Survey on zinc and copper contents in dung from Austrian livestock production

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Bestandsaufnahme der Gehalte an Zink und Kupfer im Wirtschaftsdünger aus der österreichischen Tierproduktion

1 Introduction

It is common feeding practice in livestock production to supply animals with zinc (Zn) and copper (Cu) since native contents of these essential trace elements in the feeds are usually too low to match the high nutritional requirements of intensively producing animals. On the other hand, Zn and Cu are considered as heavy metals potentially accumulating in the soil and thus possibly harming its vital contribution to assure sustainable generation of food and feed, as well as of clean water. While transfer of Zn and Cu via biomass from municipal sources to the soil is submitted to environmental regulations, the input of these heavy metals into the agricultural area through spreading of dung from agricultural livestock production is controlled indirectly by feed law setting upper limits of Zn and Cu to the animals' feeds. But Zn and Cu from dung are considered to contribute to about ¾ of total entry of these heavy metals into agricultural areas in central Europe (e.g. Aichberger et al., 1995; Müller, 1997; Danneberg, 1997; Kilian, 1999; Uba, 2004; Nicholson et al., 2005). Environmental authorities are therefore about to discuss limitations of Zn and Cu contents in dung in the magnitude of 200 to 450 mg Zn per kg of dung dry matter (DM), and 60 to 90 mg Cu/kg DM, respectively (Schultheiss et al., 2002; Schwarz and Freudenschuss, 2004). However, assessment of consequences of these limits to agricultural practice and feasibility of their application under common conditions requires knowledge about the current status of Zn and Cu contents in dung and the major sources of variation. In this context the present study describes the Zn and Cu contents in a large set of dung samples collected randomly from Austrian livestock production during years 1994 to 2004 with special emphasis to animal species, category of agricultural production and type of dung.

2 Material and Methods

The present study describes Zn and Cu analysis of a total of 374 dung samples collected by 3 separate campaigns be-

Zusammenfassung

Im Zeitraum von 1994 bis 2004 wurden von landwirtschaftlichen Betrieben aus den österreichischen Bundesländern Oberösterreich und Niederösterreich zufällig insgesamt 347 Proben von Wirtschaftsdüngern gezogen und auf ihre Gehalte an Zink (Zn) und Kupfer (Cu) in der Trockenmasse (T) untersucht. Die Proben umfassten Wirtschaftsdünger verschiedener Spezies und Produktionskategorien (Schweinezucht, Schweinemast, Milchkühe, Rindermast, Legehennen und Masthühner, Puten) sowie verschiedene Arten von Wirtschaftsdüngern (Gülle, Festmist). Die Zn-Gehalte in Wirtschaftsdüngern von Schweinen, Rindern und Geflügel betrugen im Mittel 1171, 237 bzw. 430 mg/kg T. Die entsprechenden Cu-Gehalte lagen bei 332, 54, bzw. 99 mg/kg T. Die mittleren Gehalte an Zn und Cu im Festmist von Schweinen, Rindern und Geflügel erreichten etwa 60, 90 bzw. 75 % der jeweiligen Werte in der Gülle. Im Zeitverlauf der Probenahme erwiesen sich die Zn- und Cu-Gehalte der Wirtschaftdünger als konstant. Insgesamt schienen die Zn und Cu-Gehalte der Wirtschaftsdünger weitgehend die jeweilige Praxis der Supplementierung des Tierfutters mit Zink und Kupfer widerzuspiegeln (inklusive der hohen Cu-Gehalte im Ferkelfutter im Rahmen der futtermittelrechtlich zulässigen Grenzen). Bei den Wirtschaftsdüngern aus der Schweinehaltung deuteten die außergewöhnlich hohen Gehalte jedoch auf einen zusätzlichen Zn-Eintrag außerhalb der Fütterung nach guter fachlicher Praxis hin.

Schlagworte: Zn, Cu, Dünger, Gülle, Schwein, Milchkuh, Rind, Geflügel.

Summary

Between the years 1994 and 2004 a total of 347 dung samples were collected randomly from common farms in the Austrian Federal Countries of Upper Austria and Lower Austria and were analyzed for the contents of zinc (Zn) and copper (Cu) in dry matter (DM). The samples comprised dung from varying species and categories of production (pig breeding, pig fattening, dairy cows, cattle for fattening, laying hens and broiler, turkey) as well as from different types of dung (manure, solid dung). Zn contents in dung from pigs, cattle and poultry averaged 1171, 237, and 430 mg/kg DM. Respective Cu contents were 332, 54, and 99 mg/kg DM. The mean contents of Zn and Cu in solid dung from pigs, cattle and poultry reached about 60, 90 and 75 % of respective values in manure. With respect to time course of sample collection, Zn and Cu contents revealed to remain constant. In total, the Zn and Cu contents in dung seemed to reflect largely the current practice to supplement the animals' feeds with Zn and Cu (including high dietary Cu contents in piglet feeds according to limits given by feed law). In case of Zn in pig dung, however, the exceptionally high contents indicated additional Zn entries apart from feeding according to best practice.

