Study

THE EFFECTS OF HUMIC ACID METAL CHELATES ON RATS

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Introduction

Based on recent research data on the physiological role of microelements, it can clearly be concluded that certain metal ions play a fundamental role in the different biological processes. Presently, from among the elements that occur in a long-lasting form, approximately 76 elements have been shown to have some kind of a physiological role.

It is known that – with regard to their metal ion requirements – these biological processes are strongly specific, i.e. only a certain metal ion, in a defined state is capable of participating in a particular biological reaction. However, there are less specific processes as well, in which a given metal ion can be substituted by another one without affecting the process significantly.

From the viewpoint of the physiological roles of microelements, the direct effects upon the structure of enzymes, or the indirect effects upon the activation of enzymes, are of primary importance.

In our experiments we studied the changes in the deposition, translocation and elimination properties of cobalt, iron, zinc, selenium, copper, molybdenum, and cadmium introduced into the bodies of rats either in inorganic compounds, or bound to an organic carrier, in chelated form. We also studied the changes in the whole-body and the organ weights of the experimental animals.

When making the study design, we took into account the wish of Horizon Multiplan KKT. – even though we disagreed with their professional justification based primarily on complex chemical arguments – to apply the metal ions in the same form as they appear in their product called HUMET-R, which is already approved for human consumption.

Metal ion-ligand interactions, the possibility of microelement absorption

Even though thousands of ligands and many metal ions are present simultaneously in living organisms, the formation of only certain metal-complexes is possible. A particular metal ion prefers certain ligands, while practically it does not interact with others.

The complex-forming reaction can be regarded as an acid-base reaction, in which the metal ion, functioning as Lewis-acid (it picks up an electron pair), unites with one or more ligands functioning as Lewis-base (it releases an electron pair). Thus, it can be concluded that if the basicity of the ligand and/or the acidity of the metal ion increases, the stability of the formed complex will increase as well. The stability of the complexes of different metal ions shows a certain pattern, which is related to the size and charge of the ion. The complexes of some temporary metal's divalent ions formed with different ligands are given as follows in the order of stability: e.g. Mn < Fe < Co < Ni < Cu > Zn. The stability of the complex increases significantly, if the metal ion binds to a multi-site ligand, and so chelate complexes are formed.

Hence the microelement absorption depends on the parameters of the system in which it occurs, or into which it is to integrate. The key parameters are the pH-value, the redox-potential and the chemical form, in which the given element can be found.

Beside the complex chemical processes, the question of synergism and antagonism, i.e. the way in which simultaneously present microelements influence each other's physiological roles, is highly important.

The synergistic and antagonistic effects of the studied metal ions on one another is going to be highlighted below.

Cadmium – as a toxic heavy metal – plays an important role in the physiological interaction of certain microelements. The toxic effect of cadmium is due to its effect by which it decreases the activity of several, zinc-containing enzymes; and thus by administering zinc

in large doses, cadmium toxicity can be avoided. It has also been proven that by administering selenium, the physiological consequences of a toxic dose of cadmium can be reduced, or prevented, as selenium blocks cadmium absorption.

Cadmium-copper interaction varies with different animal species. Copper absorption through the placenta is reduced in the presence of cadmium, however, by adding copper, the adverse physiological effect of cadmium can be avoided.

Copper and zinc, selenium and copper, molybdenum and copper, and selenium and zinc are typical antagonists. For example introducing copper in large doses alone can result in zinc-deficiency, and similarly, by adding zinc we can get copper-deficiency. The high copper content of the feed will reduce the molybdenum and selenium uptake in rats.

The uptake of microelements, beside of course the synergistic and antagonistic effects, is influenced by many factors, including the presence of other cations and anions.

Materials and methods

- **Test animals**

We used Wistar female rats of 205 g (± 10 g) average weight randomised into groups at the beginning of the treatment. The animals were kept in a room of constant temperature (23 ± 2 °C) and humidity (55 ± 12%), and alternating lighting. For feed the rats were given trace element deficient rat food (hereinafter NYHT, LATI, Gödöllő) and tap water ad libitum.

The animals were kept in plastic rat cages of types II and III (5 animals/cage). For the purpose of quantitative and qualitative study of metabolism 5-5 animals selected into different experimental groups were kept in special cages fit for measuring metabolism.

