



## Sorption of phosphorus in soil



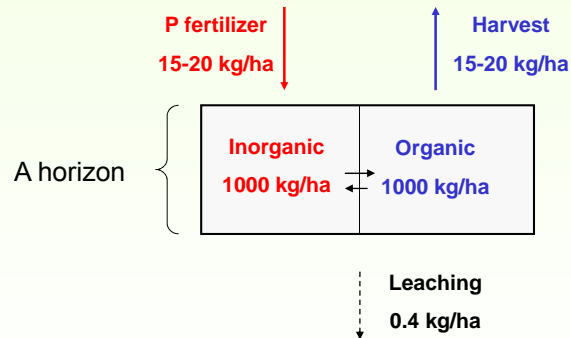
Jon Petter Gustafsson



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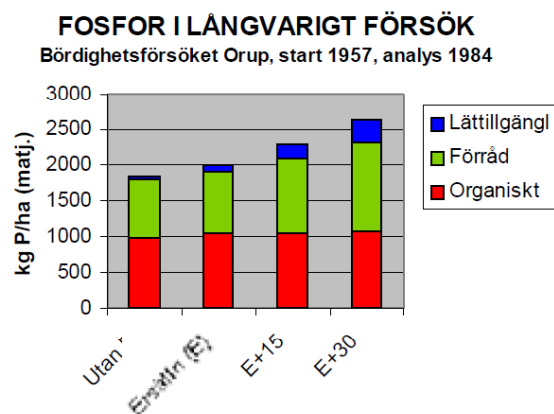
- Mass balances of phosphorus in agricultural soils
- Processes affecting long-term storage of P in soils
- Phosphorus in soil infiltration systems
- Needs for research and development

## Mass balances of P in agricultural soils



- Pools and annual fluxes in a typical agricultural soil (Bertilsson et al., 2005)
- Note: Large soil pool, very little P is lost to surface waters

## What happens at higher loads of P?



- Most of the extra P is bound in the soil as inorganic P!

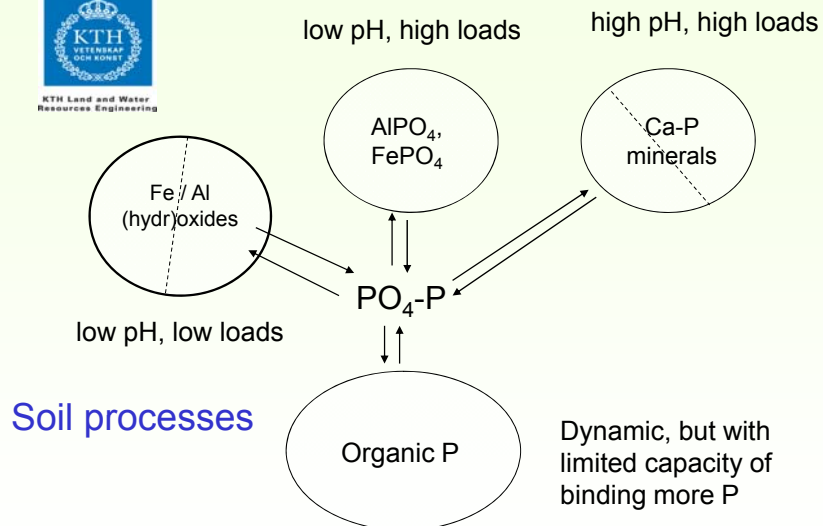


## What happens at higher loads of P?

*P in extracted soil water*

1963-	Kungsängen 0:	5 $\mu\text{g}$ / l P
2007	Kungsängen + 30 kg P/ha	550 $\mu\text{g}$ / l P
1966-	Klostergården 0:	20 $\mu\text{g}$ / l P
2008	Klostergården + 30 kg P/ha	430 $\mu\text{g}$ / l P

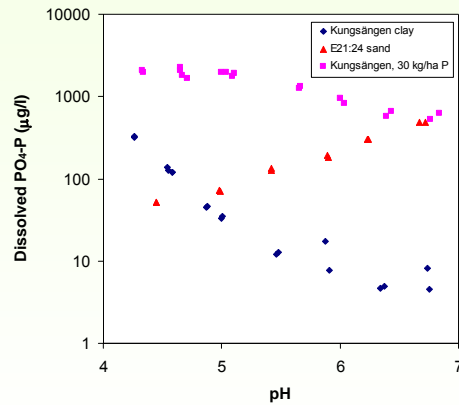
- High P fertilization for a long time increases soluble P in soils; risk for P leaching increases





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## pH dependence of P sorption



- The pH value affects the sorption of P, but the effect is different depending on the soil and on the P load



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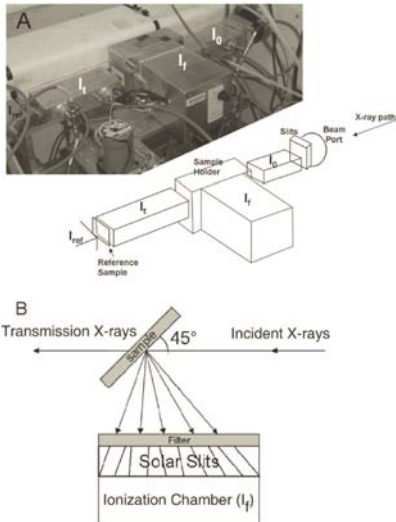
## Research needs for P dynamics in soils

