Micro- and macro-element composition of animal feedstuffs sold in Austria

Über die Haupt- und Spurenelementzusammensetzung kommerzieller Futtermittel in Österreich

M. SAGER

Summary

The inorganic composition of various commercial feedstuffs sold in Austria mainly within 2002 – 2005, was monitored by multi-element ICP optical emission spectrometry. The data are interpreted with respect to mean crust and to mean soil levels, levels encountered in green plants, waste treatment of unconsumed feeds, and environmental contaminations from the resulting manures. Ca and Mg, as well as essential micro elements Cu, Mn, Fe and Zn additions, and occasionally Co and Mo additions ensure to obtain sufficient supply of the respective domestic animal. For most elements, concentrations increased in the order complete feeds – supplementary feeds – mineral feeds – premixes, except for nutrient elements in the premixes (K, Na, P). In single and supplementary feeds, the elements Cu, P, Zn and maybe also Ca and K were found enriched versus arable soils. No contaminations from unwanted trace elements, like As, Be, Cr, Ni, Pb, V were found.
With respect to the target animals, the inorganic composition of feedstuffs was largely similar, with a few exceptions; thus, laying hens got more Ca and piglets got more Cu than others. Rock phosphates were the main source for Cd, Be, Cr and V in the samples. Particularly Cu and Zn may exceed soil levels and threshold values for common waste deposition, although even higher levels have been reported from other European countries, the US and China.

Key words:
animal feedstuffs, element cycling in agriculture, essential element supplementation, non essential elements, element proportions

Zusammenfassung

Die anorganische Zusammensetzung von in Österreich im Handel befindlichen Futtermitteln, hauptsächlich aus dem Zeitraum 2002 bis 2005, wurde durch Multi-Elementanalysen mittels ICP-optischer Emissions Multielementspektrometrie nach Veraschen und Aufschluss mit Salpetersäure überwacht. Die erhaltenen Daten wurden im Hinblick auf ihre Abreicherung oder Anreicherung im Verhältnis zum durschschnittlichen Vorkommen in der Erdkruste und in Böden, zu den Gehalten in Pflanzen, der Ablagerung entsprechender Abfälle aus unverbrauchten Futtermittelresten sowie Umweltkontaminationen durch die resultierenden Ausscheidungsprodukte interpretiert. Zugaben von Ca und Mg sowie von den essentiellen Mikroelementen Cu, Mn, Fe and Zn und gelegentlich von Co und Mo stellen die ausreichende Versorgung der entsprechenden Haustiere sicher. Für die meisten Elemente stiegen die Konzentrationen in der Reihe Alleinfutter – Ergänzungsfutter – Mineralfutter – Vormischung stark an, außer für die Nährelemente K-N-P in den Vormischungen. In Alleinfuttermitteln und Ergänzungsfuttermitteln waren die Elemente Cu, P, Zink und zuweilen Ca und K gegenüber Ackerböden angereichert. Kontaminationen mit unerwünschten Spurenelementen, wie As, Be, Cr, Ni, Pb und V, wurden nicht gefunden.
Im Hinblick auf die Zieltiergruppen war die anorganische Zusammensetzung der Futtermittel mit wenigen Ausnahmen ähnlich; so bekamen die Legehennen mehr Calcium und die Ferkel mehr Kupfer als andere Tiere. Rohphosphate waren die Hauptquelle für Cd, Be, Cr und V in den Proben. Besonders Kupfer und Zink können die Konzentrationen in Böden und die Grenzwerte für die Ablagerung in gewöhnlichen Hausmülldeponien übersteigen, obwohl sogar noch höhere Werte aus anderen europäischen Ländern und China berichtet wurden.

Kennwörter:
Futtermittel, essentielle Elemente, Nährelemente, nicht-essentielle Elemente, Elementverhältnisse

Introduction

Within the last decades, decoupling of cropping and animal farming in agriculture has led to an appreciable market for animal feedstuffs. In other words, many farmed animals are not fed with feeds growing on their own farm. It has been our task to control the quality and composition of these feedstuffs to ensure adequate nutrition and growth of these animals, as well as their products. Similar data for meat [1] and also for dung and manure samples [2] are available to obtain a profound database for the interpretation of element cycling.
In keeping domestic animals, feeds are widely rated on their productive energy and protein content, and deficiencies in minerals and vitamins are usually com-

pensated by supplementation. The diet of animals should provide all the essential nutrients. Diets that promote growth may shorten life, but food producing animals generally do not live long enough to experience these consequences [3].

This compilation of data is aimed to review expectable concentration ranges in commercially available feedstuffs sold in Austria, but interpretations of nutritional aspects are beyond the scope of this article.

Materials and methods

Animal feedstuffs and their components were taken by state control authorities in the Eastern half of Austria, according to official guidelines [4]. The current evaluation is based on about 1100 samples taken mainly between January 2002 and May 2005. Sampling has been done at the producing facilities and commercial traders, weighted according to annual production or sales, respectively.
5 g of sample (for samples low in inorganics: 10 g) were dry ashed in covered glass beakers in a muffle furnace at 560 °C, the ash was dissolved in 10 mL 1+3 HNO_3 and transferred to a 250 mL volumetric flask, than boiled with 40 mL conc. HNO_3, made up to the mark after cooling down and finally filtered. The digests were submitted to ICP-OES multi-element measurement in at least three dilutions, in order to meet an adequate calibration range and to recognize matrix effects. In the calibrant solutions, main and trace elements were simultaneously present to imitate a probable matrix. Together with each batch, two blanks and two digests of a control sample (fungal mycelium) were run, to indicate long term precision. The control sample was used in a ring test among Austrian agricultural labs some years before (ALVA plant sample ring test in 1994).

Detection limits are taken from the repeatability (2 s) of eleven pairs of blank digests.
Usually, the elements (in alphabetical order) Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Sr, V and Zn were read. Due to variable blanks from the glass, the boron data were not evaluated.

Sample homogeneity and grain size distribution of our mills require sample weights of 2-3 g [5]. At least half a kilogram is available. Thus dry ashing was preferable over wet ashing in pressure bombs, which is limited to about 0.3 g of dry sample. In case selenium data were needed (for evaluation see [6]), the samples were digested in presence of magnesium nitrate, and the resultant ash dissolved at the boiling water bath with 1+1 HCl for half an hour. For these samples, ICP calibrant solutions had to be matrix matched with equal amounts of magnesium, and just about half of the analytical lines could be used. The data were saved in EXCEL sheets and imported from there into SPSS sheets to perform selected runs of factor analyses, taking the element concentrations as start variables.

There are some reasons for slightly different numbers of valid sample numbers: data showing obvious spectral interferences were discarded (like for arsenic). Similarly, the matrix of digest with magnesium nitrate, which yields excellent results for selenium, arsenic and sulphur, yields spectral interferences or too high blanks for a lot of other elements, like Al, As, B, Ba, Be, Co, Mo, Ni, Sr and V. Some macro-elements were too much to meet the calibration curve.

Results and discussion

General

Complete feeds are solely fed to the domestic animal, whereas supplementary (or complementary) feeds are given in addition to feeds grown at the farm. For fish, these labels are frequently overlapping. Mineral feeds and premixes are not given per se, but they are components for the adequate mixing of ready feeds to satisfy requirements of essential elements, which are not sufficiently contained in the basic feed materials. Discrimination between mineral feeds and premixes has been kept due to administrative reasons. Whereas mineral feeds may be sold to farmers as well, premixes are only permitted to be utilized by commercial producers of mixed feeds, or by special permissions.

The current dataset permits to connect macro-elements (P, Ca, Mg, Na, K) with essential and frequently added elements (Cu, Mn, Fe, Zn) and also with acknowledged toxicant elements (Cd, Pb) and rarely determined traces (e.g. Be, Ba, Li, Sr, V), taken from the same samples. It may serve as a pattern recognition for unknown samples. Most of the datasets have an asymmetric frequency distribution, i.e. many small and a few large values. Within the subsequent tables, data assorted due to types of feeds and target animals are presented. In order to discard possible outliers a priori, the respective median concentrations are given together with the 5 - 95 % range; in case the sample number was below 10, just one outlier was permitted to be rejected. The number of samples is the total number investigated.

Some kinds of feeds were not available, leaving empty space in the tables, like complete feed for cattle and horses, or supplementary feed for growing chicken and turkeys, or a lot of premixes.

For some trace elements, like Pb, Cd, As and Hg limits have been set on the EU- level. Other elements are toxic in even small amounts as well like Be and Tl, but have not been looked for very often. Within the control period, however, no case of intoxications from these rarely controlled elements has been found. For a lot of samples, other parameters like crude fiber, fat, total nitrogen, as well as vitamins, antibiotics etc. have been done also, which will be evaluated later.

Within the subsequent tables, no corrections for water contents have been done. Usually, water content is 4-8 %, and at maximum 12 % for reasons of stability during storage. The feeds for dogs and cats, however, were all canned feeds, which contain water at 79 ± 5 %; this has to be considered when the datasets are compared.

Aluminum (*table 1*)

Acid soluble aluminum may cover a wide range, but in bio-materials it is rather an indicator of dirt. With respect to mean crust abundance of 8.1 % [13], phosphates and lime contain just a few percent, but they are nevertheless the main Al-sources, whereas fishmeal, green plants and cereals were generally low. As a non-complexed soluble salt, aluminum would be highly toxic [8], but in mineral components it might be largely present in unavailable forms, and excess of organic ligands and phosphorus also protect from toxicity. Due to adhered dust, it is higher in silage than in cereals and soya (168 resp. 20 mg/kg in Swedish feeds) [7]. In human nutrition in Great Britain, aluminum ranged between 0.3-11 mg/kg fresh weight [9], which is less than in the animal feeds presented here.

