Fate of glucosinolates and their hydrolysis products in soil – biofumigation seen from an environmental soil chemists perspective

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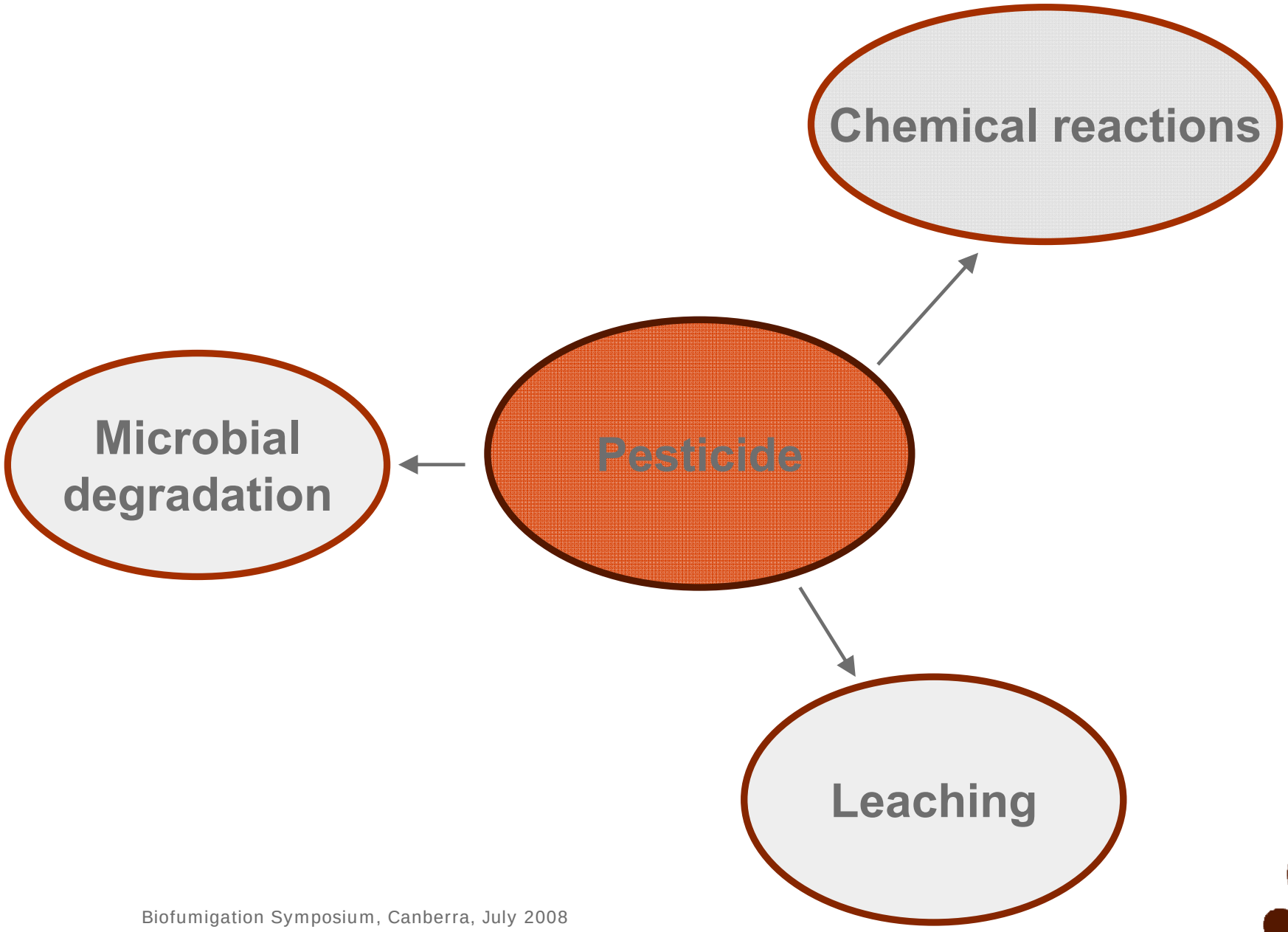
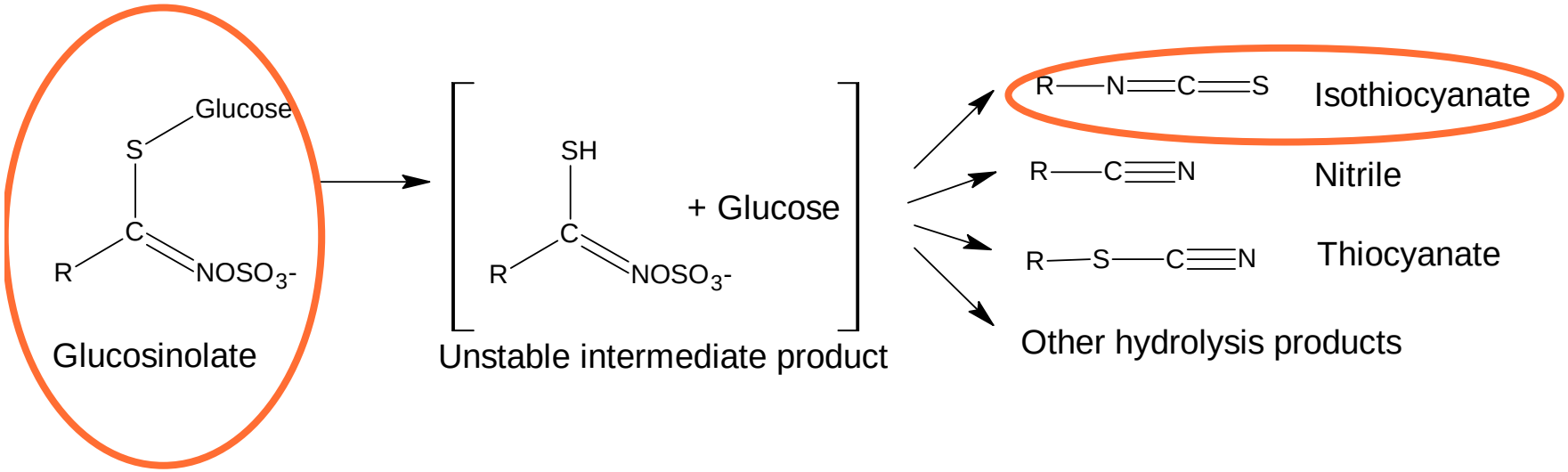
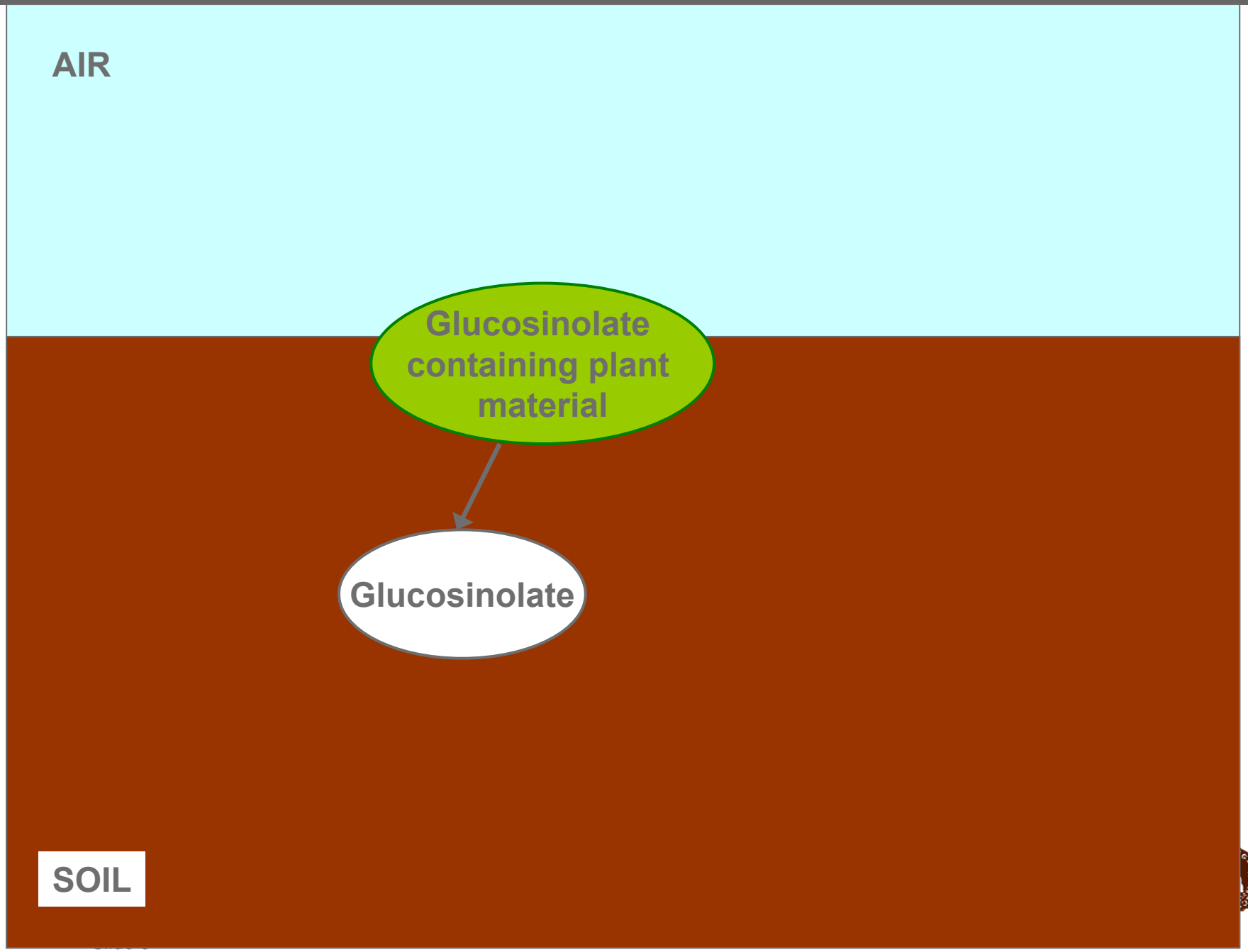
The ideal pesticide

