Heavy metal loadings from animal manures to agricultural land in england and wales.

Charge en métaux lourds apportés aux sols par les épandages de déjections animales en Angleterre et Pays de Galle.

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Abstract

The heavy metal contents of a range of animal manures (farmyard manures, slurries and poultry manures) were measured to give an indication of 'typical' concentrations, along with the metal contents of livestock feeds (dairy and beef cattle, pigs and poultry) from the same sampled farms. Based on the 'typical' manure metal analyses, standard total nitrogen (N) and dry matter contents, pig manure applications supplying 250kg/ha of N were estimated to apply ca. 2.2 kg zinc - Zn/ha and 1.6 kg copper - Cu/ha, and poultry manure applications ca.2.0 kg Zn/ha and ca. 0.4 kg Cu/ha. Cattle manure dressings were estimated to apply ca. 1.0 kg Zn/ha and 0.3 kg Cu/ha, largely representing the recycling of metals in cattle farming systems. 'Typical' manure metal concentrations were combined with farm census data on animal numbers and estimates of manure production quantities, to identify areas where heavy metals may be accumulating at elevated rates. Calculations of annual metal loadings to the agricultural land area in each 5 km^2 grid square (using GIS) indicated that the highest loadings of Zn (up to 3.3 kg/ha) and Cu (up to 2.2 kg/ha), corresponded with the main pig farming areas in East Anglia and Humberside. The highest estimated annual loadings of other metals were : nickel (up to 0.08 kg/ha), chromium (up to 0.064 kg/ha), cadmium (up to 0.007 kg/ha) and lead (up to 0.073 kg/ha).

Keywords : heavy metals, animal manures, livestock feeds, GIS mapping

Résumé

La teneur en métaux lourds de différents types de déjections (fumiers bovins, lisiers et fumiers de volailles) a été déterminée afin d'apprécier la concentration « typique » de ces produits ainsi que celle des aliments utilisés au sein des fermes échantillonnés. Sur la base de cette analyse « type » en métaux, sur une teneur courante en azote et en matière sèche, il apparaît que les épandages de lisier apportant 250 kg N/ha s'accompagnent d'un apport de 2,2 kg zinc Zn/ha et de

1,6 kg cuivre Cu/ha, alors que les doses correspondantes pour les fumiers de volailles s'établissaient à 2,0 kg Zn/ha et 0,4 kg Cu/ha. Les épandages de fumier bovin s'accompagnent d'apports en métaux de l'ordre de 1,0 kg Zn/ha et 0,3 kg Cu/ha, ce qui représente largement un recyclage des métaux en système d'exploitation bovine.

Cette concentration « type » en métaux a été croisée avec les données statistiques sur les cheptels présents afin de déterminer les quantités de déjections produits et ainsi d'identifier les zones d'accumulation importante en métaux lourds. Ces calculs sur une base unitaire de 5,5 km² (utilisation d'un SIG) indiquent que les charges maximales en zinc (jusqu'à 3,3 kg/ha) et en cuivre (jusqu'à 2,2 kg/ha) correspondent aux zones d'élevage porcin développé à l'Est Anglia et Humberside. Les charges maximales pour les autres métaux étaient : nickel (jusqu'à 0,08 kg/ha), chrome (jusqu'à 0,064 kg/ha), cadmium (jusqu'à 0,07 kg/ha) et plomb (jusqu'à 0,073 kg/ha).

Mots clés : métaux lourds, déjections animales, alimentation animale, représentation SIG.

1. Introduction

In view of concerns about heavy metal impacts on soil fertility and the potential transfer of certain metals to human diets, there is a need to quantify heavy metal inputs to agricultural soils and to assess which soils are most vulnerable to pollution. To assess the impact of agricultural management practices on heavy metal concentrations of soils, heavy metal balances or budgets can be calculated. This approach requires information on the quantities of metals which are input to and lost from the agricultural systems under consideration.

The major inputs of metals to agricultural systems are:

atmospheric deposition	inorganic fertilisers
sewage sludge	animal manures
agrochemcials	industrial by product 'wastes'

Losses occur through offtake in crops or livestock products, leaching and via soil erosion. Previous research has considered in some detail metal inputs to soils via sewage sludge, inorganic fertilisers and agrochemicals (Alloway, 1995; Smith, 1996). However, there was little up-to-date information on heavy metal inputs via animal manures (cattle, poultry and pigs) in England and Wales, and no information on their geographical distribution.