Al mg/kg	Complete feeds			Suppl. Feeds			Mineral feeds			Premixes		
	Median	Range	No.	Median	Range	No	Median	Range	No	Median	Range	no
Deer				238	173 - 372	9						
Cattle				188	30 - 755	73	867	245 - 4128	124			
Calves	6.6	1.2 - 131	10	323	73 - 824	40	656	526 - 2999	8			
Sheep + goats	96	1.1 - 370	12	124	73 - 483	11	1104	696 - 1297	4			
Horses				194	61 - 2685	46	1782	515 - 2213	5			
Pigs + sows	89	15 - 433	28	301	105 - 2070	170	895	399 - 2574	180	1937	323 - 2601	8
Piglets	57	18 - 581	61	284	33 - 1647	128	1150	349 - 3854	72			
Chicken	140	60 - 270	12				1302	988 - 1324	3	5364	3282 - 20251	4
Turkeys	133	36 - 558	11				*	*	*	1095	1019 - 1171	2
Laying hens	128	61 - 328	20	331	76 - 790	40	796	657 - 1059	5	1383	451 - 2621	6
Dogs + cats	42	11 - 87	35	71	5 - 539	7						
Trouts	65	13 - 166	5	263	229 - 519	5						
Carps	418	8 - 1951	7									

Tab. 1: Aluminium in feeds

Arsenic (*table 2*)

Arsenic is rather insensitive in the ICP-OES and sometimes there is appreciable background noise. For more details, another set of samples was analyzed by hydride-AAS [6]. Phosphates and lime may significantly contribute to the arsenic load of ready feeds, but the data for feeds are still far below the levels encountered in arable soils, the medians of which range from 5-15 mg/kg [10].
In the US, arsenicals are used in poultry feeds to control coccidiosis and to promote chicken growth. Arsenilic acid is added to poultry rations at a rate of 100 mg/kg [12], finally leading to a median of 19 mg/kg in the broiler litter, which is substantially more than in Austria [2,11]. Arsenic additions are not permitted in Austria, and would have been easily recognized here.

In the EU, threshold limits have been set for complete feeds at 2 mg/kg (except for fish at 6 mg/kg), for supplementary feeds at 4 mg/kg and for mineral feeds at 12 mg/kg [31], which have never been exceeded within this period of sampling.

As mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	no	Median	Range	no	Median	Range	no	Median	Range	no
Deer				<0.4	<0.4 - 0.43	7						
Cattle				<0.4	<0.4 - 1.20	50	1.90	<0.4 - 4.15	101			
Calves	<0.4	<0.4	5	<0.4	<0.4 - 0.72	29	0.99	<0.4 - 1.81	7			
Sheep + goats	<0.4	<0.4	9	<0.4	<0.4 - 0.35	5	1.92	1.92 - 2.59	3			
Horses				<0.4	<0.4 - 1.21	39	1.44	<0.4 - 4.07	4			
Pigs + sows	<0.4	<0.4 - 0.62	24	<0.4	<0.4 - 1.20	133	1.67	<0.4 - 3.16	137	4.89	1.78 - 14.2	6
Piglets	<0.4	<0.4 - 0.60	55	0.34	<0.4 - 1.15	108	1.44	<0.4 - 3.77	54			
Chicken	<0.4	<0.4	9				<0.4	<0.4	*	4.60	1.05 - 6.02	3
Turkeys	<0.4	<0.4	5				*	*	*	2.4	2.3 - 2.5	2
Laying hens	<0.4	<0.4	17	<0.4	<0.4 - 0.58	33	1.65	<0.4 - 2.30	4	1.58	1.08 - 2.10	4
Dogs + cats	<0.4	<0.4	24	<0.4	<0.4	5						
Trouts	<0.4	<0.4	2	<0.4	<0.4	3						
Carps	<0.4	<0.4 - 1.86	5									

Tab. 2: Arsenic in feeds

Barium (*table 3*)

Ba data were found to be within a rather narrow range. Almost all barium concentrations were below mean crust (500 mg/kg) [13] and compost values, except for premixes for growing chicken. All animals get about the same barium levels. Ba levels in manure were slightly higher than in supplementary feeds [2]. Ba in single and supplementary feeds was within the range of Ba reported from grass (10 mg/kg), clover (6 mg/kg), lucerne (6 mg/kg) and similar feed plants [14], but potatoes would be lower (1.5 mg/kg). Contrary to most other salts, Ba contents in plant tissues do not decrease with the age of the plant. Among possible feed materials, Ba sources have been presumably lime and oil seeds. In feeds of plant origin, barium correlates with calcium at about r=0.55.

For poultry and pigs, Ba was lower than in similar feeds from China (19.1 mg/kg for chicken 13.0 mg/kg for pigs) [15], but for cattle it was the same range. Barium in Austrian potatoes has been found at a median of just 0.48 mg/kg dry mass (unpublished data).

Ba mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	no	Median	Range	no	Median	range	no	Median	Range	no
Deer				6.3	3.3 - 12.0	7						
Cattle				6.8	3.6 - 16.6	72	13.7	4.6 - 43.9	121			
Calves	1.2	0.3 - 5.3	10	7.0	2.1 - 25.9	39	17.2	3.5 - 62.9	8			
Sheep + goats	3.2	0.5 - 7.5	12	5.5	2.12 - 8.1	9	23.5	14.1 - 33.5	4			
Horses				5.7	1.9 - 13.3	46	14.0	6.6 - 18.2	5			
Pigs + sows	4.0	0.8 - 11.1	28	9.3	3.4 - 26.2	169	16.7	4.8 - 48.7	177	34	15 - 175	8
Piglets	3.8	1.1 - 9.1	61	6.8	2.2 - 25.2	127	12.9	3.8 - 58.7	72			
Chicken	7.6	3.7 - 12.6	11				11.7	5.1 - 13.3	3	492	199 - 1423	4
Turkeys	5.6	1.4 - 9.0	11				*	*	*	280	169 - 247	2
Laying hens	3.55	1.6 - 6.6	20	5.2	1.3 - 13.0	40	10.9	5.2 - 16.1	5	55	22 - 100	6
Dogs + cats	3.0	1.4 - 4.5	35	4.0	0.24 - 6.2	7						
Trouts	3.4	1.1 - 18.0	5	10.1	4.7 - 17.9	5						
Carps	9.8	4.6 - 10.9	6									

Tab. 3: Barium in feeds

Beryllium (*table 4*)
Beryllium in feedstuffs was significantly lower than mean crust levels (2.6 mg/kg) [13] and compost (about 2 mg/kg) and also lower than in manure and dung samples [2]. Phosphates are the main source for Be.

Be mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	No	Median	Range	No	Median	Range	no	Median	Range	No
Deer				0.046	0.026 - 0.068	8						
Cattle				0.046	0.008 - 0.222	73	0.49	0.09 - 1.36	125			
Calves	0.010	<0.002 - 0.054	10	0.070	0.019 - 0.42	44	0.35	0.22 - 0.88	8			
Sheep + goats	0.027	0.002 - 0.084	13	0.030	0.015 - 0.073	9	0.36	0.35 - 0.55	4			
Horses				0.042	0.019 - 0.31	46	0.62	0.42 - 1.65	5			
Pigs + sows	0.028	<0.002 - 0.056	28	0.093	0.032 - 0.31	170	0.55	0.23 - 1.10	180	1.19	0.42 - 2.18	8
Piglets	0.034	0.013 - 0.093	61	0.119	0.018 - 0.33	128	0.62	0.28 - 1.25	72			
Chicken	0.034	0.021 - 0.072	12				0.77	0.54 - 0.86	3	1.48	0.74 - 3.87	4
Turkeys	0.049	0.014 - 0.056	11				*	*	*	0.46	0,46	2
Laying hens	0.041	0.028 - 0.081	20	0.084	0.038 - 0.192	40	0.81	0.58 - 1.09	5	0.44	0.30 - 0.65	6
Dogs + cats	0.027	0.013 - 0.053	35	0.069	0.010 - 0.204	7						
Trouts	0.026	0.016 - 0.072	5	0.110	0.053 - 0.130	5						
Carps	0.106	<0.002 - 0.310	7									

Tab. 4: Beryllium in feeds

Calcium (*table 5*)
Lime, phosphates, bones and oilseeds are main sources of Ca in feedstuffs, and respective additions may vary widely. Cereals and potatoes contain about 1/10th of the calcium of complete feeds [21]. For ruminants, addition of ground bones is not permitted in Austria. Laying hens get significantly more Ca than other domestic animals (including turkeys and young chicken) by their supplementary feeds, which they may need to produce mechanically stable eggs.

Ca %	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	no	Median	range	no	Median	Range	no	Median	Range	no
Deer				1.94	0.87 - 3.54	8						
Cattle				1.80	0.30 - 8.34	75	18.1	6.42 - 24.4	140			
Calves	0.91	0.61 - 1.58	13	1.72	0.71 - 9.72	45	16.6	0.77 - 22.5	8			
Sheep + goats	1.41	0.96 - 3.59	13	1.18	0.12 - 1.98	9	20.4	8.8 - 21.9	5			
Horses				1.12	0.22 - 2.73	46	16.5	10.8 - 21.7	5			
Pigs + sows	0.84	0.26 - 1.50	28	3.22	0.92 - 5.79	176	21.1	9.55 - 24.0	193	23.0	2.25 - 28.8	9
Piglets	0.76	0.33 - 1.39	62	2.49	0.42 - 9.03	137	16.8	9.97 - 22.0	75			
Chicken	1.18	0.56 - 1.69	12				2.55	2.50 - 2.60	2	2.49	1.07 - 23.6	5
Turkeys	1.28	1.09 - 1.48	11				*	*	*	26.6	23.9 - 29.4	2
Laying hens	3.64	3.05 - 5.87	21	8.78	3.80 - 12.0	41	14.9	10.7 - 19.8	6	29.9	15.7 - 35.9	6
Dogs + cats	1.33	0.82 - 2.12	35	2.11	0.77 - 4.43	7						
Trouts	1.89	1.42 - 2.28	6	2.35	1.65 - 2.49	5						
Carps	1.73	0.43 - 3.01	6									

Tab. 5: Calcium in feeds

Cadmium (*table 6*)

Whereas supplementary feeds contain Cd at about mean crust and mean soil levels (medians various types of arable soils in Austria 0.11-0.34 mg/kg) [10], mineral feeds and premixes may be higher and may exceed the soil contamination level of 1 mg/kg. Like in mineral fertilizers, raw phosphates are probably the main source of cadmium in mineral feeds [16, 17]. The threshold for waste deposits on soils is currently 2 mg/kg [18], which was hardly reached, however.
After our sampling period in December 2005, threshold values have been set in the EU [32] to limit Cd in complete feeds at 0.5 mg/kg for calves, horses, pigs, piglets and poultry, to limit Cd at 1 mg/kg in complete feeds for sheep, goats and fish, and at 2 mg/kg for dogs and cats. Similarly a new threshold was set for supplementary feeds for cattle, pigs, piglets and poultry at 0.5 mg/kg also, which would have been exceeded in some of the investigated samples. However, the new threshold for mineral feeds, at 5 mg/kg and for premixes at 15 mg/kg would have been kept throughout. In China, Cd-levels in feeds were found slightly higher, e. g. a median of 0.64 mg/kg for chicken, 0.57 mg/kg for pigs, and 0.22 mg/kg for dairy cows [15].