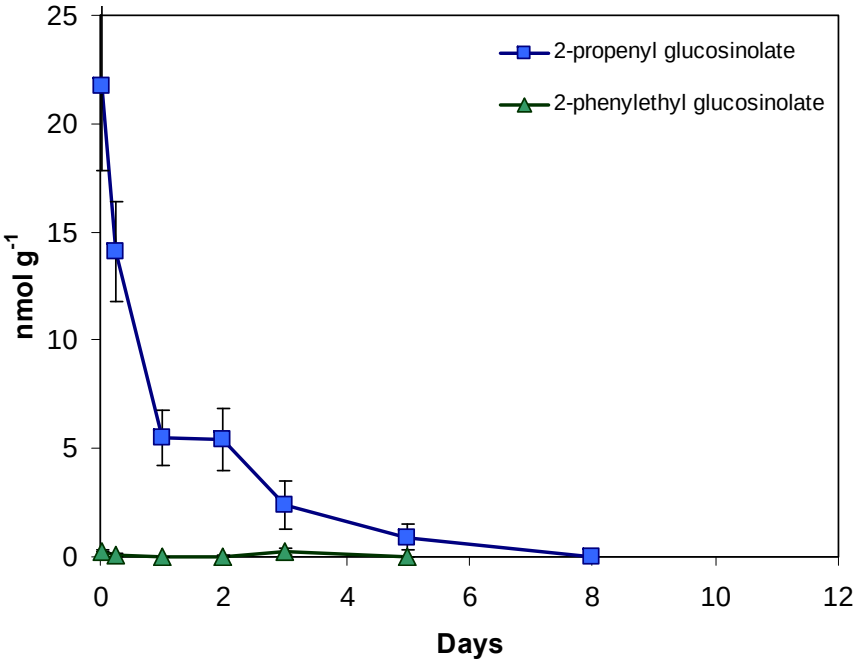
- Persists long enough to affect the pest organisms and then it is degraded or sorbed so that it will not be leached from the soil or harm non-target organisms


Chemical reactions
Microbial degradation
Pesticide
Leaching


Glucose
S
C
R
NOSO3-
Glucosinolate
SH
C
R
NOSO3-
+ Glucose
Unstable intermediate product
R—N=C=S
Isothiocyanate
R—C≡N
Nitrile
R—S—C≡N
Thiocyanate
Other hydrolysis products


AIR
Glucosinolate containing plant material
Glucosinolate
SOIL

Glucosinolates in soil in the field



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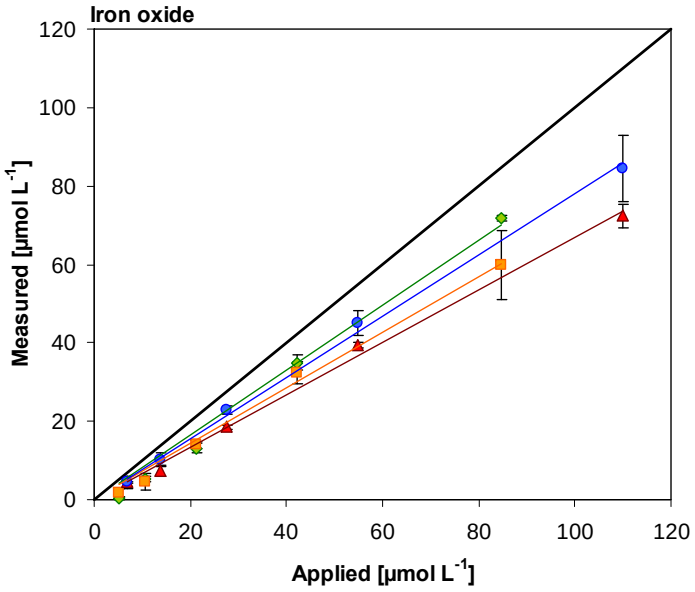
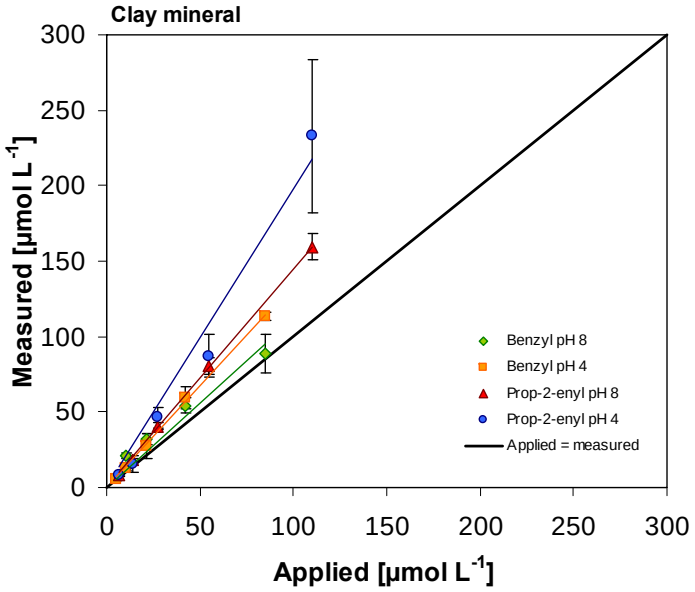
P xvwdug#J VO#klj k#	63#p lq#	46(#
#	9#k#	<(#
P xvwdug#J VO#or z #	9#k#	8(#
Uds h#J VO#klj k#	63#p lq#	: (#
#	9#k#	7(#
Uds h#J VO#or z #	9#k#	8(#

