Trace Elements in Animal Waste
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Virginia Cooperative Extension
Knowledge for the CommonWealth

Introduction

- Animal manures (esp., swine and poultry) comprise significant agricultural soil inputs of:
  - arsenic (As)
  - copper (Cu)
  - zinc (Zn)
- Soils
  - long-term sinks for trace elements (esp., heavy metals)
  - trace element accumulation: potential impairment of soil & water quality and human, animal and plant health.

Trace Elements are Essential in Livestock Diets

- The immune status and health of livestock may be enhanced when their diet contains certain trace elements at levels above those considered to be necessary to maintain normal metabolism, growth, production and reproduction.

Essential	Non-essential
Chromium (Cr)	Arsenic (As)
Copper (Cu)	Cadmium (Cd)
Manganese (Mn)	Lead (Pb)
Nickel (Ni)	
Zinc (Zn)	

Manure Applications Can Rapidly Exceed Soil Metal Loading Limits

- Nicholson et al. (1998) estimated that if pig and poultry manures with ‘typical’ concentrations of Zn and Cu were applied annually at ‘real-world’ rates it would take <100 years for some tillage and grassland soils to reach the soil total Zn and Cu limit values that apply where sewage sludge is recycled to agricultural land (DETR, 1996).

Source Effect on Metal Accumulation in Soils of England and Wales (Nicholson et al., 2000)

Sources	Zn	Cd	Cu
	----------tons/year----------		
Atmospheric deposition	2457	21	631
Livestock manure	1858	4.2	643
Biosolids	385	1.6	271
Phosphate fertilizers	213	10	30

Sources of Soil Arsenic

Source	Soil conc.	Land area	Risk
Geologic	Low	All	Low
Poultry litter, biosolids	Low	Low	Low
Plant defoliants	Med	Med	Low-Med
$PbAsO_4$	High	Med	Med
CCA lumber	High	Low	High

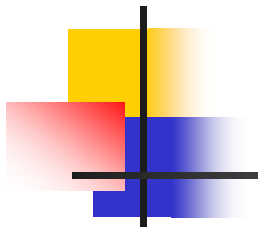
Concentrations of As in U.S. Soils

Mean (mg/kg)	Range (mg/kg)	N	Ref
7.2	<0.1-97	1318	Schacklette and Boerngen, 1984
11.3	0.1-194	>3000	Ure and Berrow, 1982

- As concentration of 3 mg/kg proposed by U.S. EPA as regulatory maximum is lower than many natural soils and soils influenced by previous agricultural practices!

- Risk assessment indicates soil concentrations >40 mg/kg may present risk to children who ingest manure-amended soil.

Equilibria of Metal Ions with Soil Components



Plant Shoots

↑

Plant Roots

↗

Chelated to Organic Matter ↖↘

Adsorbed ← on Fe/Mn →

Soil Solution

$M^{2+} + L \Leftrightarrow ML$

↙↗

Occluded in Fe/Mn oxides

↑↓

Inorganic Compounds

↖↘

Soil Microbes

L = Ligands

Soil-Plant Barrier

- Processes in soils or plants that prevent excessive food chain transfer of elements (can be circumvented by direct ingestion)
- Mechanisms
  - Insolubility or adsorption in soil or plant roots
    - Cr, Pb, Fe, Hg, Ag, Al
  - Phytotoxicity limits plant accumulation
    - Zn, Cu, Ni, As, Mn, B
- Exceptions
  - Cd, Se – humans
  - Mo, Se, Co - livestock

Biosolids U.S. EPA 503 Rule Trace Element Limits

Element	PCL (mg/kg)	CCL (mg/kg)	CPLR (lbs/ac)
As	41	75	36
Cd	39	85	35
Cu	1500	4300	1340
Se	100	100	89
Zn	2800	7500	2500

PCL = Pollutant Concentration Limit
CCL = Ceiling Concentration Limit
CPLR = Cumulative Pollutant Loading rate

