


# Soil quality guidelines for copper and zinc for soils receiving biosolids

Michael Warne on behalf of the NBRP team

7 December 2007

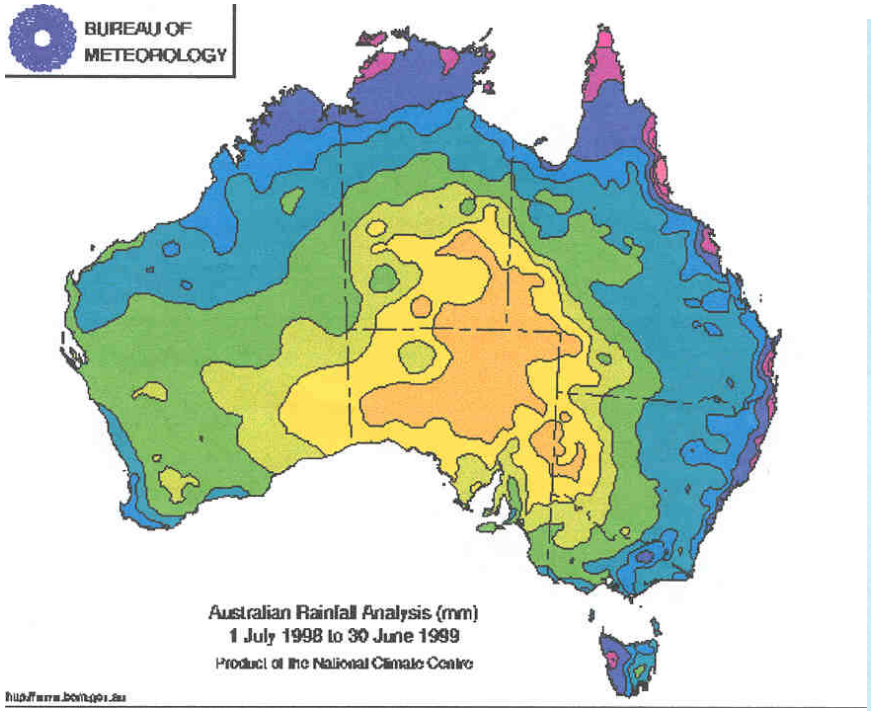
# We already had biosolid guidelines. So why did we need the NBRP?

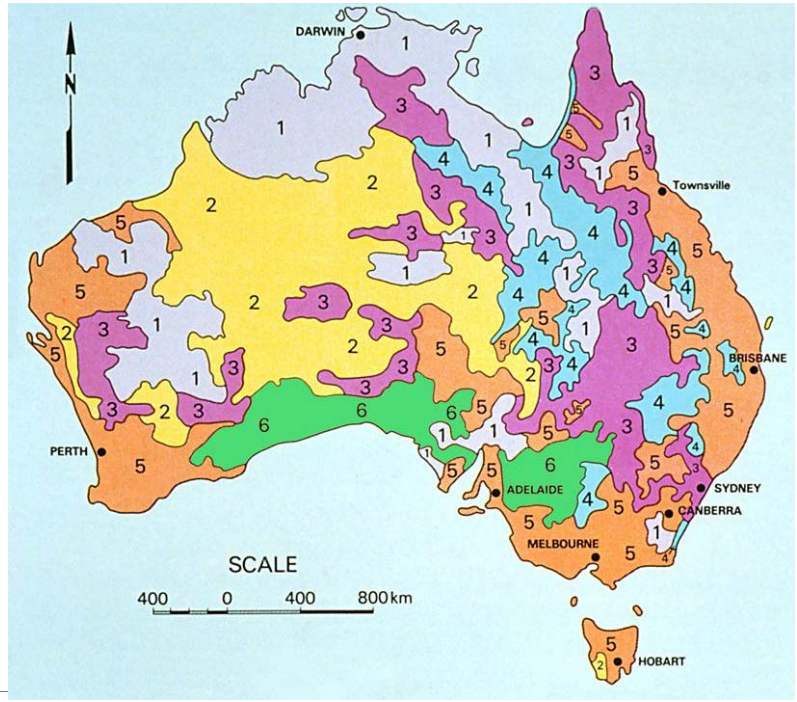
The contaminant part of the existing guidelines was predominantly based on data generated by the NSW Dept of Ag from one site – Glenfield.

This was done for NSW because Glenfield was considered a worst case soil to which the biosolids generated by Sydney would be applied.

As the guidelines are based mainly on results from one site (with one set of soil physicochemical properties) they may be under- or over-protective at any given location

# Australia has a wide variety of climatic and soil types



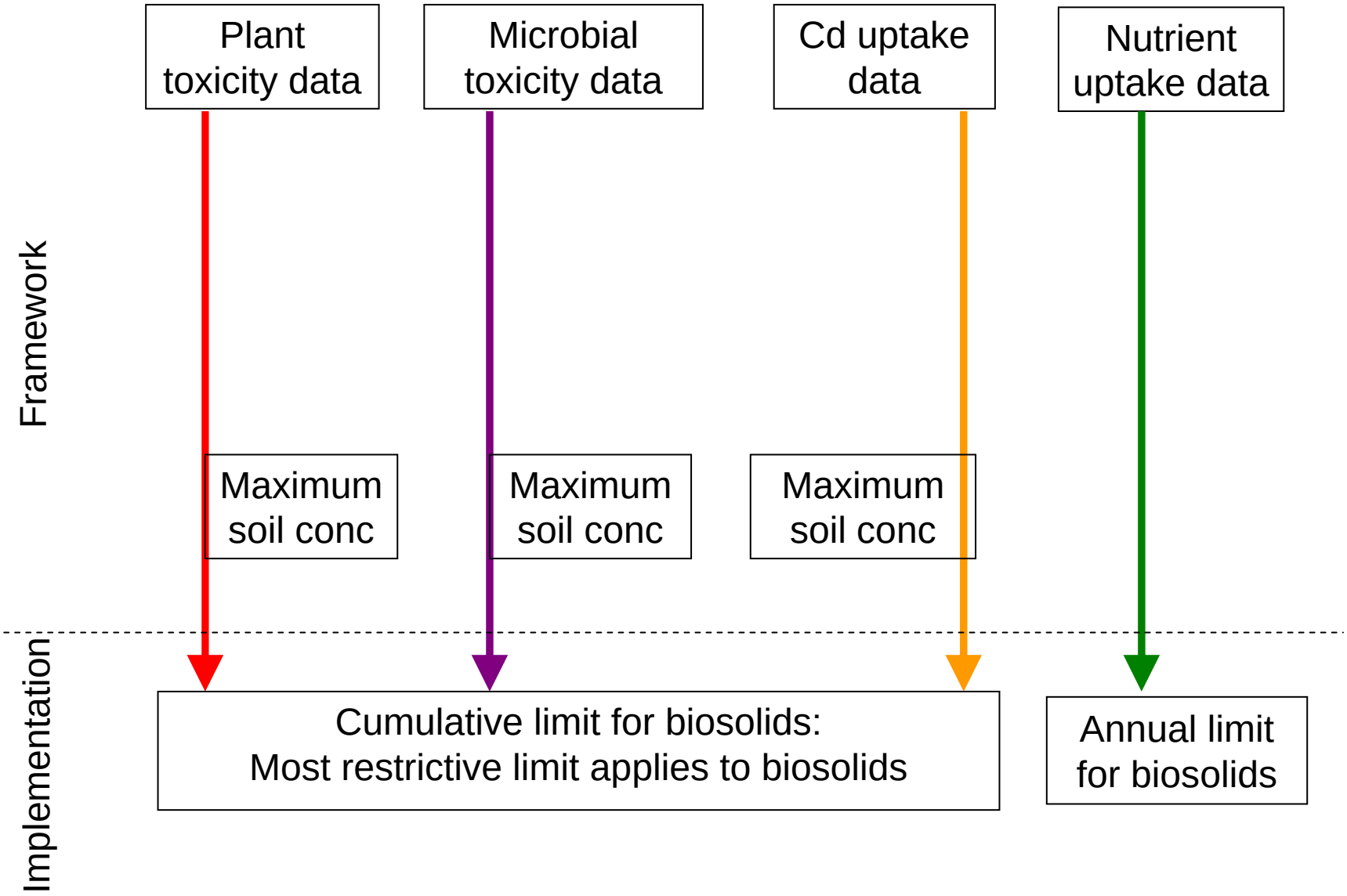

**Soil physicochemical properties and climatic conditions affect the behaviour and toxicity of contaminants in soil**

# Site specific guidelines

The Australian and New Zealand water quality guidelines permit the derivation of site-specific guidelines that account for site specific characteristics

It was felt that a similar approach would be appropriate for biosolids and metal soil guidelines. This approach is also being proposed in the new soil quality guidelines.

