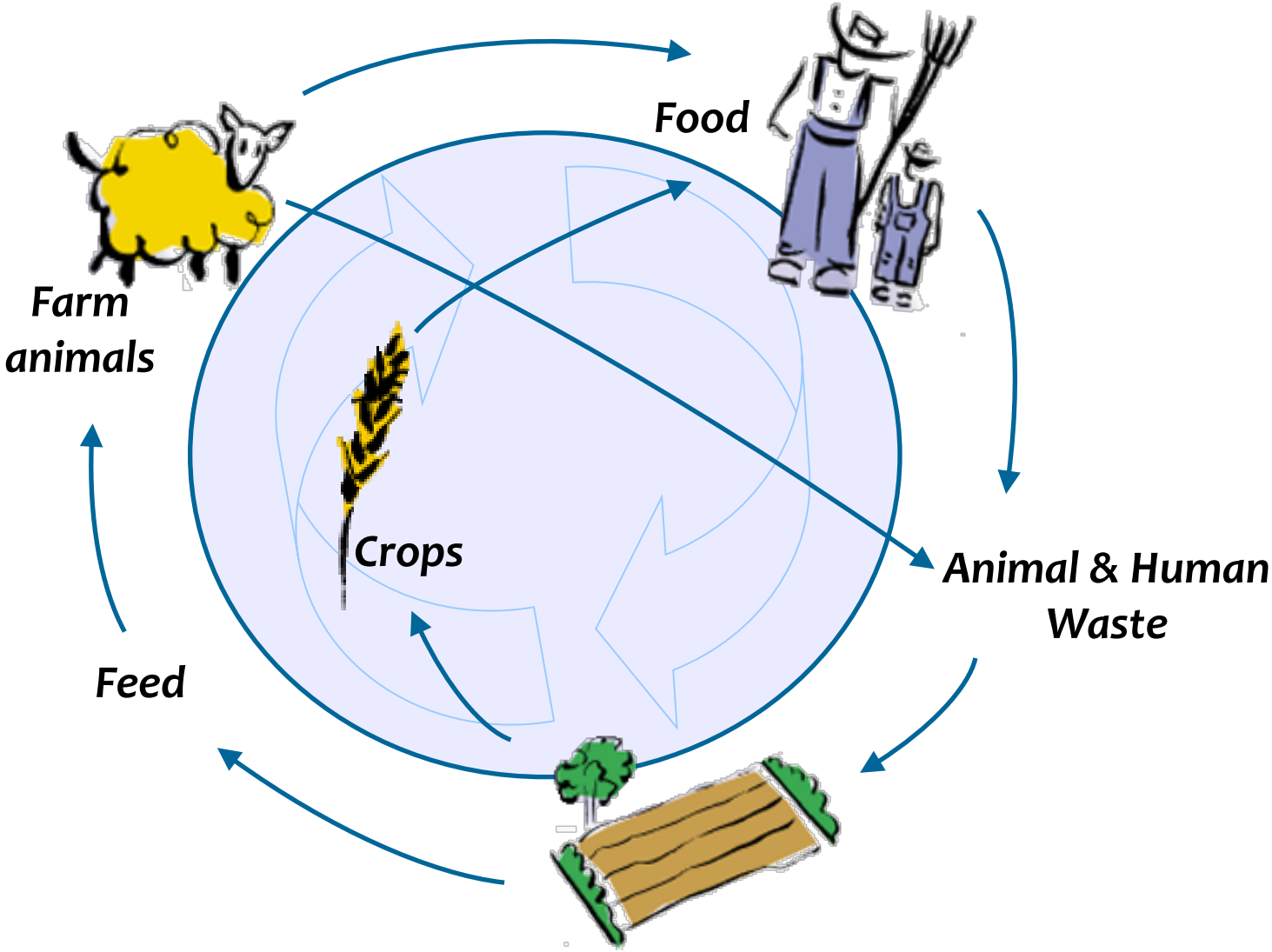




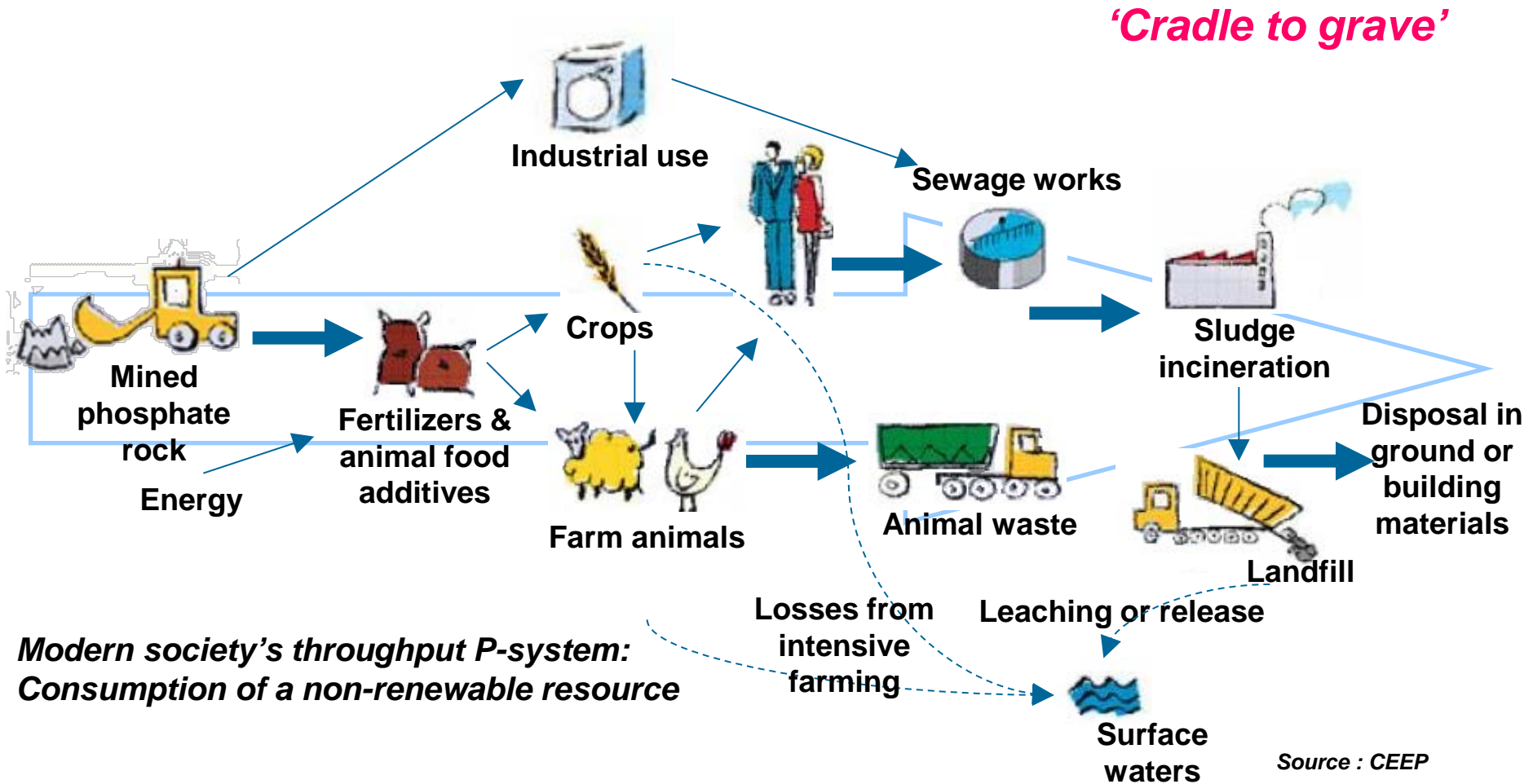
keeping P
in cycles



Traditional phosphorus cycle



Modern phosphorus use



things should not work this way

we need to get P back in cycles

- Being an element, P is perfectly suited for this
- dilution and availability
- use wisely
- get it back
- start where P is found in **concentrated form**
- necessity for everybody (and industry...)
- advantages: Cd, U -> Zn, Cu



plus.....



your dream beach?

- P often limiting for life / growth
- P input to environment = algal bloom
- we need sewage treatment, manure limits