Cd mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	no	Median	Range	no	Median	Range	no	Median	Range	no
Deer				0.13	0.043 - 0.21	7						
Cattle				0.10	<0.035 - 0.63	78	0.76	0.16 - 2.4	136			
Calves	<0.035	<0.035 - 0.05	13	0.13	<0.035 - 0.29	45	0.30	0.19 - 1.6	6			
Sheep + goats	0.056	<0.035 - 0.12	12	0.07	<0.035 - 0.13	8	0.78	0.29 - 1.4	5			
Horses				0.06	<0.035 - 0.14	43	0.74	0.05 - 3.0	6			
Pigs + sows	0.065	<0.035 - 0.19	30	0.17	0.039 - 0.50	173	1.12	0.12 - 2.1	201	0.24	<0.04 - 1.70	11
Piglets	0.065	<0.035 - 0.17	62	0.21	<0.035 - 0.55	132	1.03	0.39 - 2.0	74			
Chicken	0.099	0.040 - 0.153	11				2.04	1.28 - 2.55	3	2.26	1.37 - 3.83	5
Turkeys	0.090	<0.035 - 0.20	11				*	*	*	0.44	0.39 - 0.44	2
Laying hens	0.13	0.08 - 0.19	21	0.20	0.059 - 0.46	39	2.36	1.57 - 3.85	7	0.53	0.23 - 2.29	6
Dogs + cats	0.070	<0.035 - 0.18	34	0.10	0.042 - 0.19	6						
Trouts	0.29	0.088 - 0.29	6	0.20	0.079 - 0.31	5						
Carps	0.20	<0.035 - 0.36	6									

Tab. 6: Cadmium in feeds

Cobalt (*table 7*)

The mean concentration encountered in mineral feeds meets about the mean crust (20 mg/kg) [13], and mean soil levels. Among the feed materials, Co in phosphates and lime is also met far below mean crust levels. Some mineral feeds and premixes which contain added cobalt salts, exceeded the soil contamination level of 50 mg/kg, and must not be discarded in the open field (see also Cu, Zn). Growing chicken got significantly more Co via their premixes than others, but the same samples were also higher in copper, chromium, iron, manganese, and nickel (see below). The Co-levels in manure samples were higher than in complete feeds [2].

Feeds in China contained as much Co as the Austrian complete feeds presented here [15]. Occasionally, the general threshold of 2 mg/kg in the EU [30] for composite feeds was exceeded for carps and trouts.

Chromium (*table 8*)

Among presumable feed components, Cr in Canadian silages ranged between 1.1-2.3 mg/kg, whereas in cereal grains it was below 0.3 mg/kg [19]. The Cr-levels met in mineral feeds meets the Cr-levels of aqua-regia leachable Cr in Austrian arable soils [10]. The threshold for waste deposition (300 mg/kg) is never exceeded. Main Cr-sources are raw phosphates (like for vanadium also), whereas Cr contents in lime is clearly below mean crust, and green plants, cereals and fishmeal range just at a few percent of mean crust levels. Some chromium contamination may result from milling and grinding processes in the production of composite feeds [20]. Though the number of samples is not quite representative, young chicken diet contains more chromium than for all the other domestic animals, but maybe this is just an impurity in the iron. Feeds sampled in China were significantly higher in their chromium levels than samples from Austria. Thus, feeds for chicken ranged between 6.6-162 mg/kg, for pigs between 5.9-98 mg/kg and for dairy cows between 7.6-19.9 mg/kg Cr [15].

Co mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	no	Median	Range	No	Median	Range	No	Median	Range	no
Deer				1.51	0.36 - 2.22	9						
Cattle				1.50	0.24 - 10.5	74	29.4	2.80 - 77.0	134			
Calves	0.46	0.20 - 0.92	13	4.35	0.32 - 51.9	45	28.9	2.36 - 72.7	7			
Sheep + goats	0.33	0.19 - 1.85	13	0.46	0.08 - 2.13	9	22.8	13.6 - 31.3	4			
Horses				1.01	0.45 - 3.28	46	15.6	4.9 - 22.1	5			
Pigs + sows	0.49	0.22 - 1.25	28	2.21	0.58 - 9.65	173	16.2	4.1 - 33.6	184	40.1	18.8 - 106	8
Piglets	0.60	0.11 - 1.79	62	2.43	0.32 - 13.1	131	20.2	4.8 - 44.6	72			
Chicken	0.69	0.25 - 0.97	12				13.7	10.4 - 28.8	3	262	142 - 738	4
Turkeys	0.61	0.42 - 0.99	11				*	*	*	25.8	18.8 - 32.8	2
Laying hens	0.65	0.35 - 1.43	20	1.12	0.39 - 3.55	41	12.6	7.7 - 42.2	6	17.2	9.9 - 40.4	6
Dogs + cats	0.40	0.09 - 1.21	35	0.17	0.10 - 1.06	7						
Trouts	1.94	0.52 - 3.28	6	1.32	1.13 - 2.15	5						
Carps	1.76	0.06 - 3.07	7									

Tab. 7: Cobalt in feeds

Cr mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	no	Median	Range	no	Median	Range	no	Median	Range	no
Deer				3.35	0.87 - 4.46	8						
Cattle				2.12	0.32 - 18.4	76	26.5	2.5 - 71.6	137			
Calves	<0.19	<0.19 - 1.15	10	2.58	0.43 - 6.05	45	9.7	3.10 - 45.5	8			
Sheep + goats	0.89	<0.19 - 2.51	13	2.22	0.24 - 3.99	9	21.5	4.28 - 28.7	5			
Horses				1.72	0.29 - 5.49	46	36.2	12.7 - 97.4	6			
Pigs + sows	1.30	<0.19 - 3.38	28	4.75	0.80 - 11.7	172	28.8	4.1 - 58.0	191	4.7	2.4 - 30.1	11
Piglets	1.37	0.23 - 4.04	61	5.70	0.47 - 18.3	130	32.4	7.2 - 67.1	72			
Chicken	2.53	1.38 - 3.05	12				39.1	8.0 - 61.8	3	7.9	4.9 - 9.5	4
Turkeys	3.04	1.20 - 4.63	11				*	*	*	1.73	1.61 - 1.85	2
Laying hens	2.61	0.80 - 4.47	20	5.46	1.37 - 11.0	40	66	42 - 99	6	3.8	3.2 - 10.7	6
Dogs + cats	0.83	0.41 - 2.66	35	3.39	<0.19 - 5.87	7						
Trouts	0.52	<0.19 - 1.18	5	7.31	2.54 - 9.52	5						
Carps	4.73	<0.19 - 8.38	7									

Tab. 8: Chromium in feeds

Copper (*table 9*)

Apart from geogenic enrichments, Austrian soils contain median Cu concentrations within 12-25 mg/kg [10]. Cereal grains grown in Lower Austria contained median concentrations of 1.9-6.2 mg/kg Cu, depending on plant and soil type [21] and maize was even lower. Similarly, median Cu concentrations of cereals and potatoes grown in Germany and Poland ranged from 3.7-7.6 mg/kg Cu, in soya the concentration was at 12 mg/kg and rape seeds and sunflower seeds contained even 27 and 28 mg/kg [22, 23]. Green plants, fish meal and lime contain thus just a few mg/kg Cu, but in most samples, soluble salts like $CuSO_4$ had been mixed with the basic feed materials to satisfy more than minimum requirements. Cu levels in mineral feeds were thus far above the levels met in soils (medians of various types of arable soil in Austria: 12-60 mg/kg) or sediments and exceed the threshold for waste deposition in open landfill sites (100 mg/kg) [18]. Thus, high Cu supplementation of domestic animals produces hazardous waste in the shape of excrements. Sheep have an extraordinary low tolerance versus Cu, possibly because they accumulate Cu much more in their liver than others; the current threshold has been set to 15 mg/kg in complete feeds for sheep. In the EU, various thresholds have been set for complete feeds [30], which are given in the above table, and which have been exceeded rather often for all kinds of domestic animals, thus necessitating thorough controls. Similar to

Austria, in China feeds with a median Cu concentration of 19.1 mg/kg Cu were fed to dairy cows, of 22.6 mg/kg to chicken and of 105 mg/kg to pigs. Enrichment in the respective manure samples was three- to fourfold [15]. In the US, $CuSO_4$ is routinely added (125 or 250 mg/kg) to the diets of poultry to promote weight gain and feed efficiency. As much as 80-95 % of dietary copper is excreted in manure [12]. In France, Cu is added within 150-250 mg/kg to pig feeds, which is apparently more than in Austria and in China [24].

