David Spurgeon

Centre for Ecology and Hydrology Wallingford

A comparison of laboratory vs field effects for non-radioactive pollutants

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Factors influencing toxicity in the field (Van Straalen and Denneman, 1989)

Increase toxicity in the field

- In the laboratory, organisms are tested under optimal conditions
- In the field, organisms are exposed to mixtures of stressors
- Adaptation often entails cost in ecological performance
- In the field, exposure is long term compared to short term in lab tests

Reduce toxicity in the field

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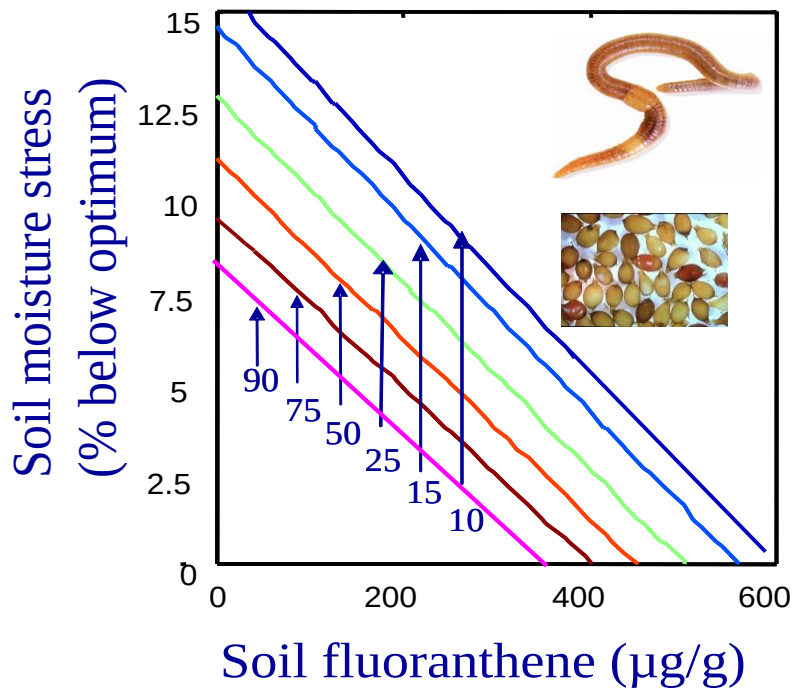
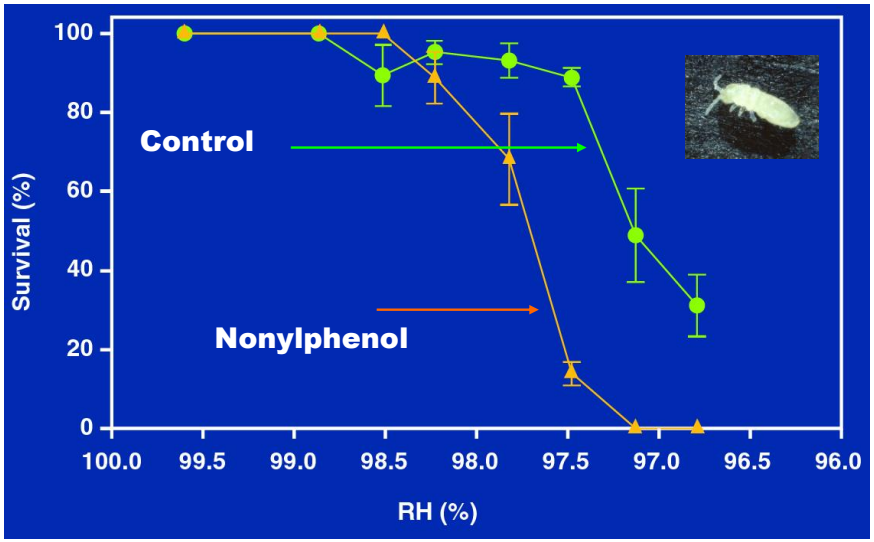
Results from combined stressor studies

Studies have shown no effect, additive (according to the principle of response addition) and also interactions. Case by case.