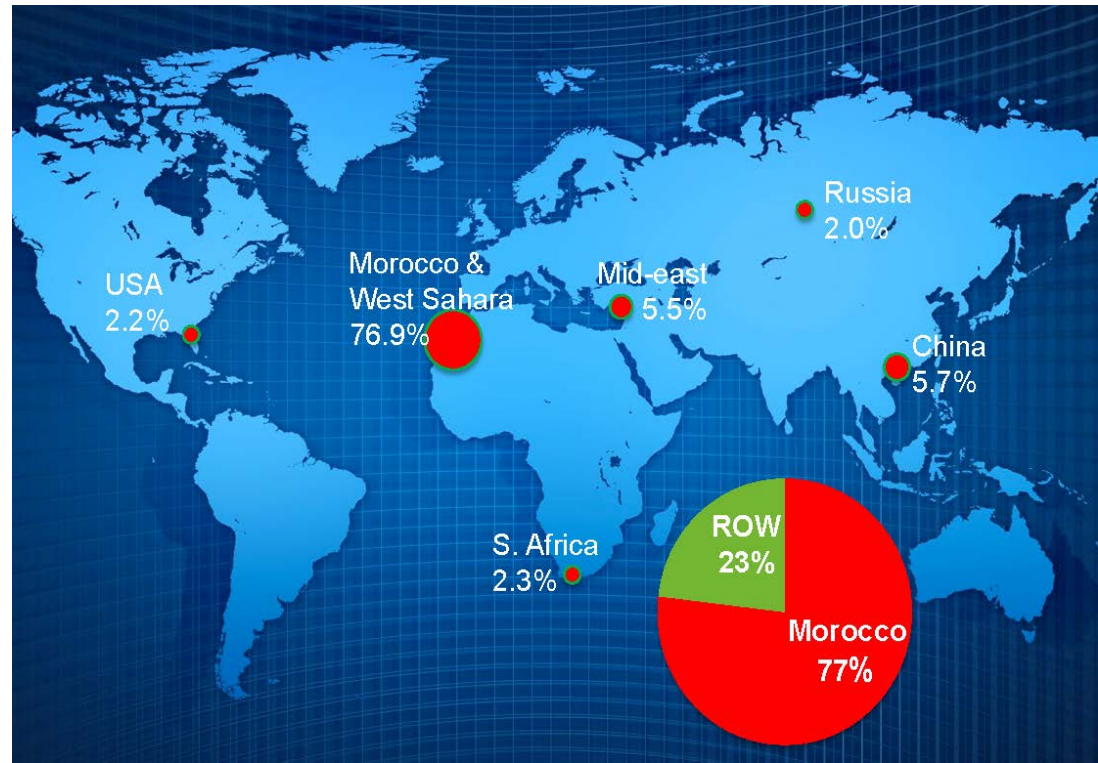


too much or too little?

- mineable resources are finite
- diluted phosphorus is lost to reuse

The P issue – beyond scarcity

- Strategic / geopolitics; supply security
- Sensible waste management – cost avoidance, environmental issues, preventing landfill
- Societal: circular economy, urban mining, Cradle-to-Cradle...
- rock prices
- EU critical materials list- P rock added 2014



agriculture, an important contribution to preserving P (50%)

- P washed out or bound to soil in some form - prevent runoff
- soil often saturated (NL)
- optimize agricultural practices
- soil management
- precision fertilizers, hydroponics etc



industry contribution: recycling

- about 50% of total solution to issue
- urbanisation breaks the P cycle
- more complicated / technological / centralized
- from waste

drivers

- recycling makes sense regardless of scarcity issue
- political measures expected or implemented (Switzerland, Germany) to prevent dilution and loss of accessibility [EU: ??]
- rock price and quality decrease are incentives

where do we access P?

wherever it presents itself in *concentrated form*:

- sewage
- meat industry (meat and bone meal)
- manure
- chemical / metallurgical industry

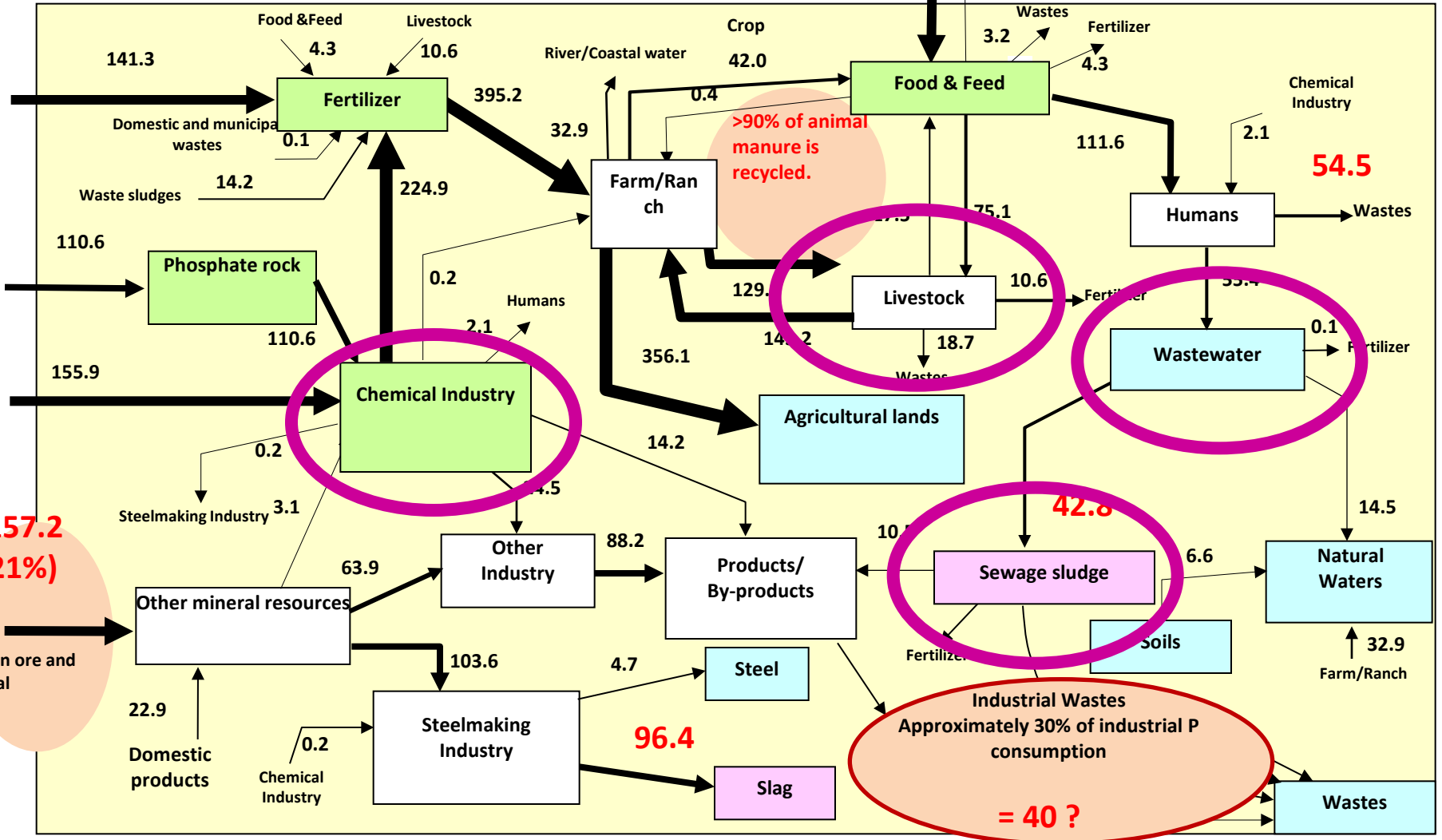
example illustrating this is an issue elsewhere