#

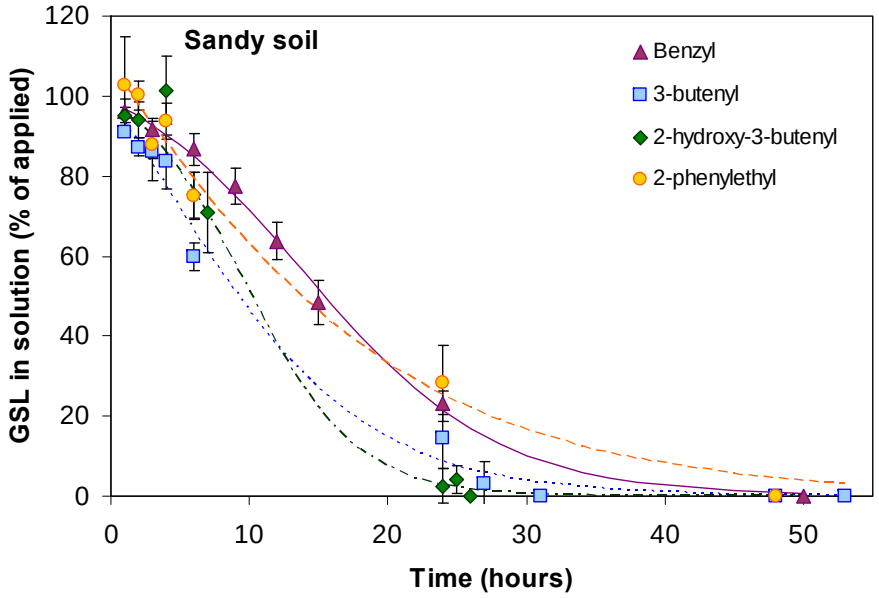
Sorption of glucosinolates

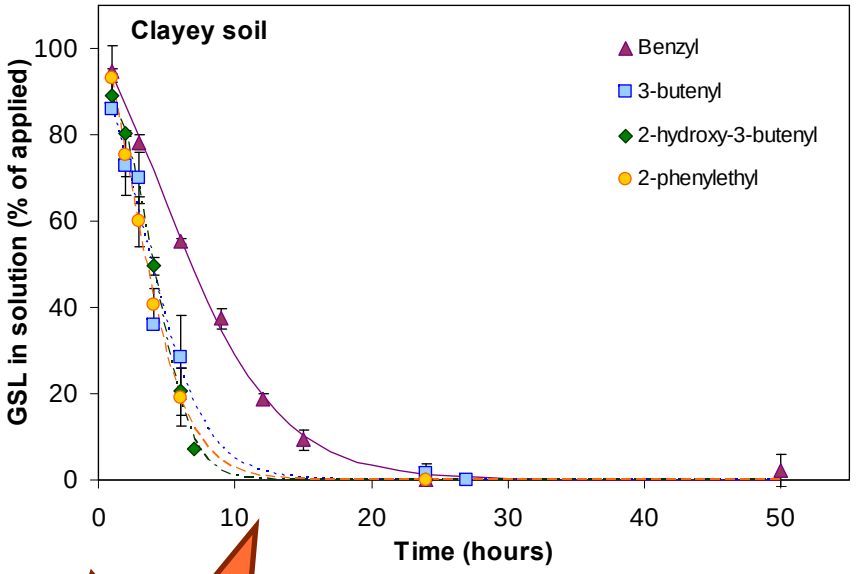
- Glucosinolates are very water soluble anions
- Have no functional groups which can form strong bonds with the surfaces in soil
- Weak sorption is anticipated
- Adsorption was higher at pH 4 than 8 indicating that adsorption takes place by electrostatic interactions between the negatively charged glucosinolates and positive surfaces in the soil
- Anion exclusion was observed with one clay mineral