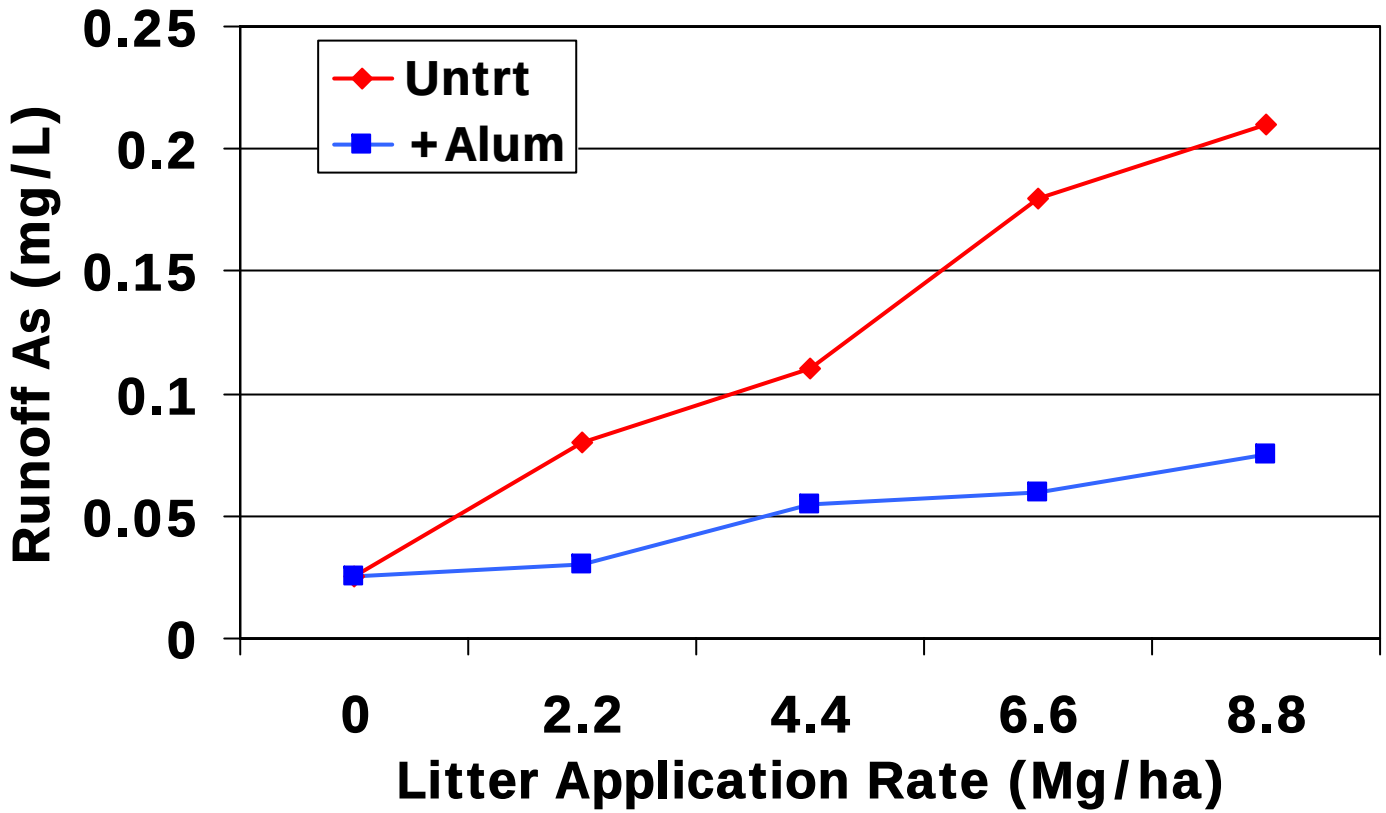
Trace Element Concentrations in Broiler Litter (Edwards and Daniel, 1992) and Biosolids Risk Assessment PCL

Element	BL Mean	BL Range	Bios PCL
	----------mg/kg----------		
As	22	11-38	41
Cu	56	25-127	1500
Fe	842	526-1,000	NA
Mn	268	175-321	NA
Zn	188	105-272	2800