In this study, farm census data on animal numbers (MAFF, 1996), best estimates of manure production (MAFF, 1994) and manure metal concentrations, and total topsoil heavy metal concentrations were combined in order to identify areas of England and Wales where heavy metal additions from animal manures may be occuring at elevated rates. To verify that the 'typical' manure metal concentration measurements were representative of pig and poultry manures, studies were

initiated to enable manure metal concentrations to be predicted from a knowledge of feed metal analyses.

2. Methodology

2.1 Heavy metal concentrations in livestock feeds and manures

The heavy metal (Zn, Cu, Ni, Pb, Cr, Cd) contents of a range of animal manures (straw based farmyard manures, slurries and poultry manures) were measured on a number of sample farms to give an indication of 'typical' manure metal concentrations in England and Wales. The metal contents of livestock feeds (dairy and beef cattle, pigs and poultry) from the same sample farms were also measured. A total of 85 manure samples and 270 feed samples were analysed.

To verify that these 'typical' manure metal concentration measurements were representative of pig and poultry manures, further studies were initiated using a 'balance' approach, measuring all metal inputs and outputs in selected poultry (broiler) and pig (grower and finisher) farming systems.

2.2 Heavy metal loading from animal manures in England and Wales

Farm census data on animal numbers (1995), best estimates of manure production and manure metal concentrations were combined in order to identify areas of England and Wales where heavy metal additions from livestock manures may be occuring at elevated rates. The data and calculations were input into a GIS mapping system in order to create heavy metal loading maps based on the agricultural land area in each 5km grid square.

3. Results and discussion

3.1 Heavy metal concentrations in livestock feeds and manures

The heavy metal content of animal manures is largely a reflection of metal concentrations in the feeds consumed and the efficiency of food dry matter conversion.

Manure type (no. of samples)	Dry matter (%)	Zn	Cu	Ni	Pb	Cr	As	Cd
Dairy FYM (6)	16	145	31.4	2.8	2.24	2.58	1.15	0.42
Beef FYM (12)	21	63	15.6	2.1	1.40	1.50	0.71	0.14
Pig FYM (7)	21	387	346	5.0	2.83	1.87	0.73	0.68
Dairy slurry (20)	7	176	51.0	5.5	4.79	5.13	1.09	0.20
Beef slurry (8)	13	132	30.9	3.3	5.80	2.62	0.98	0.22

Pig slurry (12)	3	403	364	7.8	<1.00	2.44	1.33	0.30
Broiler/turkey litter (12)	56	403	92.4	4.9	2.94	7.53	0.75	0.38
Layer manure (8)	37	423	65.6	6.1	9.77	4.79	0.45	1.03

Table 1
Median dry matter and heavy metal concentrations (mg/kg dry matter) in animal manures in England and Wales

Heavy metal analysis of animal manure samples showed that pig manures typically had Zn concentrations of ca. 400 mg/kg dry matter (dm) and Cu concentrations of ca. 350 mg/kg dm, reflecting Zn and Cu additions to the pig diets (Table 1). The poultry manures had Zn concentrations of ca. 400 mg/kg dm and Cu concentrations of ca. 80 mg/kg dm, which was 2-5 times higher than concentrations in the poultry feeds, reflecting the efficiency of food dry matter conversion. Typical Zn concentrations in cattle manures were ca. 130 mg/kg dm and Cu concentrations ca. 30 mg/kg dm. Dairy cattle manures had higher concentrations of most metals than beef cattle manures, probably due to the mineral supplements fed to dairy cattle.

Results from the experimental metal balance studies showed that broiler litter Zn and Cu concentrations were similar to those found in the previous survey (Table 1) at ca. 400 mg/kg Zn and ca. 100 mg/kg Cu, respectively. Excreta metal concentration factor (CF) calculations showed that all metals, except Pb (CF ca. 1.5), were similar to the CF for dry matter at ca. 5, indicating that they were not preferentially retained by the birds. The study suggests that a CF of ca. 5 could be used to estimate most heavy metal concentrations in broiler excreta from a knowledge of feed heavy metal concentrations.

In the experimental grower and finisher pig balance studies, Zn and Cu concentrations in faeces and urine were measured separately and the data combined to provide overall excreta concentrations. Again, excreta metal CF calculations showed that all metals, except Pb (CF ca. 2), were similar to the dry matter CF at ca. 7, indicating that they were not preferentially retained by the pigs. The study suggests that a CF of ca.7 can be used to estimate most heavy metal concentrations in pig excreta from a knowledge of feed heavy metal concentrations.

