Mobility and toxicity of heavy metal(loid)s arising from contaminated wood ash application to a pasture grassland soil.

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Experimental context:

Waste wood ash

-Generated with increasing frequency

-Good liming and soil fertiliser (Ca, Mg etc)

-Concentrated heavy metals (CCA wood)

Material	Cr mg kg^{-1}	Cu mg kg^{-1}	Zn mg kg^{-1}	As mg kg^{-1}	Pb mg kg^{-1}
Soil	23.9 ± 2.1	8.8 ± 0.6	23.2 ± 1.4	4.5 ± 0.2	15.5 ± 1.1
Ash	**9914.1 ± 714.9**	**8793.4 ± 632.0**	**4666.7 ± 373.5**	**9259.4 ± 649.3**	**1988.4 ± 92.0**
ICRCL trigger values	*< 1000*	*< 130*	*< 300*	*< 40*	*< 2000*

Study aims:

-Examine mobility [leaching] of heavy metals from ash, when applied to soil with and without manure

-Determine toxic response to increasing doses of ash using bioassays

-Assess risk of heavy metals in the environment using plant uptake and modelling

Heavy metals; potentially toxic if mobile and bioavailable within the environment

Hypotheses:

1) Leaching of heavy metals from ash can be reduced by co-applying manure

2) Arsenic will be very soluble and bioavailable due to high pH

3) Co-applying manure can reduce phyto-toxicity and plant uptake of metals

Organic amendment; manure co-applied to bind metals and prevent plant uptake/toxicity

Experimental set-up:

Soil

Soil + M

Soil + M + 0.1% A

Soil + M + 0.3% A

Soil + M + 1% A

Soil + M + 3% A

Soil + 3% A   X 5 rep.

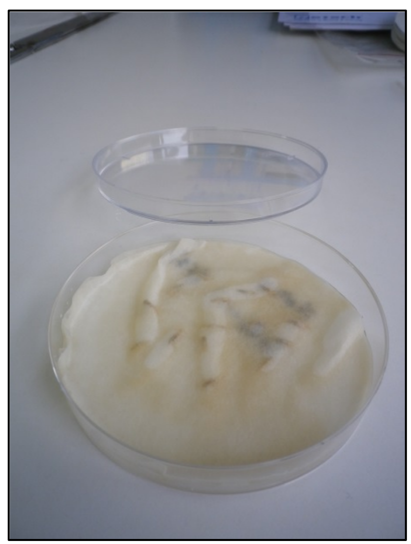
Duration; 60 days

Materials and methods:

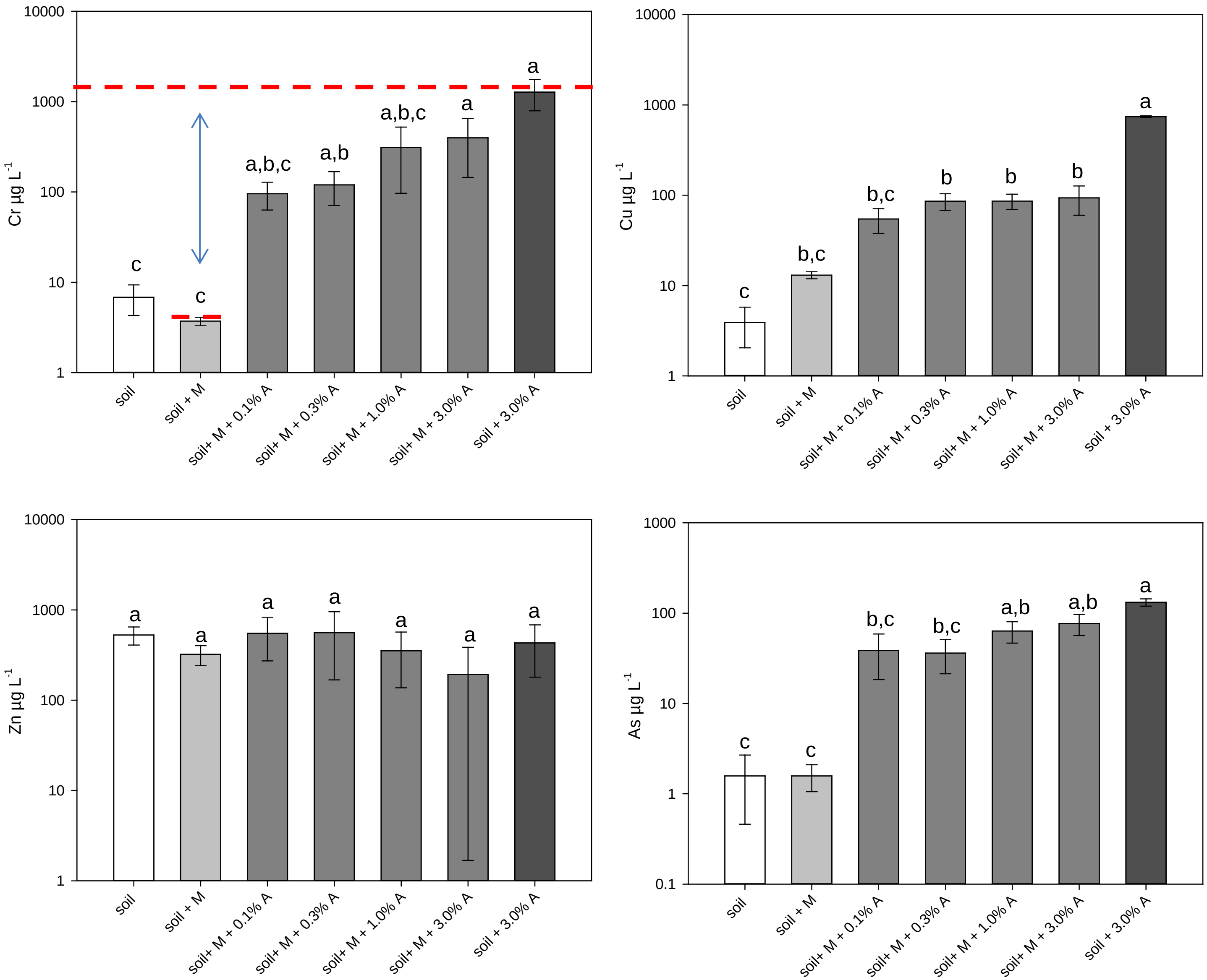
1) Pore water collected by rhizon sampler (picture), measured by ICP-MS for metals

2) Ryegrass germinated and harvested after 9 weeks, mass, digested and ICP-MS for metals

3) Toxicity bio-assays performed on pore water as 'bioavailable' fraction of metals (E.coli HB101 pUCD607)



Results-pore water:

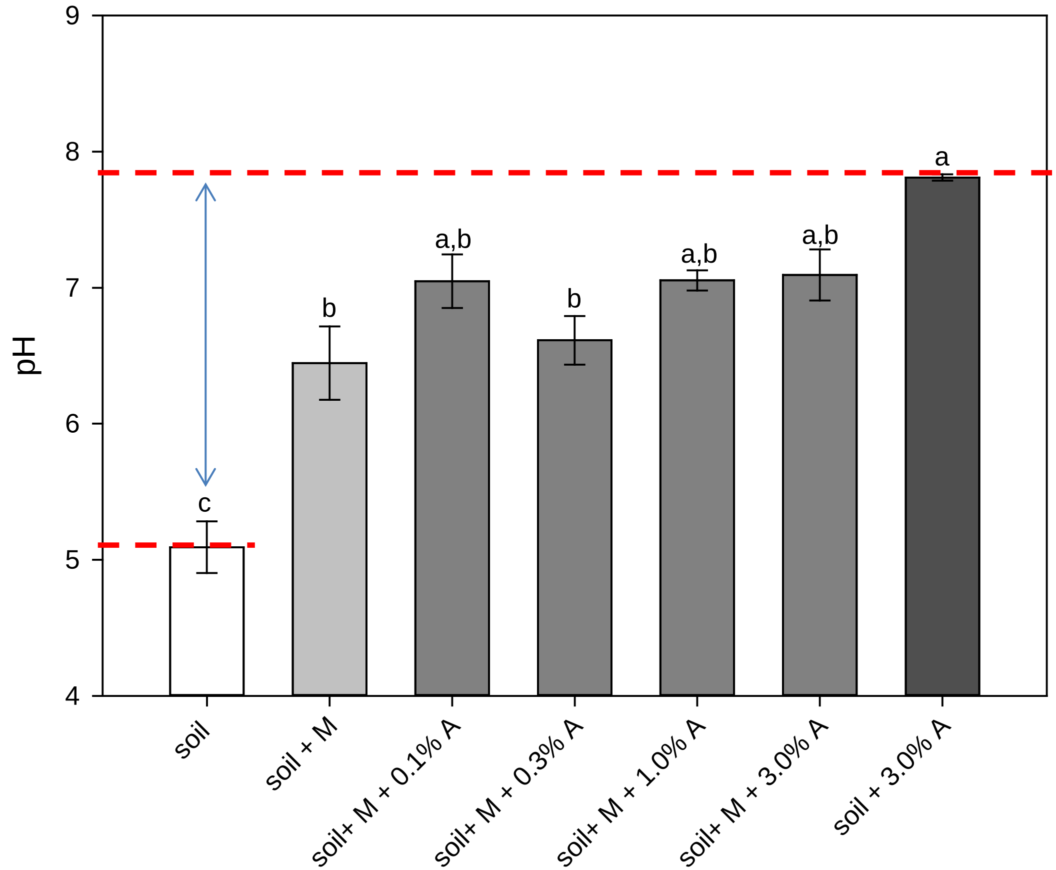


Arsenic, cadmium, copper, lead and zinc concentration ($\mu g\ l^{-1}$) in the pore water of several field trials.

Site & location	As	Cd	Cu $\mu g\ l^{-1}$	Pb	Zn
United Kingdom					
Byrom Street, Liverpool	1–3		2–10	n.d.–21	n.d.–360
Quaker Meeting House, St Helens	2–83	n.d.–2	4–55	1–22	6–93
Merton Bank, St Helens	15–52	n.d.	25–47	13–495	67–205
Kidsgrove, Staffordshire	1–2	20–6120	n.d.–0.71	n.d.–8	63–6470
Thornton Hough, Cheshire	2–110	n.d.–2	16–104	n.d.–9	22–449
Prescot, Merseyside	1–108	5–1400	49–1190	2–72	72–3749
Spain					
Mina Mónica, Madrid	2–2901	1–17	n.d.–48	n.d.–2	147–871
Pinares de la Fuente del Collado, Madrid	n.d.	n.d.–2	15–45	n.d.	71–111
La Unión, Murcia	n.d.	n.d.–3000	1400–27900	n.d.	36000–927000

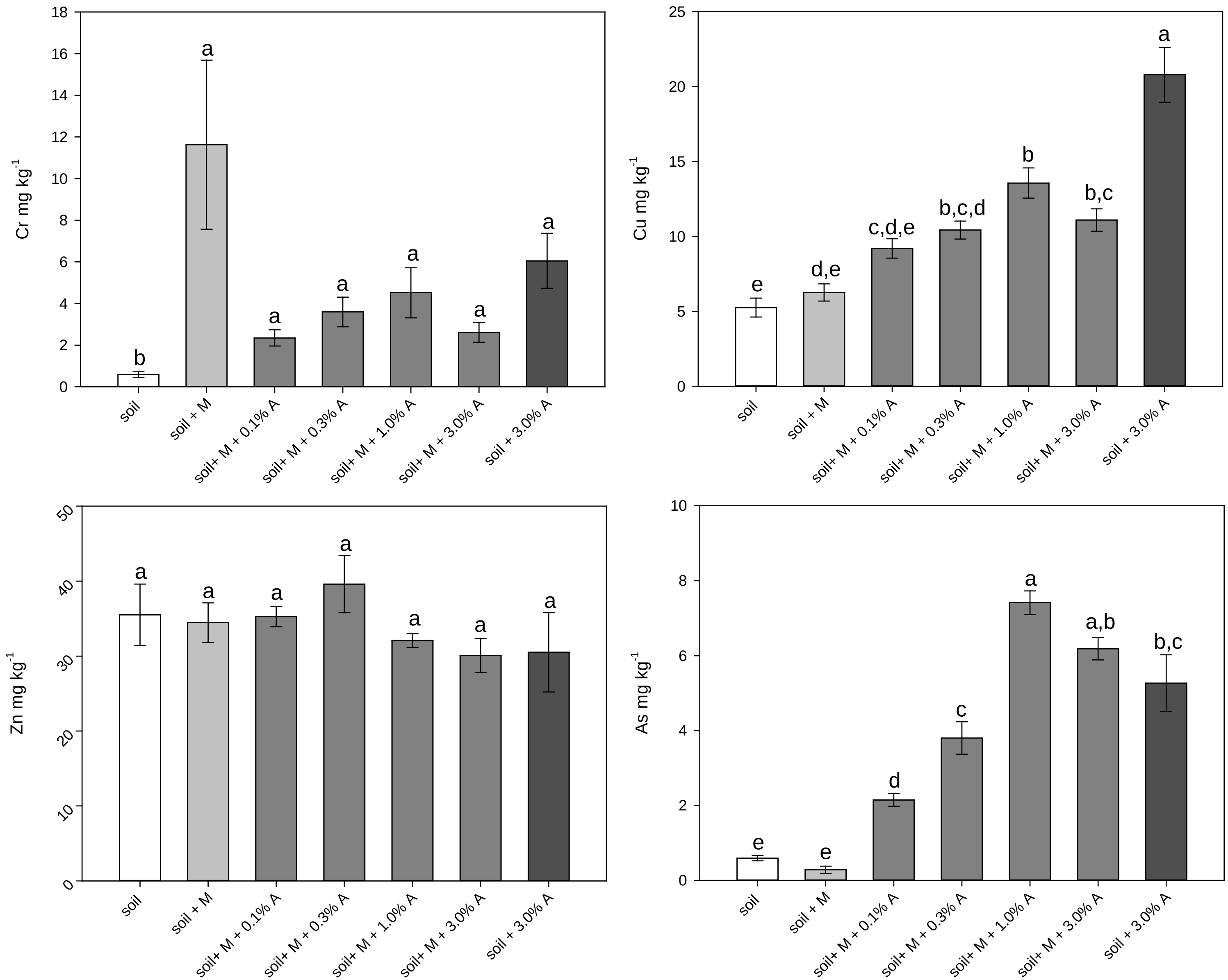
n.d., not detected.