Total inflow of P = 750 kt/Y

Food & Feed production outside Japan ~ 850 kt/Y

173.4 (23%)

(10³ ton/year)



EU P recycling potential

[kton P/year]	Total	Recycled	
Sewage sludge (human P)	300	40%	
Biodegradable solid waste	130	30%	
Meat & bone meal	130	5%	
Total	560 (+)	160	400
Manure		2000	
<i>Mineral fertiliser use</i>		<i>1500</i>	

Van Dijk & Oenema "Overview of phosphorus flows in wastes in Europe", 2013, Fertilisers Europe seminar, 6 Feb. 2013.

very significant amounts

sewage

- human excretion: 1-2 g pppd
- minor contribution: (dishwashing) detergents (0.1-0.2)
- P needs to be taken out

not a new idea



Joseph Wright,
The Alchemist in Search of the
Philosopher's Stone

stumbling onto phosphorus

...by boiling his own
urine with charcoal!

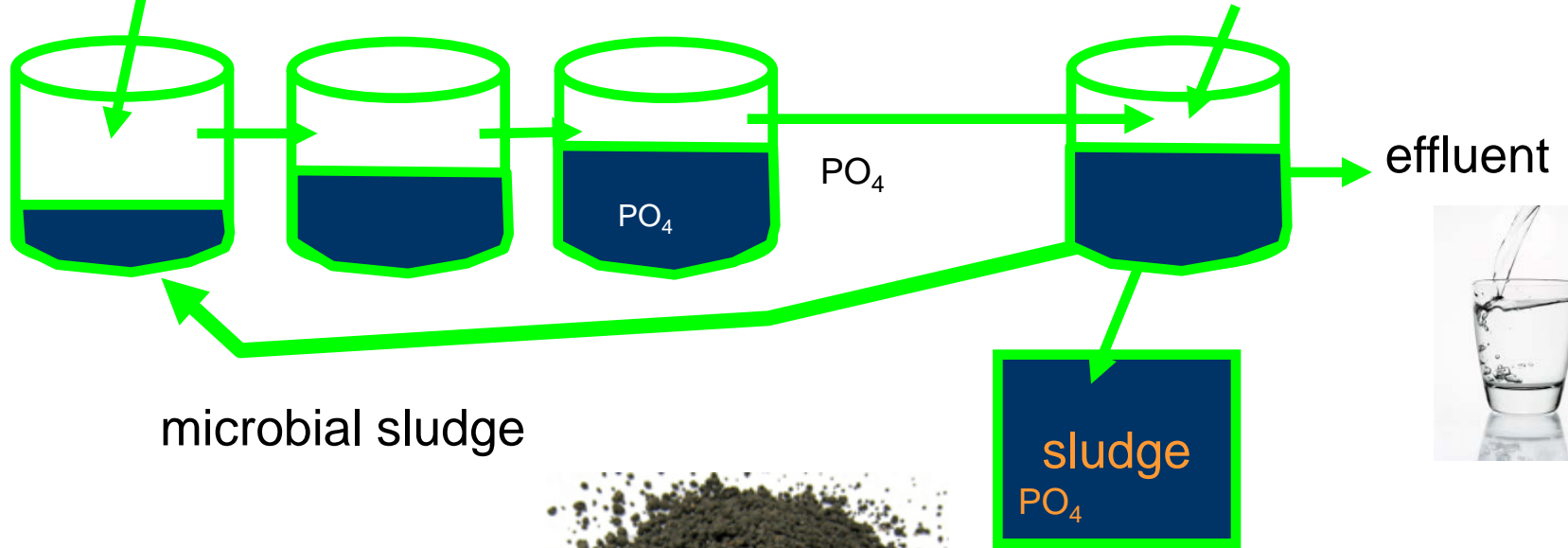




Waste Water Treatment Plant accumulates P

PO_4 , NO_3 , NH_4 ,
organic matter, sand

salts (Fe, Al)
or bioP



P recovery routes from sewage

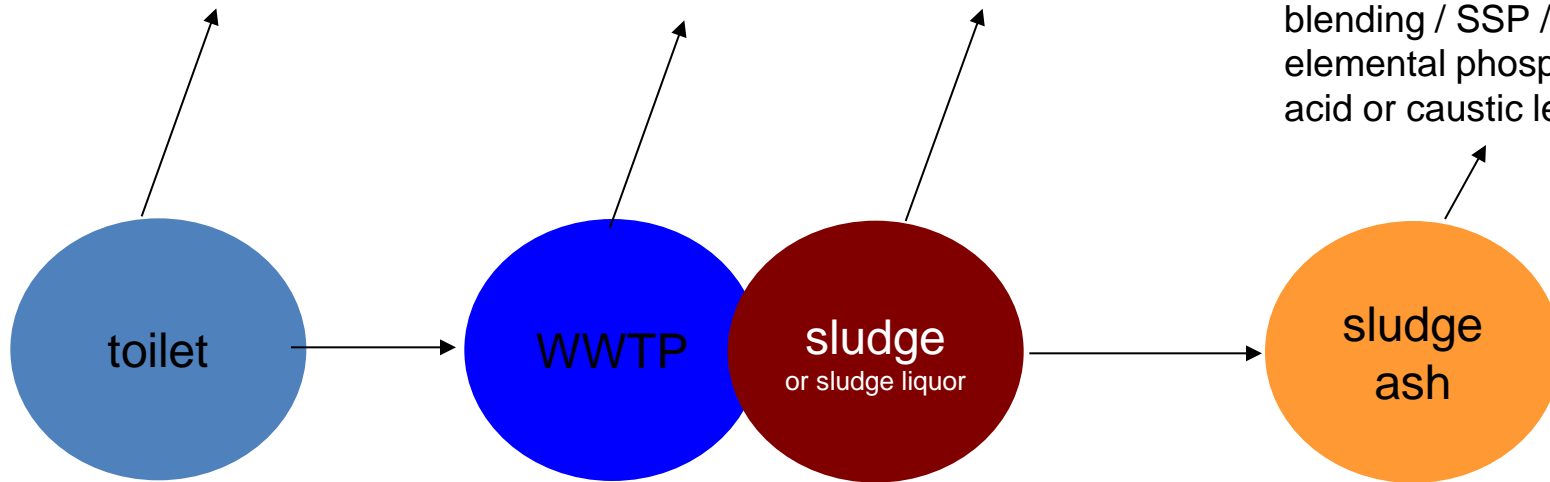


struvite from urine

struvite (from cycle)
Ca phosphate

direct fertilizer
digestion and struvite precip.,
extraction or adsorption
thermal treatment and P precipn.
acid treatment
biopolymers

thermal treatment to fertilizer
blending / SSP / TSP fertilizer
elemental phosphorus
acid or caustic leaching



0% recovery efficiency (% of total in sewage) 100%

sewage sludge in agriculture

- some love sewage sludge (“biosolids”) in agriculture, some hate it
- F: +, DE/NL: -; USA:+
- pathogens, drug residues, heavy metals (Zn, Cu) - less in rural areas
- plant availability of P = ??? Fe phosphate



sludge on fields