Additive



Synergistic



Lots of studies of this type

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Review

Interactions between effects of environmental chemicals and natural stressors: A review

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ABSTRACT

Ecotoxicological effect studies often expose test organisms under optimal environmental conditions. However, organisms in their natural settings rarely experience optimal conditions. On the contrary, during most of their lifetime they are forced to cope with sub-optimal conditions and occasionally with severe environmental stress. Interactions between the effects of a natural stressor and a toxicant can sometimes result in greater effects than expected from either of the stress types alone. The aim of the present review is to provide a synthesis of existing knowledge on the interactions between effects of "natural" and chemical (anthropogenic) stressors. More than 150 studies were evaluated covering stressors including heat, cold, desiccation, oxygen depletion, pathogens and immunomodulatory factors combined with a variety of environmental pollutants. This evaluation revealed that synergistic interactions between the effects of various natural stressors and toxicants are not uncommon phenomena. Thus, synergistic interactions were reported in more than 50% of the available studies on these interactions. Antagonistic interactions were also detected, but in fewer cases. Interestingly, about 70% of the tested chemicals were found to compromise the immune system of humans as

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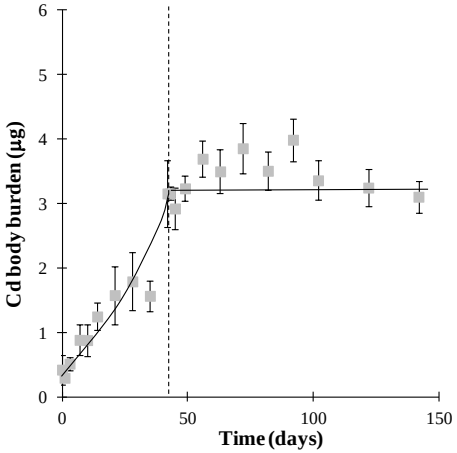
Longer exposure greater toxicity?

- Based on the assumption that toxicity is time dependent
- Time dependence based on assumption that body concentrations increases with time
- So time dependent patterns in body concentration give insight into effects of exposure duration

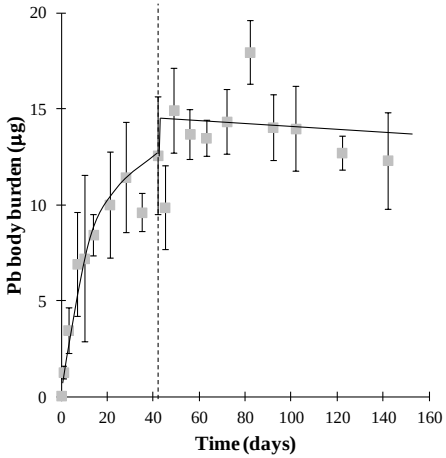
Metal uptake *Eisenia fetida* in field soil

Non-essential metals

Cadmium



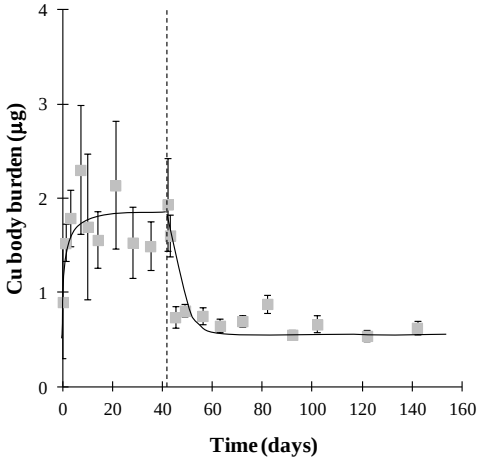
Lead



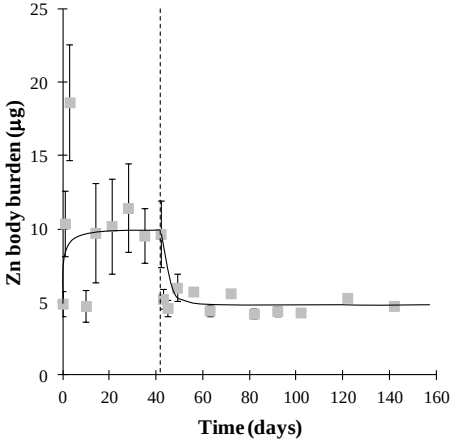
- Low rates of elimination
- Body burden is time dependent