Key words: Zn, Cu, dung, manure, pig, dairy, cattle, poultry.

tween years 1994 and 2004. Data set (1) was collected in year 1994 by the Government Office of the Austrian Federal State of Upper Austria in the area of this federal state (n = 221). Data set (2) originated from the Agricultural Office of the Austrian Federal State of Lower Austria. It was collected from farms in Lower Austria over a time period between year 1997 until 2003 (n = 90). Data set (3) was provided by the Austrian Agency of Health and Food Safety (AGES). It represents dung samples (n = 63) from the Austrian Federal States of Upper Austria and Lower Austria collected between year 1997 and 2004. The collection pattern was random testing without any specific indications (i.e. no suspect for unusual contents of Zn and Cu in dung). Further information provided were the type of dung (manure, solid dung, or non-specified type of dung), animal species (pig, bovines, and poultry) as well as category of livestock production (pig breeding (sows + piglets), pig fattening, non-specified pig production, dairy cows, cattle for fattening, non-specified bovine production, laying hens and broiler, turkey and non-specified poultry production). The distribution of samples among animal species, category of animal production and type of dung is presented in Table 1.

Dung samples were retrieved from different farms directly when being applied to the agricultural area. In case of manure, the dung was stirred thoroughly for one hour before taking several sub-samples from different position of the dung cell into a clean 1 L plastic container. The sub-samples were homogenized and about 1 L was transferred into an airtight plastic vessel and transiently stored at +4 °C until further analysis. Samples were homogenized, subsequently submitted to dry matter analysis and then mineralized in a muffle furnace at 550 °C (Naumann and Bassler, 1997). The ash was transferred into HCl solution and analyzed for Zn and Cu contents using ICP-AES, or in case of very low concentrations, by AAS (graphite furnace) using standard solutions for calibration and references samples for quality control. Acidity of diluted sample solutions was adjusted to ini-

Table 1: Distribution of dung sample numbers among animal species, category of animal production and type of dung
Tabelle 1: Verteilung der Wirtschaftsdüngerproben auf Tierspezies, Kategorie der Tierproduktion und Art des Düngers

Animal species	Category of animal production	Number of samples within type of dung		
		Manure	Solid[1)]	n.sp.[2)]
Pig	Pig breeding (sows and piglets)	22	17	12
	Pigs for fattening	76	16	17
	Pig (category not specified)	15	1	11
Bovines	Dairy cows	45	43	—
	Cattle for fattening	40	5	—
	Bovines (category not specified)	4	1	3
Poultry	Chicken for fattening and laying hens	3	16	—
	Turkey for fattening	—	5	—
	Poultry (category not specified)	—	22	—

[1)] solid waste without slurry [2)] n.sp. = type of dung not specified tial acidity after digestion. Standard solutions were added with major elements in order to simulate the matrix. In the following, all data on Zn and Cu are expressed as contents in dung dry matter.

The following tables present descriptive statistics (n, arithmetic mean, standard deviation (±), median, minimum, maximum) with respect to the type of element (Zn, Cu), the animal species including the respective category of animal production, and the type of dung. Furthermore, the data sets (2) and (3) provided by the Austrian Federal State of Lower Austria and the Austrian Agency of Health and Food Safety (AGES) were analyzed for possible changes of Zn and Cu contents during time period 1997 until 2004 by calculation of Pearson's correlation coefficients.

Table 2: Zinc contents in dung (mg/kg dry matter)
Tabelle 2: Zinkgehalte im Wirtschaftsdünger (mg/kg Trockenmasse)

	Type of dung	Descriptive statistics.					
		n	Mean	±	Median	Min.	Max.
Pigs, total	Manure	112	1227	682	1135	107	3700
	Solid dung	34	705	464	567	242	2627
	Non specified	40	1411	729	1224	215	3115
	Total	*186*	*1171*	*695*	*1100*	*107*	*3700*
Pig breeding (sows + piglets)	Manure	21	1367	908	1190	107	3470
	Solid dung	17	837	587	698	279	2627
	Non specified	12	1820	888	2170	215	3115
	Total	*50*	*1295*	*877*	*1172*	*107*	*3470*
Pigs for fattening	Manure	76	1253	640	1147	283	3700
	Solid dung	16	594	241	563	351	1337
	Non specified	17	1262	706	1104	392	3088
	Total	*109*	*1158*	*649*	*1100*	*283*	*3700*
Pigs, not specified	Manure	15	898	401	1061	173	1339
	Solid dung	1	242	—	242	242	242
	Non specified	11	1197	345	1220	648	1801
	Total	*27*	*996*	*421*	*1074*	*173*	*1801*
Bovines, total	Manure	89	242	172	184	56	1277
	Solid dung	49	236	155	201	80	859
	Non specified	3	123	90	120	49	223
	Total	*141*	*237*	*165*	*199*	*49*	*1277*
Dairy cows	Manure	45	189	100	160	56	486
	Solid dung	43	238	159	201	110	859
	Non specified	—	—	—	—	—	—
	Total	*88*	*213*	*134*	*168*	*56*	*859*
Cattle for fattening	Manure	40	297	218	243	97	1277
	Solid dung	5	242	142	206	80	461
	Non specified	—	—	—	—	—	—
	Total	*45*	*291*	*210*	*242*	*80*	*1277*
Bovines, not specified	Manure	4	284	129	309	122	395
	Solid dung	1	142	—!	142	142	142
	Non specified	3	123	90	97	49	223
	Total	*8*	*206*	*128*	*183*	*49*	*395*
Poultry, total	Manure	3	636	270	680	346	881
	Solid dung	41	415	214	381	86	1050
	Non specified	—	—	—	—	—	—
	Total	*44*	*430*	*222*	*384*	*86*	*1050*
Laying hens and broiler	Manure	3	636	270	680	346	881
	Solid dung	16	482	247	432	234	1050
	Non specified	—	—	—	—	—	—
	Total	*19*	*506*	*250*	*456*	*234*	*1050*
Turkey	Manure	—	—	—	—	—	—
	Solid dung	5	222	234	112	86	635
	Non specified	—	—	—	—	—	—
	Total	*5*	*222*	*234*	*112*	*86*	*635*
Poultry, not specified	Manure	—	—	—	—	—	—
	Solid dung	20	409	152	364	197	739
	Non specified	—	—	—	—	—	—
	Total	*20*	*409*	*152*	*364*	*197*	*739*