3.2 Heavy metal loadings from animal manures in England and Wales

Animal manures are a valuable source of organic matter and major plant nutrients, however care must be taken to ensure that heavy metal applications in animal manures do not result in unnecessary levels of soil heavy metal accumulation.

The survey slurry metal analyses (Table 1) were adjusted to more ‘typical’ manure dry matter contents for undiluted slurry (ca. 10%), using the survey-derived relationships between slurry dry matter content and fresh weight manure metal

concentrations (eg. Figure 1). Metal concentrations in solid manures were recalculated based on typical rates of straw (FYM) or woodchip (broiler/turkey litter) additions to excreta (MAFF, 1994). Using the adjusted manure metal concentrations and total nitrogen (N) contents at 'typical' dry matter contents (MAFF, 1994), metal loading rates from manure applications at 250 kg/ha total N were estimated (Table 2).

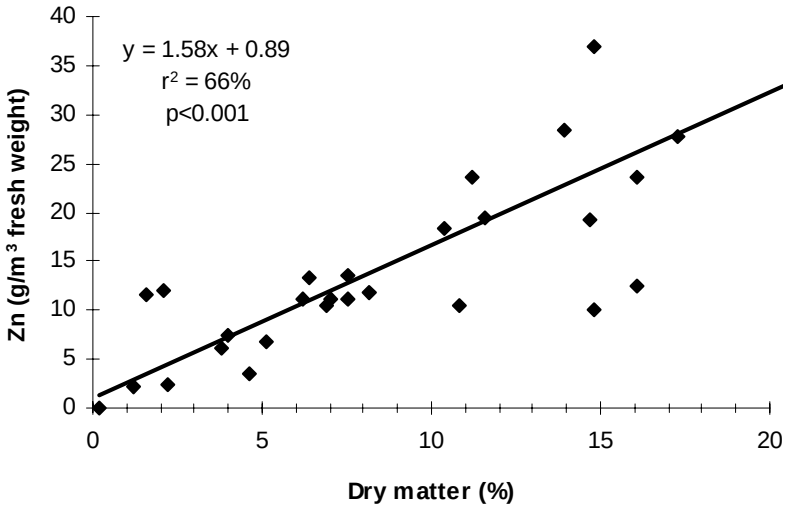

Figure 1
Relationship between dry matter content and fresh weight Zn concentrations for cattle slurry

Manure type (dry matter content)	Total N (kg/t or m^3)[1]	Zn	Cu	Ni	Pb	Cr	As	Cd
Cattle FYM (25 %)	6.0	0.7	0.2	0.03	0.03	0.02	0.01	<0.01
Pig FYM (25 %)	7.0	2.1	1.5	0.05	0.03	0.02	0.01	<0.01
Dairy slurry (10%)	4.5	0.9	0.3	0.03	0.04	0.03	0.01	<0.01
Beef slurry (10%)	3.5	1.2	0.3	0.04	0.05	0.04	0.02	<0.01
Pig slurry (10%)	7.0	2.3	1.7	0.05	0.03	0.02	0.01	<0.01
Broiler/turkey litter (60%)	29	1.1	0.2	0.02	0.02	0.01	<0.01	<0.01
Layer manure (30%)	15	2.9	0.5	0.05	0.05	0.03	<0.01	0.01

[1]Typical total N content of manure (MAFF, 1994)

Table 2
Estimated 'typical' heavy metal loading rates (kg/ha)
from animal manures applied at 250 kg/ha total N.

Pig manure applications at these rates were estimated to apply ca. 2.2 kg/ha Zn and ca. 1.6 kg/ha Cu. Poultry manures were estimated to apply 1.1-2.9 kg/ha Zn and 0.2-0.5 kg/ha Cu when spread at this rate. Cattle manure dressings applied ca. 1.0 kg/ha Zn and ca. 0.3 kg/ha Cu, largely representing the recycling of metals in the cattle farming system.

Calculations of annual metal loadings from animal manure additions indicated that the highest loadings of Zn (up to 3.3 kg/ha) and Cu (up to 2.2 kg/ha) to the agricultural land area in the 5 km^2 grid square, largely corresponded with the main pig farming areas in East Anglia and Humberside (Figures 2 and 3). The highest estimated annual loadings of other metals were : nickel (up to 0.08 kg/ha), chromium (up to 0.064 kg/ha), cadmium (up to 0.007 kg/ha) and lead (up to 0.073 kg/ha).