Cu mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	no	Median	Range	no	Median	Range	no	Median	Range	no
Deer				19.0	13.1 - 32.5	7						
Cattle				52.3	15.3 - 919	78	894	38 - 1625	146			
Calves	14.5	3.3 - 34.6	10	56.2	8.5 - 474	46	281	26.4 - 704	8			
Sheep + goats	10.1	1.3 - 21.4	13	14.2	3.4 - 16.8	11	67	64.9 - 134	5			
Horses				28.1	10.4 - 45.1	46	471	359 - 1102	5			
Pigs + sows	25.0	17.3 - 139	30	87	19 - 264	175	747	240 - 1580	195	3618	906 - 9398	11
Piglets	129	17 - 174	62	439	10 - 1543	135	2521	575 - 4044	75			
Chicken	18.2	9.7 - 34.7	12				291	252 - 903	3	15701	5787 - 36932	5
Turkeys	31.2	23.9 - 87.0	11				*	*	*	2986	2823 - 3148	2
Laying hens	18.1	13.1 - 28.6	21	35.2	16.6 - 73.0	41	520	274 - 599	7	1684	454 - 2124	6
Dogs + cats	16.8	8.5 - 30.8	35	3.7	2.8 - 19.5	7						
Trouts	17.1	14.0 - 28.8	6	56.7	17.6 - 98.2	5						
Carps	25.6	16.7 - 56.7	7									

Tab. 9: Copper in feeds

Iron (*table 10*)

From the composition of meteorites and the stability of the atomic nuclei it is known that Fe is a main component in space and the inner part of our planet and at the earth crust its average content is still 4.1 % [13]. For living organisms, their general main problem is to get Fe in available forms. The data presented here had been obtained to control the addition of soluble Fe salts to basic feed materials, but they reflect all the Fe soluble after hot nitric acid digestion, which might be clearly more than the available fraction. Nevertheless, threshold limits have been set at 500 mg/kg for sheep and goats, at 750 mg/kg for pigs and fish and at 1250 mg/kg for dogs and cats, which have not been obeyed in all samples investigated. Most of the data ranges were overlapping. In complete feeds, lowest Fe-levels were met for calves, and highest for fish. The premixes for pigs and growing chicken contained more Fe for turkeys and laying hens.

Fe mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	no	Median	Range	no	Median	Range	no	Median	Range	no
Deer				547	219 - 827	8						
Cattle				398	140 - 1701	78	3044	901 - 6830	140			
Calves	80	5 - 390	10	485	202 - 4164	46	3915	2962 - 6609	8			
Sheep + goats	235	37 - 864	13	284	111 - 470	9	3845	2425 - 4191	5			
Horses				423	174 - 3499	46	4520	3482 - 7159	6			
Pigs + sows	243	126 - 405	30	864	386 - 3203	174	4518	2301 - 7374	191	16786	8290 - 30401	11
Piglets	293	118 - 1323	62	1190	269 - 3113	135	5664	2058 - 9408	74			
Chicken	225	187 - 288	12				3861	3604 - 5155	3	21888	12572 - 70788	5
Turkeys	230	191 - 384	11				*	*	*	6303	5737 - 6869	2
Laying hens	280	148 - 430	20	624	230 - 1010	41	3017	2199 - 3684	7	6117	3464 - 11304	6
Dogs + cats	273	128 - 917	35	374	64 - 712	7						
Trouts	401	139 - 600	6	469	409 - 621	5						
Carps	432	63 - 621	6									

Tab. 10: Iron in feeds

Potassium (*table 11*)
Potassium makes 2.1 % of mean earth crust [13]. It is largely bound to silicates like feldspars and micas, but it is also enriched in biota up to a few percent on a dry weight basis. Mineral feeds and premixes contain less K than supplementary feeds.

K %	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	No	Median	Range	no	Median	Range	no	Median	Range	no
Deer				0.98	0.64 - 1.43	8						
Cattle				1.20	0.43 - 1.74	74	0.507	0.21 - 1.21	119			
Calves	1.55	1.06 - 2.14	10	1.08	0.61 - 1.52	43	0.736	0.242 - 1.58	8			
Sheep + goats	1.13	0.59 - 1.63	13	1.02	0.76 - 1.52	9	0.493	0.47 - 0.89	5			
Horses				0.96	0.66 - 1.58	44	0.431	0.259 - 0.96	5			
Pigs + sows	0.777	0.44 - 1.23	30	1.63	0.44 - 2.15	164	0.329	0.153 - 0.94	182	0.181	0.118 - 0.306	8
Piglets	0.790	0.510 - 1.32	61	1.05	0.541 - 1.77	126	0.307	0.143 - 0.61	72			
Chicken	0.845	0.644 - 1.12	12				0.133	0.132 - 0.43	3	0.467	0.358 - 0.576	2
Turkeys	0.905	0.622 - 1.28	11				*	*	*	0.133	0.112 - 0.154	2
Laying hens	0.746	0.61 - 0.93	19	1.27	0.88 - 1.64	40	0.216	0.190 - 0.28	4	0.172	0.106 - 0.522	6
Dogs + cats	0.627	0.45 - 0.91	35	0.67	0.181 - 1.26	7						
Trouts	1.03	0.86 - 1.44	5	1.26	0.92 - 1.94	5						
Carps	1.21	0.23 - 1.21	7									

Tab. 11: Potassium in feeds

Lithium (*table 12*)
In the earth crust, major parts of Li might be bound to the silicate lattice and the concentration levels in limestones, phosphates and biota is significantly below the average. Mineral feeds and premixes contain more Li than single and supplementary feeds, which probably happened accidentially. The premixes designed for growing chicken contained more lithium than for laying hens. Lithium has been used in the treatment of manic depressive disorders of humans, but this phenomenon is not so important for the growth of domestic animals.

Li mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	no	Median	Range	no	Median	Range	no	Median	Range	no
Deer				1.18	0.47 - 2.50	9						
Cattle				1.19	0.39 - 3.54	72	5.10	1.00 - 15.7	114			
Calves	0.94	0.16 - 2.04	10	1.46	0.63 - 5.84	44	4.29	0.82 - 18.4	7			
Sheep + goats	1.08	0.16 - 3.89	13	0.63	0.41 - 1.46	8	4.73	2.59 - 10.4	4			
Horses				1.11	0.37 - 4.59	46	7.47	2.80 - 10.5	5			
Pigs + sows	0.66	0.35 - 1.64	27	1.61	0.38 - 6.11	169	4.21	1.44 - 11.9	177	3.83	1.28 - 10.9	8
Piglets	0.99	0.18 - 2.50	61	1.70	0.26 - 4.68	123	4.13	1.09 - 8.78	74			
Chicken	0.75	0.25 - 2.76	12				3.21	2.12 - 7.24	3	9.55	6.48 - 14.0	4
Turkeys	0.94	0.27 - 1.44	11				*	*	*	5.3	4.6 - 5.9	2
Laying hens	1.05	0.27 - 3.27	20	1.95	0.67 - 4.37	39	3.29	1.58 - 6.99	5	3.34	1.75 - 5.07	6
Dogs + cats	0.77	0.16 - 4.44	35	0.79	0.19 - 2.15	7						
Trouts	1.38	1.02 - 1.69	5	1.26	0.60 - 1.72	5						
Carps	1.65	<0.003 - 3.13	7									

Tab. 12: Lithium in feeds

Magnesium (*table 13*)

Cereals and potatoes grown in Germany contained 0.11-0.13 % Mg on the average, depending on sort and soil type [22] and the median of Austrian potatoes was 0.091 % (unpublished data), referring to dry mass. Whereas the Mg concentrations encountered in single and supplementary feeds roughly reflect their levels in basic feed materials, dolomite or magnesite addition is the cheapest way to raise available Mg concentrations in mineral feeds. Athletic activities require more Mg in the muscles, but athletic activities are not so common for most of domestic animals except for horses, which really get more Mg in their mineral feeds.

Mg %	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	no	Median	Range	No	Median	Range	no	Median	Range	no
Deer				0.369	0.224 - 0.46	8						
Cattle				0.503	0.236 - 2.18	75	3.14	0.572 - 6.68	133			
Calves	0.147	0.085 - 0.55	10	0.341	0.142 - 2.34	45	0.65	0.112 - 3.59	8			
Sheep + goats	0.242	0.114 - 0.38	13	0.264	0.094 - 0.34	9	2.74	1.65 - 2.91	5			
Horses				0.266	0.145 - 0.51	46	4.01	1.65 - 4.82	5			
Pigs + sows	0.221	0.148 - 0.44	28	0.495	0.198 - 1.16	172	2.19	0.608 - 3.37	189	0.635	0.361 - 3.28	7
Piglets	0.175	0.120 - 0.29	62	0.328	0.062 - 1.13	133	1.69	0.662 - 3.12	75			
Chicken	0.241	0.176 - 0.35	12				1.12	1.01 - 2.14	3	0.492	0.222 - 0.624	4
Turkeys	0.215	0.155 - 0.33	11				*	*	*	0.897	0.74 - 1.05	2
Laying hens	0.246	0.178 - 0.33	21	0.352	0.258 - 0.685	41	1.88	0.644 - 2.48	6	0.902	0.413 - 2.82	6
Dogs + cats	0.108	0.072 - 0.14	35	0.128	0.091 - 0.58	7						
Trouts	0.262	0.191 - 0.28	6	0.326	0.282 - 0.71	5						
Carps	0.358	0.285 - 0.66	7									

Tab. 13: Magnesium in feeds

Manganese (*table 14*)

Manganese occurs at an average concentration of 950 mg/kg in the earth crust, but contrary to Fe and Al it is largely soluble in the nitric acid digest. The data below were obtained to control the addition of soluble salts to basic feed materials. Cereal grains grown in Lower Austria contained 9-46 mg/kg Mn (median values), depending on sort and soil type [21].