Essential metals

Copper



Zinc



- High rates of elimination
- Body burden only time dependent over 7 days

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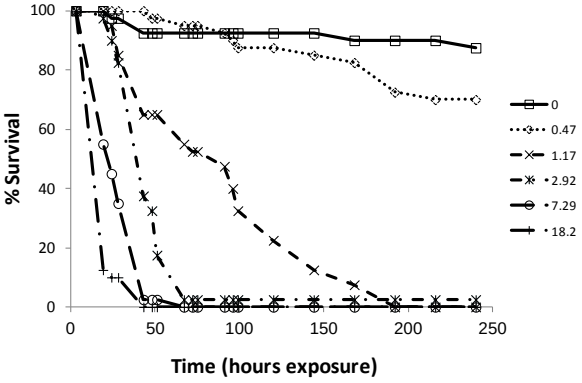
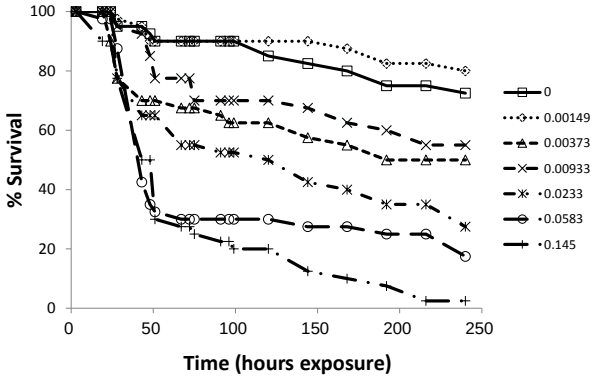
Time dependence of toxicity

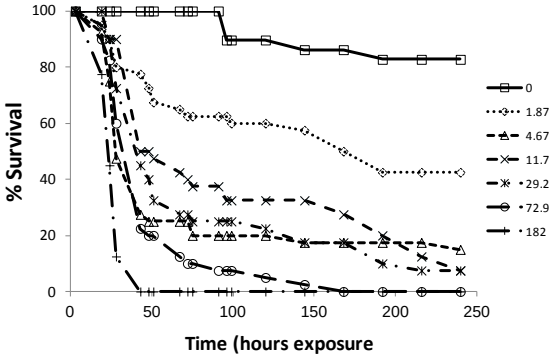
Dimethoate



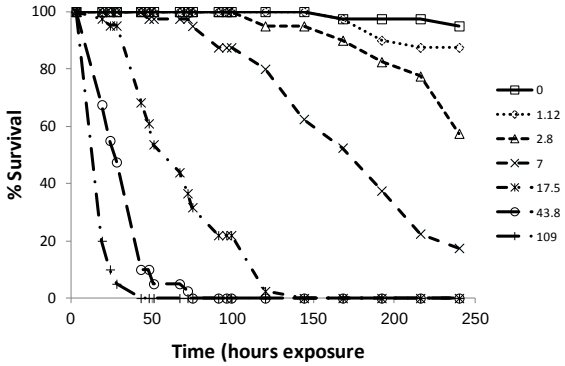
Clothianidin



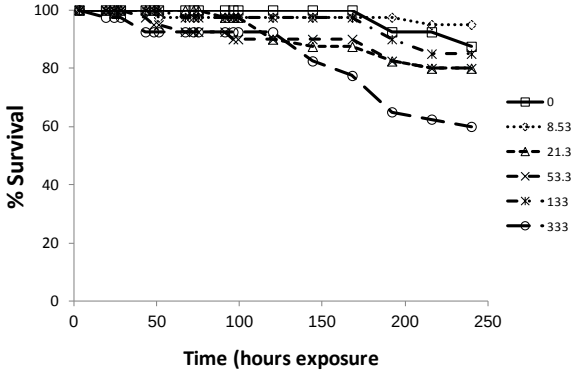
Cadmium



Arsenic



Propiconazole



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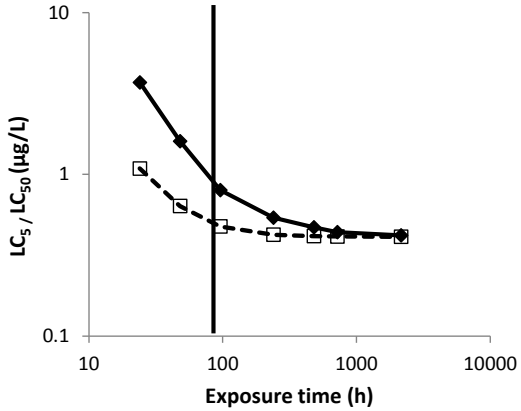