# Application of the various limiting factors



# Guideline derivation pathway

**Collate and screen toxicity data**

↓

**Account for the effect of soil properties on toxicity**

↓

Calculate the Added Contaminant Limit (ACL) i.e. the soil conc that will protect a % of species

↓

Account for the effect of bioavailability of the chemical in biosolids

↓

Calculate ambient background conc and add to appropriate ACL

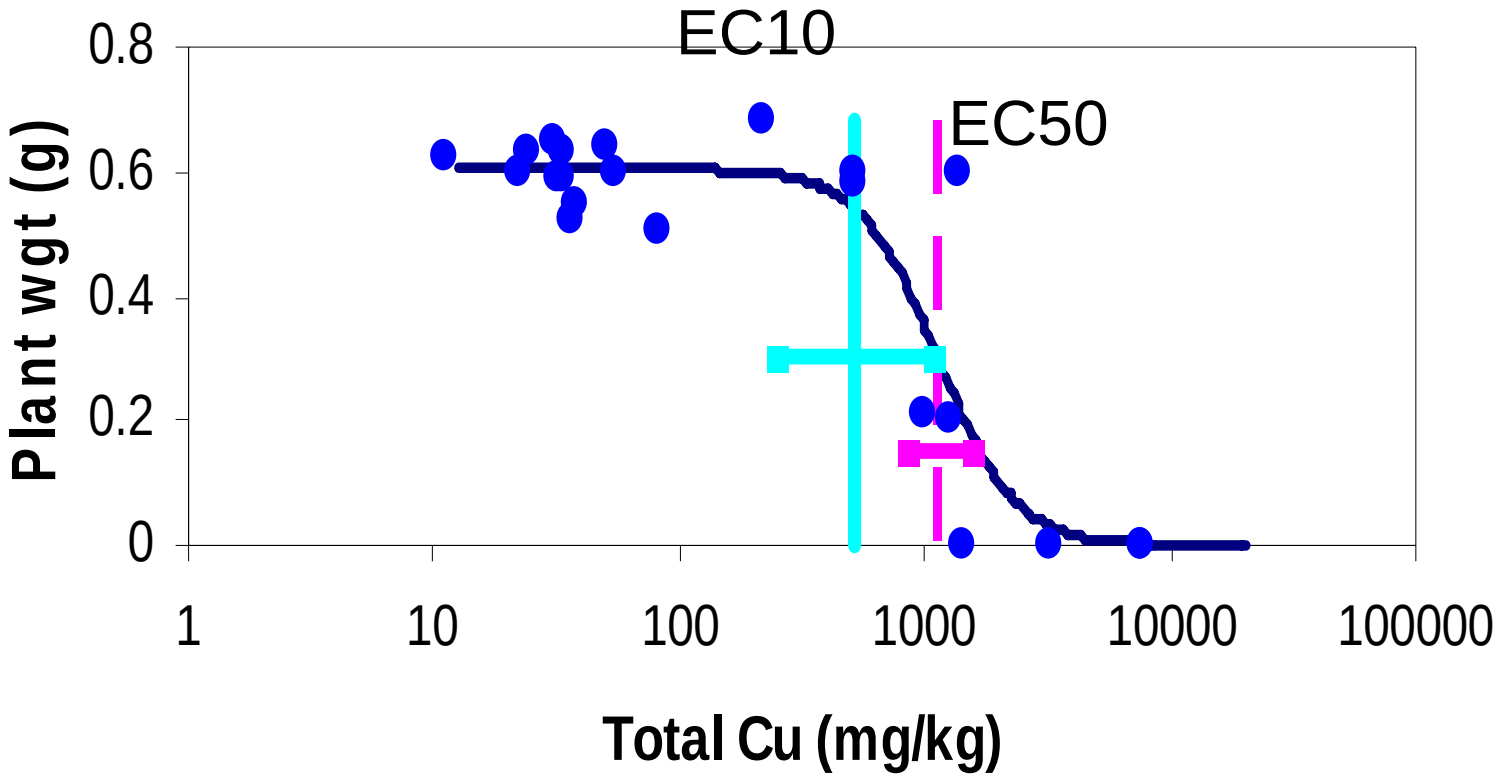
# Toxicity data

The NBRP has generated a substantial toxicity data set of crops grown in agricultural land, and of microbial processes regarding nutrient cycling in soils.

Therefore we only use the NBRP generated toxicity data

Increasing zinc or copper content

# Conducting toxicity tests

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↓

Calculate background conc and add to appropriate ACL

# Field-based Cu & Zn toxicity to wheat

| Field trial | EC50 (grain yield) (mg/kg) | |
|---|---|---|
| | Cu | Zn |
| Avon | 1 150 | **4 790** |
| Brennans | 290 | **265** |
| Cecil Plains | **5 700** | 4 560 |
| Dookie | 475 | 835 |
| Dutson Downs | 650 | 700 |
| Flat Paddock | **210** | 630 |
| Kingaroy | 310 | 390 |
| Night Paddock | 3 170 | 1 320 |
| Spalding | 630 | 1 780 |
| Tintinara | 1 040 | 1 350 |
| Wilsons | 1 760 | 365 |

Cu EC50 values vary by 28 fold

Zn EC50 values vary by 18 fold

Therefore soil properties strongly modify toxicity.

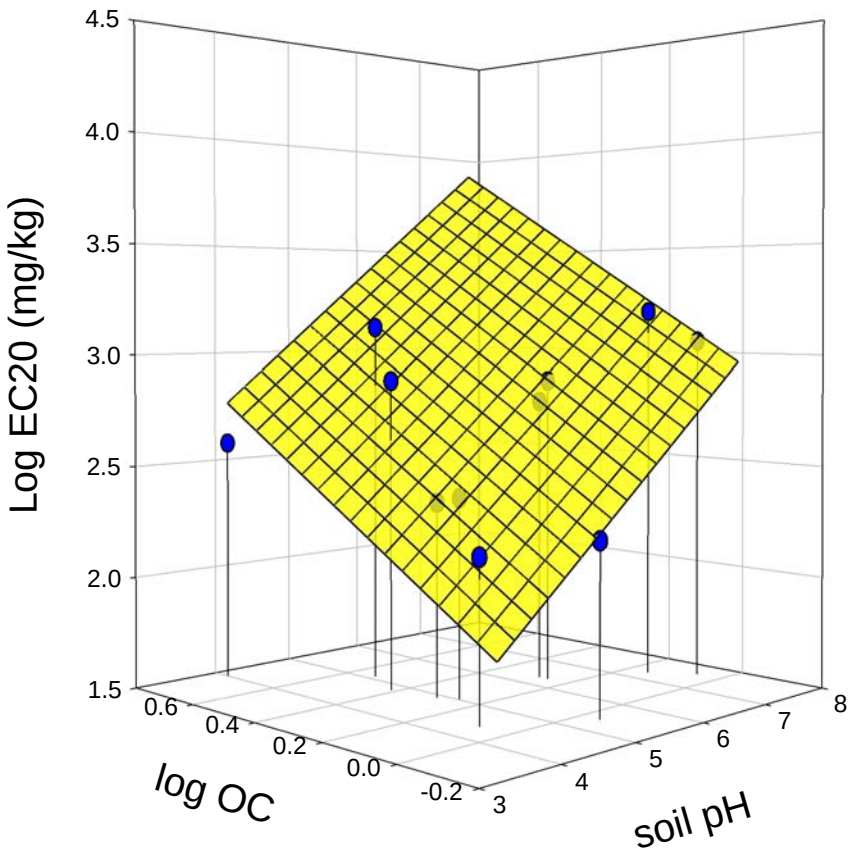
# How do we remove the effect of soil properties from the toxicity data?