"Die Ausbringung von Klärschlamm ist jedem Bauern strengstens untersagt"

"Spreading of sewage sludge is strictly forbidden for all farmers"



Produkte

Rezepte

Kartoffel

Daten & Fakten

Geschichte

Sorten

Kontrollierte Qualität

Das ist drin

AMA-Gütesiegel

Historie

Fun & Gewinne

Kinder-Ecke

Kontakt

Die Kartoffel Kontrollierte Qualität

bevor eine Kartoffel wurzeln schlagen darf, wird die Bodenqualität geprüft. Die Anbauflächen werden bei gleichzeitiger Verpflichtung zur Einhaltung einer dreijährigen Fruchtfolge genau festgelegt. So können Monokulturen und Fruchtfolgekrankheiten vermieden werden.

Düngung

Jede Kartoffel hat andere Ansprüche. Also wird nach dem spezifischen Bedarf der jeweiligen Sorte auf Basis von Bodenanalysen gedüngt. Die Ausbringung von Klärschlamm ist jedem Bauern strengstens untersagt!

Datenerfassung

Hier ist alles gespeichert: Die Daten jedes einzelnen Kartoffelfeldes werden in Schlagkarteien gesammelt und liefern somit Informationen



Daten & Fakten



Geschichte



Sorten



Kontrollierte Qualität



Das ist drin



AMA-Gütesiegel



“Sewage sludge must not be spread on fields that are used in farm production activities” (Industry requirement, Arla Foods requirement)



Arlagården® Quality Assurance Programme

It is not permitted to fertilize fields with sewage sludge from municipal sewage treatment plants or private domestic sewage treatment plants, as this may pose a risk of introduction of unwanted substances into the farm production cycle. [...] If sewage sludge has been spread on fields, no coarse fodder may be grown in these for at least three years from the time of spreading.