In the experiments with pregnant animals (2 males and 2 females per animals cage) after keeping the males together with the females for 4 days, actual mating was controlled by taking daily vaginal smears. The pregnant animals were then kept alone in plastic cages of type II.

During the experiment, the general physical condition of the animals was checked daily and any eventual deaths were also recorded. The weights of the animals were recorded one week before starting the test, then weekly, until the termination of the experiment.

- **Compounds used**

In our comparative studies we used two products supplied by Horizon Multiplan KKT., one was the HUMET (AHR) product containing the desired trace elements (Cu, Co, Fe, Zn, Mo, Se) in an activated form, the other was a product (SZNYK) containing the active trace elements in their inorganic compound form. In both cases the metal contents of the products were identical.

The compounds were given to the test animals according to the predetermined trace element dosage, in quantities of 1.0 ml per day through gastric tube.

In Group 2.b, as a decorporating compound, we applied an undoted humic acid product (HA). (For treatment details see the sections on study groups below.)

In the case of pregnant animals the activated trace elements were given to the animals in inorganic and chelate forms, respectively, similarly to the other animals, through a gastric tube, from the date of the mating. For Groups 3.b and 3.c the daily gastric tube treatments were continued until delivery, while the animals in Group 3.a were given normal food.

- **Assessing the change in whole-body and organ weights**

Animal weights were recorded one week before starting the experiment, then weekly, for 4 weeks.

On Days 3, 7, 14, 17 and 28, following the starting of the experiment, the animals were anaesthetised and blood samples were taken, then we removed the brain, lungs, heart, spleen, liver, kidneys, we took samples from the thigh bone, vertebra and thigh muscle. The weights of the organs and the occurring macroscopic alterations were recorded. The organ samples, and the daily faeces and urine samples, after weighing, were placed in sample containers and following proper marking with identification numbers, were given to the representatives of Horizon Multiplan KKT. for activity measurement.

In the case of pregnant animals, after delivery, the weights of the newborn animals were recorded regularly. From each litter 2-2 newborn rats, after body weight and activity measurement, were placed in a sample container, and similarly to the organ samples, were dispatched for activity measurement.

- **Determination of trace element content by activation analysis method**

Of the experimental animals that were pre-fed with trace element deficient food, we anaesthetised 4 (Day 0 of the experiment), and after taking blood samples, we removed the liver, spleen, kidneys, we took a sample from the thigh muscle, and after weighing them into a quartz vial, we dispatched the samples for activation analysis. From the samples potassium, magnesium, iron, zinc, manganese, copper, vanadium, cobalt, molybdenum and selenium content were determined. The same metals were determined in samples of the trace element deficient food.

In a similar manner, Horizon Multiplan performed the metal assay on Day 14, and also, including cadmium, on Day 28 of the experiment.

- **Measurement of whole-body, excretion and newborn radioactivity**

The whole-body activity of the radioactive trace elements administered to the experimental animals through a gastric tube was measured 30 minutes after the first dose, then before the gastric tube treatments daily, with a NUC-8100 measurement system furnished with a semiconductor detector (Oxford Instruments Inc. Nuclear Measurements Group). Each time, measurement results were compared to an etalon or standard (rat phantom), the activity of which was identical with that characteristic of the given isotope. We measured the change of whole-body activity of the experimental animals through time for 28 days. In the case of every single test animal, the first single dose was regarded as the initial whole-body load (100%) and then all additional measured activity values were compared to this baseline (expressed as a percentage thereof).

After starting the experiment the quantity of the excrement (faeces) and urine during 24 hours was measured daily and their radioactivity was also checked. Our measurement results were compared with the "excretion" etalon, the activity of which was identical with the whole-body etalon. We followed a similar procedure in the case of the newborn rats.

The retention and other measurements were performed for each animal; then the resulting data were averaged by groups. For the better illustration of the results the graphs show the mean values of the measurement scores and not the interpolated curves.

The retention values of radioactive elements and the biological half-times were determined using an equation expressed as the sum of two exponential values, i.e. the method of non-linear regression. The differences between treatments were analysed using the Student t-test.

- **Test Groups**

The laboratory rats were acclimatised to experimental conditions for one week before starting the study.