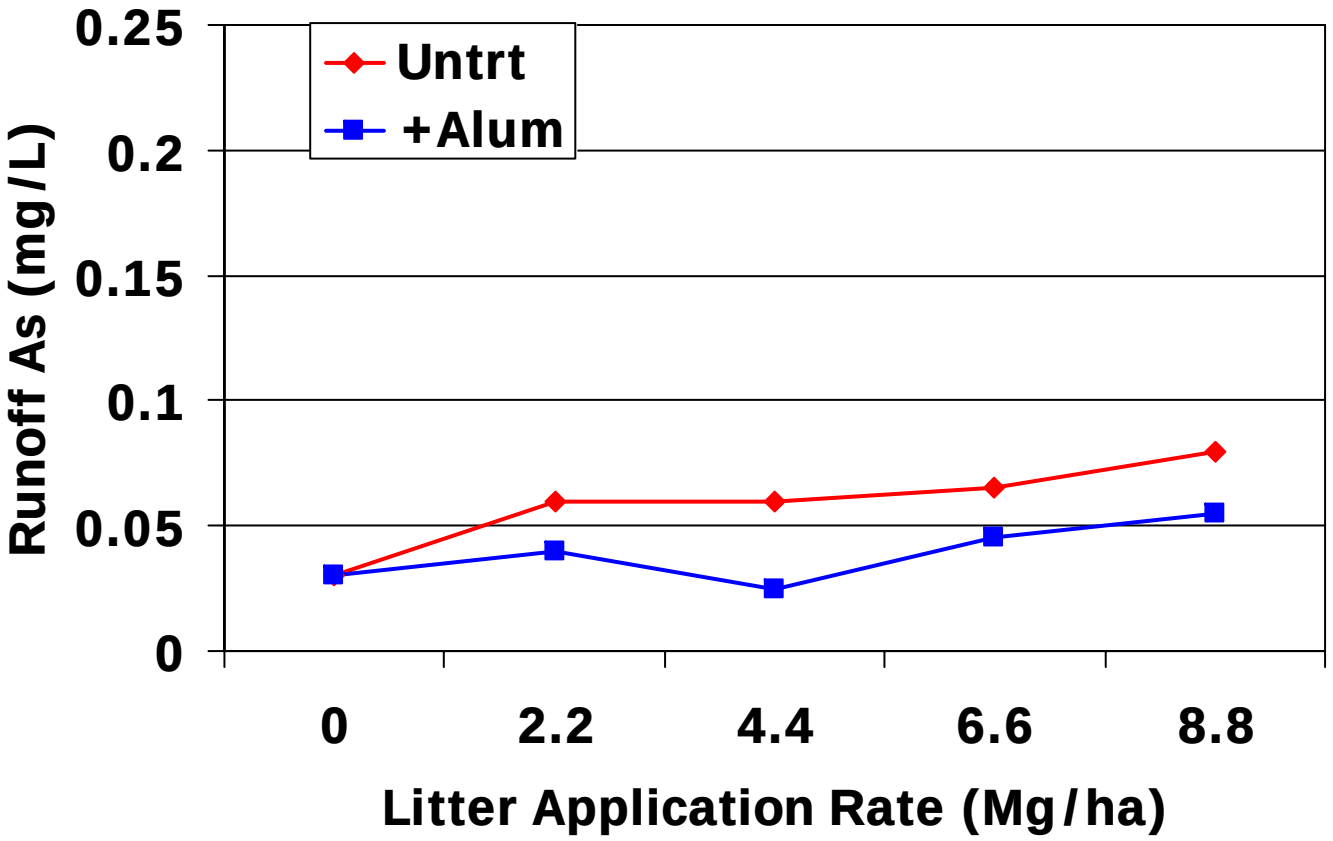
Effect of long term poultry litter application on soil trace element concentrations (Gupta and Charles, 1999)

		Soil profile depth (in)		
Element	Trt	0-4	4-8	8-12
		mg extracted/kg dry soil		
As	CTL	4.4	4.7	5.5
	PL	5.9*	5.6*	5.6*
Cd	CTL	0.83	0.97	0.36
	PL	2.07*	1.20*	0.76*
Cu	CTL	3.4	2.8	2.7
	PL	12.4*	7.5*	5.4*

Soluble As from Poultry Litter-Amended Soil in Runoff on Application Date (Moore et al., 1998)



Soluble As from Poultry Litter-Amended Soil in Runoff 7 Days after Application (Moore et al., 1998)



Soil effects of 10 annual applications of swine Cu (1316 mg/kg) (Anderson et al., 1991)

Copper Treatment		Soil pH	DTPA-Cu (mg/kg)
Source	Rate (kg Cu/ha)		
		Guernsey silt loam	
CTL	0	7.0a	1.6b
Swine	311	6.8a	38.6a
		Bertie fine sandy loam	
CTL	0	6.8a	1.7b
Swine	308	6.9a	21.2a
		Starr-Dyke clay loam	
CTL	0	7.1a	8.2b
Swine	303	7.1a	51.4a

Plant effects of 11 annual applications of swine Cu (1316 mg/kg) (Anderson et al., 1991)

Copper Treatment		Corn grain Cu conc. (mg/kg)	Corn grain yield (Mg/ha)
Source	Rate (kg/ha)		
		Guernsey silt loam	
CTL	0	2.1a	11.83a
Swine	329	2.0a	12.59a
		Bertie fine sandy loam	
CTL	0	2.2a	8.08a
Swine	326	2.0a	8.18a
		Starr-Dyke clay loam	
CTL	0	2.1a	7.83a
Swine	321	1.9a	9.66a