Comparable with values from contaminated industrial and mine areas in Europe; from Moreno-Jimenez et al, 2011

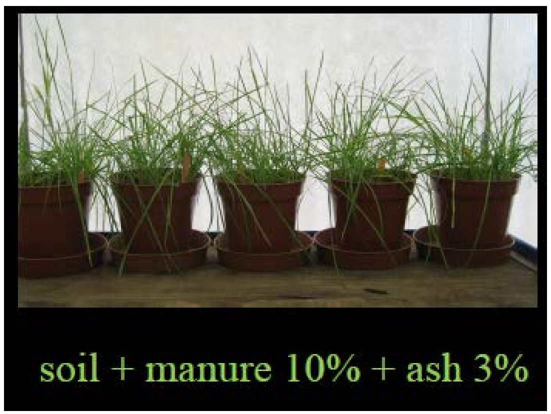


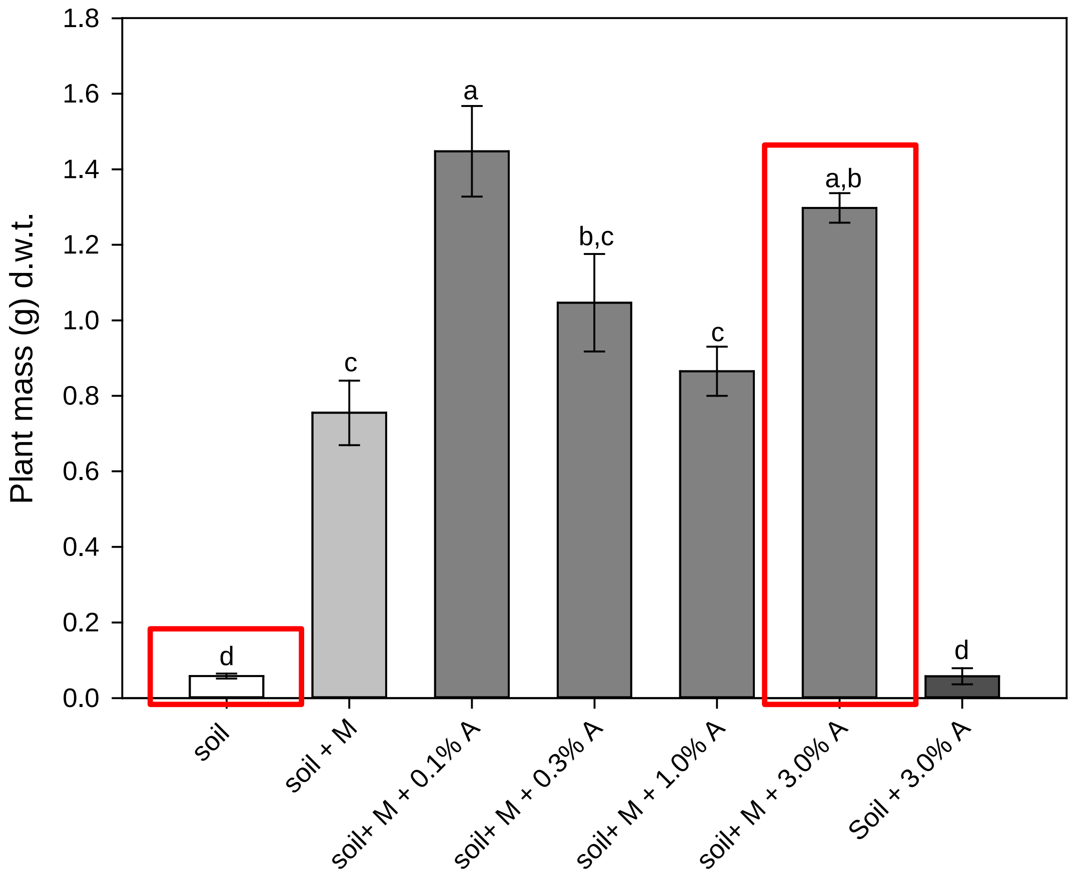
9
8
7
6
5
4
pH
c
b
a,b
b
a,b
a,b
a
soil
soil + M
soil+ M + 0.1% A
soil+ M + 0.3% A
soil+ M + 1.0% A
soil+ M + 3.0% A
soil + 3.0% A