German potatoes had just a median of 6.4 mg/kg dry mass [22] and Austrians had 5.1 mg/kg dry mass, which is below the data of all complete feeds investigated here. Meat and other feeds of animal origin contain much less Mn than green plants [1], which is reflected in the lower Mn-level met in supplementary feeds for dogs and cats.

In the EU, complete feeds have been permitted to contain 150 mg/kg Mn in general, except just 100 mg/kg for fish [30].

The premixes for growing chicken had the highest Mn concentrations. Some samples of fish and poultry feed were found above these limits. In China, chicken receive more Mn (median =190 mg/kg) than pigs (median = 134 mg/kg) and dairy cows (85 mg/kg) [15].

Molybdenum (*table 15*)

Median values of various types of Austrian arable soils ranged from 0.19-0.67 mg/kg [10]. Usually, Mo gets enriched in green plants with respect to corresponding soils to contain about 1-2 mg/kg Mo in their dry mass and median levels in feeds were found within this range also. Apart from leafy plants, soya might contribute to the Mo-load of feeds, because it contains four to five times more Mo than cereals; soya fed in Germany had 2.1 mg/kg Mo [22].

Feeds of plant origin contain appreciably more Mo than feeds of animal origin. Contrary to many other metals, Mo in all type of feeds was at the same levels. Some samples were below the detection limit of 0.2 mg/kg. In the mineral mixtures and premixes, background noise in the emission spectrum necessitated reliable measurement in 1+1 dilution, resulting in a detection limit of 0.4 mg/kg. In the EU, a general limit of 2.5 mg/kg has been set for molybdenum content [30], but some samples of feeds for piglets, poultry and carps contained more than the permitted value.

In Chinese feeds, Mo contents were in the same range than presented here [15].

Mn mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	No	Median	Range	no	Median	Range	no	Median	Range	no
Deer				121	32.2 - 219	9						
Cattle				124	51 - 1895	78	1922	219 - 4676	146			
Calves	60.6	31.6 - 81.6	10	162	51 - 2237	46	1071	105 - 1929	8			
Sheep + goats	59.6	24.2 - 155	13	118	5.3 - 180	9	2180	1947 - 18478	5			
Horses				105	51 - 163	46	1218	844 - 1834	6			
Pigs + sows	73.5	28.4 - 137	30	215	54 - 1024	176	1674	459 - 3690	198	8985	3290 - 36286	10
Piglets	91	40 - 140	62	291	42 - 1817	137	1642	698 - 3492	72			
Chicken	118	53 - 147	12				3489	2321 - 4180	3	60858	38410 - 170707	4
Turkeys	115	79 - 157	11				*	*	*	6688	-	1
Laying hens	105	73 - 160	21	231	119 - 414	41	5193	1939 - 6102	7	15364	7614 - 18791	6
Dogs + cats	53.3	21.3 - 82	35	22.1	14.9 - 85.3	6						
Trouts	43.8	37.7 - 170	5	132	57 - 248	5						
Carps	65.0	25.5 - 189	6									

Tab. 14: Manganese in feeds

Mo mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	No	Median	Range	no	Median	Range	no	Median	Range	no
Deer				0.79	0.30 - 3.96	9						
Cattle				1.18	0.26 - 3.02	70	0.79	< 0.4 - 7.4	120			
Calves	0.59	<0.2 - 1.26	13	0.95	<0.2 - 2.43	44	0.72	< 0.4 - 1.67	8			
Sheep + goats	0.68	<0.2 - 1.43	13	0.58	<0.2 - 1.95	9	0.91	< 0.4 - 0.94	3			
Horses				0.76	0.25 - 2.44	46	1.32	< 0.4 - 1.88	5			
Pigs + sows	0.96	0.26 - 2.06	28	2.58	0.39 - 6.6	170	0.82	< 0.4 - 2.94	173	0.45	0.45 - 2.4	7
Piglets	0.92	0.25 - 2.31	61	1.24	<0.2 - 3.88	128	0.93	< 0.4 - 2.63	75			
Chicken	2.15	0.78 - 3.93	12				1.11	1.07 - 7.10	3	<0.4	<0.4	3
Turkeys	1.70	0.82 - 2.95	11				*	*	*	<0.4	<0,4	2
Laying hens	1.33	0.82 - 2.37	20	2.11	0.89 - 4.04	40	1.46	1.36 - 5.65	5	<0.4	<0.4 - 0.73	6
Dogs + cats	0.42	0.20 - 0.81	35	0.48	0.20 - 0.97	6						
Trouts	0.85	<0.2 - 2.49	5	1.82	1.01 - 4.35	5						
Carps	1.13	0.24 - 3.34	7									

Tab. 15: Molybdenum in feeds

Sodium (*table 16*)

Na can enter ready mixed feeds via basic feed material, via simple NaCl addition or just as a counter ion for added anions, like sulphate, selenate, molybdate or organic acids, particularly in the mineral mixtures. Na in feeds of vegetable origin is lower than in feeds of animal origin.

The Na content of the flora is species specific and ranges between 300-3000 mg/kg. Na in vegetation significantly decreases with plant age and also depends on available amounts from the soil.

Mineral feeds for laying hens contained about double as much Na as for growing chicken. In their composite feeds trouts get more Na than carps.

Na %	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	no	Median	Range	no	Median	Range	no	Median	Range	no
Deer				0.334	0.147 - 0.55	8						
Cattle				0.433	0.101 - 2.01	75	7.74	1.05 - 11.45	133			
Calves	0.542	0.41 - 0.71	13	0.552	0.234 - 3.64	45	3.83	0.88 - 6.10	8			
Sheep + goats	0.357	0.241 - 0.81	13	0.393	0.308 - 2.58	9	6.04	5.05 - 6.19	5			
Horses				0.396	0.164 - 6.27	46	7.11	3.44 - 7.55	5			
Pigs + sows	0.176	0.100 - 0.46	28	0.612	0.219 - 1.52	171	5.10	2.11 - 7.11	190	0.187	0.044 - 0.64	8
Piglets	0.226	0.128 - 0.51	61	0.682	0.195 - 2.93	134	4.42	1.93 - 6.36	72			
Chicken	0.150	0.090 - 0.22	12				4.01	3.90 - 4.47	3	1.82	1.04 - 3.18	3
Turkeys	0.171	0.099 - 0.21	11				*	*	*	0.355	0.264 - 0.447	2
Laying hens	0.147	0.121 - 0.21	21	0.328	0.210 - 0.633	41	7.12	6.07 - 8.65	6	0.141	0.059 - 0.46	5
Dogs + cats	0.417	0.231 - 0.69	35	0.472	0.054 - 1.37	7						
Trouts	0.528	0.464 - 0.72	6	0.265	0.142 - 0.33	5						
Carps	0.207	0.021 - 0.33	7									

Tab. 16: Sodium in feeds

Nickel (*table 17*)

In case of nickel, feeds and green plants are usually lower than the levels met in arable soils, which are 8-29 mg/kg in the median, except for a few geochemically enriched locations [10]. Among possible feed materials, soya (4.8 mg/kg) and sun flower seeds (3.7 mg/kg) may be the main sources of Ni [22]. Like for chromium, some contamination from milling and grinding during the feed production processes may be possible [20]. The rather modest detection limits obtained within this dataset were unfortunately due to laboratory blanks, whereas the sensitivity of the instrument itself would be about four times better. The threshold limit for waste deposition on bare soil, which is currently 100 mg/kg, was hardly reached. In China, the median concentration of Ni in feeds for chicken was found at 12.6 mg/kg, for pigs at 7.8 mg/kg and for dairy cows at 2.3 mg/kg, which is substantially higher for chicken [15].

Ni mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	no	Median	Range	no	Median	Range	no	Median	Range	no
Deer				2.70	1.2 - 7.6	9						
Cattle				3.82	1.5 - 20.1	72	14.5	5.6 - 46	125			
Calves	<0.8	<0.8 - 2.3	10	4.46	1.2 - 8.4	44	6.7	2.3 - 16.0	8			
Sheep + goats	1.66	<0.8 - 5.6	13	2.04	0.9 - 8.4	8	8.0	3.8 - 12.5	4			
Horses				2.37	0.85 - 7.12	46	14.7	6.9 - 49	5			
Pigs + sows	1.78	<0.8 - 3.9	28	5.94	1.7 - 13.8	170	12.9	6.4 - 35	180	47.1	7.8 - 127	8
Piglets	1.78	<0.8 - 12.0	59	6.09	1.0 - 15.9	116	26.2	10.3 - 45	73			
Chicken	2.33	2.00 - 3.19	12				12.6	11.6 - 20	3	174	66 - 237	4
Turkeys	2.36	1.58 - 3.83	11				*	*	*	22.1	20.8 - 23.3	2
Laying hens	2.05	1.34 - 4.15	20	3.42	2.00 - 10.1	40	28.9	15.7 - 62	5	18.0	7.5 - 37.2	12
Dogs + cats	1.01	<0.8 - 2.8	35	1.19	<0.8 - 2.5	7						
Trouts	1.80	<0.8 - 2.6	5	2.86	2.4 - 4.8	5						
Carps	2.47	1.62 - 4.8	7									

Tab. 17: Nickel in feeds

Phosphorus (*table 18*)

Except for the premixes, phosphorus is of course largely enriched in feeds and consequently in the corresponding excrements, which may lead to eutrophication problems of rivers and lakes adjacent to larger farms. To the contrary, phosphorus in cereals ranges at about 0.3 %, and in potatoes at about 0.2 % dry mass.