3 Results

Table 2 presents Zn contents in dry matter (DM) of different types of dung from pigs, bovines and poultry of varying categories and animal production systems. One exceptionally high value was omitted from evaluation as it was considered to be an isolated case (manure from pig breeding: 12018 mg Zn/kg DM). Zn contents in pig dung averaged 1171 mg/kg DM. The respective median was only slightly lower (1100 mg/kg DM) indicating that the distribution of single values was not biased by some isolated peak observations. Within pig production systems, pig breeding tended to exhibit somewhat elevated average contents compared to pig fattening and non-specified origin (1295 vs. 1158 vs. 996 mg/kg DM). However, this difference was small compared to the standard deviation. Average Zn content in bovine dung reached only about ¼ of the pig dung level (237 (mean) and 199 (median) mg Zn/kg DM). The respective subgroups of bovine production exhibited a rather uniform distribution of dung Zn contents (mg/kg DM: 213 in dairy, 291 in cattle, 206 in non-specified origin). Also standard deviation and peak levels were smaller. In poultry dung, average Zn content was 430 mg/kg DM with the turkey subgroup showing comparably low values (222 mg/kg). The turkey data, however, were based on 5 observations only. Within type of dung, Zn contents in solid dung from pigs were about 20 to 50 % lower than in manure, while for bovine and poultry dung the differences were of minor magnitude or not representative due to low number of observations (esp. in poultry).

Table 3 presents Cu contents in dung dry matter. Similar to Zn, highest Cu contents were observed in dung from pig production (overall mean 332 mg/kg DM). Within pig production, dung from pig breeding and fattening were almost identically regarding arithmetic means (355 and 343 mg Cu/kg DM). But the respective medians were somewhat lower in pig fatteing compared to pig breeding (mg Cu/kg DM: 302 vs. 358) indicating the presence of some isolated peak values in pig fattening. Cu contents in bovine dung averaged 54 mg/kg DM with highest values in samples from cattle fattening (73 mg Cu/kg DM) compared to dairy and non-specified bovine origin (46 and 40 mg/kg DM). Respective medians were lower for these subgroups of dung origin (49, 35, and 35 mg/kg DM) indicating some bias towards high values especially in dung from cattle fattening (maximum: 441 mg/kg DM). Cu contents in poultry dung averaged 99 (mean) and 69 (median) mg Cu/kg DM. Like for Zn, comparably low contents were found in dung from turkey (53 mg/kg DM), but this data was based on 5 observations only. Within type of dung, the solid type from pig production contained considerably less Cu than manure dry matter, while for other species the differences were comparably small.

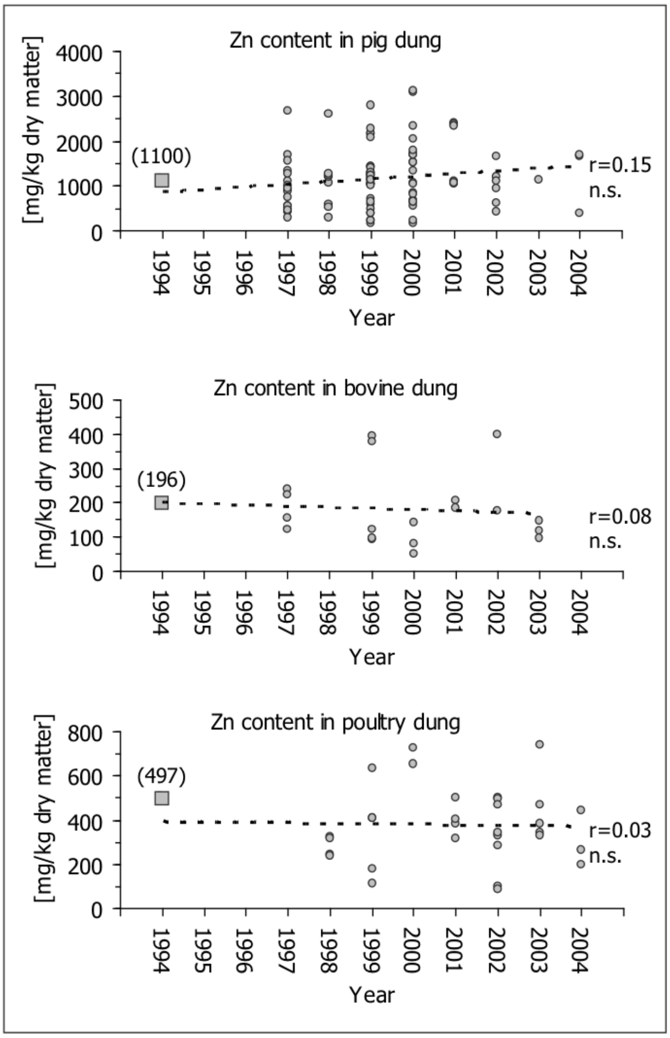

Figure 1: Time pattern of Zn contents in dung dry matter from pigs, bovines and poultry between year 1997 and 2004 (mg/kg DM) (median of data set from year 1994 indicated as □)