Version 4.4 / January 2015



P wastage: sewage sludge

- P misplaced as fertilizer (“diffuse landfill”)
- or used for its fuel value in cement works
- phosphorus end up diluted in cement
- same for other P rich biomass with heating value
- cement works like the ash, but not the P
- separate onsite incineration possible

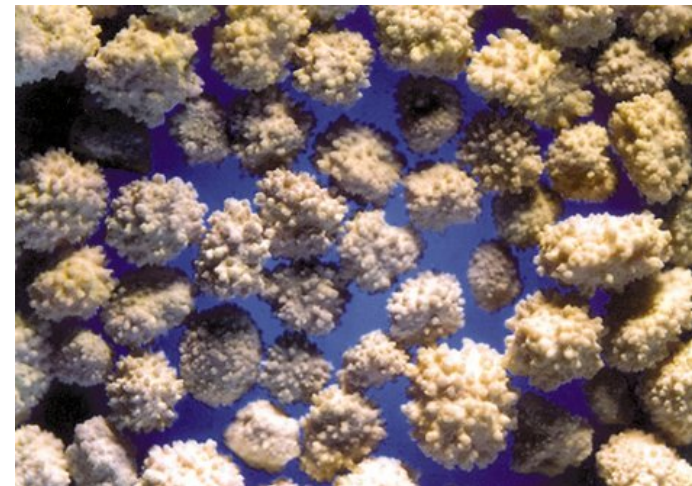
P recovery from sludge

- possible – e.g. struvite
- economic? application?
- or incinerate



STRUUVITE

- is formed in WWTPs anyway
- antiscaling technology - > P recovery
- rollout NA, EU
- 10% of total, maximum
- uses limited
- incompatible with industry



sludge incineration (mono)

- energy recovery (but moisture)
- works for all sludges
- ash currently landfilled etc
- ash needs to go to re-use
- increasing trend EU, NA, Japan

PROS / CONS

- + health/safety
- +/- energy recovery
- + > 90% P yield
- + centralized
- C, N lost to reuse

example

German phosphate mines!

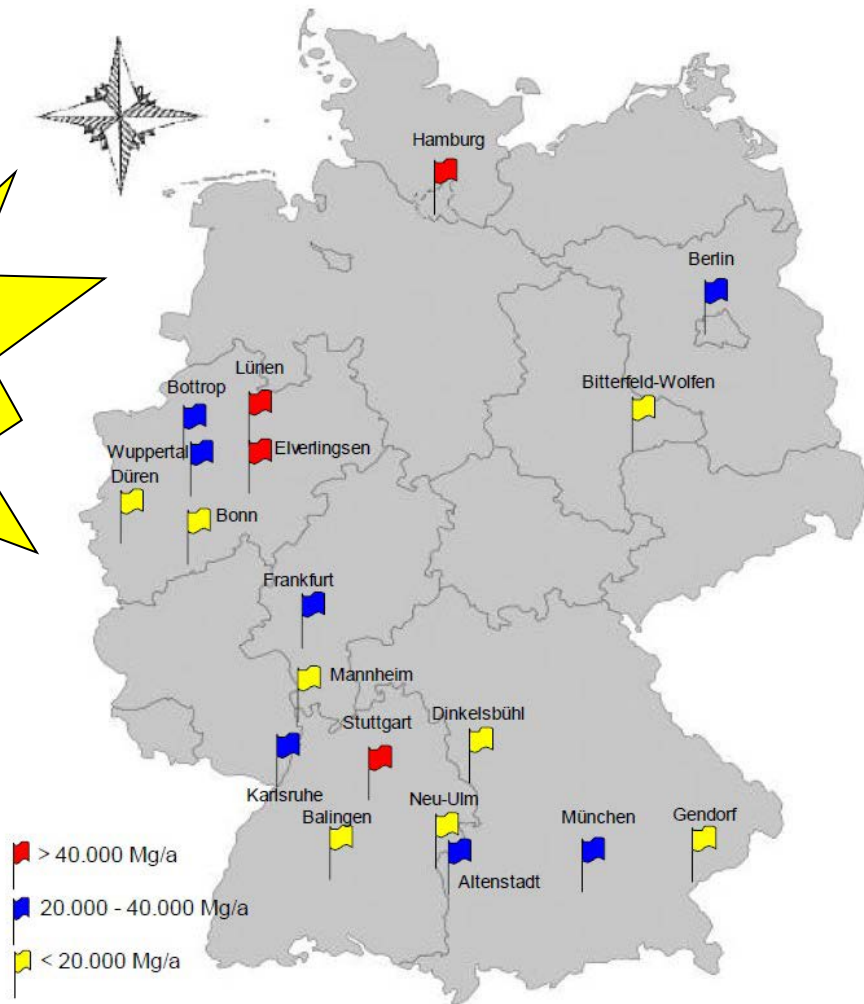


Abb. 2: Klärschlammverbrennungsanlagen in Deutschland (Standorte nach Lehrmann, 2010a)

sewage sludge ash

- centrally collected, dry powder
- contains almost all P from sewage
- industry compatible as raw material?