P %	Complete feeds			Supplementary feed			Mineral feeds			Premixes		
	Median	Range	no	Median	Range	no	Median	Range	no	Median	Range	no
Deer				0.836	0.488 - 1.38	8						
Cattle				0.919	0.369 - 1.74	76	5.25	1.45 - 12.63	138			
Calves	0.751	0.535 - 1.01	13	0.801	0.408 - 3.74	46	4.67	0.767 - 6.10	8			
Sheep + goats	0.701	0.413 - 1.24	13	0.568	0.154 - 0.76	9	7.46	6.04 - 9.12	5			
Horses				0.546	0.375 - 0.90	46	6.64	2.14 - 8.34	5			
Pigs + sows	0.666	0.386 - 1.03	28	1.445	0.594 - 2.70	176	6.35	2.88 - 8.34	193	0.097	0.040 - 3.45	11
Piglets	0.627	0.418 - 1.94	61	1.383	0.411 - 3.99	136	5.18	2.81 - 8.35	74			
Chicken	0.788	0.697 - 1.065	12				6.88	5.08 - 8.68	2	0.171	0.024 - 0.988	5
Turkeys	0.859	0.781 - 1.14	11							0.022	0.019 - 0.026	2
Laying hens	0.662	0.577 - 0.785	21	1.196	0.847 - 1.89	41	12.7	7.47 - 16.2	7	0.284	0.015 - 0.59	6
Dogs + cats	1.079	0.677 - 1.37	35	0.766	0.202 - 1.83	7						
Trouts	1.336	1.23 - 1.50	6	1.275	1.009 - 1.36	5						
Carps	1.156	0.84 - 1.40	6									0

Tab. 18: Phosphorus in feeds

Lead (*table 19*)

Mean crust level of Pb is about 18 mg/kg. In Austrian arable soils median values of 5-33 mg/kg were found, but river and lake sediments may contain much more. Phosphates and lime hardly contribute to the Pb load of mixed feeds. Inside-kept domestic animals surely ingest less Pb than humans, particularly those who move in urban traffic have got high intakes. Pb contents in many single and supplementary feeds were below the detection limit, but for monitoring purposes it was not necessary to apply more sensitive determination methods. In areas without anthropogenic Pb pollution, grains, seeds, potatoes and fruits are expected to contain 0.1-0.5 mg/kg dry mass, whereas herbs, leafy vegetables and green plants usually range within 0.5-3.0 mg/kg. Food of animal origin (for men, dogs and cats) is usually below 0.1 mg/kg dry mass [25].

In the EU, complete feeds have been permitted to contain 5 mg/kg, supplementary feeds 10 mg/kg and mineral feeds 15 mg/kg [31]; these were not exceeded within the sampling period. In China, Pb contents of feeds were generally higher at a median of 7.2 mg/kg for chicken, 10.7 mg/kg for pigs and 5.8 mg/kg for dairy cows [15].

Pb mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	no	Median	Range	no	Median	Range	no	Median	Range	no
Deer				0.49	<0.3 - 1.39	8						
Cattle				0.49	<0.3 - 2.7	73	3.1	<0.5 - 9.5	127			
Calves	<0.3	<0.3 - 0.53	13	0.64	<0.3 - 2.10	43	2.0	0.7 - 4.5	8			
Sheep + goats	0.38	<0.3 - 2.4	12	0.38	<0.3 - 0.82	9	4.7	3.7 - 13.7	4			
Horses				0.37	<0.3 - 1.0	44	2.5	0.9 - 5.4	6			
Pigs + sows	0.30	<0.3 - 0.68	28	0.68	<0.3 - 2.3	173	2.8	0.9 - 11.2	189	10.2	6.3 - 25	8
Piglets	<0.3	<0.3 - 1.19	62	0.68	<0.3 - 2.3	132	2.7	1.0 - 8.2	72			
Chicken	<0.3	<0.3 - 0.39	11				2.1	2.0 - 2.4	3	38.1	15.2 - 80	4
Turkeys	<0.3	<0.3 - 0.66	11				*	*	*	3.5	3.5	2
Laying hens	0.42	<0.3 - 1.08	19	0.68	0.32 - 3.43	38	2.5	1.6 - 4.1	6	7.7	4.0 - 19.3	5
Dogs + cats	0.42	<0.3 - 0.80	35	0.57	<0.3 - 0.93	6						
Trouts	0.31	<0.3 - 0.59	6	<0.3	<0.3 - 0.62	5						
Carps	0.89	<0.3 - 2.12	6									

Tab. 19: Lead in feeds

Strontium (*table 20*)

The mean crust level of Sr is 370 mg/kg [13]. Sr sources are lime, particularly mussel shells. In green plants and cereals strontium concentrations hardly change with plant age [26]. Chinese samples were at the same levels [15]. Whereas Ca- and Na-intake for laying hens seem to be higher than for growing chicken, Sr-intake seems to be just slightly more, which might be due to the use of chemicals instead of naturally occurring limestone.

Sr mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	no	Median	Range	no	Median	Range	no	Median	Range	no
Deer				24.0	17.0 - 67.4	7						
Cattle				21.4	9.3 - 70.4	72	151	39 - 435	120			
Calves	3.0	2.6 - 8.6	10	21.1	5.9 - 420	43	109	7.5 - 264	8			
Sheep + goats	13.0	2.1 - 22.6	12	12.5	5.5 - 16.5	9	237	139 - 741	4			
Horses				15.7	5.5 - 63.0	46	132	72.2 - 284	5			
Pigs + sows	10.1	4.8 - 25.7	28	35.3	10.9 - 112	169	178	51 - 474	177	96	47 - 177	8
Piglets	10.1	4.1 - 33.9	61	22.6	5.1 - 119	128	128	55 - 380	72			
Chicken	20.8	9.7 - 32.0	11				135	108 - 315	3	151	70 - 241	4
Turkeys	17.0	7.2 - 38.0	11				*	*	*	93	87 - 100	2
Laying hens	21.3	14.0 - 38.5	20	46.7	22.5 - 86.0	40	328	225 - 402	5	117	77 - 174	6
Dogs + cats	13.1	6.5 - 34.0	35	11.0	2.4 - 21.4	7						
Trouts	43.1	27.4 - 68	5	24.9	19.2 - 57.0	5						
Carps	26.5	18.1 - 62.1	6									

Tab. 20: Strontium in feeds

Vanadium (*table 21*)

Vanadium mean crust level is 160 mg/kg, but about half of the V is not soluble in soils and sediments without using hydrofluoric acid [13].

Main sources for feedstuffs are crude phosphates; some of them contain more than 200 mg/kg, but a threshold has not been set. In green plants, V is expectable at about 0.1 mg/kg.

Top levels of vanadium were encountered in mineral feeds for laying hens.

V mg/kg	Complete feeds			Supplementary feeds			Mineral feeds			Premixes		
	Median	Range	No	Median	Range	No	Median	Range	no	Median	Range	no
Deer				2.35	0.31 - 3.87	8						
Cattle				0.75	0.15 - 2.86	72	17.5	2.4 - 64	125			
Calves	0.03	<0.02 - 0.8	10	2.39	0.21 - 6.06	44	13.2	4.5 - 35	8			
Sheep + goats	0.29	<0.02 - 0.8	13	0.38	0.07 - 1.01	9	15.3	7.2 - 63	4			
Horses				1.11	0.35 - 18.5	46	17.2	8.2 - 41	5			
Pigs + sows	0.79	0.18 - 2.6	28	3.10	0.82 - 10.7	169	26.9	5.2 - 56	180	12.0	2.4 - 47	8
Piglets	0.94	0.08 - 3.0	60	3.81	0.15 - 14.8	127	23.9	7.1 - 41	72			
Chicken	1.29	0.67 - 2.5	12				44	12 - 58	3	5.9	2.6 - 24.3	4
Turkeys	1.90	0.39 - 4.0	11				*	*	*	2.5	2.3 - 2.7	2
Laying hens	1.57	0.17 - 2.6	20	4.14	0.86 - 6.5	40	73	53 - 101	5	3.7	2.0 - 8.4	6
Dogs + cats	0.20	0.10 - 1.14	35	3.45	<0.02 - 4.79	7						
Trouts	1.17	0.30 - 4.9	5	2.62	1.93 - 3.43	5						
Carps	2.06	<0.02 - 5.8	7									

Tab. 21: Vanadium in feeds

Zinc (*table 22*)

Cereals grown in Lower Austria contained median Zn concentrations within 10-47 mg/kg, depending on sort and soil type [21] and maize was even lower. Similar average Zn concentrations in cereals, oil seeds and soya were found in Germany between 25 and 52 mg/kg, potatoes had just 14 mg/kg [22].

Products of animal origin and fishmeal contain higher Zn concentrations than green plants and limestones. The Zn contents in crude phosphates ranged from 34-329 mg/kg (ten samples), which is higher than for non-contaminated soils. Very often, Zn was added as ZnO or similar compounds to supplementary feeds, mineral feeds and premixes. Many samples of the mineral feeds exceed the threshold values for waste deposition or storage at bare soil, which is 500 mg/kg [18]. For pigs, feeding 250 mg/kg organically bound zinc was as effective as 2000 mg/kg fed as ZnO [27].

In the southeast US, laying hens were fed a diet containing 2000 mg/kg Zn in order to prevent degradation of uric acid to ammonia in their excrements. 3000 mg/kg finally depressed their body weight, feed consumption and egg production. Main problem was the threefold enrichment (based on dry weight) of zinc in the respective manure [28]. In China, zinc was used as an additive in feeds for chicken, pigs and cattle within the range 27-400 mg/kg [15].

In the EU, permitted zinc levels are rather low [30] and they have been exceeded quite often; in case of complete feeds for piglets and poultry, even the median value for our samples was higher than the EU-threshold, thus necessitating further strict controls.