Abbildung 1: Zeitverlauf der Zinkgehalte im Wirtschaftsdünger von Schweinen, Rindern und Geflügel zwischen den Jahren 1997 und 2004 (mg/kg Trockenmasse) (in Klammern: Median des Datensatzes aus dem Jahr 1994; Datenpunkt dargestellt als □)

Figure 1 presents the time course of Zn contents of individual dung samples from pig, bovines and poultry, collected between year 1997 and 2004 (data set 2 and 3). For comparison, the respective medians of the data set (1) from year 1994 were included into the graphs. For all animal species, time

Table 3: Copper contents in dung (mg/kg dry matter)
Tabelle 3: Kupfergehalte im Wirtschaftsdünger (mg/kg Trockenmasse)

	Type of dung	Descriptive statistics. n	Mean	±	Median	Min.	Max.
Pigs, total	Manure	113	367	251	316	37	1616
	Solid dung	34	211	143	167	52	603
	Non specified	40	337	172	303	50	755
	Total	*187*	*332*	*226*	*291*	*37*	*1616*
Pig breeding (sows + piglets)	Manure	22	380	195	380	55	722
	Solid dung	17	245	134	178	92	512
	Non specified	12	464	238	445	50	755
	Total	*51*	*355*	*203*	*358*	*50*	*755*
Pigs for fattening	Manure	76	391	278	325	48	1616
	Solid dung	16	184	148	109	58	603
	Non specified	17	281	115	302	78	569
	Total	*109*	*343*	*254*	*302*	*48*	*1616*
Pigs, not specified	Manure	15	227	100	254	37	364
	Solid dung	1	52	—	52	52	52
	Non specified	11	287	71	269	172	413
	Total	*27*	*245*	*98*	*266*	*37*	*413*
Bovines, total	Manure	89	57	62	39	8	441
	Solid dung	49	51	46	38	7	282
	Non specified	3	36	11	31	25	48
	Total	*141*	*54*	*56*	*38*	*7*	*441*
Dairy cows	Manure	45	42	27	34	8	139
	Solid dung	43	51	46	38	21	282
	Non specified	—	—	—	—	—	—
	Total	*88*	*46*	*37*	*35*	*8*	*282*
Cattle for fattening	Manure	40	74	85	52	21	441
	Solid dung	5	62	52	43	7	126
	Non specified	—	—	—	—	—	—
	Total	*45*	*73*	*82*	*49*	*7*	*441*
Bovines, not specified	Manure	4	47	29	50	13	74
	Solid dung	1	24	—	24	24	24
	Non specified	3	36	11	36	25	48
	Total	*8*	*40*	*22*	*35*	*13*	*74*
Poultry, total	Manure	3	111	63	115	46	171
	Solid dung	43	98	113	68	29	742
	Non specified	—	—	—	—	—	—
	Total	*46*	*99*	*110*	*69*	*29*	*742*
Laying hens and broiler	Manure	3	111	63	115	46	171
	Solid dung	16	116	172	66	29	742
	Non specified	—	—	—	—	—	—
	Total	*19*	*115*	*158*	*68*	*29*	*742*
Turkey	Manure	—	—	—	—	—	—
	Solid dung	5	53	23	47	35	93
	Non specified	—	—	—	—	—	—
	Total	*5*	*53*	*23*	*47*	*35*	*93*
Poultry, not specified	Manure	—	—	—	—	—	—
	Solid dung	22	95	59	71	30	242
	Non specified	—	—	—	—	—	—
	Total	*22*	*95*	*59*	*71*	*30*	*242*

patterns of Zn contents in dung samples revealed to be quite constant. The coefficients of correlation were numerically small and statistically not significant indicating the absence of a time trend. Furthermore, the medians of data set (1) from year 1994 matched quite well into the distribution of the other data, indicating overall homogeneity with data set (2) and (3) collected during year 1997 and 2004.

Figure 2 is structured in the same way as Figure 1. It shows the respective time pattern of Cu contents in dung samples. Like with Zn, data set (1) from year 1994 demonstrated homogeneity with data set (2) and (3) collected during year 1997 and 2004. Within data set (2) and (3), dung from pigs and poultry revealed some numerically positive correlation between Cu contents and time (r =

Table 4: Reports on Zn and Cu contents (mg/kg DM) in dung from pigs, bovines and poultry
Tabelle 4: Literaturdaten über Zn- und Cu-Gehalte im Wirtschaftsdünger von Schweinen, Rindern und Geflügel

	Zn content in dung (mg/kg DM)			Cu content in dung (mg/kg DM)		
Reference	pig	bovine	poultry	pig	Bovine	poultry
Present study	1171	237	430	332	54	99
Severin et al. (1991)	896	222	456	294	45	78
Driessen and Westhoek (1997)	619 1) 935 2)		170	381 1) 499 2)	—	137
Müller (1997)	1185	238	—	528	43	—
Müller and Ebert (2002) (data for year 1999)	1150	319	—	353	48	—
Uba (2004)	1507	323	—	531	43	—