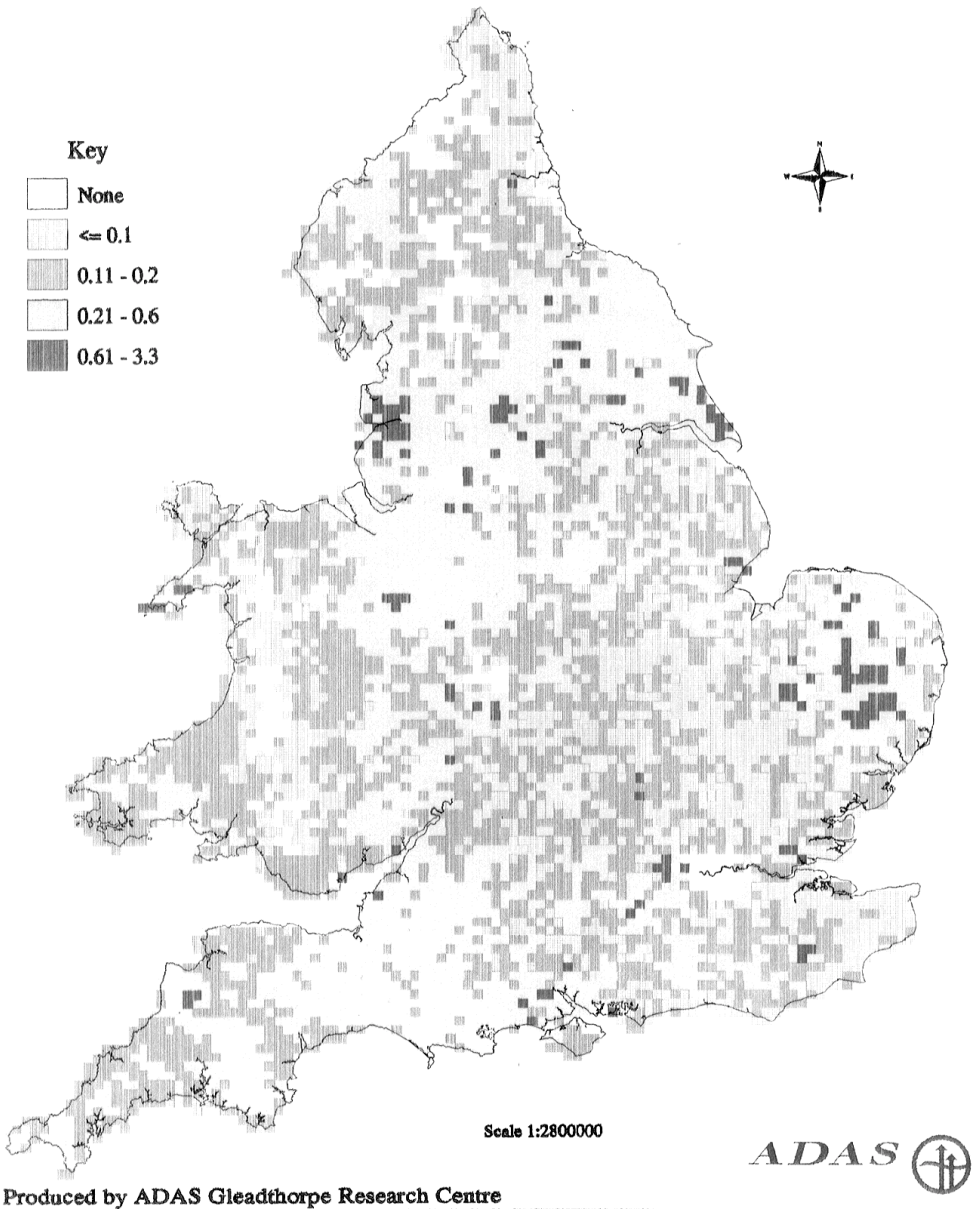

Figure 2
Total annual loading of zinc (kg/ha) from livestock manures on agricultural land in England & Wales.