Zn	Complete feeds mg/kg			Supplementary feeds mg/kg			Mineral feeds %			Premixes %		
	Median	Range	no	Median	Range	no	Median	Range	no	Median	Range	no
Deer				138	69.1 - 198	7						
Cattle				305	75 - 1717	75	0.442	0.041 - 0.945	103			
Calves	130	54 - 456	25	354	61 - 4419	40	0.203	0.121 - 0.335	7			
Sheep + goats	142	36.4 - 267	53	118	12.7 - 196	11	0.470	0.444 - 0.563	3			
Horses				166	57 - 389	46	0.363	0.144 - 0.415	6			
Pigs + sows	119	54 - 201	30	398	120 - 1215	170	0.317	0.126 - 0.807	187	1.45	1.08 - 4.27	7
Piglets	144	63 - 241	61	521	42 - 2636	133	0.309	0.152 - 0.688	65			
Chicken	116	60 - 163	12				0.366	0.196 - 0.535	2	2.70	1.09 - 4.32	2
Turkeys	98	74 - 161	11				*	*	*	*	*	*
Laying hens	92	65 - 149	21	189	103 - 384	41	0.277	0.208 - 0.411	5	1.08	0.73 - 1.93	5
Dogs + cats	208	40 - 309	35	21	12.4 - 48	5						
Trouts	183	117 - 312	6	206	137 - 380	5						
Carps	154	51 - 273	7									

Tab. 22: Zinc in feeds

Element proportions

Due to reasons of text shortage, the presentation of element proportions is restricted to data from complete feeds. This is, what the animals exclusively get. Like for the concentrations presented above, the range covers 5-95 % of data.

In the mineral feeds, the Na/K proportions differed widely, probably because of the addition of Na as a counter ion for other additives (data not given). In complete feeds, Na/K ranged largely within 0.1-1.3 and the ranges between poultry as the lowest (0.16) and dogs and cats as the highest (0.61) were not overlapping (*table 23*).

With respect to mean crust occurrence of 4.1 % Ca and 2.3 % Mg, Ca was found enriched in all type of feedstuffs over Mg. The proportion of Ca/Mg in feeds for laying hens was significantly higher than for other kinds of domestic animals (just slightly overlapping with feeds for cats and dogs). Whereas Ca/Mg in complete feeds largely ranged within 1-10, the proportion was 15.2 for laying hens (range 10.5-23.7). Premixes for pigs and poultry, mineral feeds for calves and supplementary feeds for cats and dogs covered a wide range of Ca/Mg with occasionally high Ca, whereas for cattle, sheep, horses and piglets Ca/Mg was kept at a narrow range (*table 23*).

Al and Fe have many common properties in oxic environments, but different physiology. In spite of 8.2 % Al and 4.1 % Fe as their mean crust abundance,

Fe was four- to fivefold in excess in most types of feeds. Complete feeds for poultry and carps showed a significantly higher proportion of Al/Fe than those for dogs and cats, the others were inbetween. Also Ca/P proportions in complete feeds ranged within 0.5-3, but for laying hens it was within 4.7-6.9. In cattle, too low Ca:P ratios lead to osteopenia, whereas Ca:P > 6:1 results in excessive calcification [3].

Complete feeds	Na/K			Ca/Mg			Al/Fe			Ca/P		
Calves	0.313	0.28 - 0.38	13	7.02	3.1 - 10.6	13	0.114	0.056 - 0.40	13	1.31	1.03 - 1.44	13
Sheep	0.313	0.23 - 0.72	13	5.84	3.7 - 8.1	12	0.391	0.013 - 1.12	12	2.22	1.35 - 3.16	12
Pigs	0.224	0.14 - 0.50	26	3.85	1.5 - 5.7	28	0.360	0.088 - 1.39	28	1.29	0.60 - 2.01	28
Piglets	0.282	0.17 - 0.59	60	4.72	1.9 - 6.7	59	0.208	0.073 - 0.82	56	1.20	0.47 - 1.88	58
Laying hens	0.200	0.13 - 0.29	19	15.2	10.5 - 23.7	21	0.513	0.24 - 1.12	20	5.36	4.67 - 6.87	21
Chicken	0.155	0.13 - 0.22	12	5.78	2.9 - 6.3	12	0.512	0.31 - 0.94	12	1.34	1.23 - 2.00	12
Turkeys	0.192	0.10 - 0.32	11	5.65	3.9 - 8.9	11	0.597	0.28 - 1.45	11	1.32	1.27 - 1.66	11
Dogs + cats	0.610	0.40 - 1.30	35	12.2	7.8 - 17.7	34	0.155	0.049 - 0.31	34	1.28	0.94 - 1.55	34
Trouts	0.476	0.32 - 0.83	4	6.93	5.3 - 10.2	5	0.282	0.096 - 1.47	4	1.39	1.15 - 1.63	5
Carps	0.190	0.02 - 0.36	7	4.97	1.0 - 8.4	6	0.787	0.131 - 1.87	6	1.44	0.51 - 2.15	6

Tab. 23: Proportions of macro-elements

Similarly, among the complete feeds, the Na/P ratio was lowest for turkeys (median 0.18) and with 0.68 highest for calves (*table 24*).

When Fe/Mn ratios are considered, Mn was enriched about tenfold with respect to their mutual global occurrence. Occasionally low Mn concentrations made the Fe/Mn proportion highly variable in feeds for cats and dogs. In mineral feeds for poultry, Fe/Mn was just about half of the level for the others. Among the complete feeds, Fe/Mn was lowest for calves (*table 24*).

Cu and Zn are often added as soluble salts, and Cu/Zn is kept largely at 1/5. Significantly more Cu was found in feeds for piglets, whereas mineral mixtures for sheep were extremely low in Cu. With respect to mean crust occurrence of Zn at 75 mg/kg and Cu at 50 mg/kg, this means a strong enrichment of zinc.

For most feeds, median level of the Co/Ni proportion was about 0.3, which is the expectable ambient level. More Co was given to calves in all types of feeds and to trouts. In addition, some more mineral mixtures were enriched in Co over Ni, at highest for sheep.

Fortunately, Cd/Zn ratios were found below ambient levels of 0.001-0.003, which means that the added Zn salts hardly contain Cd. Cd/Zn was slightly higher in feeds for poultry, sheep and fish. Cd/P was within the same range throughout, strongly indicating the raw phosphates as the Cd source.

Complete feeds	Na/P			Fe/Mn			Cu/Zn			Co/Ni		
Calves	0.68	0.53 - 0.86	13	1.73	0.10 - 3.98	13	0.154	0.06 - 0.36	13	2.37	0.30 - 8.01	13
Sheep	0.51	0.34 - 1.27	13	3.87	2.81 - 7.51	13	0.123	0.01 - 0.24	13	0.30	0.12 - 1.49	11
Pigs	0.28	0.20 - 0.52	26	3.28	0.98 - 10.03	30	0.228	0.10 - 1.98	30	0.24	0.09 - 1.12	28
Piglets	0.35	0.14 - 0.63	58	3.32	1.80 - 7.87	60	0.864	0.18 - 1.33	60	0.29	0.05 - 0.98	54
Laying hens	0.22	0.18 - 0.32	21	2.48	1.12 - 3.80	20	0.191	0.14 - 0.27	21	0.31	0.13 - 0.66	20
Chicken	0.19	0.14 - 0.23	12	1.91	1.76 - 3.51	12	0.163	0.12 - 0.27	12	0.26	0.19 - 0.39	12
Turkeys	0.18	0.10 - 0.25	11	2.00	1.38 - 3.26	11	0.357	0.18 - 0.91	11	0.25	0.17 - 0.44	11
Dogs + cats	0.41	0.28 - 0.74	34	6.26	2.33 - 20.0	32	0.094	0.06 - 0.19	35	0.30	0.11 - 0.96	33
Trouts	0.40	0.33 - 0.48	5	9.58	2.25 - 13.8	5	0.137	0.05 - 0.22	5	0.78	0.37 - 6.46	4
Carps	0.16	0.03 - 0.26	6	4.89	2.45 - 9.21	6	0.170	0.11 - 0.50	7	0.89	0.04 - 1.09	7

Tab. 24: Proportions of macro- and micro-elements

Differences due to target animals

Though physiology and feeding habits of precursor forms of our domestic animals may differ widely (e. g. ruminant – pig – cat – chicken – trout), differences in inorganic compositions are low and identification of the target animal from inorganic data only looks hardly possible. Single element data are overlapping, but some differences can be recognized in element proportions. Piglets were fed with significantly more Cu over Zn than all others. Feeds for calves and cattle differed rarely, except that calves sometimes got more Co over Ni, than the older ones. Mineral feeds for sheep also contained more Co over Ni than feeds for other receptors. Cats and dogs received more Cd over Zn, more Ca over Mg via all feeds than others and among the supplementary feeds, variation of Fe over Mn was by far the largest. Referring to poultry, growing chicken and turkeys roughly got feed of the same (inorganic) composition, whereas the premixes for the laying hens were significantly lower for a lot of elements (Al, B, Ba Be, Co, Cu, Fe, Li, Mn, Na, Ni, Pb). To the contrary, complete feeds and premixes for laying hens contained significantly more calcium. Similarly, some differences in complete feed composition for trouts and carps appeared due to their different habitats and feeding habits, which necessitated a subdivision: more crude fat, crude protein and Na for trouts and more Al and Mg for carps (for details see [29]). Carps got less Cd over Zn, Fe over Al, and Co over Ni than trouts. When just the main elements Na-K-Mg-Ca-P in complete feeds were considered, cluster analysis roughly parted the datasets into cats+dogs/sheep/trouts as first group, poultry as a second group, pigs and piglets as a third group and calves as a fourth one, whereas datasets for cattle and horses could match everywhere.

Factor analysis

In two separate runs, the data of all complete feeds, and also the data of all supplementary feeds were submitted to factor analysis in order to reduce the number of variables and subsequently to recognize significant components. For the SPSS program, the element concentrations were taken as start variables and the samples as datasets. The factor analyses were run separately for all complete feeds together, for all supplementary feeds together, as well as for the largest datasets per se. The subsequent *table 25* shows the rotated factor matrices (factor weights > 0.6).

