HEAVY METAL CONCENTRATIONS IN LIVESTOCK MANURES IN ENGLAND AND WALES.

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1 INTRODUCTION

Reducing heavy metal inputs to agricultural soils is a strategic aim of UK and EU soil protection policies (Defra 2009; EC, 2002). The recently published Defra "Soil Strategy for England" outlines the English government's approach to protecting soils in the long-term and acknowledges the need to reduce the levels of pollutants entering soils from materials spread to land. To underpin this aim, information on the significance and extent of heavy metal inputs from different sources is required to enable the effective targeting of policies to reduce metal loadings. A quantitative inventory of heavy metal (zinc - Zn, Copper - Cu, nickel - Ni, chromium - Cr, lead - Pb, cadmium - Cd, mercury - Hg and arsenic - As) inputs to agricultural soils can be used to determine the scale and relative importance of different sources of metals, either deposited from the atmosphere or applied to agricultural land. Information on heavy metal inputs is also useful for estimating accumulation rates in soils at national and catchment scales and at the field-level, and for estimating the temporal capacity of soils to accept heavy metal inputs.

1.1 Metal concentration in livestock manure

The heavy metal contents of livestock manures are largely a reflection of trace element inputs in livestock feed. The Defra "Agricultural Soil Heavy Metal Inventory" (year 2000) estimated that *c*.30% of annual heavy metal inputs to agricultural soils were from the application of livestock manures (in particular pig and poultry manures). However, as information in the "Agricultural Soil Heavy Metal Inventory" was derived using typical livestock manure metal concentrations measured in samples collected in the mid-1990s, it did not capture the effects of more recent reductions in maximum permitted levels of trace elements in certain livestock feeds (EC, 2003; Table 1). The objective of this research was to obtain up to date data on heavy metal concentrations in a range of livestock manures in England and Wales.

TABLE 1 **Previous and current maximum permitted levels of Zn and Cu in livestock feeds (mg/kg complete feed)**

Livestock category		Zinc		Copper	
		Previous[1]	Current[2]	Previous[1]	Current[2]
Pigs	Up to 16 weeks	na	na	175	na
	Up to 12 weeks	na	na	na	170
	17 weeks – 6 months	na	na	100	25
	Other pigs	na	na	35	25
	All pigs	250	150	na	na
Poultry	Layer	250	150	35	25
	Broilers (grower & finisher)	250	150	35	25
Ruminants	Pre-rumination	na	200	na	15
	Dairy and beef cattle	250	150	35	35
	Sheep	250	150	15	15

[1]SI (2000); [2]EC (2003); na = not applicable

2 METHODS

The sampling programme was designed to provide robust data on the metal content of a range of livestock manure types, with a proportionately greater emphasis on pig and poultry manures, reflecting their greater contribution to Zn and Cu loadings to agricultural soils (Table 2). One hundred and ninety livestock manure samples were collected between 2007 and 2009 (mean date 2008). The manure samples were analysed to determine dry matter, total nitrogen, Zn, Cu, Ni, Cr, Pb, Cd, Hg and As concentrations. Metal concentrations (in dried samples) were measured following aqua-regia digestion and analysis using ICP-MS. To identify temporal trends livestock manure metal concentrations from the current survey were compared with those from the previous survey (Nicholson *et al*., 1999), using the Mann Whitney test.

TABLE 2 **Livestock manure type and sample number**

Manure type	**Sample number**
Dairy slurry	24
Dairy farmyard manure (FYM)	18
Beef slurry	11
Beef FYM	15
Pig slurry	49
Pig FYM	26
Layer manure	17 (10 free range)
Broiler/turkey litter	19
Sheep FYM	6
Duck FYM	5
Total	*190*

3 RESULTS AND DISCUSSION

3.1 Poultry

Zinc concentrations in layer manures decreased from 459 in the ‘previous’ survey to 287 mg/kg dry matter - dm (P<0.01; Figure 1), reflecting the decrease in maximum permitted Zn levels in feeds from 250 to 150 mg/kg (Table 1). Zinc concentrations in broiler litter (*c*.360 mg/kg dm) did not differ (P>0.05) between the two sampling dates. Duck FYM (only sampled in 2007-09) had a zinc concentration of 323 mg/kg dm, which was similar to broiler litter and layer manure concentrations. Interestingly, the ‘current’ sampling programme measured higher (P<0.05) Zn concentrations in layer manure from caged hens (349 mg/kg dm) than free-range hens (244 mg/kg dm).