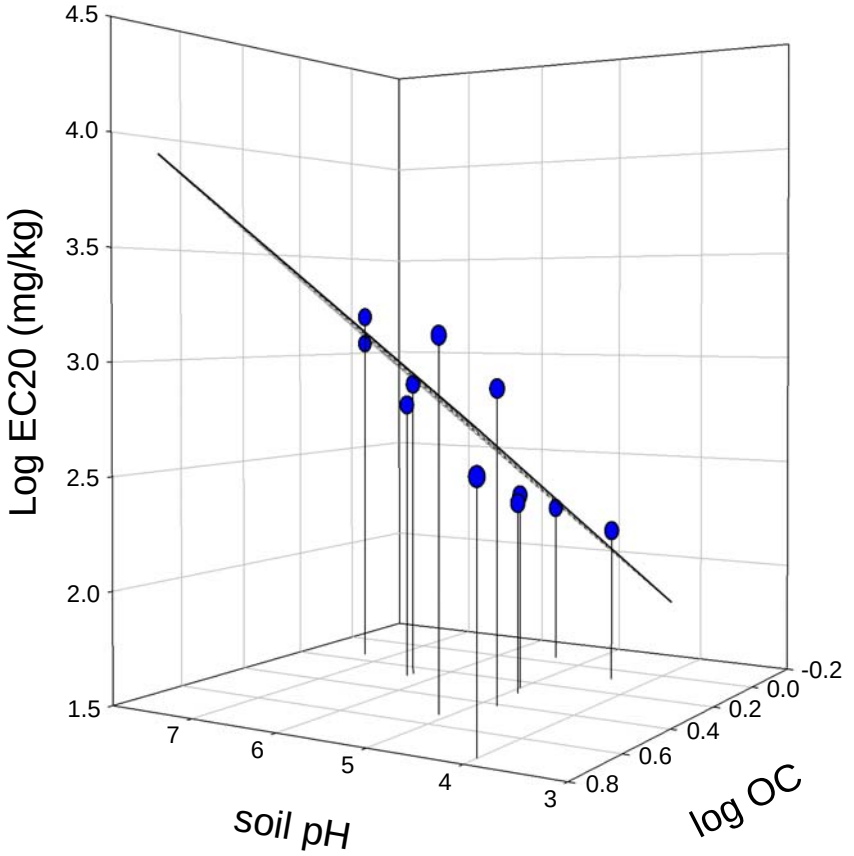
**Normalisation relationships**

**These are empirical relationships between the toxicity of a chemical and soil properties.**

# Field-based normalisation equation for Cu to wheat

## Cu log EC20 = 0.63 + 0.32*pH + 1.17 log OC



# Normalisation eqtns for Cu & Zn toxicity to wheat

| Element | Measure of toxicity | Equation | Adj $r^2$ |
|---|---|---|---|
| Cu | log EC10 | 0.31 pH + 1.05 log OC + 0.56 | 0.80 |
| Zn | log EC10 | 0.27 pH + 0.70 log CEC + 0.48 | 0.66 |

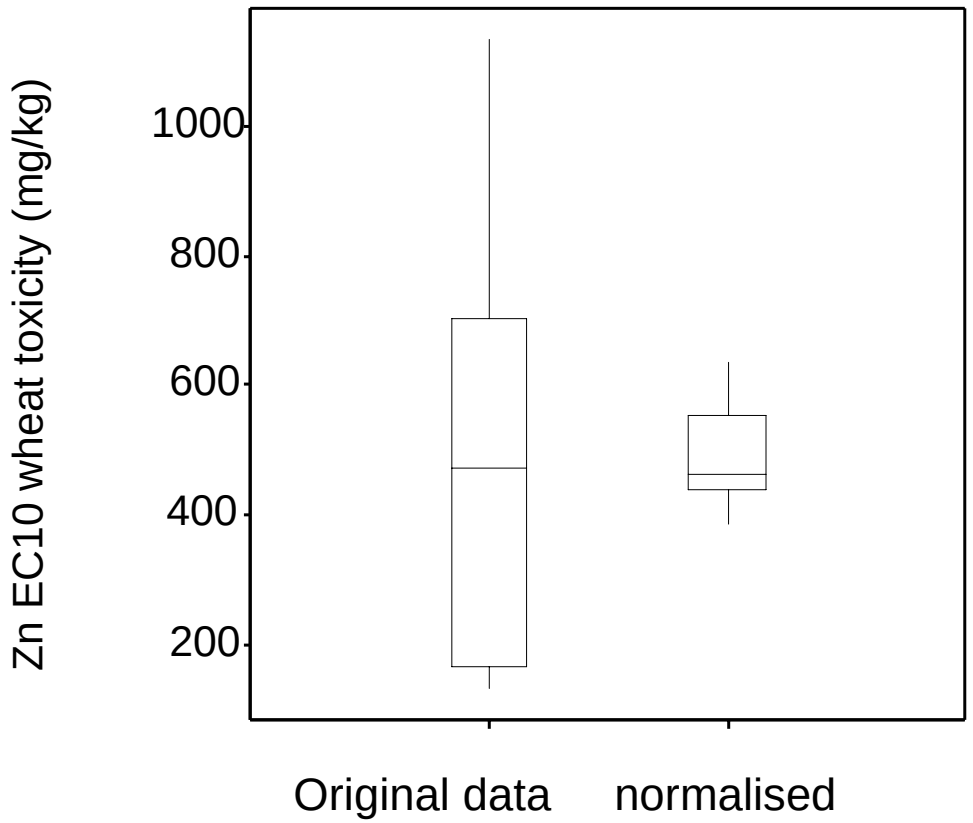
# Normalisation equations

Can be used to estimate the toxicity of a chemical to a species tested in a standard soil

We have chosen a standard soil with the following properties:

| | |
|---|---|
| pH: | 6 |
| Clay: | 10 % |
| CEC: | 10 ($cmol_c/kg$) |
| Org. Carbon: | 1% or equivalent OM |

# Normalisation of toxicity data




Reduction in variability

# Australian normalisation equations

Microbial toxicity (field-based)

Plant toxicity (field- and laboratory- based)

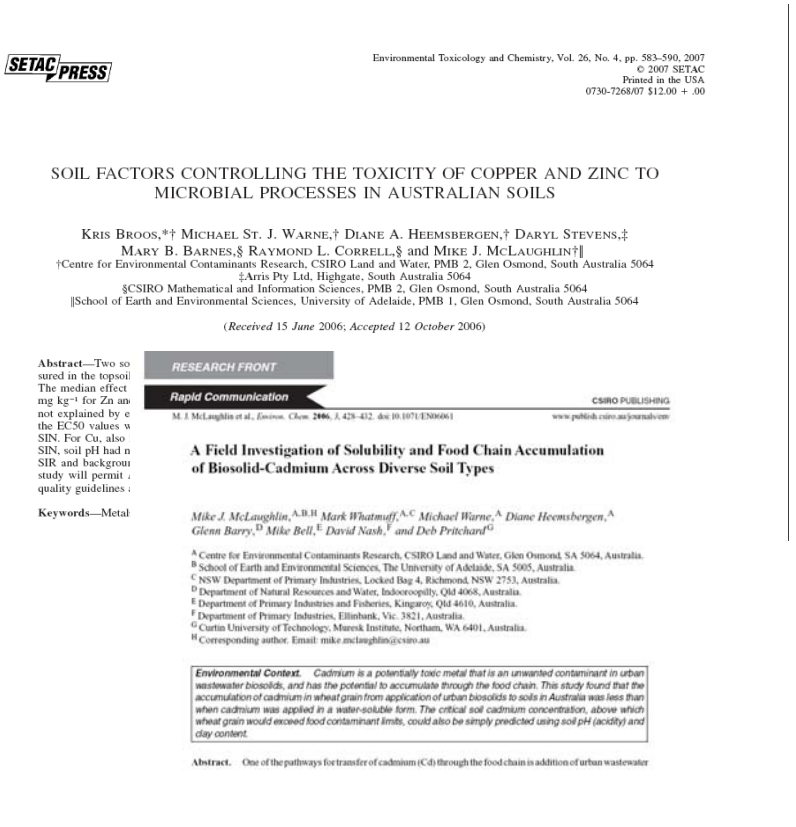
Cd plant uptake (field-based)

McLaughlin *et al*., 2006. *Env. Chem*, 3, 428 – 432.