1) data from pigs for fattening   2) data from sows

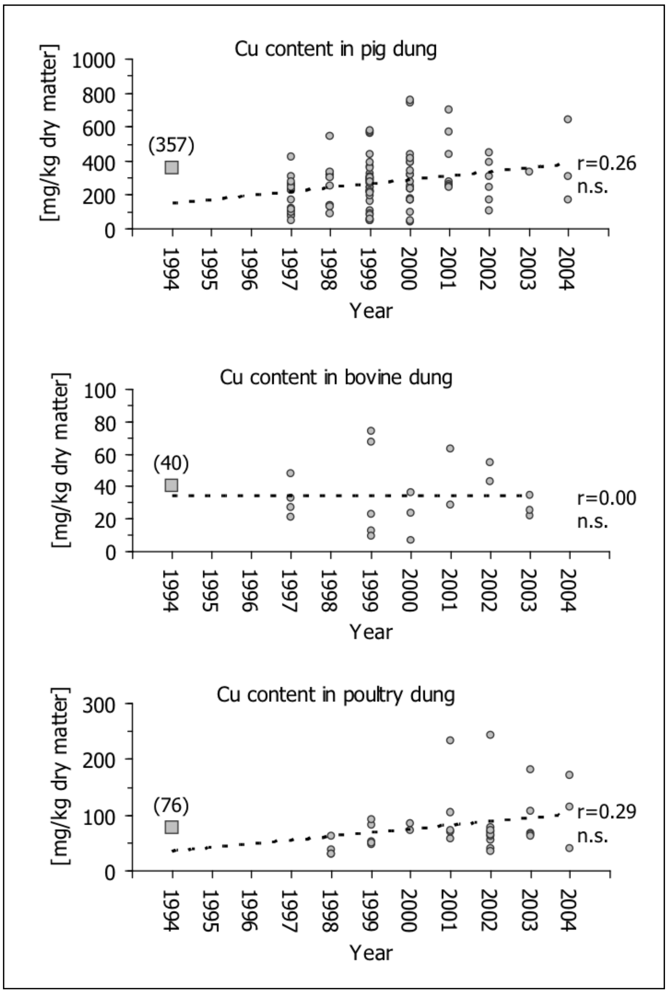

Figure 2: Time pattern of Cu contents in dung dry matter from pigs, bovines and poultry between year 1997 and 2004 (mg/kg DM) (in brackets: median of data set from year 1994; data point indicated as □)

Abbildung 2: Zeitverlauf der Kupfergehalte im Wirtschaftsdünger von Schweinen, Rindern und Geflügel zwischen den Jahren 1997 und 2004 (mg/kg Trockenmasse) (in Klammern: Median des Datensatzes aus dem Jahr 1994; Datenpunkt dargestellt als □).

0.26 and r = 0.29), but in neither case the evidence was statistically significant. In bovine dung, Cu contents remained constant over time.

4 Discussion

The data presented in this study originated from 3 sets of collections of dung samples from agricultural livestock production in the Austrian Federal States of Upper and Lower Austria from different authorities and time. In total, the data sets showed to be sufficiently consistent among origin to be discussed jointly. Also regarding time, there was no indication of a systematic change. Consequently, the overall means upon collecting bodies and year represent the most recent situation in livestock production of the Austrian Federal State of Upper and Lower Austria, which in turn may be considered to largely reflect Austria in total due to the high density of agricultural animal production in these regions.

According to the present study, Zn contents in dung from Austrian pig production are characterized by comparably high contents of Zn and Cu in the range of 1200 and 330 mg/kg of dry matter, while in bovines and poultry the respective contents of Zn and Cu ranged in the magnitude of 240 and 50 mg of bovine dung DM, and 430 and 100 mg per kg of poultry dung DM, respectively. Studies on Zn and Cu contents in dung from animals kept in central Europe under comparable conditions reported similar values along a comparable time period of observation (Table 4). According to these reports, high Zn and Cu loads in pig dung are persistent and a characteristic feature to central European pig production in general (e.g. Doehler et al., 2002).

Zn and Cu in dung from agricultural livestock production originate primarily from the animals' excrements and hence from native trace minerals in feedingstuffs and added supplements, respectively. With typical feed rations to agricultural livestock, the excrement dry matter from faeces and urine accounts for about 25 % of feed dry matter intake in pigs, 35 % in bovines, and 20 % in poultry. Assuming full excretion of Zn ingested with feeds being permanently supplemented with Zn at the maximum permitted level (during the time period of dung sampling: 250 mg Zn per kg of complete feed dry matter; DIRECTIVE (EC) No. 524/1970), the respective Zn contents in dung dry matter would account for about 1000 mg/kg in pigs, 750 mg/kg in bovines and 1250 mg/kg in poultry, respectively. These estimates reflect the theoretical maximum of dung Zn contents according to best practice in feeding of agricultural livestock. Actual dung Zn contents, however, should be considerably lower due to absorption of Zn by the animal, dietary Zn levels not fully utilizing the permitted maximum (esp. in bovines), and the use of material for animal beddings (e.g. straw) which is usually low in native Zn. These factors may explain quite well the Zn contents of dung from bovines and poultry, as well as the ratio of average dung Zn contents among these species. But in case of pig dung, the actual Zn content should have ranged at about 330 mg/kg DM when extrapolating the same factors of dilution compared to the theoretical maximum observed for dung from cattle and poultry (0.32 and 0.34, respectively). Consequently, the remarkably high Zn content of pig dung is difficult to explain only on base of supplementing Zn according to best practice.