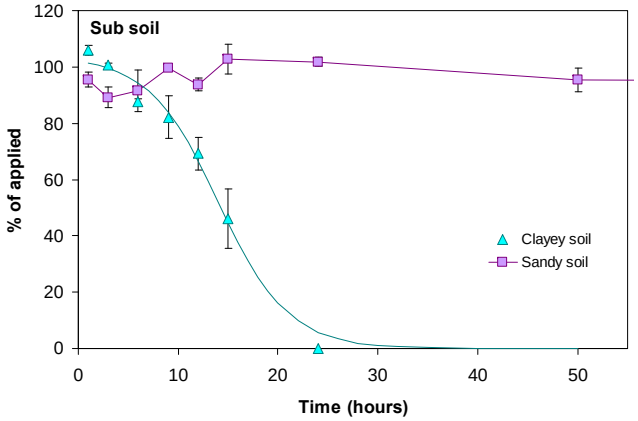




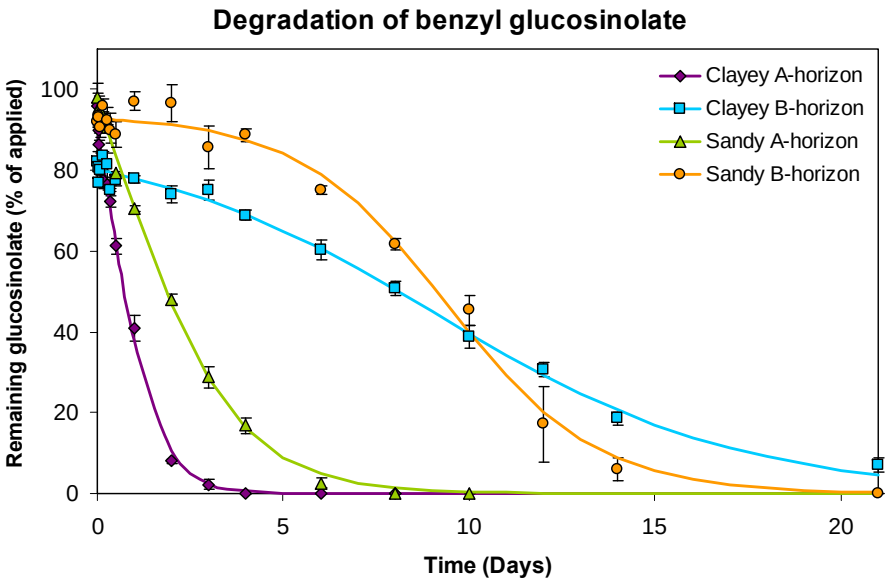
Degradation of glucosinolates

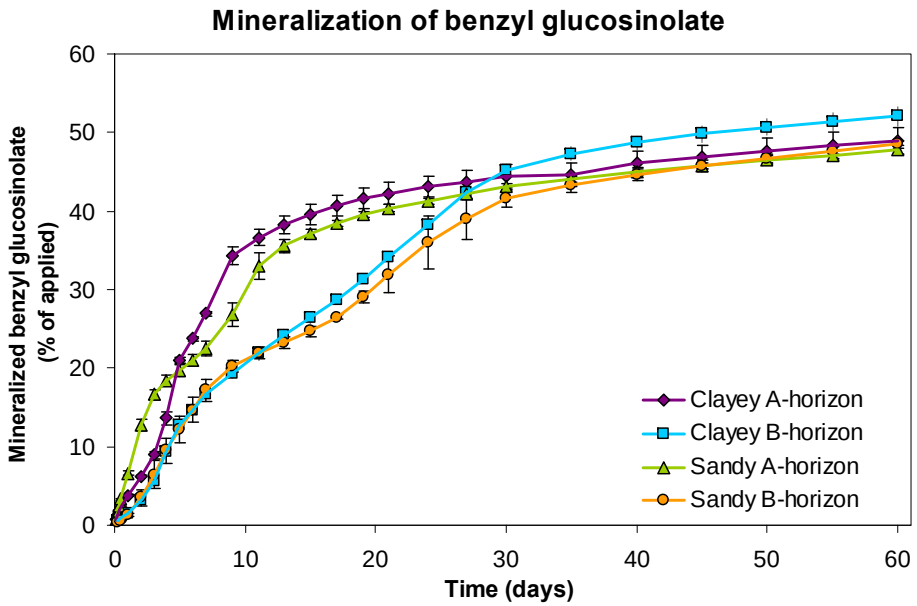




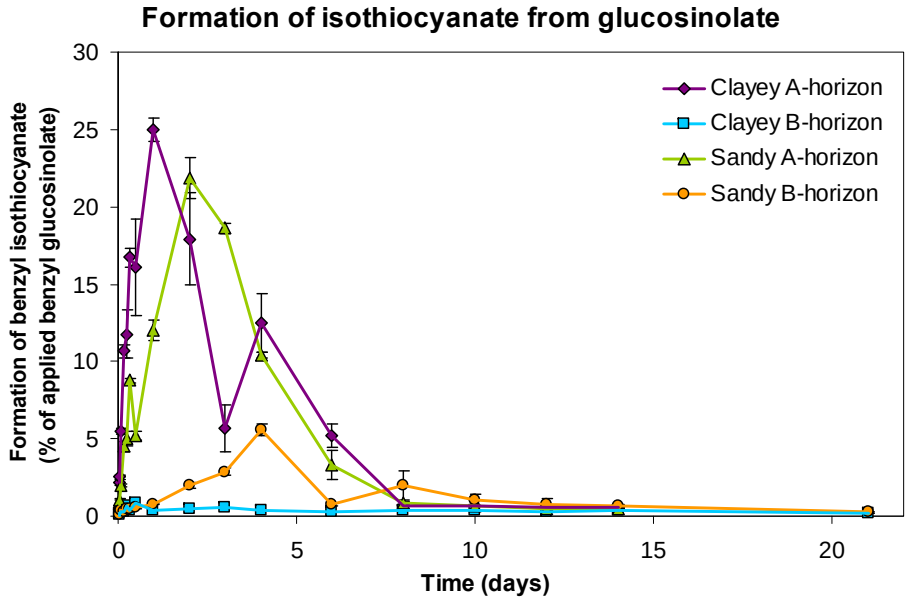


1:1 soil water slurry
20 °C

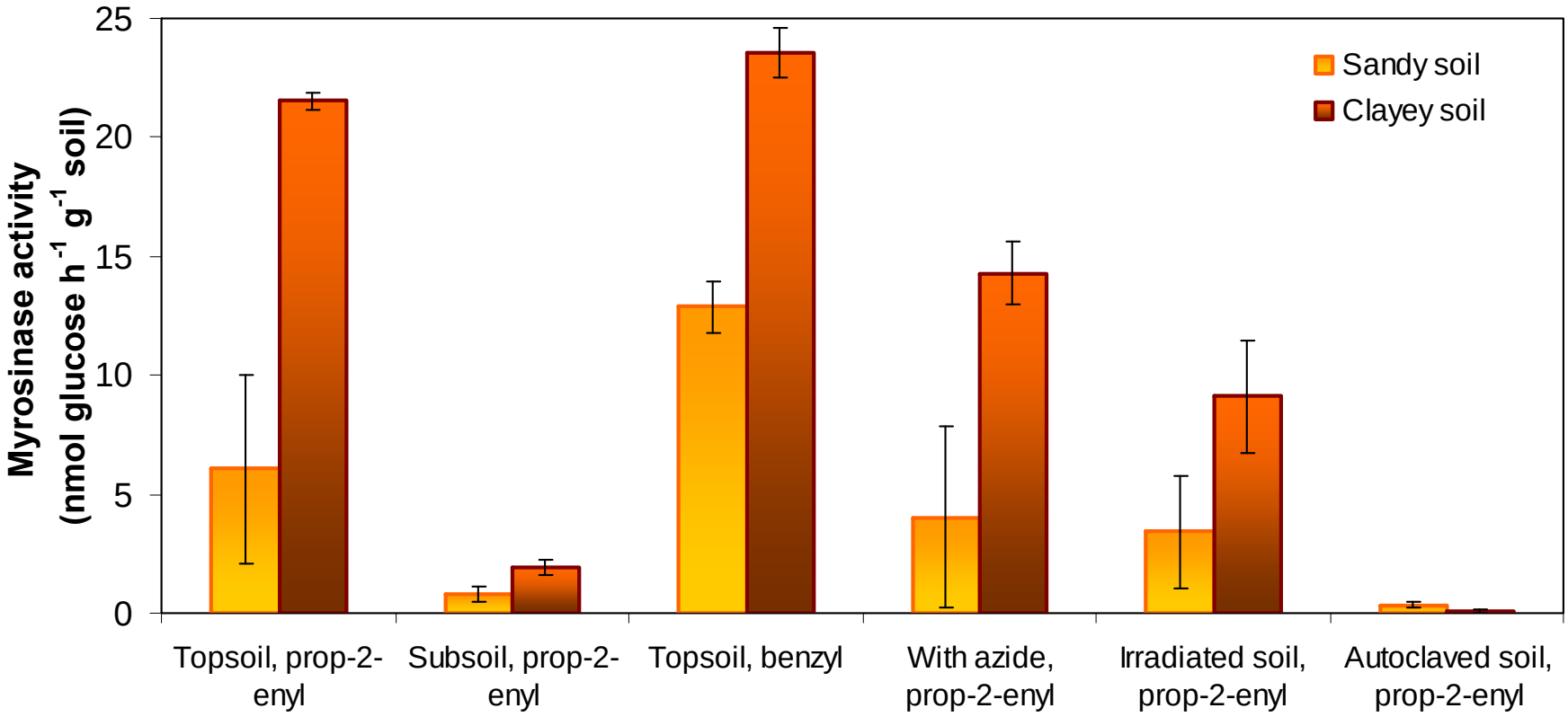

Degradation of benzyl glucosinolate
Remaining glucosinolate (% of applied)
Time (Days)
Clayey A-horizon
Clayey B-horizon
Sandy A-horizon
Sandy B-horizon

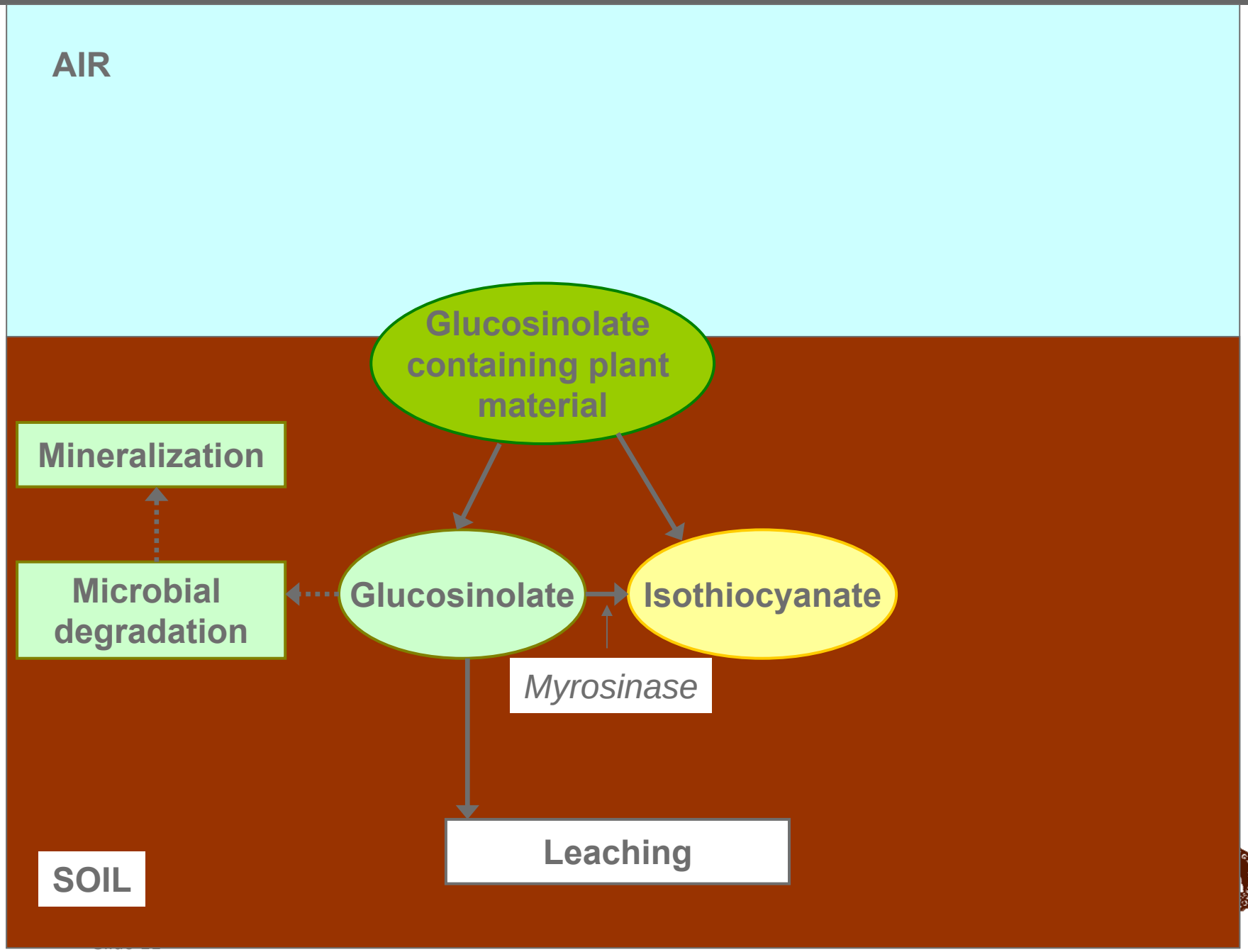

Mineralization of benzyl glucosinolate
Mineralized benzyl glucosinolate (% of applied)
Time (days)
Clayey A-horizon
Clayey B-horizon
Sandy A-horizon
Sandy B-horizon