Broos *et al*., 2007. *ET&C*, 26(4), 583 – 590.

Warne *et al*., *ET&C, in press*.

Warne *et al., Env Polltn*, submitted.



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SOIL FACTORS CONTROLLING THE TOXICITY OF COPPER AND ZINC TO MICROBIAL PROCESSES IN AUSTRALIAN SOILS

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(*Received* 15 *June* 2006; *Accepted* 12 *October* 2006)

**Abstract**—Two so
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SIR and backgrou
study will permit
quality guidelines

**Keywords**—Metal

RESEARCH FRONT

Rapid Communication

CSIRO PUBLISHING
M. J. McLaughlin et al., *Environ. Chem.* **2006**, *3*, 428–432. doi:10.1071/EN06061 www.publish.csiro.au/journals/env

**A Field Investigation of Solubility and Food Chain Accumulation of Biosolid-Cadmium Across Diverse Soil Types**

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***Environmental Context.*** *Cadmium is a potentially toxic metal that is an unwanted contaminant in urban wastewater biosolids, and has the potential to accumulate through the food chain. This study found that the accumulation of cadmium in wheat grain from application of urban biosolids to soils in Australia was less than when cadmium was applied in a water-soluble form. The critical soil cadmium concentration, above which wheat grain would exceed food contaminant limits, could also be simply predicted using soil pH (acidity) and clay content.*