The number of animals given for each group received the following treatments:

Group 1: trace element intake in **inorganic** form — 29 animals

Group 1.a.:

After pre-feeding with NYHT for 3 days (Day 0 of the experiment), SZNYK given daily until the end of the experiment through gastric tube. The animals were kept in a special metabolism cage. — 5 animals

Group 1.b.:

After pre-feeding with NYHT for 3 days (Day 0 of the experiment), SZNYK given daily until Day 14 of the experiment, and after Cd exposures on Days 14 and 15 starting from Day 16 1 ml tap water given daily until the end of the experiment through gastric tube. — 24 animals (9 animals)

Group 2: trace element feeding in **chelate complex** form — 29 animals

Group 2.a.:

After pre-feeding with NYHT for 3 days (Day 0 of the experiment), AHR given daily during the entire test period through gastric tube, plus Cd exposure on Days 14 and 15. The animals were kept in a special metabolism cage. — 5 animals

Group 2.b.:

After pre-feeding with NYHT for 3 days (Day 0 of the experiment), AHR given daily until Day 14 of the experiment, and after Cd exposure Days 14 and 15, starting from the 16th day, 1 ml HA daily until the end of the experiment through gastric tube. — 24 animals (9 animals)

Group 3: pregnant animals 3 x 5 — 15 animals

After the mating of the rats (From Day 0 of the experiment).

Group 3.a.:

Normal food given until the end of the experiment. — 5 animals

Group 3.b.:

Parallel with NYHT feeding, SZNYK given daily through gastric tube until delivery. On Day 18 of pregnancy Cd exposure through gastric tube. — 5 animals

Group 3.c.:

Parallel with NYHT feeding, AHR given daily through gastric tube until delivery. On Day 18 of the pregnancy Cd exposure through gastric tube. — 5 animals

After delivery the litters of differently treated dams were replaced in order to determine the newborn animals' trace element excretion (active newborn – inactive dam) and uptake (inactive newborn – active dam).

Results

Table 1 gives a summary of the fundamental chemicophysical (half-life, specific activity etc.) and biological (target organ, biological half-time etc.) properties of the radioisotopes applied.

Table 1: Summary of the chemicophysical and biological properties of the applied radioisotopes

Isotope	Absorption % (GIT)	Target organ	Half-life (day)		Symptoms		Daily dose (μg)
			Physical	Biological	Deficiency	Excess weight	
59-Fe	(2-15)	WB, S	45	800, 600	Anemia	Siderosis	200
60-Co	(20-30)	L	5,27 year	125	Anemia	Cor. Deficiency Polycytemia	2.9
64-Cu	(20-30)	WB, Li, B	12,8 hours	80, - , -	Anemia Hair loss	Wilson disease	28.7
65-Zn	(10-30)	WB, L, Li	245	930, 120, -	Dwarfism Gonad atrophy	Fever	140
75-Se	(80-90)	L, K, Li	121	125, 11, -	Liver necrosis Muscle atrophy	Mad cow disease (cattle)	1.7
99-Mo	(80-90)	Li, K, RB	67 hours	5 (WB)	-	-	2.5
115-Cd	(5-8)	Li, K, RB	53 hours	30 years (WB)	Growth inhibition	Nephritis	1000

Abbreviations: GIT – gastrointestinal system
WB – whole-body; S – spleen; L – lungs; Li – liver; B – bone; K – Kidney; RB - blood

Whole-body weight results are given in Tables 2-3 and Figure 1. It has been found that the body weights of rats increased constantly by minimum extent up to Day 14 of the treatment both in the case of metals administered in inorganic and that in chelated form. As from Day 14, body weight growth accelerated in the group receiving chelate treatment, however this increase was not significant in the comparison of the two treatment groups. For better comparison, the figure also shows the changes in the weights of animals fed with normal food for similar duration and kept under similar circumstances also.

Changes in the organ weights of experimental animals through the treatment period are summed up in Figures 2 and 3 and Tables 4 and 5, respectively. The results show no differences either in organ weights or in relative organ weight (organ weight as of whole-body weight) in the two groups treated with trace elements in inorganic and chelated compounds, respectively.