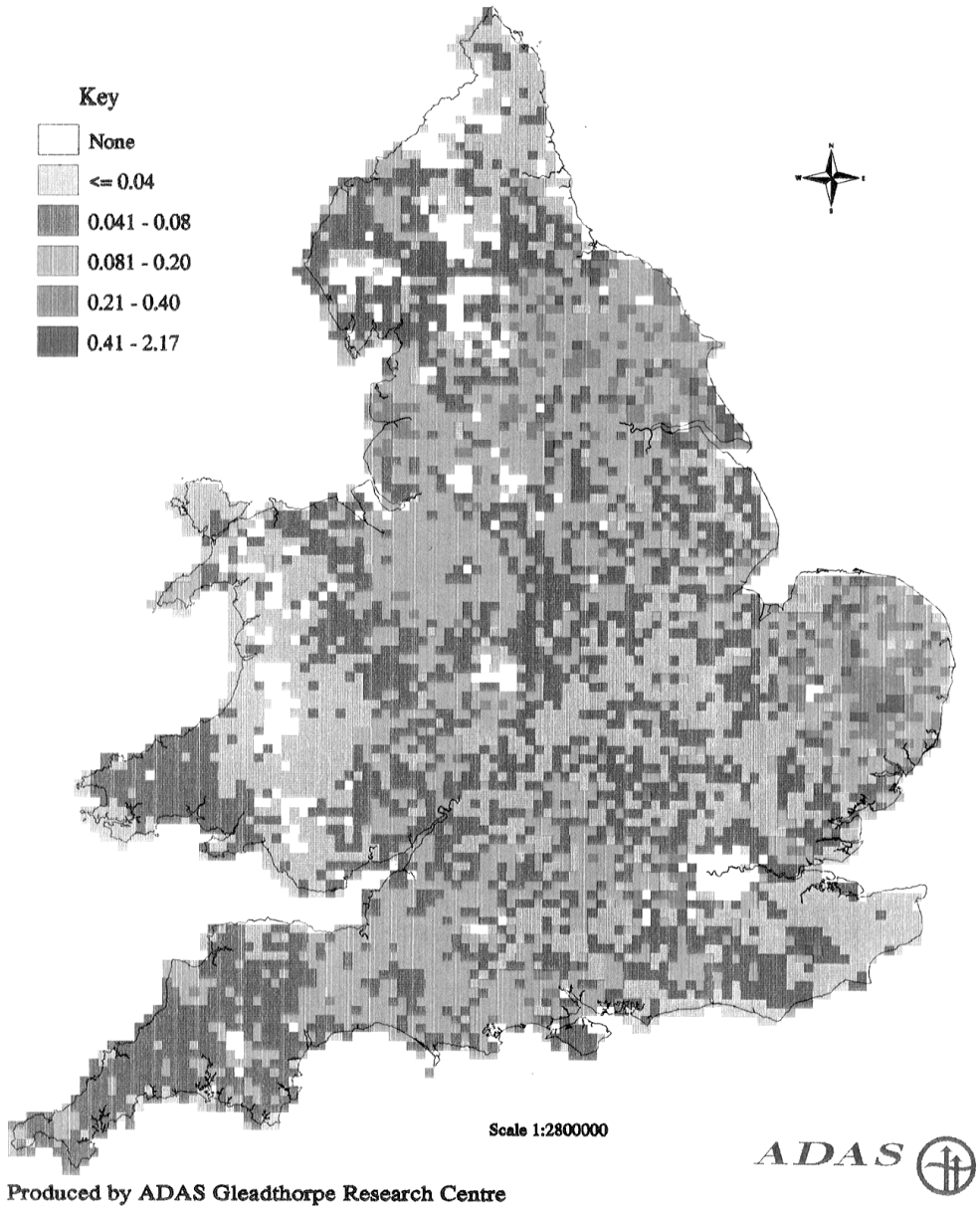

Figure 3
Total annual loading of copper (kg/ha) from livestock manures on agricultural land in England & Wales.

4. Summary and conclusions

A survey of 85 animal manure samples in England and Wales found that the highest concentrations of Zn and Cu were in pig and poultry manures, largely reflecting metal inputs in the feeds. Metal balance studies have shown that it is possible to estimate heavy metal concentrations in poultry and pig excreta from a knowledge of the feed heavy metal contents.

The highest estimated loadings of Zn, Cu, Ni, Cd, Cr and Pb to agricultural soils in the England and Wales were from pig manures. As the pig industry is concentrated in two main areas in England and Wales (East Anglia and Humberside), these are the areas where soil metal accumulation (particularly Zn and Cu) is likely to be occurring at the greatest rates.

5. Acknowledgments

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6. References

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