**Abstract.** One of the pathways for transfer of cadmium (Cd) through the food chain is addition of urban wastewater

# Guideline derivation pathway

Collate and screen toxicity data

↓

Account for the effect of soil properties on toxicity

↓

**Calculate the Added Contaminant Limit (ACL)**
**i.e. the soil conc that will protect a % of species**

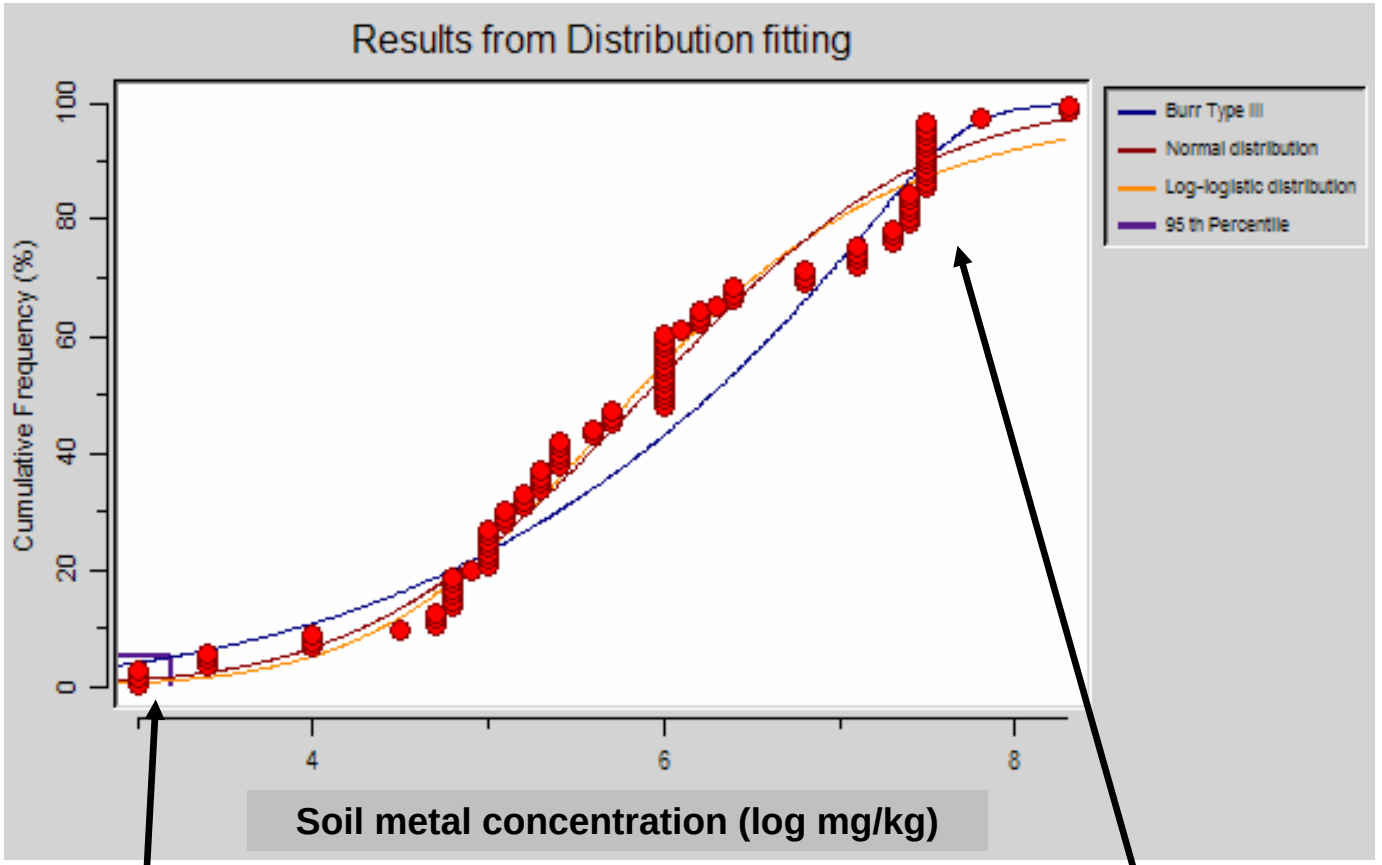
↓

Account for the effect of bioavailability of the chemical in biosolids

↓

Calculate background conc and add to appropriate ACL

# How do we account for species sensitivity?




**Sensitive species**

**Tolerant species**

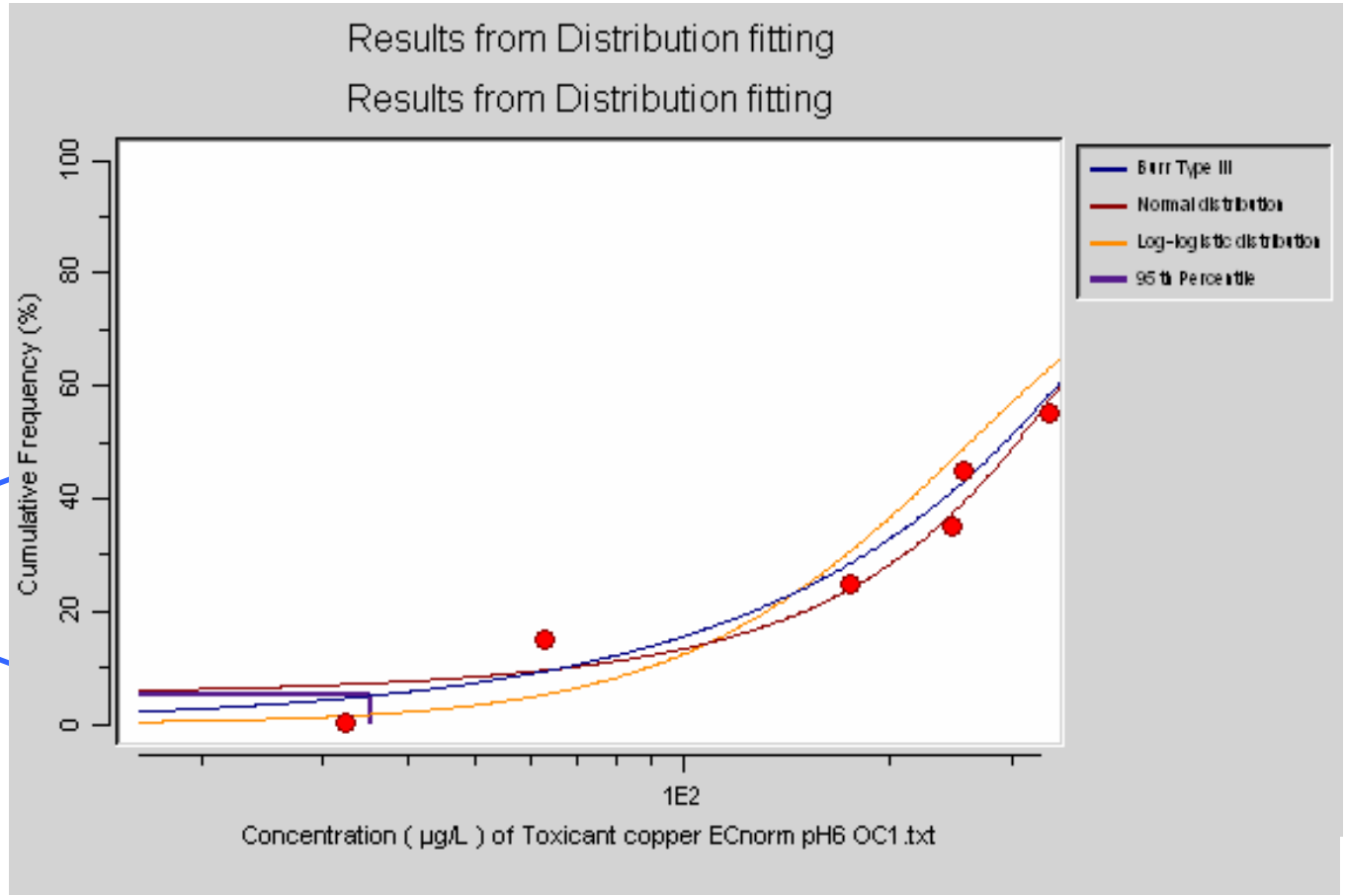
# What percentage of species should be protected?

The percentage of species to be protected can be modified. For example 90, 80%.

**The level of protection to be provided is a policy decision**

**Our recommendation is to protect 95% of crop species**

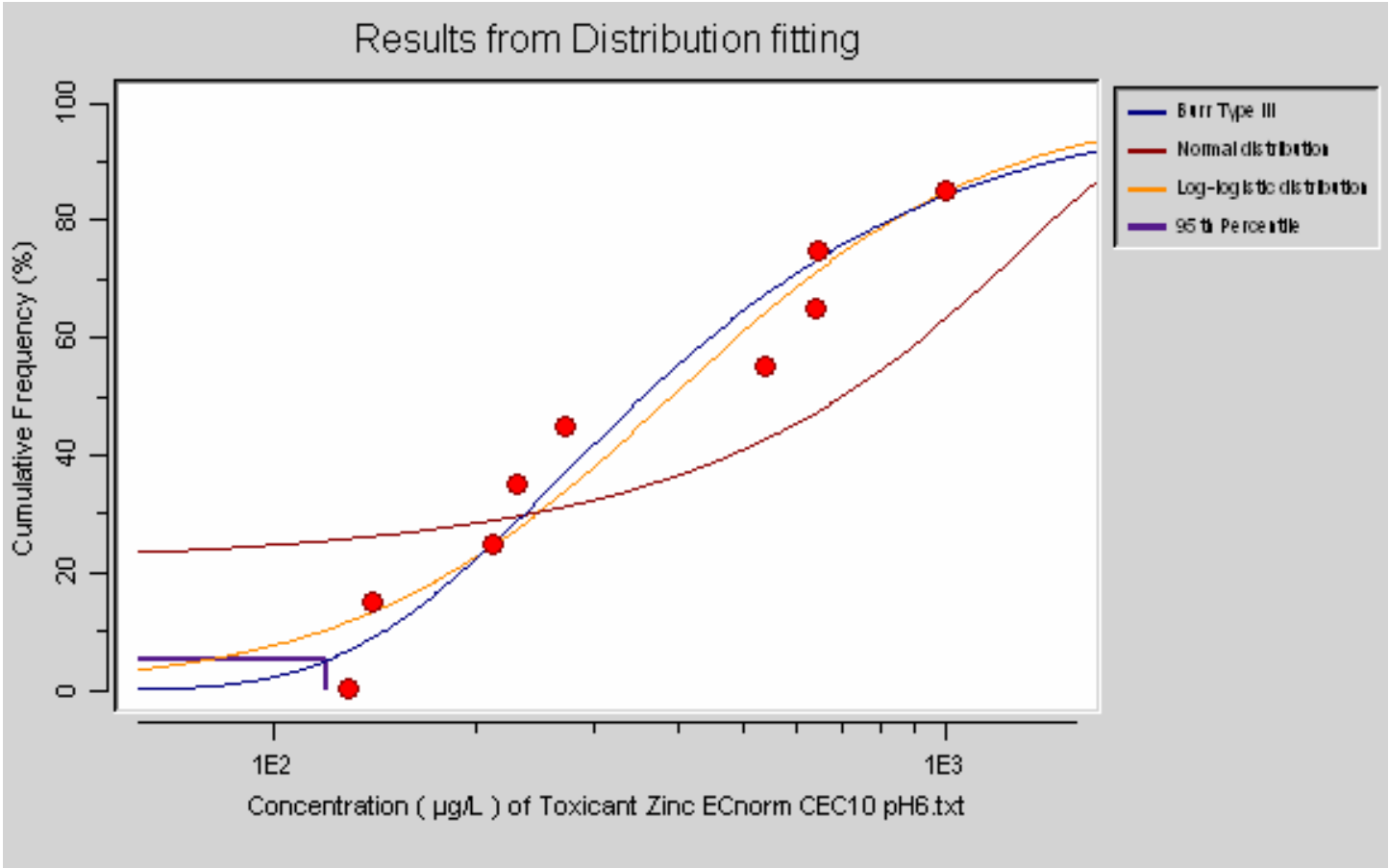
# Species sensitivity distribution of NBRP Cu plant EC10 data




| | |
|---|---|
| 32 | triticale |
| 63 | barley |
| 175 | maize |
| 245 | cotton |
| 255 | wheat |
| 340 | canola |
| 380 | millet |
| 385 | sorghum |
| 520 | peanuts |
| 665 | sugar cane |

Cu ACL = 35 mg/kg

# Species sensitivity distribution of NBRP Zn plant EC10 data




| | |
|---|---|
| **130** | **barley** |
| **140** | **peanuts** |
| **215** | **sorghum** |
| **230** | **canola** |
| **270** | **cotton** |
| **540** | **millet** |
| **640** | **wheat** |
| **645** | **maize** |
| **1000** | **triticale** |
| **3220** | **sugar cane** |

Zn ACL = 120 mg/kg

# Guideline derivation pathway

Collate and screen toxicity data

↓

Account for the effect of soil properties on toxicity

↓

Calculate the Added Contaminant Limit (ACL) i.e. the soil conc that will protect a % of species