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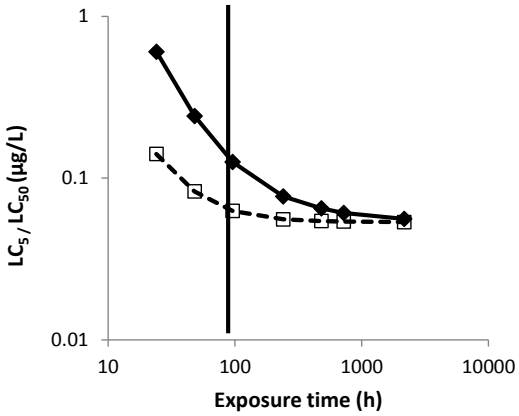
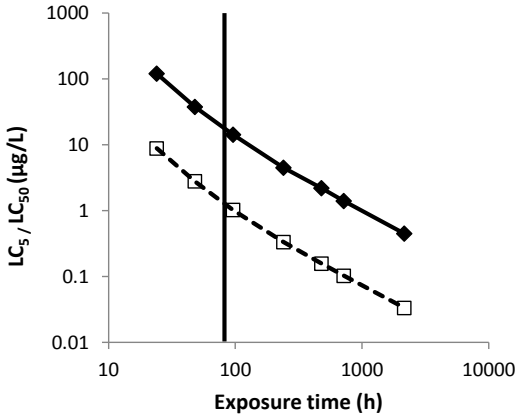
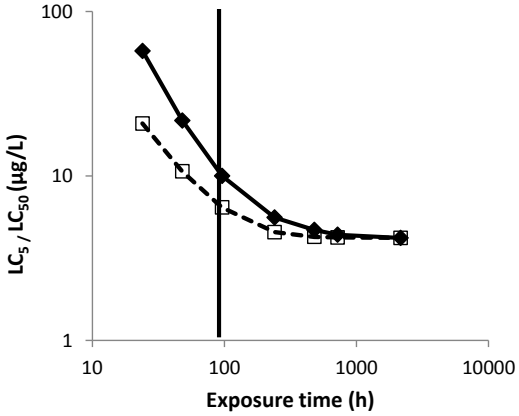


Cadmium



Arsenic



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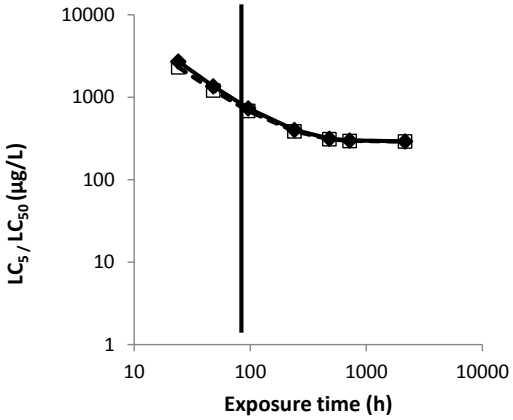

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Longer exposure greater toxicity?

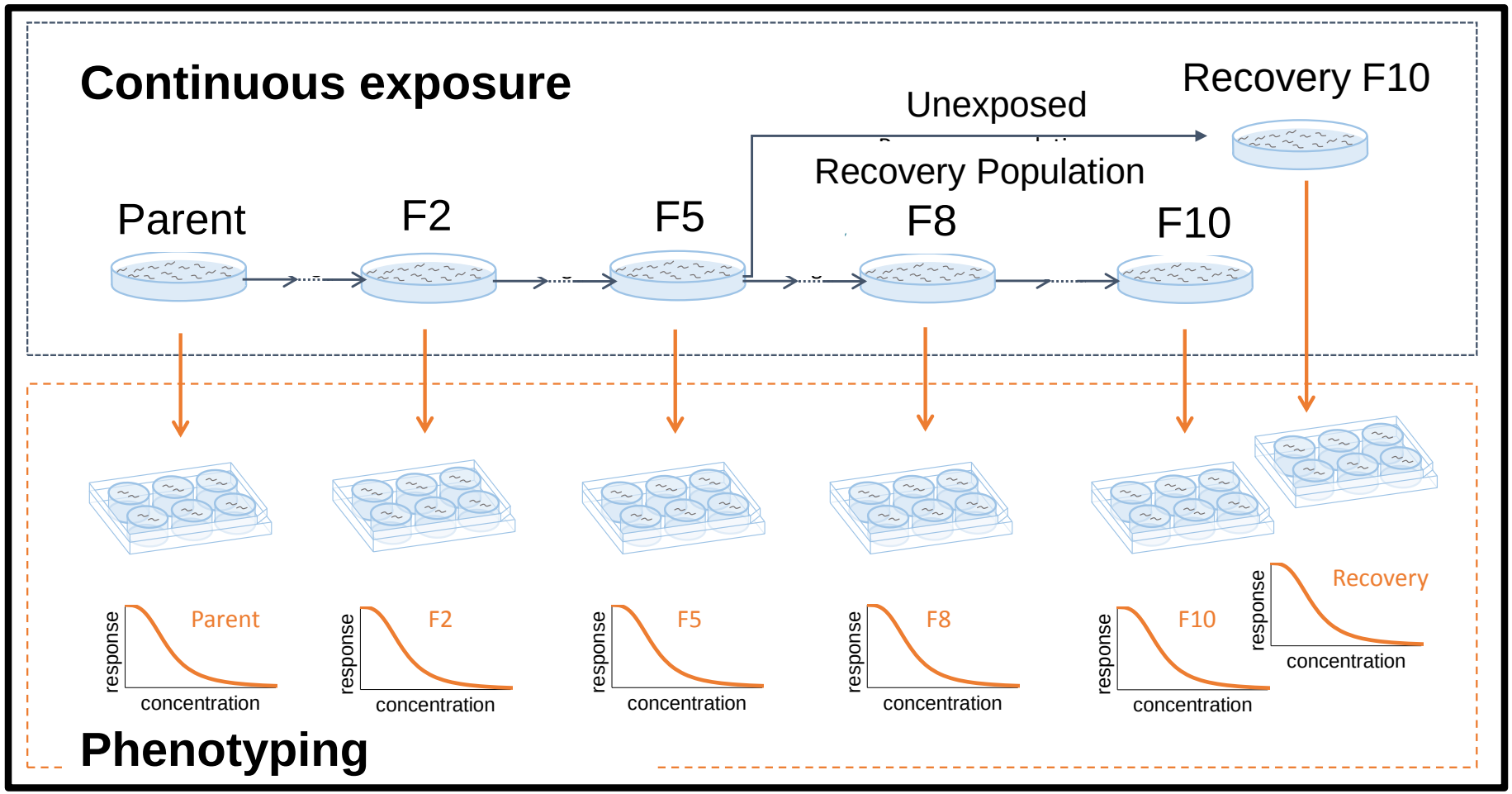
Does long-term increase toxic effects in the field