	Complete feeds	Interpretation	Supplementary feeds	Interpretation
I	Mn-Mo-Na	Added chemicals	Ca-Co-Mn-Na-P-Sr-Zn	Added lime and chemicals
II	Al-Be-Li-V	Background elements	Be-Cd-Cr-V	Background elements
III	Ba-Fe		Al-Ba	Background elements
IV	Ca-Cd-Cu-P-Sr	Added lime and phosphate	K-Mo	Green plants
V	Zn	Added zinc salts		
VI	K			

	Suppl. feeds for cattle	Interpretation	Suppl. feeds for pigs	Interpretation
I	Al-Be-Ca-Cr-Fe-Mg-Na-Sr-Zn		Be-Ca-Fe-Pb-Zn	
II	Cu-Mn	Added chemicals	K	
III	Li-Pb-V	Dust	Cr	
IV	K-Mo	Green plants	Ni	
V	P-Ba		Co	Added chemical
VI	Ni		Ba	

	Mineral feed for cattle	Interpretation	Mineral feed for piglets	Interpretation
I	Be-Cr-Fe		Be-Cd-Cr-P	Crude phosphate
II	Cr-V	Steel abrasion ?	Cu-Fe-Mn	Added chemicals
III	Ca		Ca-Na	
IV	-		Al-Ba	Geogenic component
V	Sr		Mg-Zn	Added chemical
VI	Li		Co-V	
			Mo-Ni	
			Li-Pb	

Tab. 25: Qualitative results of factor analyses

The commercial feeds are a mixture of various components, like added chemicals, added phosphates and background elements (clays?), which is reflected in the interpretation below: Whereas in the complete feeds, added chemicals and added phosphates yielded two independent components, they built one common component in the supplementary feeds. In case of supplementary feeds for cattle, for pigs, as well as for mineral feeds for cattle and for pigs, enough samples were available to run a special factor analysis calculation. In supplementary feeds for cattle, Cu-Mn formed a significant component, whereas Co dominated factor 5 in supplementary feeds for pigs. In mineral feeds for cattle, Ca and Sr fell apart, which is contrary to the ambient abundance of Sr. In the mineral feeds for piglets, the factors can be clearly interpreted as component chemicals containing Cu-Mn-Fe, Ca-Na, Zn-Mg and Co. The cadmium came along with the phosphates.

Conclusions

Screenings of suitable sample digests by multi-element techniques like ICP-OES yield rapid overviews about the macro- and micro-element contents and cover also a lot of elements which are not usually considered for current evaluations, without spending further efforts. As expected, complete feeds are lower in macro- and micro-elements than supplementary feeds than mineral feeds and premixes. Composite feeds are usually higher in macro- and micro-elements than cereals or potatoes. Some concentration ranges may be quite ample and just a few differences between target animals appear. In domestic animals feeding practice, proportions of essentials have been kept within narrow ranges. The current dataset can be used to recognize atypical element patterns.
Element screening is recommended before starting more detailed investigations.

References

[1] *Sager M.*: Aktuelle Elementgehalte in Fleisch und Innereien aus Österreich. Ernährung/Nutrition 2005; 29(5): 199-206.

[2] *Sager M.*: Trace and nutrient elements in manure, dung and compost samples, Soil Biology & Biochemistry 2006; in press.

[3] *Van Soest P.J.*: Nutritional Ecology of the Ruminant, Cornell University Press, Ithaca and London, 1994.

[4] EU Richtlinie 76/371/EWG.

[5] *Sager M.*: Statistische Betrachtungen zur Vermahlung von Getreide, ALVA Jahrestagung Fachgruppe Pflanzenanalyse, Hollabrunn 3.6. 1998.

[6] *Sager M.*: Selenium in agriculture, food and nutrition. Pure Appl. Chem. 2006; 78(1): 43-65.

[7] *Gustafson G. M., Olsson I.*: Partitioning of nutrient and trace elements in feed between body retention, faeces and urine by growing dairy-breed steers. Acta Agric. Scand. 2004; 54 A: 10-19.

[8] *Sager M.*: Ökologie des Aluminiums, Schweiz. Z. Hydrol. 1986; 48(1): 71-103.

[9] *Ysart G., Miller P., Crews H., Robb P., Baxter M., De L´Argy Ch., Lofthouse S., Sargent Ch., Harrison N.*: Dietary exposure estimates of 30 elements from the UK total diet study. Food Add. Contam. 1999; 16(9): 391-403.

[10] *Danneberg O.H.*: Hintergrundwerte von Spurenelementen in den landwirtschaftlich genutzten Böden Ostösterreichs. Mitt. Österr. Bodenk. Ges. 1999; 57: 7-24.

[11] *Sager M.*: Occurrence and mobility of arsenic in environment and agriculture in Austria, Inz. Chim Ekol. 2006; 13: 1-16.

[12] *Kpomblekou A.-K., Ankumah R.O., Ajwa H.A.*: Trace and nontrace element contents of broiler litter. Commun. Soil Sci. Plant Anal. 2002; 33(11& 12): 1799-1811.

[13] *Bowen H.J.M.*: Environmental Chemistry of the Elements. Academic Press London, New York Toronto 1979.

[14] *Anke M., Jaritz M., Dorn W., Seifert M., Müller R., Hoppe Ch.*: The biological importance of barium in the food chain of humans. In: Metal elements in environment, medicine and biology, Vol. 5: *Z. Garban, P. Dragan, G. Garban* (eds.), Timisoara 2002.

[15] *Cang L., Wang Y.-J., Zhou D.-M., Dong Y.-H.:* Heavy metals pollution in poultry and livestock feeds and manures under intensive farming in Jiangsu Province, China. J. Environ. Sci. 2004; 16(3): 371-374.

[16] *Sager M.:* Cadmium in Futtermitteln – mögliche Quellen, ALVA – Herbsttagung Fachgruppe Futtermittel, Schladming 18.10. 1993.

[17] *Spiegel H., Dachler M., Böhm K.E., Pfundtner E., Roth K., Sager M.*: Cadmium in der Umwelt – ein Statusbericht über Österreich. Die Bodenkultur 1999; 50(4): 293-304.

[18] 164. Verordnung des Bundesministers für Umwelt über die Ablagerung von Abfällen (Deponieverordnung), vom 10. April 1996, BGBl.49 / 1996.

[19] *Okine E.K., Goonewardene L.A., Mathison G.W., Wang Z., Suleiman A.*: Chromium content of selected Alberta feedstuffs. Can. J. Animal sci. 2001; 81(4): 615.

[20] *Sager M., Mittendorfer J.*: Influence of Milling or Cutting Procedures on Trace Element Contents of Plant Samples, Int. J. Environ. Anal. Chem. 1997; 67: 59-71.

[21] *Sager M., Hösch J.*: Macro- and micro-element levels in cereals grown in Lower Austria. Journal of Central European Agriculture 2006; 6(4): in press.

[22] *Brüggemann J.*: Erwünschte und unerwünschte Spurenelemente in Getreide, Kartoffeln und Ölsaaten. Schriftenreihe des BM für Ernährung, Landwirtschaft und Forsten, Reihe A, Angew. Wiss. 1999; 483: 32-51.

[23] *Prosba-Bialczyk U., Mydlarski M.*: Wpływ warunków siedliska i właściwosci odmian na zawartóśc pierwiestkow śladowych w bulwach ziemniaka. Biul. Inst. Hodowli I aklim. Roslin 2000; 213: 45-53.

[24] *Jondreville C., Revy P.S., Jaffrezic A., Dourmad J.Y.*: Le cuivre dans l´alimentation du porc: oligoélément essentiel, facteur de croissance et risque pour l´Homme et l´environement. INRA Prod. Anim. 2002; 15(4): 247-265.

[25] *Anke M., Grün M., Müller M., Müller R, Schäfer U., Seifert M.*: Lead in the food chain – lead intake and lead balance of man. In: Metal elements in Environment, Medicine and Biology, *Z. Garban, P. Dragan* eds., Timisoara 2004; Vol. VI: 5-26.

[26] *Seifert M., Jaritz M., Holzinger S., Seeber O., Anke M.*: Alimentary strontium intake: first results in Germany. Trace Elem. Electrol. 2000; 17(3): 112-118.

[27] *Mullan B.P., Wilson R.H., Harris D., Allen J.G., Naylor A.*: Supplementation of weaner pig diets with zinc oxide of BiopexTM Zinc. In: Nutritional Biotechnology in the Feed and Food Industries, Proc. of Alltech´s Eighteenth Annual Symposium, *T. Lyons* and *K.A. Jacques* eds., Nottingham Univ. Press 2002.

[28] *Kim W.K., Patterson P.H.*: Effects of dietary zinc supplementation on hen performance, ammonia volatilization and nitrogen retention in manure. J. Environ. Sci. Health 2005; 40B: 675-686.

[29] *Sager M.*: Über die anorganischen Inhaltsstoffe von kommerziell erhältlichem Fischfutter. Österreichs Fischerei 2004; 57(8/9): 206-221.

[30] Richtlinie 2002/32/EG des Europäischen Parlaments und des Rates über unerwünschte Stoffe in der Tierernährung.

[31] Richtlinie 2003/100/EG zur Änderung von Anhang I zur Richtlinie 2002/32/EG des Europäischen Parlaments und des Rates über unerwünschte Stoffe in der Tierernährung.

[32] Richtlinie 2005/87/EG der Kommission vom 5. Dezember 2005 zur Änderung von Anhang I der Richtlinie 2002/32/EG des Europäischen Parlaments und des Rates über unerwünschte Stoffe in der Tierernährung in Bezug auf Blei, Fluor und Cadmium.

The author gratefully acknowledges critical comments of our in-house veterinarian expert, DI Mag. *Veronika Kolar*.

Address of the author:

Univ. Doz. Dr. Manfred Sager
Austrian Agency for Health and Food Safety
Competence Centre for Elements
(Österreichische Agentur für Gesundheit und Ernährungssicherheit
Kompetenzzentrum Elemente)
Spargelfeldstrasse 191
A - 1226 Wien
t +43 (0) 50555 /32801
e-mail: manfred.sager@ages.at

Eingelangt am: 15.3.2006
Akzeptiert am: 15.9.2006