like rock, but not quite the same

- this is what we get
- not necessarily what we want

a challenge for technology

- basic transformations
- bulk, cheap
- low energy and water

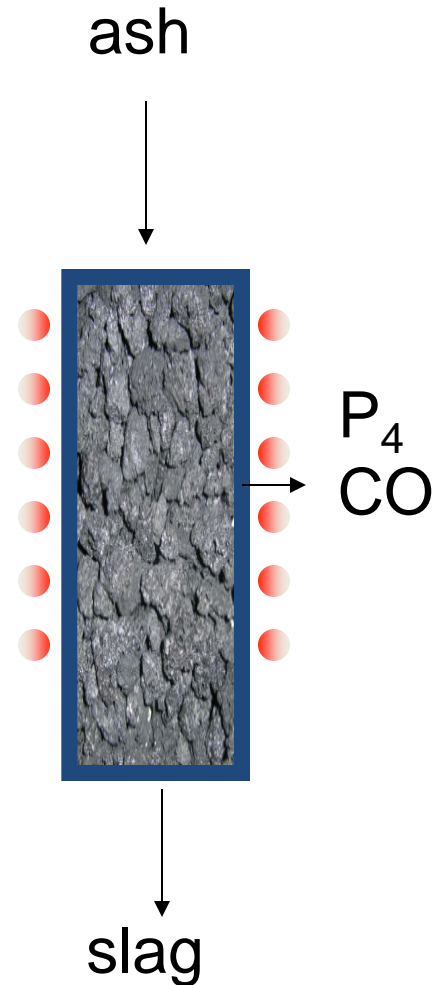
sewage ash to P_4 :



- EU FP7 funded project
- from sewage ash
- new furnace concept - inductive heating

www.recophos.org

ICL: ash to fertilizer

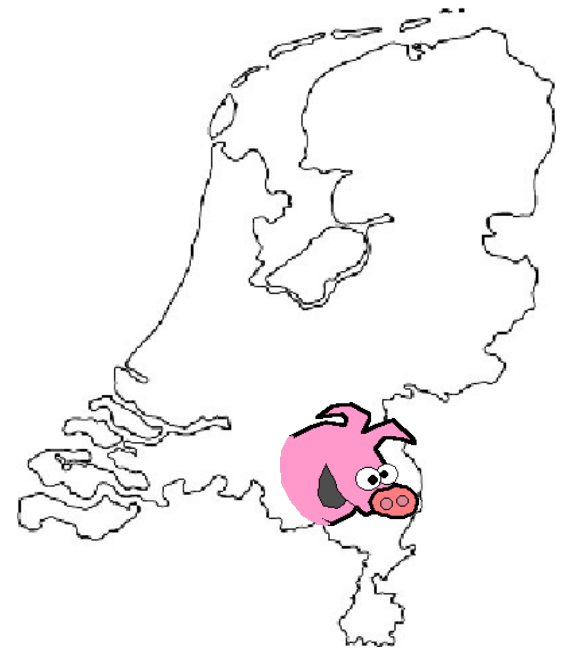


manure

- “wrong” nutrient balance in manure
- P often limiting
- treatment needed
- separation of liquid (N, K) and solid (C, P)
- ash from solids?

manure (pig/cattle)

- NL: more pigs than people
- P management issue: production vs spreading
- oversupply: value -> cost
- transport cost



slaughter waste

- protein/bone mixture - MBM
- BSE driven (MBM cat I) – no cannibalism for ruminants
- currently chiefly to cement industry = CO₂ credits
- P is lost
- **monoincineration needed**

**This and similar “sustainable”
practices are BAT in Europe**

politics

policies

- prevent wastage
- stimulate implementation
- research: largely covered, careful approach
- first movers risks, etc
- see DE, CH

P recycling research



20 years

300 studies

100+ repeats

10-20 different main routes

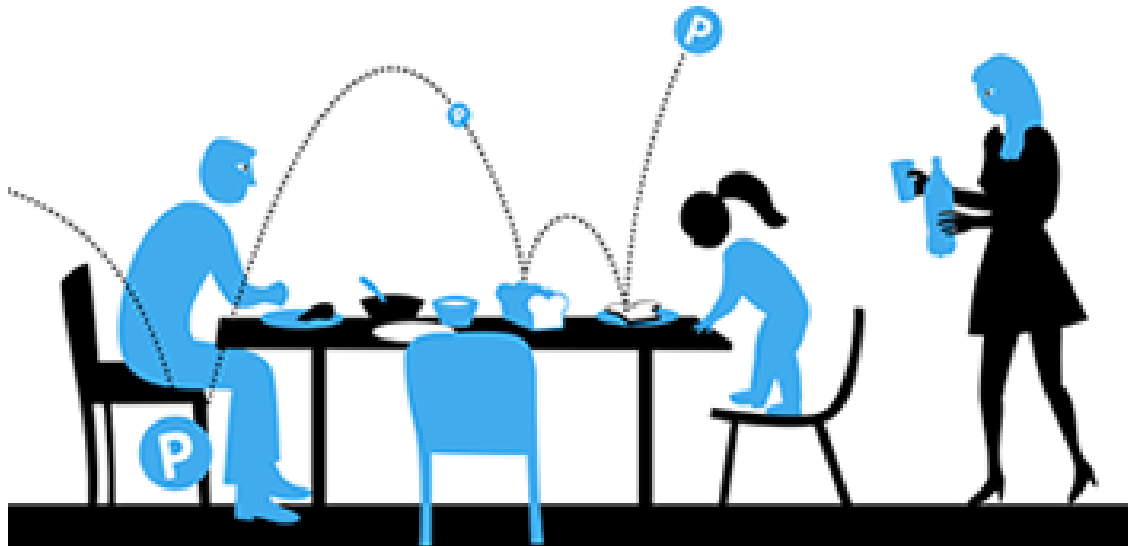
1-2 large scale introduction

Nutrient Platforms

- collaborative approach
- variety of stakeholders
- industry, technology providers, agriculture, NGOs, wastewater operators / service providers, governments, etc.....
- NL / BE /DE/ NO/ UK/ FR
- EU