3-10 % vand
8-9 °C

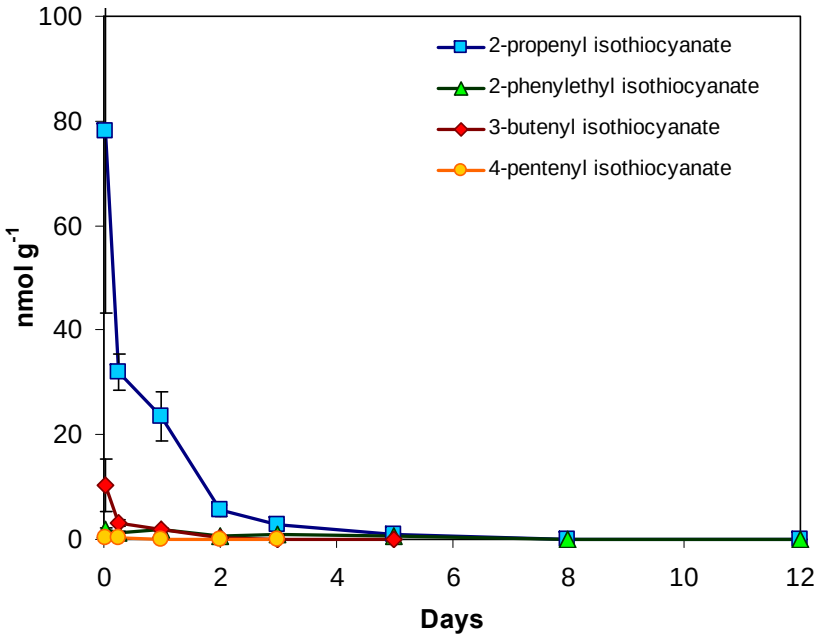

Formation of isothiocyanate from glucosinolate
Formation of benzyl isothiocyanate (% of applied benzyl glucosinolate)
Time (days)
Clayey A-horizon
Clayey B-horizon
Sandy A-horizon
Sandy B-horizon

Myrosinase activity in soil




AIR
Glucosinolate containing plant material
Mineralization
Microbial degradation
Glucosinolate
Isothiocyanate
Myrosinase
Leaching
SOIL

Isothiocyanates in soil in the field



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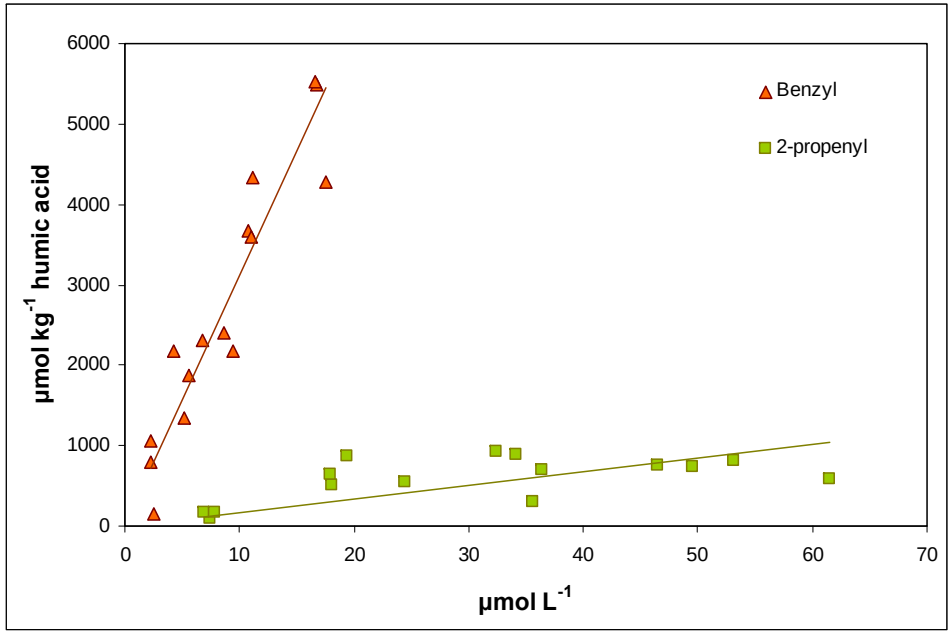
#	9#k#	<(#	55(#	64(#	56(#	
P xvwug#J VO#or z #	9#k#	8(#	53(#	58(#	55(#	
Udsh#J VO#klj k#	63#p lq#	:(#	47(#	54(#	59(#	
#	9#k#	7(#	8(#	<(#	43(#	
Udsh#J VO#or z #	9#k#	8(#	9(#	44(#	53(#	

#

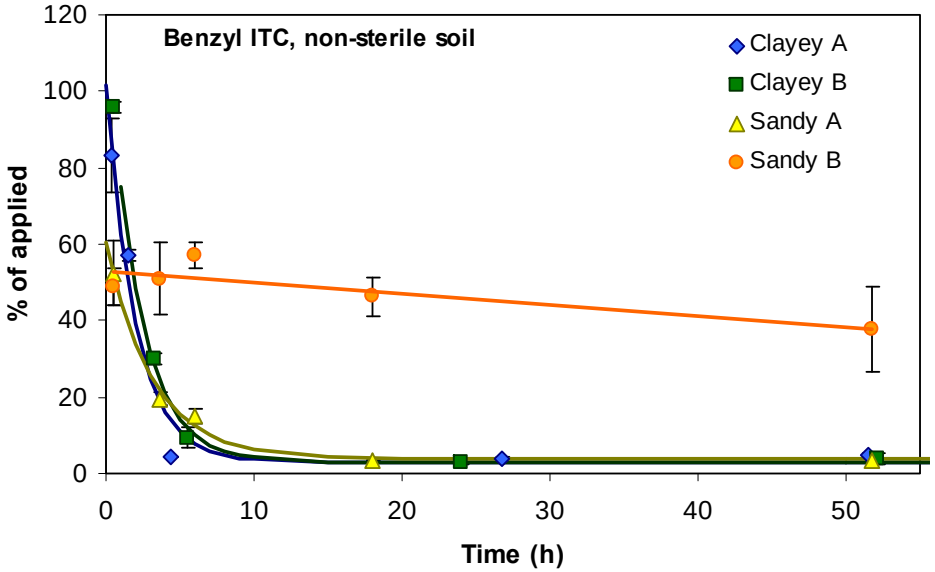
ITC release efficiency = $\frac{\text{Soil ITC concentration (nmol g-1 soil)}}{\text{Total ITC-liberating GSL in original tissue (nmol g-1 soil)}} \times 100$