Table 2. Effect of trace elements administered in inorganic form upon the organ weights of rats

Date	m/d/y	5/25/94	Killed	Diff.	6/1/94	Killed	Diff.	6/8/94	Killed	Diff.	6/15/94	Killed	Diff	6/22/94	Killed	Diff	6/29/94
	(day)	-7			0			7			14			21			28
	An'l no.			0			7			14			21			28	
No.	30	Bodyw (gr		(day)	Bodyw (gr		(day)	Bodyw (gr		(day)	Bodyw (gr		(day)	Bodyw (gr		(day)	Bodyw (gr)
1	1	226		8	234		-10	224		2	226		3	229		-6	223
2	2	203		-3	200	+	-6	194		2	196		4	200		1	201
3	3	220		8	228	+	0	228		-2	226		4	230		2	232
4	4	205		-1	204	+	-2	202		2	204		6	210		2	212
5	5	195		0	195	+	0	195		-3	192		8	200		5	205
6	6	208		8	216	+											
7	7	220		0	220	+											
8	8	214		3	217												
9	9	178		1	179												
10	10	208		8	216												
11	11	204		1	205												
12	12	192		6	198		3	201	+								
13	13	208		-3	205		-2	203	+								
14	14	212		-3	209		0	209	+								
15	15	202		8	210		3	213	+								
16	16	217		5	222		11	233		0	233	+					
17	17	207		9	216		-1	215		-2	213	+					
18	18	204		4	208		5	213		4	217	+					
19	19	197		3	200		-2	198		8	206	+					
20	20	205		3	208		2	210		4	214	+					
21	21	203		10	213		-3	210		3	213	+					
22	22	224		6	230		-9	221		4	225	+					
23	23	220		7	227		-3	224		2	226	+					
24	24	207		6	213		-2	211		-3	208		0	208	+		
25	25	204		0	204		3	207		2	209		1	210	+		
26	26	194		4	198		3	201		2	203		0	203		11	214
27	27	228		0	228		44	232		5	237		-2	235		5	240
28	28	205		3	208		-6	202		1	203		8	211		2	213
29	29	188		4	192		15	207		2	209		-2	207		2	209
30	30	211		5	216		12	228		-5	223		2	225		4	229
Average		206.97		3.67	210.63		0.63	211.71		1.40	214.15		2.67	214.00		2.80	217.80
(+/-SD)		11.34		3.80	12.44		6.08	11.67		3.14	12.21		3.47	12.37		4.24	12.66

Table 3. Effect of trace elements administered in chelate form upon the organ weights of rats

Date	m/d/y	5/25/94	Killed	Diff	6/1/94	Killed	Diff	6/8/94	Killed	Diff	6/15/94	Killed	Diff	6/22/94	Killed	Diff	6/29/94
	(day)	-7			0			7			14			21			28
	An'l no			0			7			14			21			28	
No	30	Bodyw (gr		(day)	Bodyw (gr		(day)	Bodyw (gr		(day)	Bodyw (gr		(day)	Bodyw (gr		(day)	Bodyw (gr)
1	1	198		6	204		0	204		6	210		6	216		3	221
2	2	202		4	206		-3	203		4	207		2	209		5	214
3	3	225		2	227		1	228		17	245		0	245		6	251
4	4	226		10	236		-1	235		-7	228		5	233		6	239
5	5	201		5	206		-8	198		5	203		6	209		9	218
6	6	206		3	209	+											
7	7	215		9	224	+											
8	8	198		7	205	+											
9	9	181		-1	180	+											
10	10	218		1	219	+											
11	11	198		-3	195	+											
12	12	198		5	203		1	204	+								
13	13	208		-6	202		10	212	+								
14	14	220		8	228		3	231	+								
15	15	214		0	214		-2	212	+								
16	16	219		-3	216		-1	215		6	221	+					
17	17	202		3	205		3	208		2	210	+					
18	18	218		7	225		-4	227		6	227	+					
19	19	208		8	216		-3	213		3	216	+					
20	20	204		12	216		-4	212		10	222	+					
21	21	206		9	215		1	216		9	225	+					
22	22	208		4	212		0	212		6	218	+					
23	23	180		6	186		2	188		-3	185	+					
24	24	220		6	226		3	229		0	229		0	229	+		
25	25	225		10	235		1	236		4	240		6	246	+		
26	26	219		9	228		-10	218		8	226		12	238		4	242
27	27	208		9	217		-8	209		27	236		-2	234	+		
28	28	201		7	208		-13	195		11	206		10	216		3	219
29	29	198		-3	195		-9	186		14	200		6	206		9	215
30	30	205		5	210		-12	198		8	206		7	213		11	224
Average		207.63		4.63	212.27		-2.21	211.79		6.80	218.00		4.83	224.50		6.44	227.00
(+/-SD)		11.64		4.55	13.40		5.50	13.70		7.22	14.79		4.15	14.61		2.65	13.45