There were no changes in layer manure or broiler litter Cu concentrations between the ‘previous’ and ‘current’ sampling dates. Duck FYM (only sampled in 2007-09) had a Cu concentration of 65 mg/kg dm which was broadly in line with layer manure concentrations. Ni concentrations measured in layer manure in the ‘current’ survey (3.6 mg/kg dm) were *c*.50% lower (P<0.001) than in the ‘previous’ survey. In the ‘current’ sampling programme, layer manure had higher Cd (0.7 mg/kg dm), Cr (4.9 mg/kg dm), Pb (19.9 mg/kg dm), Ni (3.6 mg/kg dm) and As (1.3 mg/kg dm) concentrations than broiler litter.

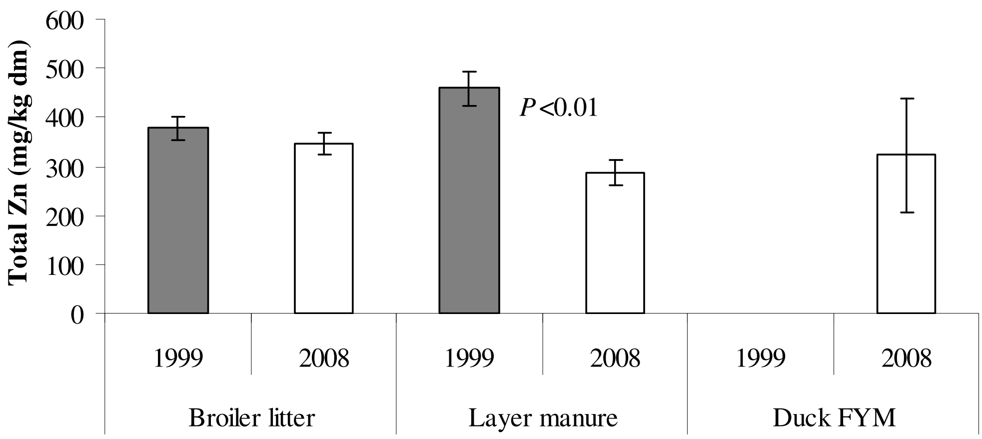

FIGURE 1 **Comparison of ‘previous’ (Nicholson *et al.*, 1999) and ‘current’ (2008) poultry manure Zn concentrations**

3.2 Pigs

Zinc concentrations in the 'current' survey in both pig FYM and slurry increased numerically (*c*.250 mg/kg dm) from the 'previous' survey, which was most probably due to the greater use of Zn on veterinary prescription (to control post-weaning scours) to compensate for the reduction in maximum permitted Cu levels in feeds. However, this increase was not statistically significant (P>0.05). Unfortunately, it was not possible to interrogate the data further to explain the variation between the different pig rearing units sampled.

Pig FYM Cu concentrations decreased between the 'previous' and 'current' sampling dates (P=0.01) from 374 to 199 mg/kg dm. There was also a numerical decrease in pig slurry Cu concentrations (from 351 to 279 mg/kg dm), although this was not statistically significant (P>0.05), Figure 2. These data indicate that the reduction in pig feed Cu concentrations (Table 1) was reflected in reduced concentrations in pig FYM and slurry.

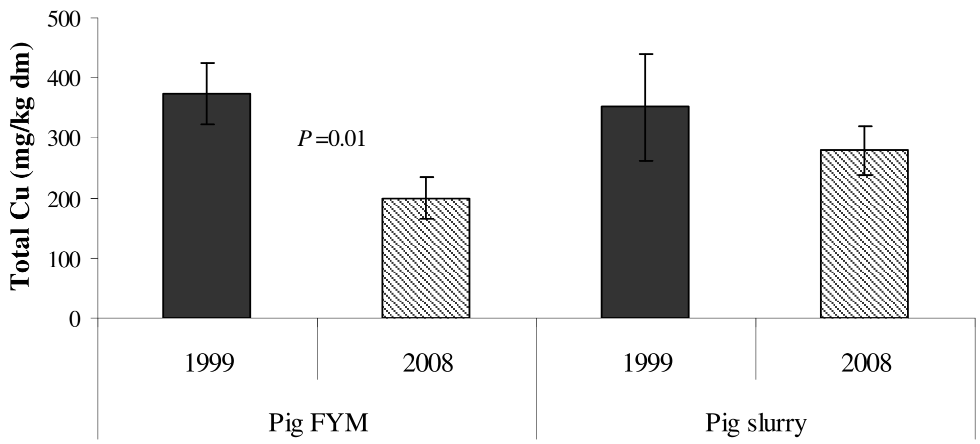

FIGURE 2 **Comparison of 'previous' (Nicholson *et al.*, 1999) and 'current' (2008) pig manure Cu concentrations**