Dietary supplementation of excessive amounts of Zn are well known to produce antimicrobial and growth promoting effects especially in piglets, but also in fattening pigs (e.g. HAHN and BAKER, 1993; POULSEN, 1995; SMITH et al., 1995; CARLSON et al. 1999; WINDISCH et al. 1999). In this context, it has to be mentioned that such feeding practice is not permitted by feed law. It may also cause negative side effects on the health of animals (Fe anaemia, tissue Zn accumulation esp. in liver) (HAHN and BAKER, 1993; SCHELL and CORNEGAY, 1996). As the effective dietary dose requires at least about 2000 mg Zn/kg DM, the corresponding Zn content in dung would then range around 10.000 mg/kg DM. The finding of one exceptionally high Zn content in pig manure from the present data set (12.018 mg Zn/kg DM) might reflect the peak value caused by such a practice, especially in the first feeding-period of piglets ("baby-piglets"). But application of excessive Zn is usually limited to about 2 weeks and the respective Zn load will be diluted among normal dung produced during the entire production cycle. When applied to piglets, the 2weeks excrements of treated animals will contribute to about 10 % of total excrements from the complete production cycle (sow + piglet), while in pig fattening the respective contributions vary between about 5 to 15 % depending on the time point of application (begin or end of fattening). These data lead to the assumption that each application of excessive Zn to pigs adds to overall Zn content in dung dry matter in the magnitude of about 1000 mg/kg (dung Zn content during application: 10.000 mg/kg; dung quantity produced during time of application: 10 % of total dung quantity). Since these figures seem to explain plausibly the gap in dung Zn content observed between pigs and the other species, it might be hypothesized that application of excessive Zn is practiced widely.

Like described above for Zn, the theoretical maximum of Cu contents in dung dry matter may be estimated by assuming complete excretion of ingested Cu and supplementation of feeds with Cu at the maximum permitted levels (during the time period of dung sampling, expressed as mg Cu per kg of complete feed dry matter: 35 for ruminating bovines, poultry, and pigs except piglets; 175 for piglets up to 16 weeks of age; DIRECTIVE (EC) No. 524/1970). The corresponding Cu contents in dung dry matter range at about 100 mg/kg for pigs except piglets, 700 mg/kg for piglets up to 16 weeks of age, 100 mg/kg for bovines, and 125 mg/kg for poultry. In case of piglets, the purpose of such high amounts of Cu to the feeds is to induce antimicrobial and growth promoting effects (CROMWELL et al., 1989; COFFEY et al., 1994; APGAR et al., 1995; APGAR and KORNEGAY, 1996; WINDISCH et al., 2001). Like with Zn, it has to be mentioned that such high doses of Cu may produce negative side effects on health of animals and product quality (Fe metabolism disorders and Cu accumulations in tissues esp. in liver) (MEYER et al., 1977; DOVE, 1991; HAHN and BAKER, 1993; SCHELL and CORNEGAY, 1996).

The high Cu loads of piglet feeds significantly affect the theoretical maximum of Cu contents in pig dung. Since the piglets' excrements contribute to about 40 % of total excrement quantity during the production cycle (sow + piglets), the theoretical maximum of Cu contents in dung from pig breeding accounts for about 350 mg/kg ($0.6 \times 100 + 0.4 \times 700$). At the onset of pig fattening, the animals are still allowed to be supplied with excessive Cu for some weeks. This practice may contribute up to about 25 % of total excrement quantity. The respective maximum Cu content of dung dry matter from entire pig fattening might thus be calculated to range at about 280 mg/kg ($0.25 \times 700 + 0.75 \times 100$). According to these figures, Cu contents in dung dry matter from pigs should be about 3 times (pig fattening) to 4 times (pig breading) higher than those of bovines and poultry. The data observed in the present study seem to reflect this ratio quite well. In absolute terms, the contents are lower due to the fact that dietary Cu contents usually range below maximum authorized levels (esp. in bovines), the incomplete excretion of ingested Cu due to absorption by animals, and additional inclusion of diluting matter (straw etc.). In total, the Cu contents of dung from pigs, bovines and poultry may be plausibly explained by current feeding practice with piglet dung being a major source of Cu due to high (permitted) dietary contents. In this context it is interesting that Cu content of dung from pigs showed the same coincidence between expected and observed values as was observed for other species. This gives further rise to the hypothesis that the exceptionally high Zn contents in pig dung were caused by other reasons than feeding according to best practice.

Corrosion from metallic equipments or abrasions from concrete could theoretically cause additional entries of Zn and Cu into dung. But due to generally low contents and mobility, this origin is considered to be of minor quantitative relevance (e.g. PUNKTE and SCHNEIDER, 2001; SCHENKEL, 2002). Veterinary drugs (applied via medicinal feed, unguents, etc.) and liquid Cu formulations to treat hoof problems (mainly in dairy herds) might be an additional source of Zn and Cu to dung (e.g. MCBRIDGE and SPIERS, 2001; UBA, 2004). However, such interventions are more likely to occur occasionally without major quantitative contribution to the overall mean of Zn and Cu contents in dung. In total, excessive doses of Zn and Cu in pig feeding for purpose of antimicrobial and growth promoting effects remains the most plausible reason for the comparably high contents of Zn and Cu in pig dung.