Sorption of isothiocyanates

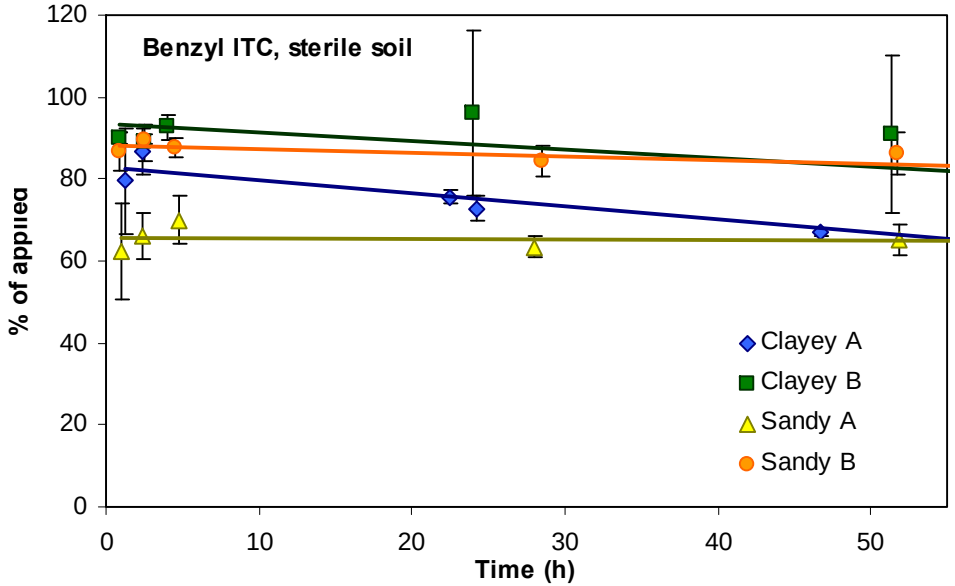
- Isothiocyanates are volatile, reactive, hydrophobic compounds
- Due to their hydrophobic nature they will mainly sorb to the organic matter in soil
- They may also react with nucleophilic groups in soil
- Loss from soil may also be caused by volatilization