Results-plant metals:

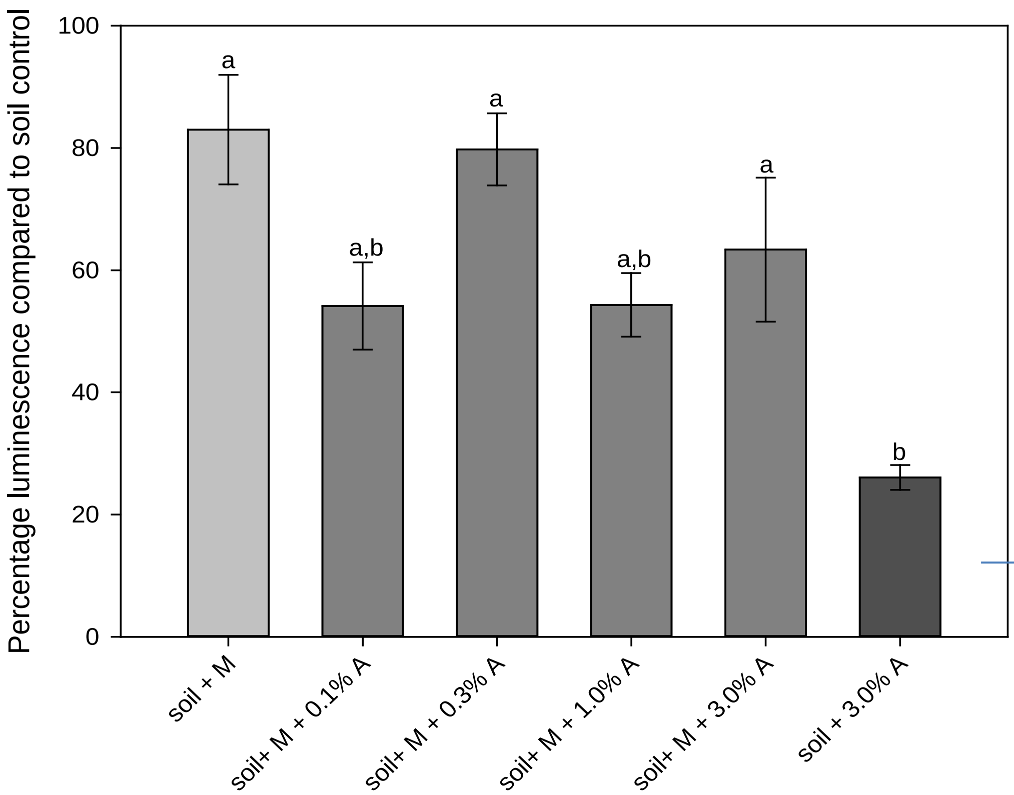


Results-plant mass:





Results-toxicity assays:



Phyto-toxicity limit

Discussion & conclusions:

-High ash doses completely phyto-toxic, moderate doses improve plant biomass

-Manure application limits Cu and Cr mobility and uptake

-Arsenic bioavailability controlled by high pH, and P

-Ash has no effects on Zn in pore water or ryegrass; co-precipitated with Ca, Mg etc, or immobile at high pH?

"Moderate doses of ash, co-applied with manure would have minimal effect on heavy metal leaching and would improve plant biomass [short term] but continued application may lead to accumulation of toxic concentrations in soil. Risk of As entering food chain in grazed pasture areas"