Zn and Cu in dung from agricultural livestock production are considered to contribute to about ¾ of total entry of these heavy metals into agricultural areas in central Europe and hence to reflect the dominating origin of rising accumulations of these heavy metals in the soils (MÜLLER, 1997; DANNEBERG, 1997; KILIAN, 1999; BONNIER, 2002; ROTH et al., 2002; DERSCH and HÖSCH, 2003; NICHOLSON et al., 2005). In context with the soils serving as the most important and vulnerable base for production of feed, food and clean water, discussions on dung from animal production have been arising among authorities responsible for soil and environmental protection. The current discussions focus on upper limits to Zn and Cu contents in dung dry matter in the range of 200 to 450 mg Zn/kg DM, and 60 to 90 mg Cu/kg DM, depending on species producing the dung and the type of soil being exposed to the dung (SCHULTHEISS et al., 2002; SCHWARZ and FREUDENSCHUSS, 2004) Compared to these values, the dominant part of dung analyzed in the present study would have to be discharged from being spread on agricultural areas. It will therefore become an essential issue to agricultural livestock production to significantly reduce emissions of Zn and Cu with dung, especially in case of pigs. Obviously, the most efficient way to achieve this aim is to reduce Zn and Cu supply to animals. This applies in detail to excessive doses of dietary Zn and Cu for purpose of antimicrobial and growth promoting effects. On the other hand, inclusions into feed according to recommendations given by animal nutrition bodies (as essential trace minerals) seem to produce Zn and Cu contents in dung matching the limits under discussion. Consequently, the proper use of Zn and Cu as essential nutrients is ecologically well compatible.

One step towards lower Zn and Cu emission via dung has already been made by reducing the maximum permitted levels in complete feed in year 2004 (Zinc: 150 mg/kg DM to all species; Copper: 170 mg/kg DM to piglets up to 12 weeks of age, 25 mg/kg DM to other pigs and to poultry, and 35 mg/kg DM to ruminating bovines; REGULATION (EC) No. 1334/2003). For bovines and poultry this might induce a significant reduction of the current dung levels. But in case of pig production, excessive dietary doses of Cu remain the major entry of these heavy metals and will further produce relatively high Cu contents in pig dung. For Zn, the cutbacks of maximum dietary Zn levels by 100 mg/kg may reduce dung Zn contents at best by about 400 mg/kg (assuming excrement dry matter accounting for 25 % of total dry matter intake). Consequently, Zn contents in pig dung can be expected to remain comparably high. In total, current development of Zn and Cu contents in dung from livestock production should be monitored for possible reactions on recent changes in feed law. In case of pig dung, however, it still needs to be verified whether excessive dietary doses of Zn (for antimicrobial and growth promoting purposes) is actually the major origin of the high dung Zn levels, and which contents of Zn and Cu are to be expected for pig dung, if supplementation of Zn and Cu is practiced according to nutritional recommendations only.

5 References

AICHBERGER, K., H. DÖBERL, A. EIBELHUBER, J. FROSCHAUER and G. HOFER (1995): Die Ergebnisse einer Untersuchung von Wirtschaftsdüngern in Oberösterreich. Schriftenreihe der Abteilung Umweltschutz 7/95; Hrsg. Amt der Oberösterreichischen Landesregierung: Linz, Österreich.

APGAR, G. A., E. T. KORNEGAY, M.D.LINDEMANN and D. R. NOTTER (1995): Evaluation of copper sulfate and a copper lysine complex as growth promoters for weanling swine. J. Anim. Sci. 73: 2640–2646.

APGAR, G. A. and E. T. KORNEGAY (1996): Mineral balance of finishing pigs fed copper sulfate or a copper- lysine complex at growth-promoting levels. J. Anim. Sci. 74: 1594–1600.

BONNIER, P. (2002): Anforderungen an die landwirtschaftliche Verwertung von Klärschlamm und anderen Düngemitteln in den Niederlanden – Gründe und Konsequenzen. In KTBL Schrift 404: 265–270. KTBL: Darmstadt, Deutschland.

CARLSON, M. S., G. M. HILL and J. E. LINK (1999): Early and traditional weaned nurserey pigs benefit from phase-feeding pharmacological concentrations of zinc oxide: Effect on metallothionein and mineral concentrations. J. Anim. Sci. 77: 1199–1207.

COFFEY, R. D., G. L. CROMWELL and H. J. MONEGUE (1994): Efficacy of a copper-lysine complex as a growth promoter for weanling pigs. J. Anim. Sci. 72: 2280– 2886.

CROMWELL, G. L., T. S. STAHLY and H. J. MONEGUE (1989): Effects of source and level of copper on performance and liver copper stores in weanling pigs. J. Anim. Sci. 67: 2996–3002.

DANNEBERG, O. (1997): Bodenschutz in Österreich. Fachbeirat für Bodenfruchtbarkeit und Bodenschutz beim Bundesministerium für Land- und Forstwirtschaft, Wien, Österreich: 6–7.

DERSCH, G. and J. HÖSCH (2003): Kupfer und Zink – In Zukunft stärker beachten. Der fortschrittliche Landwirt 11: 6–9.

DIRECTIVE (EC) No. 524/1970 (1970): Richtlinie des Rates über Zusatzstoffe in der Tierernährung. Amtsblatt L 270.

DÖHLER, H., U. SCHULTHEISS, H. ECKEL and U. ROTH (2002): Schwermetallgehalte von Wirtschaftsdüngern in Deutschland und der EU-Vergleich mit anderen Düngemitteln und Minderungsansätze. In: KTBL Schrift 404: 139–143. KTBL: Darmstadt, Deutschland.

DOVE, C. R. (1991): The effect of copper addition to diets with various iron levels on the performance and hematology of weanling swine. J. Anim. Sci. 69: 2013–2019.

DRIESSEN, J. and H. J. WESTHOEK (1997) : Schwermetalle in Düngemitteln.In: VDLUFA-Kongressband 1997, 109. VDLUFA Kongress, 15.–19.9.1997, Leipzig, 563–566; ISSN 0173–8712.

HAHN, J. D. and D. H. BAKER (1993): Growth and plasma zinc responses of young pigs fed pharmacological doses of zinc. J. Anim. Sci. 71: 3020–3024.