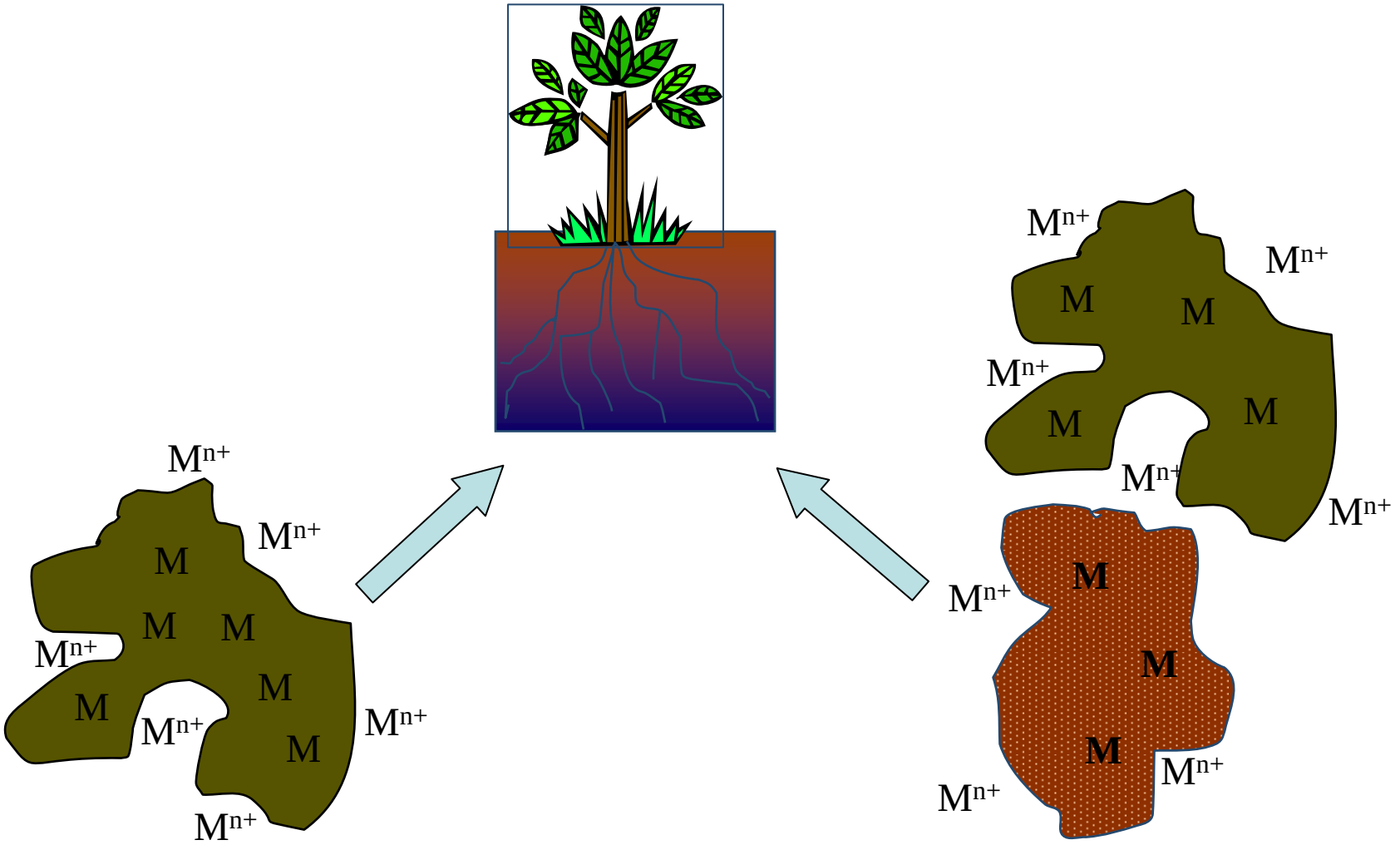
↓

**Account for the effect of bioavailability of the chemical in biosolids**

↓

Calculate background conc and add to appropriate ACL

# Relative bioavailability of metals – biosolids availability factor



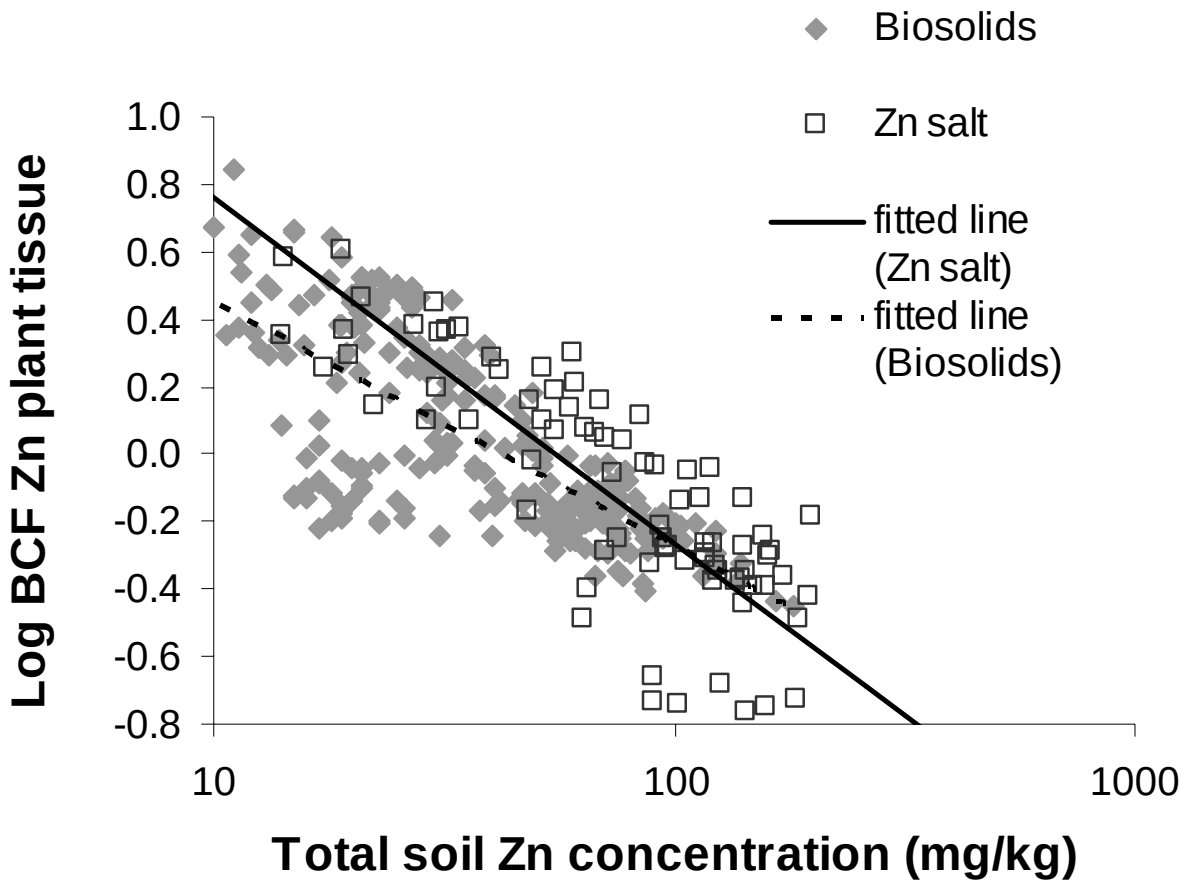
# How to assess the relative bioavailability of metals

- Uptake by plants measured as the bioconcentration factor (BCF) - **Used for Zn**

$$BCF = \frac{\text{Plant Zn concentration}}{\text{Soil Zn concentration}}$$

- Chemical solubility based methods - **Used for Cu**

# Relative bioavailability of Zn in soils amended with salts and biosolids




The biosolids availability factor for Zn is 1.