Yes, but extent chemical dependent

Need time series data

Pollution is persistent

Multigenerational change in sensitivity?



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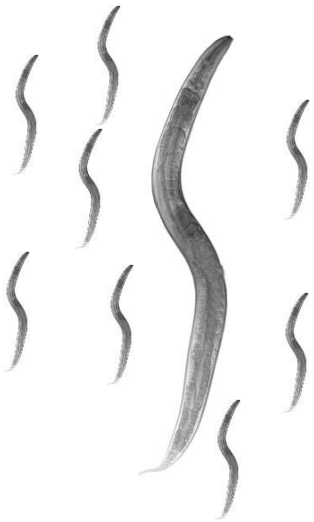
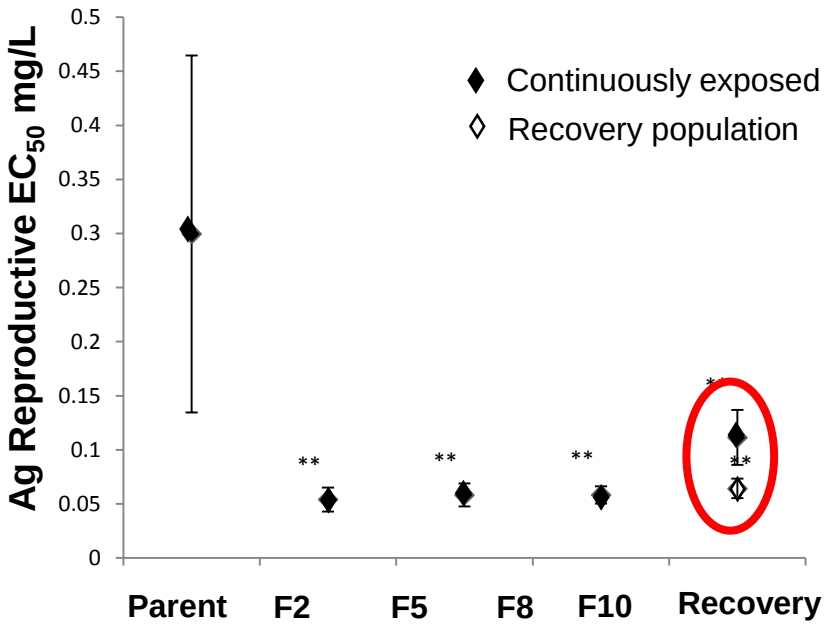
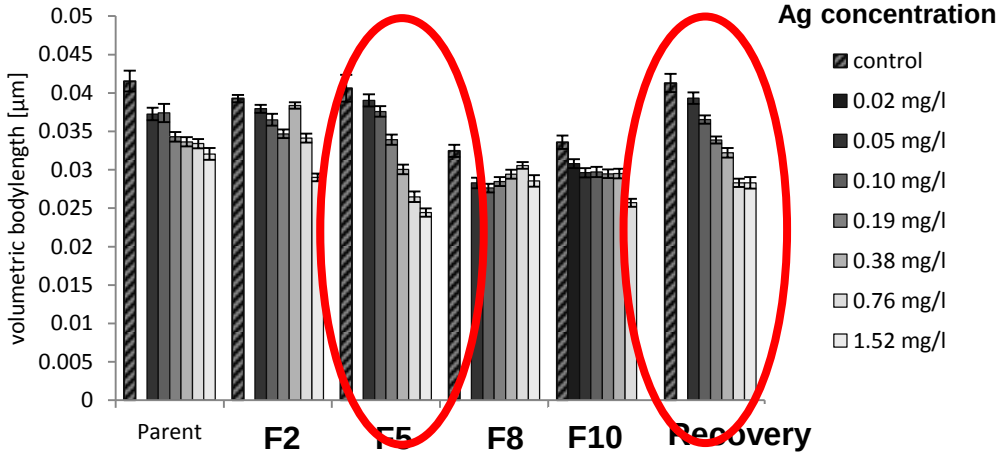
Multigenerational change in sensitivity?