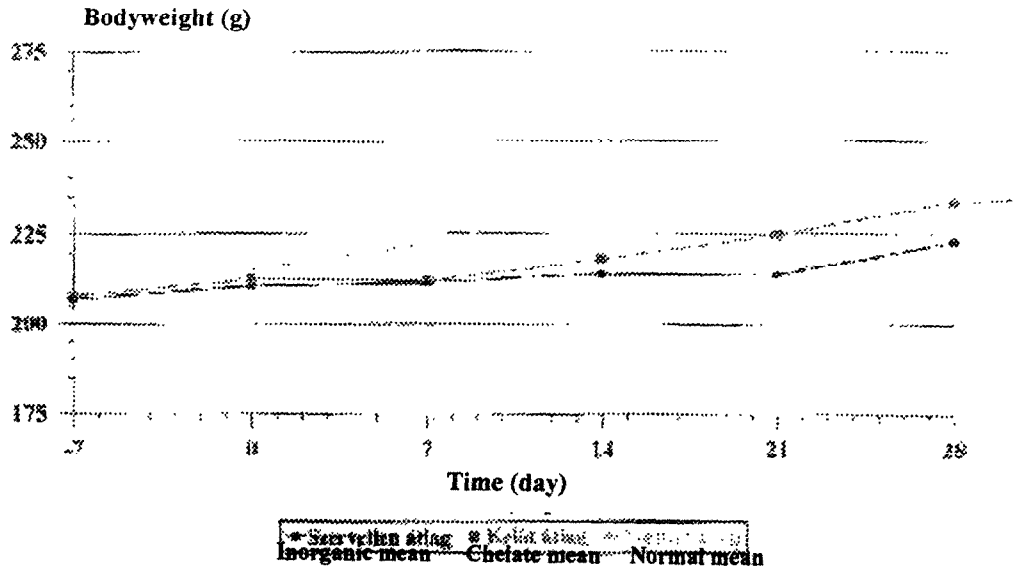

Figure 1: Effects of trace elements administered in inorganic or chelated compounds on organ weight changes of test animals

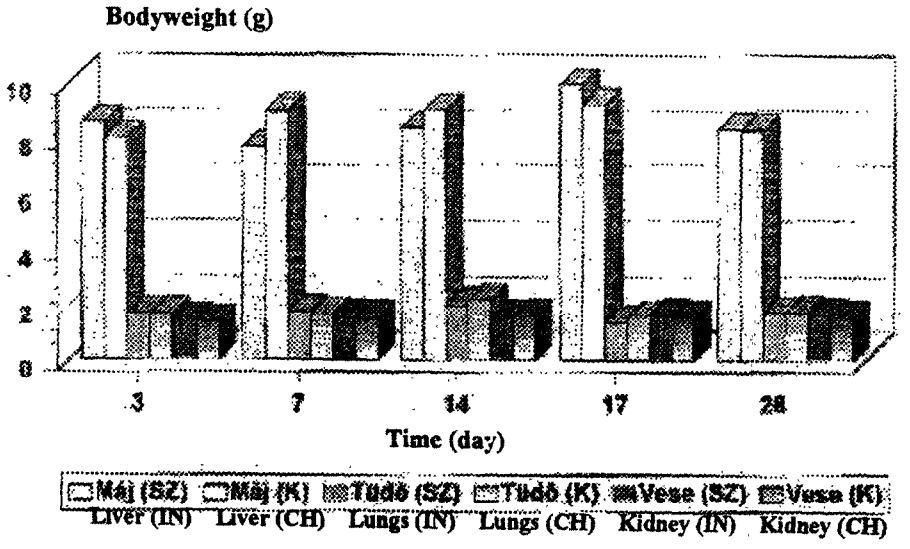

Figure 2: Effects of trace elements administered in inorganic or chelated compounds on organ weight changes of test animals

Table 4. Effect of trace element administered in inorganic form upon the body weights of rats