KILIAN, W. (1999): Richtlinien für die sachgerechte Düngung. Wien: Bundesamt und Forschungszentrum für Landwirtschaft: 339–354.

MCBRIDE, M. B. and G. SPIERS (2001): Trace element content of selected fertilizers dairy manures a determined by ICP–MS. Commun. Soil. Sci. Plant Anal. 32: 139–156.

MEYER, H., H. KRÖGER and I. PROTHMANN (1977) Untersuchungen über Rückstandsbildung beim Schwein in Abhängigkeit von Art und Dauer der Cu-Fütterung. Züchtungskunde 49: 225–232.

MÜLLER, C. (1997): Wirtschaftsdünger. In: Boden-Dauer-Beobachtungsflächen (BDF) – Bericht nach 10-jähriger Laufzeit 1985-1995. Teil II: Stoffeinträge – Stoffausträge – Schwermetallbilanzierungen verschiedener Betriebstypen. Schriftenreihe der bayrischen Landesanstalt für Bodenkultur und Pflanzenbau, 5/97 (Jg. 1).: 87–117.

MÜLLER, C. and T. EBERT (2002): Schwermetall-Einträge durch Wirtschaftsdünger von 1996 bis heute – Ergebnisse aus dem bayerischen Bodenbeobachtungsprogramm. VDLUFA-Schriftenreihe 58: 635–639.

NAUMANN, K. and R. BASSLER (1997): Die chemische Untersuchung von Futtermitteln. Methodenbuch, Bd. III, Verlag Neumann-Neudamm, Melsungen, Deutschland.

NICHOLSON, F., A. BOGHAL, U. ROTH and U. SCHULTHEISS (2005): Assessment and reduction of heavy metal input into agro-ecosystems, KTBL Schrift 432: 43–53. KTBL: Darmstadt, Deutschland.

POULSEN, H. D. (1995): Zinc oxide for weanling piglets. Acta Agric. Scand. 45: 159–167.

PUNKTE, S. and M. SCHNEIDER (2001): Das Verhalten von Schwermetallen in Zement und Beton. ZKG International 54 (2).: 106–113.

REGULATION (EC) No. 1334/2003 (2003): Verordnung zur Änderung der Bedingungen für die Zulassung einer Reihe von zur Gruppe der Spurenelemente zählenden Futtermittelzusatzstoffen. Amtsblatt L187.

ROTH, U., U. SCHULTHEISS, H. DÖHLER, H. ECKEL, V. KÜHNEN, K. FRÜCHTENICHT and A. UIHLEIN, (2002):

Spurenelement- bzw. Schwermetallgehalte in Futtermitteln und Wirtschaftsdüngern, KTBL Schrift 410: 50–59. KTBL: Darmstadt, Deutschland.

SCHELL, T. C. and T. E. KORNEGAY (1996): Zinc concentration in tissues and performance of weanling pigs fed pharmacological levels of zinc from ZnO, Zn-Methionine, Zn-Lysine, or $ZnSO_4$. J. Anim. Sci. 74: 1584–1593.

SCHENKEL, H. (2002): Spurenelemente in Futtermitteln und Futterzusatzstoffen. KTBL Schrift 410 (Fütterungsstrategien zur Verminderung von Spurenelementen/ Schwermetallen in Wirtschaftsdüngern): 9–13. KTBL: Darmstadt, Deutschland.

SCHULTHEISS, U., H. DÖHLER, E. HENNING, A. UIHLEIN, A. and W. WILCKE (2002): Bilanzierung von Spurenelementen bzw. Schwermetallen in der Milchviehhaltung, KTBL Schrift 410: 59–65. KTBL: Darmstadt, Deutschland.

SCHWARZ, S. and A. FREUDENSCHUSS (2004): Referenzwerte für Schwermetalle in Oberböden. Auswertungen aus dem österreichweiten Bodeninformationssystem BORIS. Monographien M–170, Umweltbundesamt, Wien, Österreich.

SEVERIN, K., W. KÖSTER and Y. MATTER (1991) : Zufuhr von anorganischen Schadstoffen in Agrarökosysteme mit mineralischen Düngemitteln, Wirtschaftsdüngern, Klärschlämmen und Komposten. In: VDLUFA-Schriftenreihe 32., Kongressband 103. VDLUFA-Kongress, 16.–21.9.1991, Ulm, 387–391; ISSN 0173-8712.

SMITH, J. W., M.D. TOKACH, R. D. GOODBAND, J. L. NELSSEN, W.B. NESSMITH, K. Q. OWEN and B. T. RICHERT (1995): The effect of increasing zinc oxide supplementation on starter pig growth performance. J. Anim. Sci. 73 (abstr.): 72.

UBA (UMWELTBUNDESAMT) (2004): Erfassung von Schwermetallströmen in landwirtschaftlichen Tierproduktionsbetrieben. UBA Berlin, Deutschland. UBA Texte 06–04.

WINDISCH, W., F. J. SCHWARZ, K. GRUBER and M. KIRCHGESSNER (1999): Effect of Pharmacological Dietary Doses of Zinc Oxide on Performance and Fecal Characteristics of Weanling Piglets. Agribilol. Res. 51, 277–285.

WINDISCH, W., G. G. GOTTERBARM and F. X. ROTH (2001): Effect of potassium diformate in combination with different amounts and sources of excessive dietary copper on production performance of weaning piglets. Arch. Anim. Nutr. 54: 87–100.

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