Multigenerational change in sensitivity?

Species	Chemical	Generations	Observed phenotype
C. elegans	Gamma radiation	P-F2	Greater reproduction effects in multigenerationally and transgenerationally exposed F2s than P generation
D. magna	Gamma	P-F2	Toxicity on multiple traits increased from P to F2
D. magna	Americium	P-F2	Threshold for effects on reproduction reduced from 1.5 $mGyh^{-1}$ in P generation to 0.3 $mGyh^{-1}$ in F2 and F3
D. magna	Uranium	P-F1	Greater reduction in fecundity in F1 than P at 50 μg/L
D. magna	Nickel	P-F1	Greater reduction of ATP levels in F1 compared to P
C. elegans	Ag nanoparticles	P-F10	Greater (10 fold) sensitivity in F2, F5, F8 and F10 generations compared to P generation
D. magna	Ag nanoparticles	P-F10	Population growth rate at 10 μg/L reduced by 80% in F2s compared to 21% in P generation
D. magna	Penta-chlorophnol	P-F3	Population growth rate reduction increases from 28.2% to 34.9% to 46.3% in P, F1, F2 generations
D. magna	Tetracyclin	P-F1	NOEC decreased from 5 mg/L to 0.1 mg/L from P to F3
D. magna	Enrofloxacin	P-F1	Reproduction NOEC decreased from 30 mg/L to 3.1 mg/L from P to F1 generation

Longer exposure greater toxicity?

- Body concentration are time dependent : more so for some chemicals than others

- Effect of exposure time on sensitivity is time dependent : more so for some chemicals than others

- Multigenerational exposure can lead to greater effects : widely reported in the literature - but beware publication bias (and what about adaptation long-term)!

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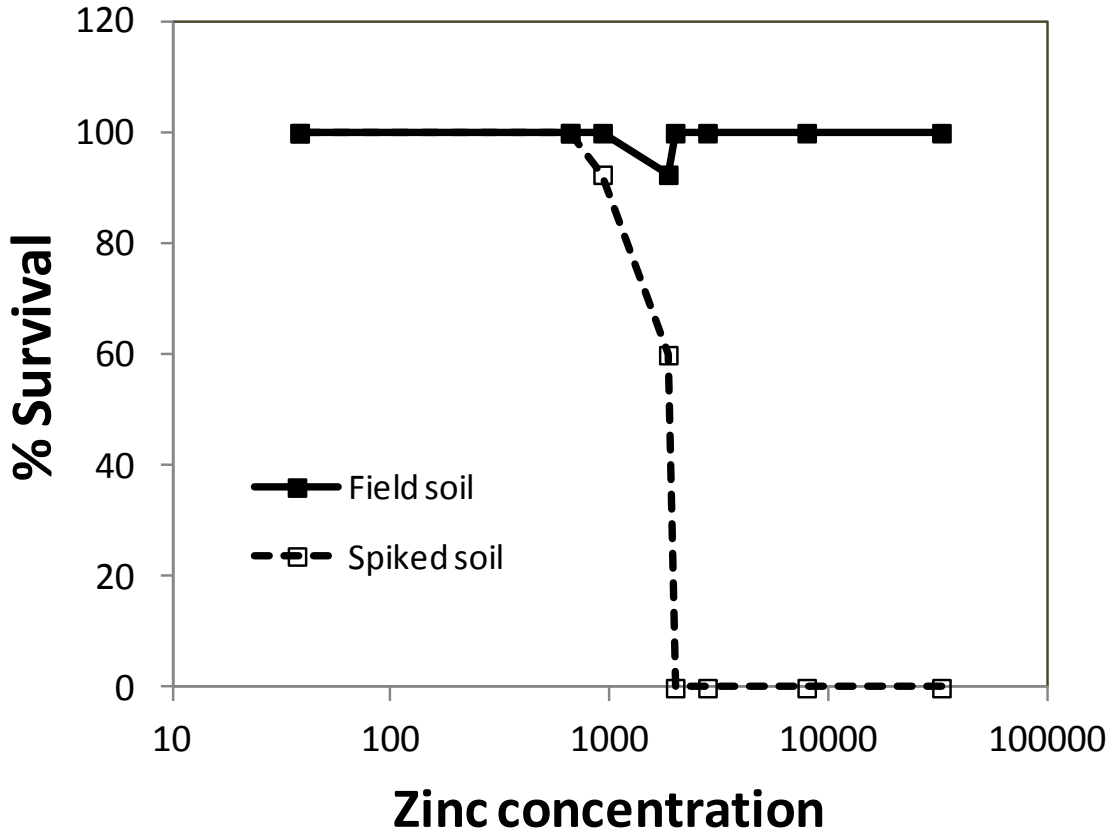
Field soil versus spiked exposures?