Zn availability from metal salts = availability from biosolids

# Cu biosolids availability factor measured on

- Bolivar 97 & 95
- Chelsea 77, 87, 96, 98
- Cronulla
- Fairfield
- Gumerancha
- Hahndorf
- Heathfield
- Luggage Point 95, 00
- Myponga
- Oxley
- Port Adelaide
- Port Kembla
- Sandgate
- St Marys
- Victor Harbour
- Wacol
- Werribee 93, 97
- West Hornsby

Biosolids from 18 plants
24 biosolids assessed
(Oliver et al., 2004)

**We recalculated the data to estimate the biosolids availability factor.**

**It ranged from 1.2 to 2.15**

# Added contaminant limits for Cu

| | | Limits (mg/kg) | | |
|---|---|---|---|---|
| pH | OC (%) | 1 | 2 | 5 |
| 5 | | 25 | 50 | 135 |
| 5.5 | | 40 | 75 | 175 |
| 6 | | 60 | 120 | 190 |
| 6.5 | | 90 | 185 | 200 |
| 7 | | 135 | 215 | 215 |
| 7.5 | | 205 | 230 | 230 |
| 8 | | 245 | 245 | 245 |

green shaded cells are plant derived

pink shaded cells are microbial respiration derived

# Added contaminant limits for Zn

| | | Limits (mg/kg) | | | |
|---|---|---|---|---|---|
| pH | CEC ($cmol_c/kg$) | 3 | 10 | 20 | 60 |
| 5 | | 28 | 65 | 105 | 160 |
| 6 | | 52 | 120 | 195 | 300 |
| 7 | | 95 | 225 | 300 | 300 |
| 8 | | 180 | 300 | 300 | 300 |

green shaded cells are plant derived

tan shaded cells are microbial nitrification derived

pink shaded cells are microbial respiration derived

# Guideline derivation pathway

Collate and screen toxicity data

↓

Account for the effect of soil properties on toxicity using normalisation methodology

↓

Calculate the Added Contaminant Limit (ACL) i.e. the soil conc that will protect a % of species

↓

Account for the effect of bioavailability of the chemical in biosolids

↓

**Calculate background conc and add to appropriate ACL**

# How to determine background concentrations at your paddock

1. Provided the paddock has no history of metal additions (e.g. intensive fertiliser, biosolid or pesticide use or located close to urban/industrial centres) – measure soil concentrations and use as the background.

2. If the paddock has a history of metal additions or the history is unknown, use the models of Hamon *et al*. (2004) to estimate the background concentration from soil iron concentrations.

# Estimated background concentrations

| Soil Fe% | Cu | Zn |
|---|---|---|
| 0.1 | <2 | <3 |
| 1 | <6 | <11 |
| 10 | <26 | <41 |
| 20 | <40 | <62 |

From: Hamon *et al.*, Global Geochem Cycles, V18, 2004.