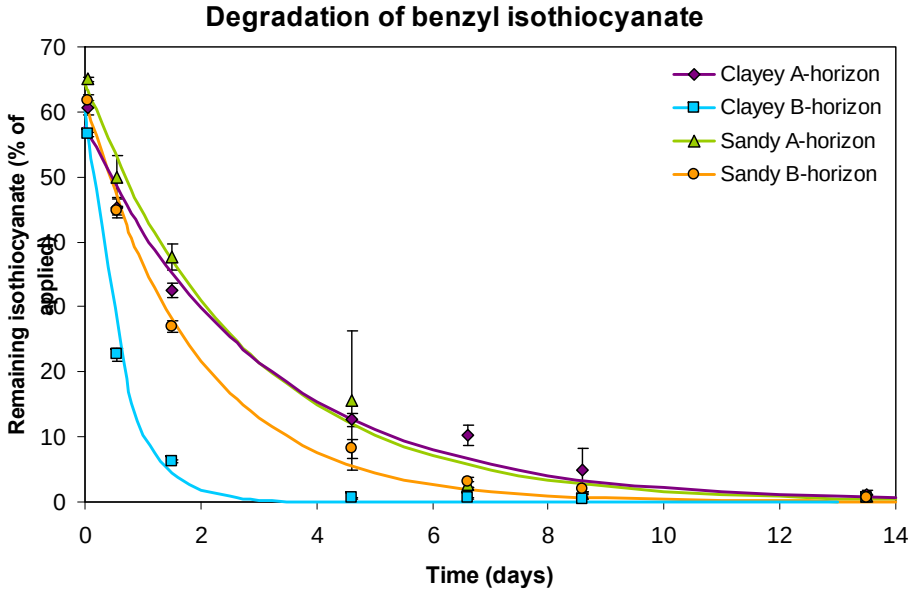
Degradation of isothiocyanates

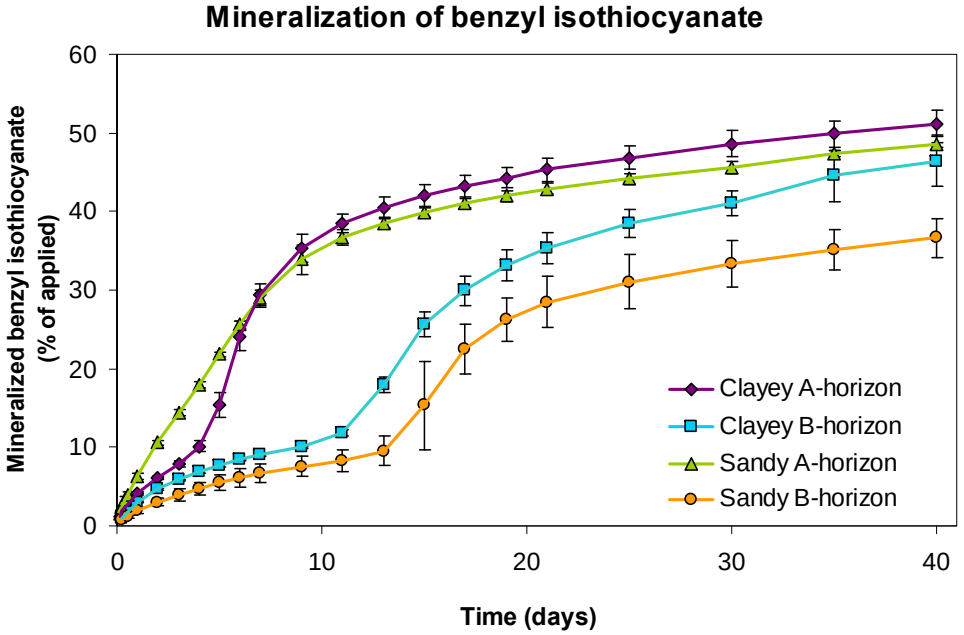


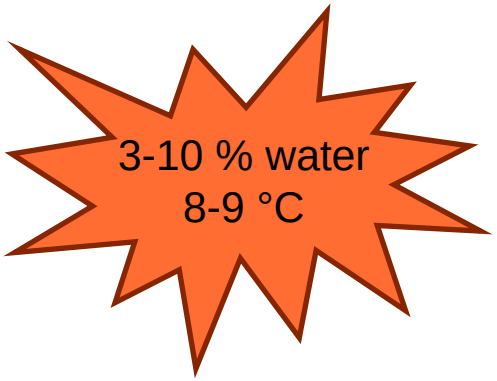
1:1 soil water slurry
20 °C



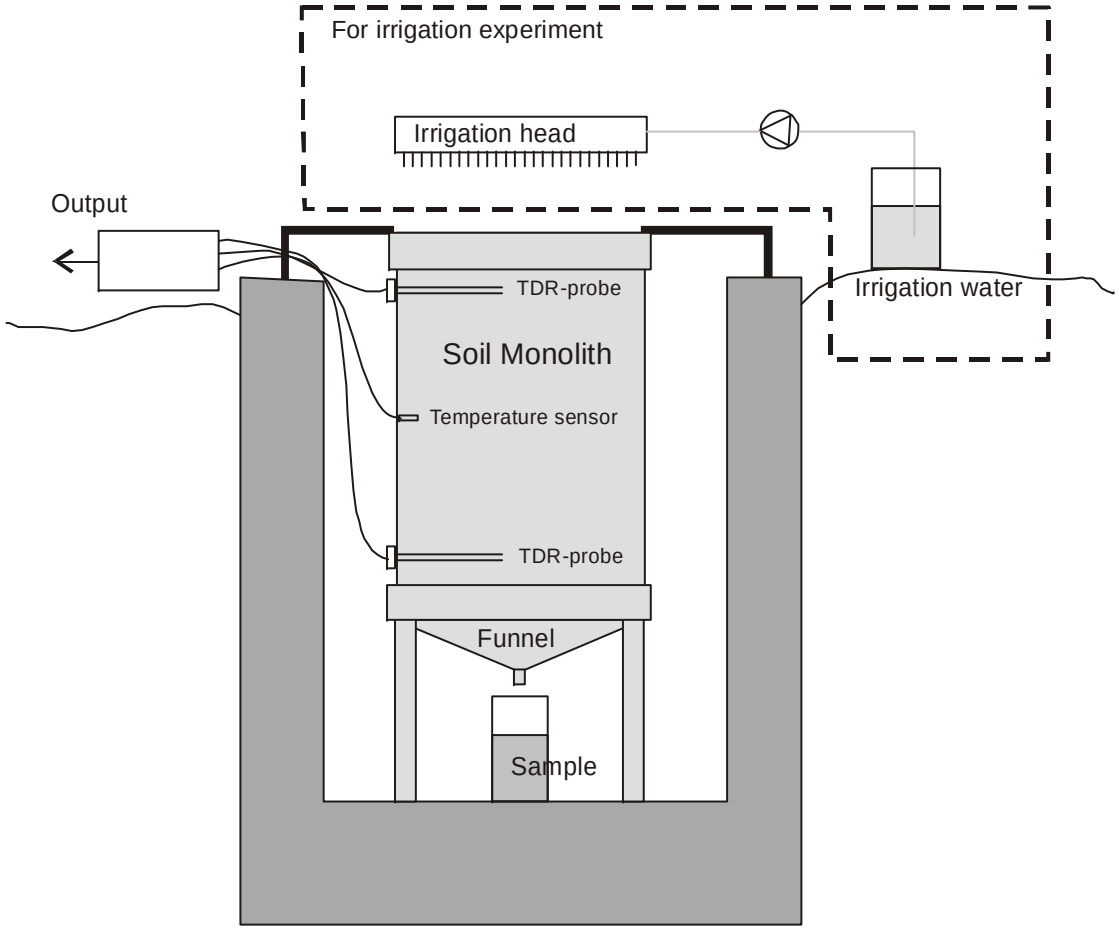
Degradation and mineralization



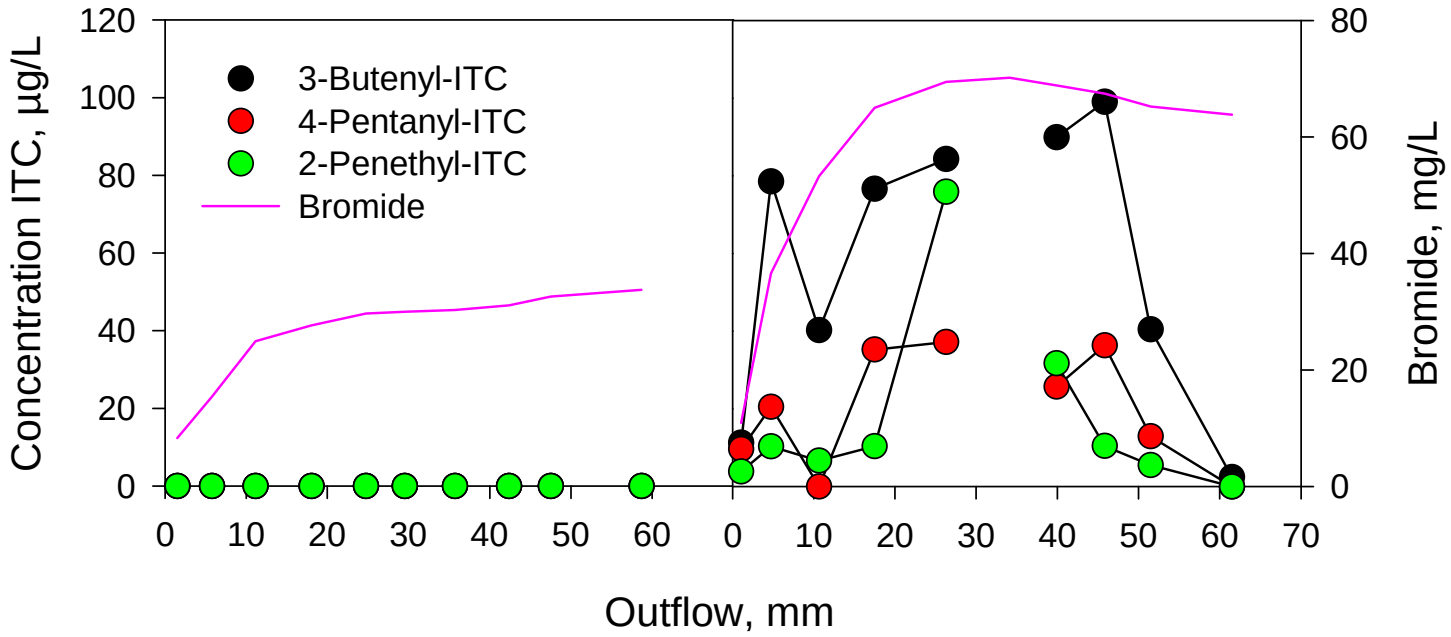




Leaching of isothiocyanates following biofumigation?