Exposed worms to

1. A field contaminated by smelter emissions over many decades

2. A laboratory soil containing the same concentrations of metals added as a solution of the nitrate salt as in a standard lab test.

Field vs spike bioavailability



Field vs spike bioavailability

Now part of EU policy

3 fold lab - field extrapolation factor in metals risk assessment

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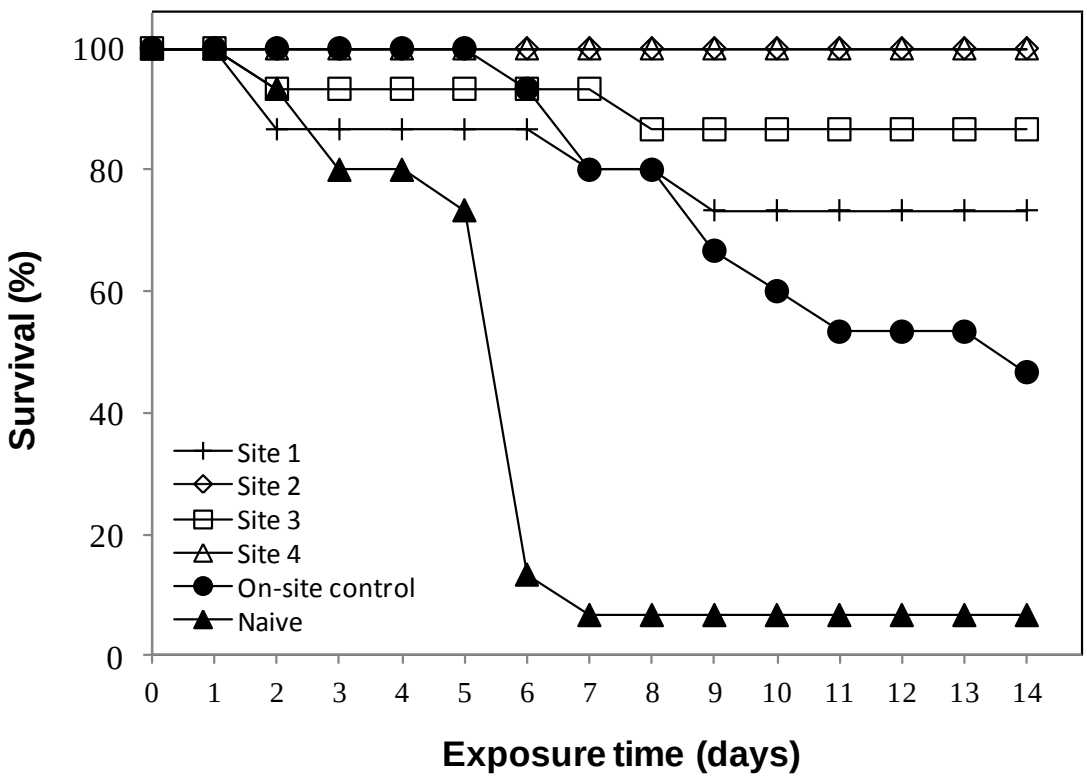
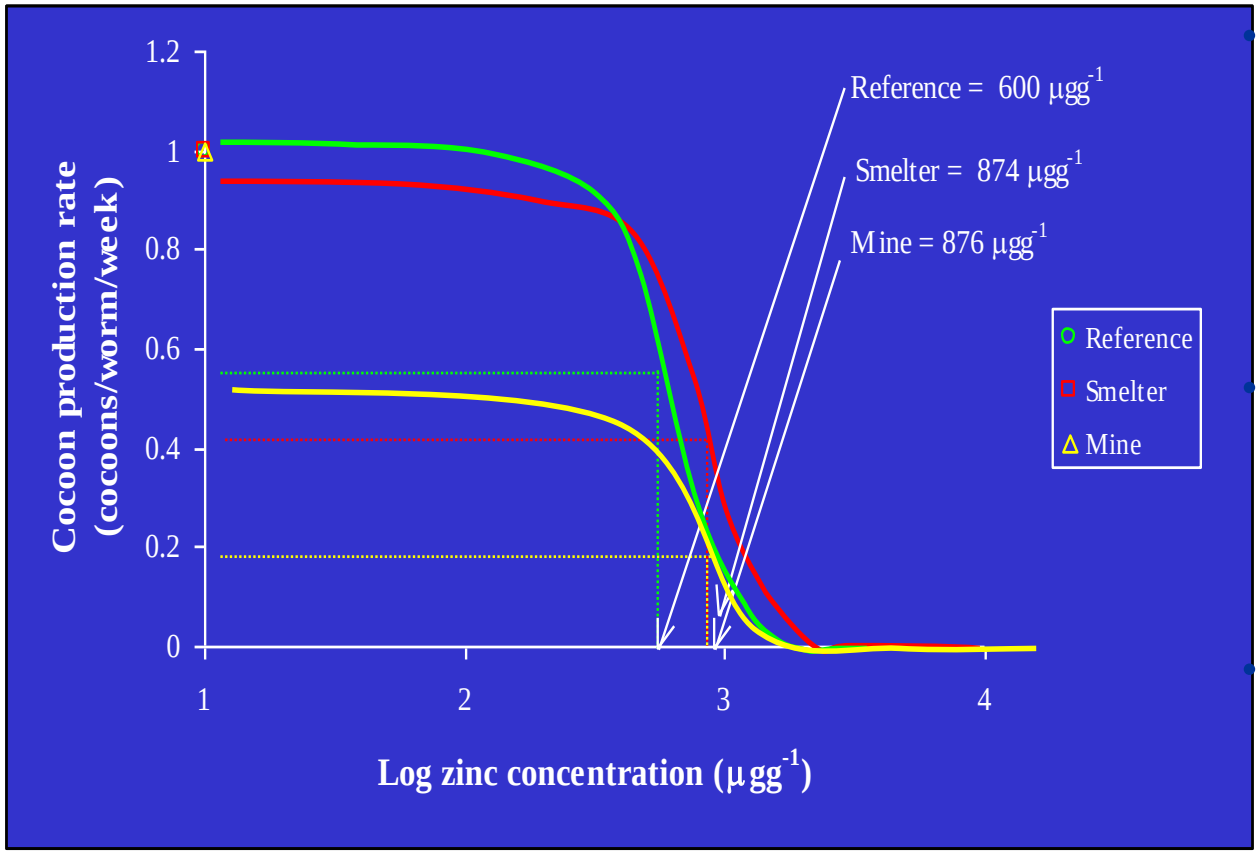
Lumbricus rubellus exposed to As - 6 populations



- Rapid mortality of the naive population and partial mortality of on-site controls
- High survival of most polluted population.
- Tolerance is conserved over 2 generation – genetic basis.

Lumbricus rubellus exposed to Zn - 3 populations



- Significant differences in the shapes of the dose response curves
- Toxicity (as EC_{50}) lowest in reference population
- Considering site exposure histories, difference is small

ADAPTATION AS AN EFFECT MITIGATION

For Arsenic

Evidence of development of genetic adaptation.

For Zinc

No clear evidence of substantial adaptation for polluted site populations even after 400 years exposure. EC_{50}s similar for the three populations.

ADAPTATION AS AN EFFECT MITIGATION

Adaptation reduces observed toxicity in the field?

Not necessarily. Evidence of adaptation for some pollutants but not all.

EXTRAPOLATION FACTORS - CONCLUSIONS

Increases toxicity in field

Exposure to non-optimal conditions increases field toxicity – can depend on factor and the extent of change

Mixed stressor increase effects – additive and can be synergistic

Long-term exposure in the field increases toxicity in the field - chemical dependent

Reduces toxicity in field

Lower availability reduces toxicity in the field – lab to field comparative work indicates this is important

Adaptation reduces effect – not in all cases

OVERALL CONCLUSION

Not always simple relationships.

Need to think in the context of the biology of the stressor and species being considered

Mechanistic info valuable.

It's Over