3.3 Cattle

Zinc concentrations in dairy and beef FYM/slurry did not differ (P>0.05) between the two sampling dates. Also, there were no differences (P>0.05) in dairy FYM, beef FYM or beef slurry Cu concentrations between the 'previous' and 'current' sampling dates (Figure 3). In contrast, dairy slurry Cu concentrations increased (P<0.05) from 62 mg/kg to 137 mg/kg. This may be linked to increased milk production per cow (since the 1990s), which has been (partly) achieved through an increase in the amount of compound feed fed to dairy cattle; as productivity increases, the importance of ensuring adequate Cu (and other essential trace elements) also increases. Also, there has been greater awareness of the need for Cu in cattle diets, including the effects of Cu deficiency on health and fertility, and the binding effects of other elements (particularly molybdenum and iron). In addition, there has been an increase in the number of herds where cows are fed complete diets (in contrast to the more traditional feeding of silage/forage and compound feed separately). Complete diets consist of mixtures of silage/forage and compound feed together, to which farmers add a mineral supplement.

Beef FYM Cr (up by 16 mg/kg dm), Ni (up by 6 mg/kg dm) and Pb (up by 27 mg/kg dm) concentrations increased (P<0.05) between the 'previous' and 'current' sampling dates, although there were no corresponding increases in beef slurry metal concentrations. These data suggest that the increased metal concentrations in beef FYM may originate from a change in metal concentrations in the animal bedding material (for example, through the use of paper crumble in part/full substitution for straw) rather than a change in animal feed composition. However, it was not possible to interrogate the data further to assess potential differences in animal bedding materials between the two sampling dates. Zinc (179 mg/kg dm) and Cu (35 mg/kg dm) concentrations in sheep FYM (only sampled in 2007-09) were similar to those measured for beef FYM.

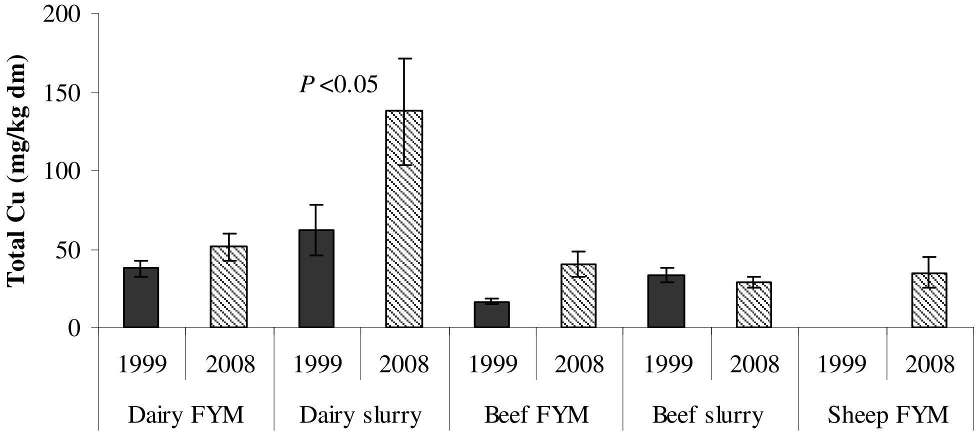

FIGURE 3 **Comparison of 'previous' (Nicholson *et al.*, 1999) and 'current' (2008) cattle and sheep manure Cu concentrations**

4 CONCLUSIONS

In this project, livestock manure heavy metal concentrations were measured (building upon a previous sampling exercise undertaken in the mid-1990s) to provide up-to-date estimates of metal inputs (particularly Zn and Cu) following reductions in the maximum permitted levels of trace element supplementation in livestock feeds (EC, 2003).

Data from the 'current' survey showed that Zn concentrations in layer manure had decreased from 459 in the 'previous' survey to 287 mg/kg dry matter (P<0.01), reflecting the decrease in maximum permitted levels in poultry feeds from 250 to 150 mg/kg. In contrast, Zn concentrations in both pig FYM and slurry increased numerically (*c*.250 mg/kg dm) from the 'previous' survey, which was most probably due to the greater use of Zn on veterinary prescription (to control post-weaning scours).

For Cu, the data showed no changes (P>0.05) in layer manure, broiler litter, dairy FYM, beef FYM or beef slurry Cu concentrations between the 'previous' and 'current' sampling dates. Notably, pig FYM Cu concentrations decreased between the 'previous' and 'current' sampling dates (P=0.01) from 374 to 199 mg/kg dm, and there was also a numerical decrease in pig slurry Cu concentrations (from 351 to 279 mg/kg dm) reflecting reductions in pig feed Cu concentrations. In contrast, dairy slurry Cu concentrations increased (P<0.05) from 62 mg/kg to 137 mg/kg, most probably as a result of an increase in the amount of compound feed fed to dairy cattle and increased use of compound diets to which farmers add a mineral supplement.

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