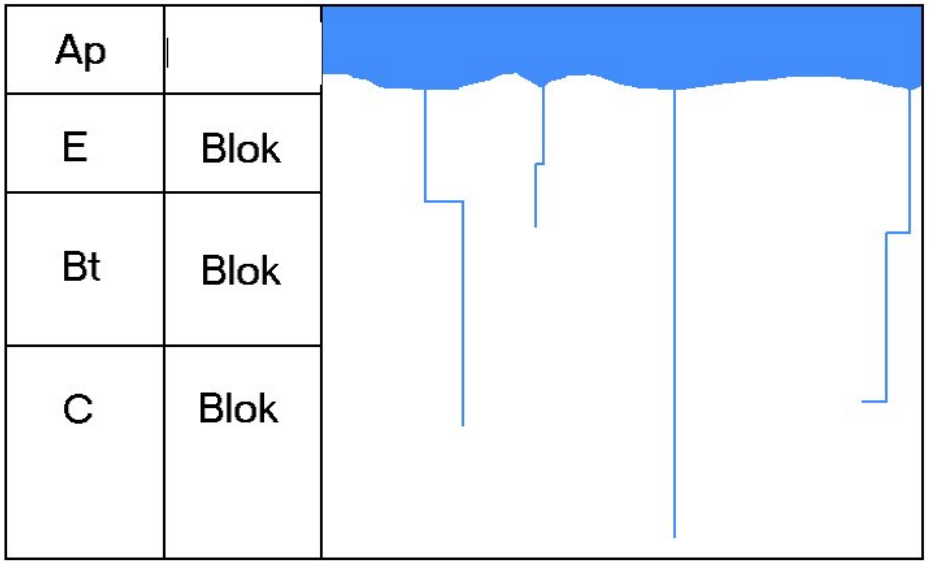


Leaching of isothiocyanates from clay soil

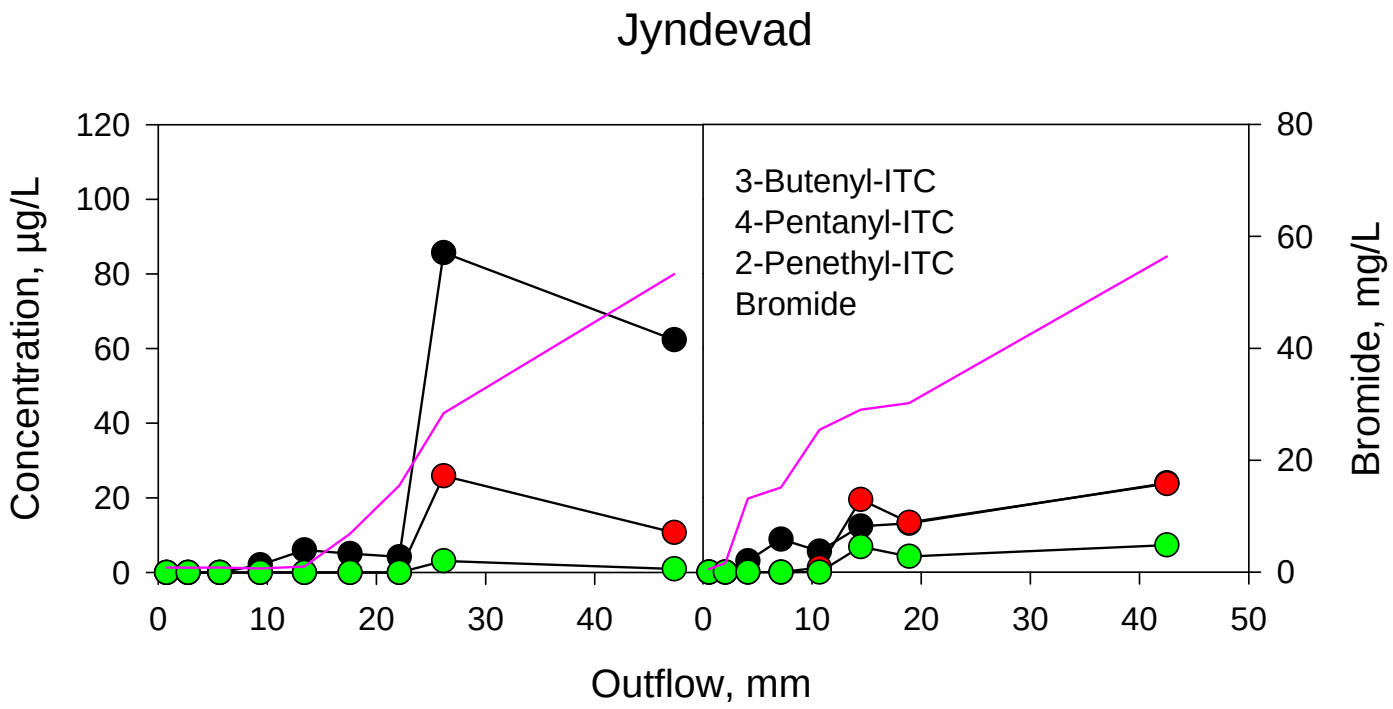


Leaching of isothiocyanates from clay soil

Clay soil



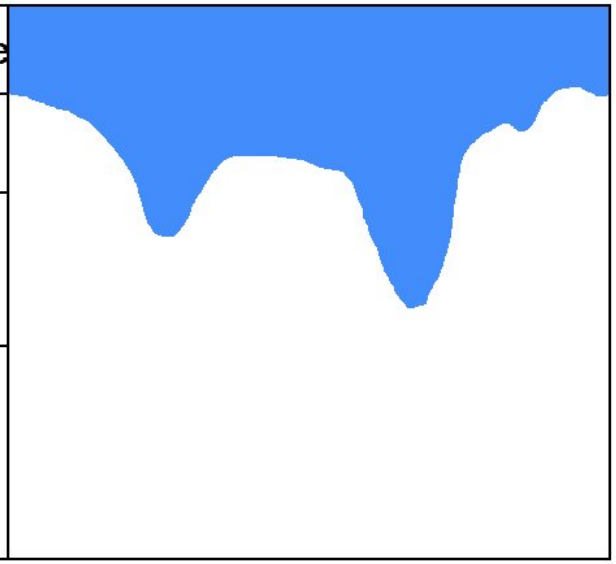
Leaching of isothiocyanates from sandy soil

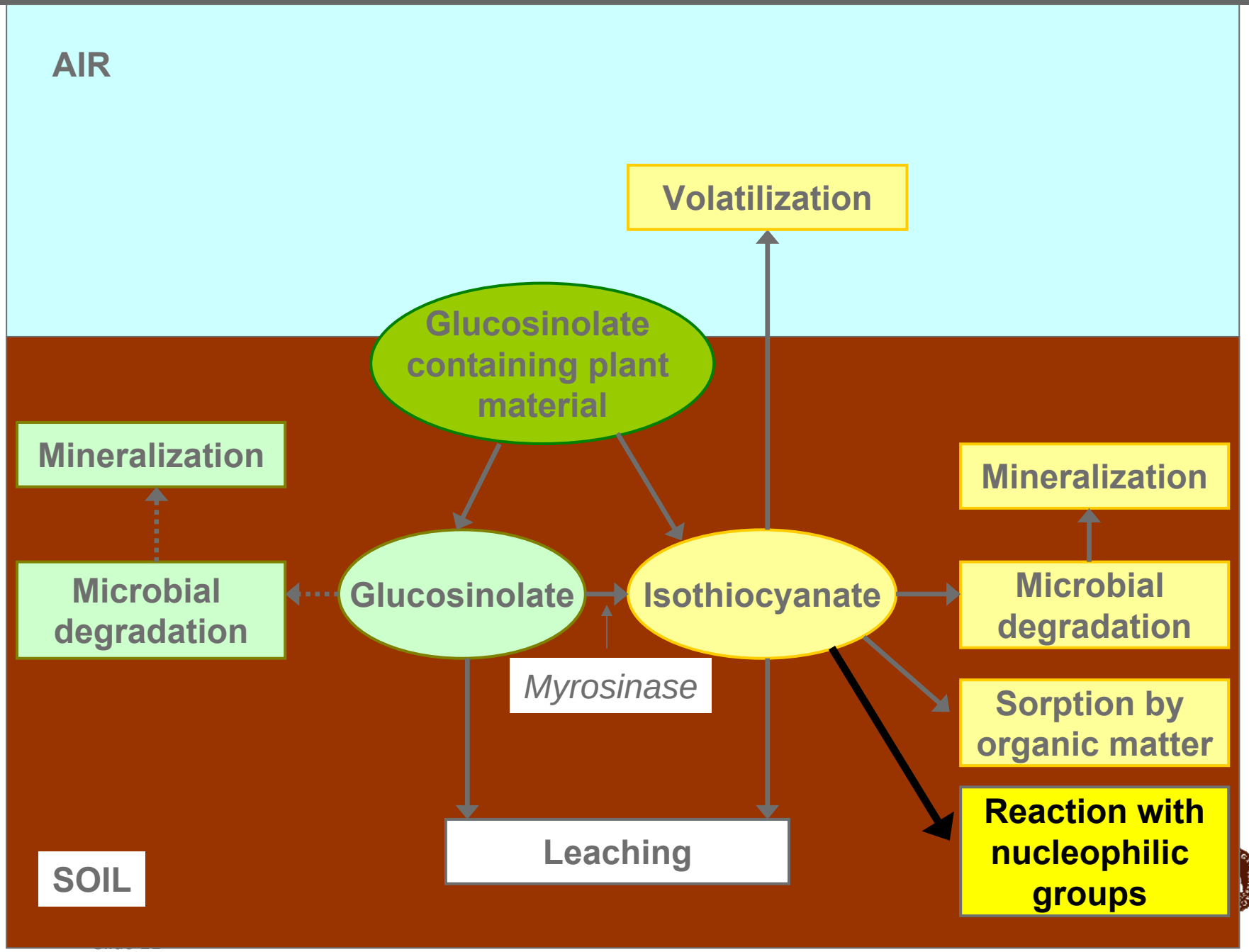


Leaching of isothiocyanates from sandy soil

Sandy soil

Ap	Krumme
E	**Single grain**
Bhs	**Single grain**
C	**Single grain**




AIR
Volatilization
Glucosinolate containing plant material
Mineralization
Mineralization
Microbial degradation
Glucosinolate
Isothiocyanate
Microbial degradation
Myrosinase
Sorption by organic matter
Reaction with nucleophilic groups
Leaching
SOIL

Other compounds

- Thiocyanate
  - Present longer in soil than isothiocyanate
  - Thiocyanate is an anion and is anticipated to be weakly sorbed in soil
  - Thiocyanate disappearance in soil is due to both to microbial degradation and sorption
- Nitriles
  - Also present longer in soil than isothiocyanates
  - Both sorption and degradation are important loss processes for nitriles in soil
- Oxazolidine
- Methanethiol, dimethyl sulphide, dimethyl disulfide and carbon disulfide

Conclusions and perspectives

- Glucosinolates are very weakly sorbed in all soil types, which may leed to leaching
- Glucosinolates are readily degraded and mineralized in soil, which minimizes the risk of leaching
- However, degradation depends on water content, temperature and soil type, and under some conditions degradation may be very slow
- Under most conditions glucosinolates will have a very small risk of accumulating in soil or leaching from the soil
- But care must be taken under dry conditions and with sandy soil, especially sub-soil where degradation is slower
- Preferential flow in clay soils may lead to leaching

Conclusions and perspectives

- Isothiocyanates are strongly sorbed to the organic matter in soil
- Isothiocyanates are readily degraded and mineralized in soil
- Isothiocyanates can also be lost from the soil by volatilization
- Under most conditions isothiocyanates will have a very small risk of accumulating in soil or leaching from the soil
- But effects on non-target organisms have to be investigated to ensure that the soil quality is not negatively affected
- And degradation under dry conditions and in sandy soils is slower, and preferential flow may lead to leaching

Conclusions and perspectives

- Field and laboratory studies have shown that effective strategies can lead to the formation of around 100 nmol/g isothiocyanate which appears to be sufficient for effective suppression of susceptible pests
- Opportunities to get higher isothiocyanate concentrations in soil:
  - Currently the highest conversion efficiencies measured in the field are around 60%, so this may be further optimized
  - Plant types with higher glucosinolate concentrations may be developed

Thank you for your attention