- What is the actual role of the organic P?
- What explains the different pH dependences, how can we model it and target high-risk areas for P leaching?
- What is the exact role of the different inorganic P phases, and why is only a small part of the inorganic P easily mobilized?
- New techniques can answer some of these questions, i.e. XANES spectroscopy, NMR spectroscopy, stable isotopes



## XANES spectroscopy

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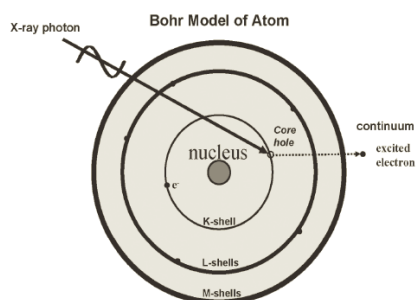


- XANES = X-ray absorption near edge structure



## XANES spectroscopy

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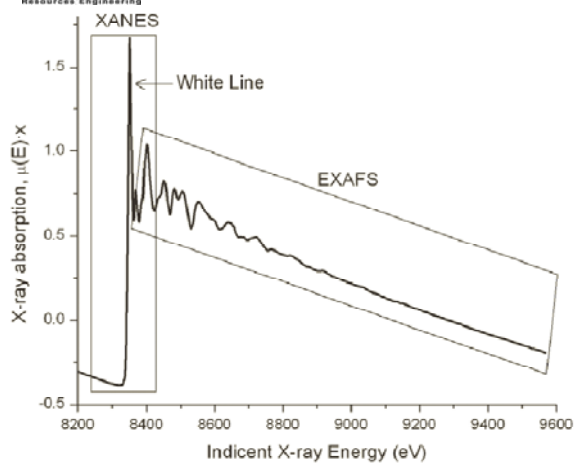


- The principle of XANES and EXAFS



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## XANES spectroscopy

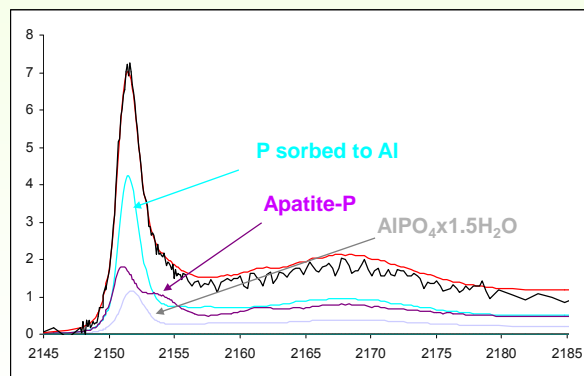


- The difference between XANES and EXAFS



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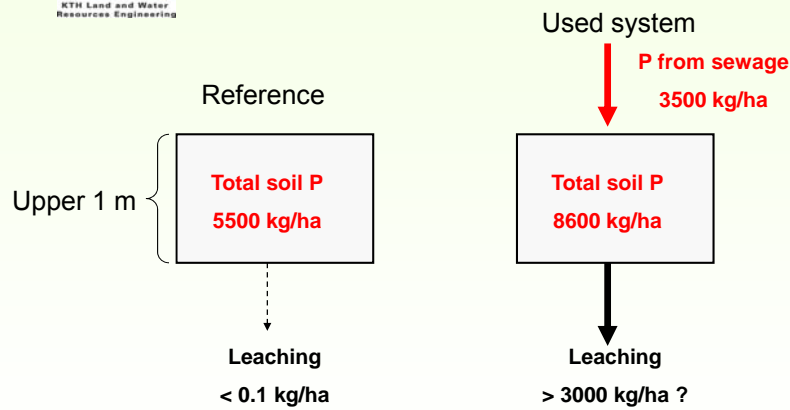
## Accumulated mineral phases in a fertilized soil (Kungsängen)



- XANES: Mostly Al-bonded P. Some present as Ca-P minerals (apatite). (Eveborn)



## Mass balances of P in Tullingsås open infiltration system



- Pools and annual fluxes (Eveborn et al., 2010)
- Fluxes are hundredfold compared with agricultural systems



## Processes affecting P sorption in infiltration systems

- Al-P precipitation is believed to play a major role for P sorption in the used sands, but is inefficient at the high P loads used
- Ca-P precipitation is a potentially more powerful P removal process, but the wastewater has a too low pH and a too high CO<sub>3</sub>/Ca ratio
- With large groundwater zones, however (tens of m) leaching of P may still be delayed for decades, fulfilling SEPA guidelines. However, after that the soils are saturated with P
- Sustainable P removal may require (i) lower loads, (ii) use (the small) potential of biological uptake, (iii) **and/or** the use of complementary techniques



## Final comments and reflections

- For efficient long-term P removal, it seems likely that many of today's soil infiltration systems employ too large P loads
- It should be studied to what extent the P removal can be increased by choosing , e.g., sands that contain calcite, and what processes that determine P removal in such soils.
- The involvement of reactive filter techniques (Polonite, Absol, Filtralite P), chemical precipitation, or source separation, may be of interest to bring down P leaching to acceptable levels