ESPP

- European platform
- involves all stakeholders
- meeting place for politics and stakeholders
- information exchange and sharing



ZÜRICH REFERENDUM

Tages-Anzeiger - Montag, 4. März 2013

**93,9 % pro new mono
sewage sludge incinerator!**

Bau zentrale Klärschlamm- verwertungsanlage

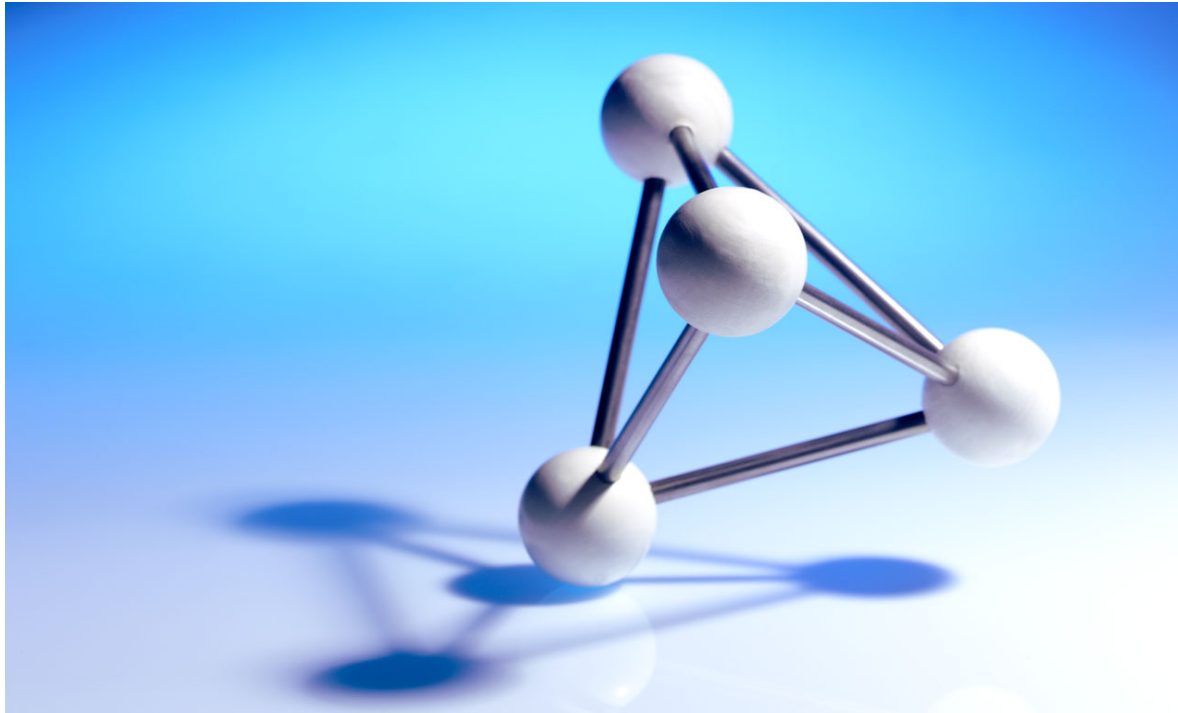
Stadtkreise	Ja	Nein	% Ja
Kreis 1+2	9161	543	94,4
Kreis 3	10449	571	94,8
Kreis 4+5	7601	404	95,0
Kreis 6	8553	412	95,4
Kreis 7+8	14828	791	94,9
Kreis 9	10252	919	91,8
Kreis 10	10621	702	93,8
Kreis 11	12209	969	92,6
Kreis 12	3935	405	90,7
Total	87609	5716	93,9

Stimmbeteiligung: 43,8%

Klärschlamm begeistert

Eine Überraschung ergab die Abstimmung zum 68 Millionen Franken teuren Bau einer Klärschlamm-Verwertungsanlage in der Abwasserreinigung Werdhölzli. Dagegen war keine Partei, doch 93,9 Prozent Ja gibt es nie in Zürich. Neue Altersheime kommen auf 90 oder 92 Prozent, Spitäler auf 89, Krankenhäuser auf 85, Schulhäuser auf über 70 Prozent, aber 94 Prozent Ja ist Rekord. Auch die dritte Vorlage hatte keine Gegner und kam auf fast 90 Prozent: die Anpassung der Vormundschaftsbehörde ans übergeordnete Recht.

Thank you!



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