# Calculation of the maximum soil concentration

soil ACL * biosolids availability factor

+

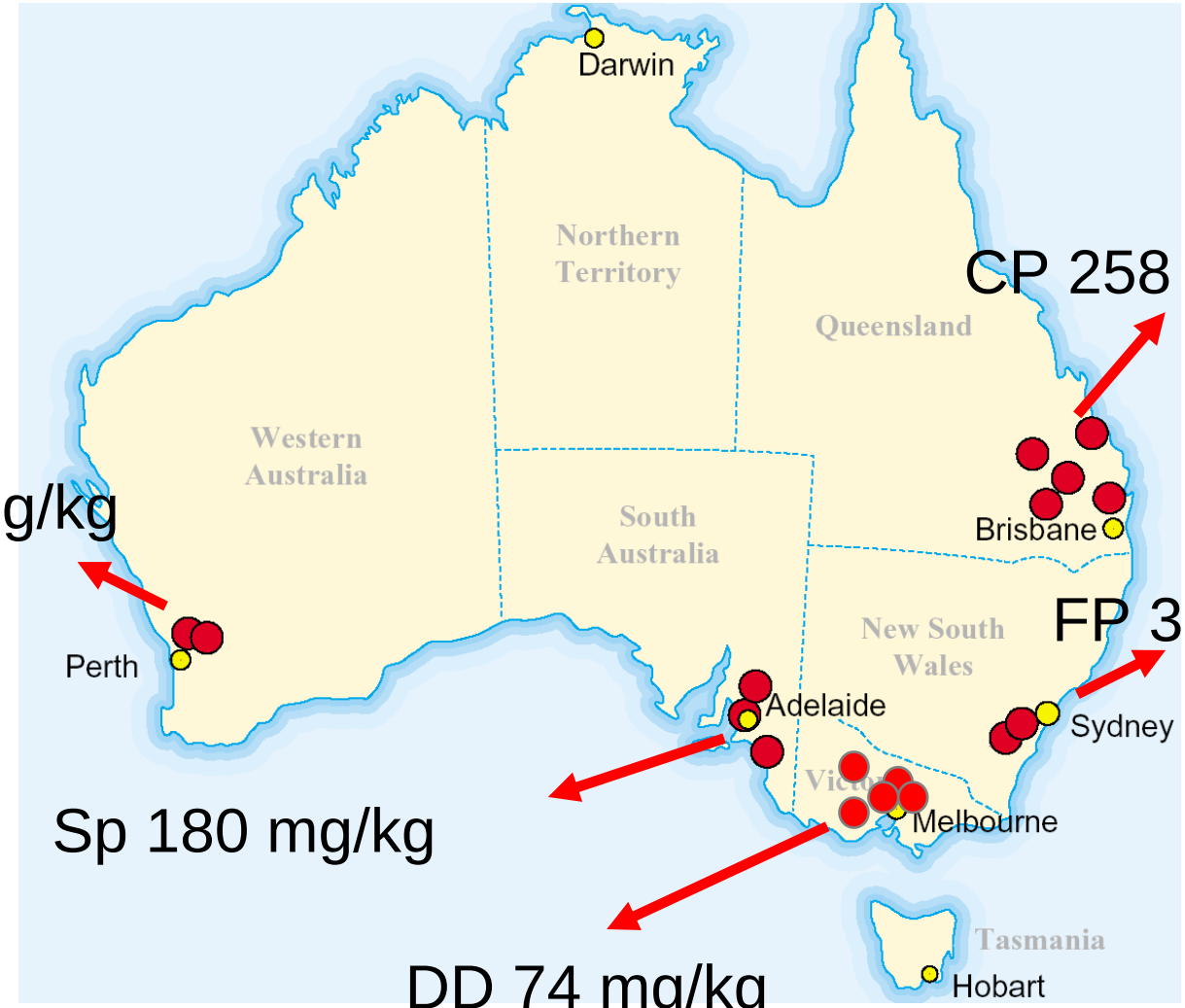
background concentration

=

maximum soil concentration

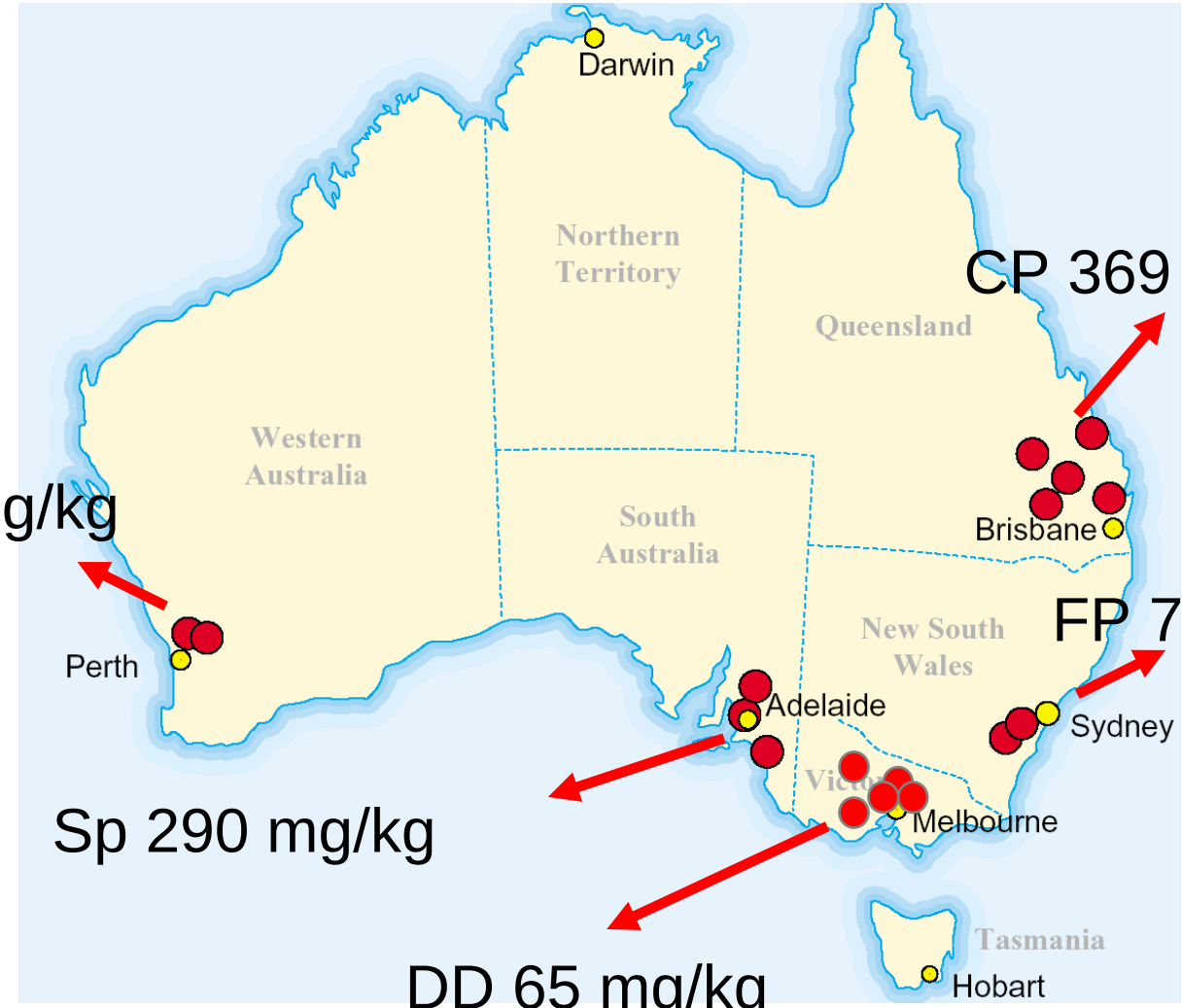
# Examples of recommended maximum soil concentrations for Cu

**Current values are 100 - 200 mg/kg**



# Examples of recommended maximum soil concentrations for Zn

**Current values are 200 - 250 mg/kg**



# So what needs to be measured?

Our recommended framework requires the measurement of:

- total Cd, Cu, Fe and Zn soil concs
- pH, CEC, OC and clay

Only new measurements required are clay and CEC

Indicative costs for these = $80

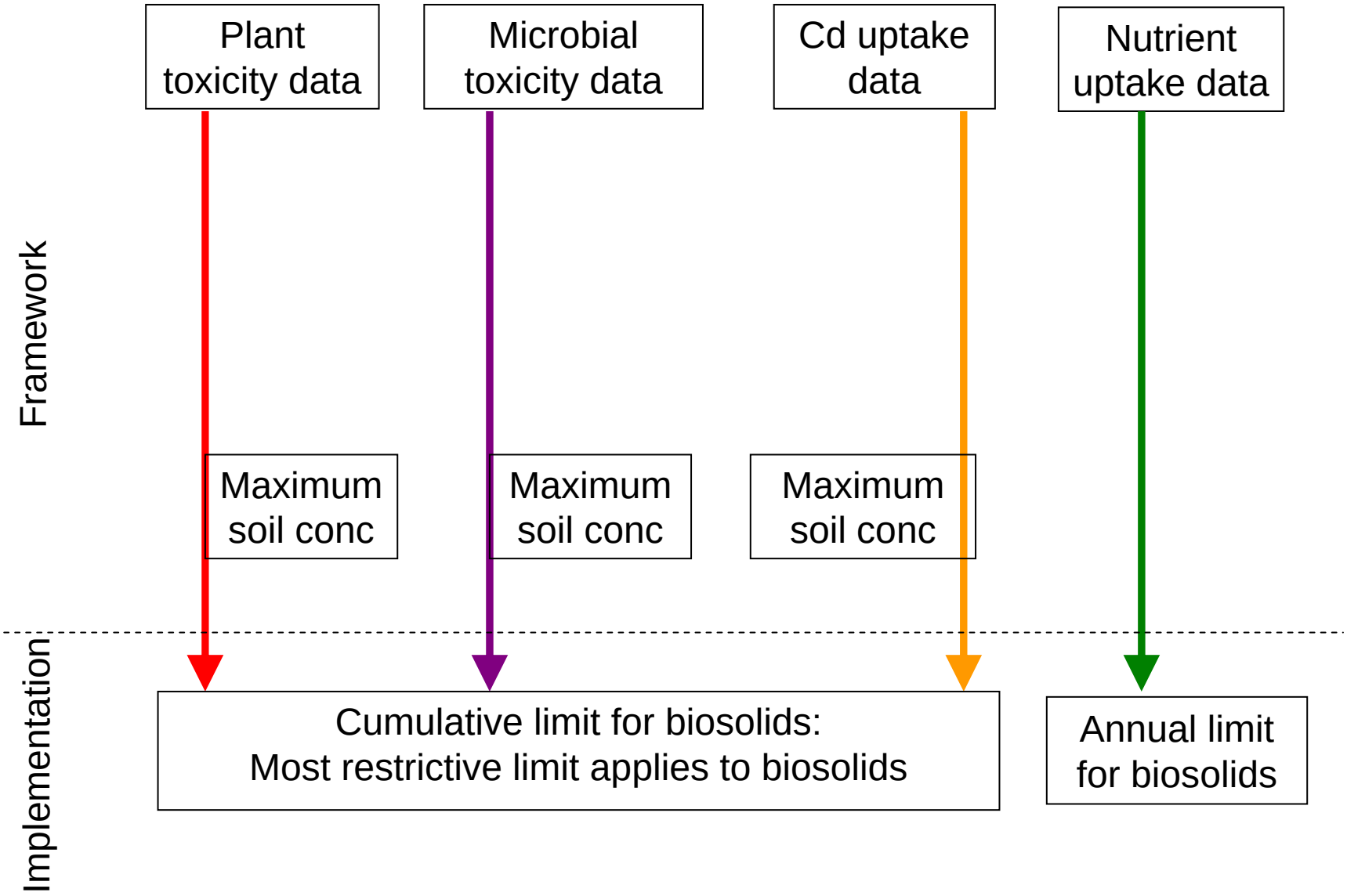
Estimates of these by MIR = $20 for both.

# Comparison of NBRP recommended ACLs

| Metal | Maximum soil limits (mg/kg) | | | | |
|---|---|---|---|---|---|
| | Australian current | NBRP* recom'd (pH 5-7) | EU current (for pH 6-7) | EU prop'd (for pH 5-7) | New York State prop'd |
| Cu | 100 - 200 | 25 - 215 (OC 1-5) | 50 - 140 | 20 - 100 | 50 - 120 (sandy-clay) |
| Zn | 200 - 250 | 28 - 300 (CEC 3-60) | 150 - 300 | 60 - 200 | 90 - 230 (sandy-clay) |

* These are ACLs and the ambient background concentrations have to be added to obtain the BA-SQGs.

# Application of the various limiting factors



# ACKNOWLEDGEMENTS



















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# Thank You