Time (day)	Animal number	Whole body (WB)	Brain weight	B/WB (%)	Lungs weight	Lu/WB (%)	Heart weight	H/WB (%)	Spleen weight	S/WB (%)	Liver weight	Li/WB (%)	Kidney weight	K/WB (%)
3	8	217	1.58	0.728	1.68	0.774	0.79	0.364	0.63	0.290	9.69	4.465	1.65	0.760
3	9	179	1.65	0.922	1.76	0.983	0.77	0.430	0.53	0.296	6.83	3.816	1.30	0.726
3	10	216	1.35	0.625	1.62	0.750	0.87	0.403	0.58	0.269	9.85	4.560	1.57	0.727
3	11	205	1.54	0.751	1.68	0.820	0.88	0.429	0.53	0.259	7.96	3.883	1.56	0.761
	Average	**204.3**	**1.53**	**0.757**	**1.69**	**0.832**	**0.83**	**0.407**	**0.57**	**0.278**	**8.58**	**4.181**	**1.52**	**0.744**
	(+/-SD)	**17.7**	**0.13**	**0.123**	**0.06**	**0.105**	**0.06**	**0.031**	**0.05**	**0.018**	**1.45**	**0.386**	**0.15**	**0.020**
7	12	205	1.20	0.585	1.97	0.961	0.88	0.429	0.45	0.220	8.22	4.010	1.51	0.737
7	13	203	1.48	0.729	1.37	0.675	0.91	0.448	0.53	0.261	8.25	4.064	1.61	0.793
7	14	209	1.51	0.722	2.11	1.010	0.75	0.359	0.65	0.311	7.34	3.512	1.65	0.789
7	15	213	1.72	0.808	1.70	0.798	0.86	0.404	0.49	0.230	6.86	3.221	1.45	0.681
	Average	**207.5**	**1.48**	**0.711**	**1.79**	**0.861**	**0.85**	**0.410**	**0.53**	**0.255**	**7.67**	**3.702**	**1.56**	**0.750**
	(+/-SD)	**4.4**	**0.21**	**0.092**	**0.33**	**0.153**	**0.07**	**0.039**	**0.09**	**0.041**	**0.68**	**0.406**	**0.09**	**0.053**
14	16	221	1.21	0.548	1.65	0.747	0.89	0.403	0.57	0.258	8.86	4.009	1.48	0.670
14	17	213	1.74	0.817	2.01	0.944	0.77	0.362	0.52	0.244	8.83	4.146	1.54	0.723
14	18	217	1.79	0.825	2.54	1.171	0.77	0.355	0.48	0.221	8.50	3.917	1.70	0.783
14	19	206	1.62	0.786	1.96	0.951	0.68	0.330	0.44	0.214	7.35	3.568	1.69	0.820
	Average	**214.3**	**1.59**	**0.744**	**2.04**	**0.953**	**0.78**	**0.362**	**0.50**	**0.234**	**8.39**	**3.910**	**1.60**	**0.749**
	(+/-SD)	**6.4**	**0.26**	**0.132**	**0.37**	**0.173**	**0.09**	**0.030**	**0.06**	**0.020**	**0.71**	**0.247**	**0.11**	**0.066**
17	22	225	1.10	0.489	1.42	0.631	0.76	0.338	0.58	0.258	10.35	4.600	1.68	0.747
17	23	226	1.40	0.619	1.39	0.615	0.72	0.319	0.65	0.288	9.53	4.217	1.70	0.752
	Average	**225.5**	**1.25**	**0.554**	**1.41**	**0.623**	**0.74**	**0.328**	**0.62**	**0.273**	**9.94**	**4.408**	**1.69**	**0.749**
	(+/-SD)	**0.7**	**0.21**	**0.092**	**0.02**	**0.011**	**0.03**	**0.014**	**0.05**	**0.021**	**0.58**	**0.271**	**0.01**	**0.004**
28	1	223	1.24	0.556	2.00	0.897	0.94	0.422	0.52	0.233	8.00	3.587	1.86	0.834
28	2	201	1.52	0.756	1.87	0.930	0.73	0.363	0.51	0.254	6.44	3.204	1.42	0.706
28	4	212	1.40	0.660	1.45	0.684	0.83	0.392	0.47	0.222	8.30	3.915	1.52	0.717
28	5	205	1.23	0.600	1.36	0.663	0.80	0.390	0.42	0.205	7.67	3.741	1.55	0.756
28	27	240	1.48	0.617	1.76	0.733	0.79	0.329	0.52	0.217	7.98	3.325	1.51	0.629
28	28	213	1.47	0.690	1.83	0.859	0.84	0.394	0.69	0.324	9.23	4.333	1.70	0.798
28	29	209	1.59	0.761	1.55	0.742	0.82	0.392	0.50	0.239	8.52	4.077	1.78	0.852
28	30	229	1.40	0.611	1.85	0.808	0.62	0.271	0.49	0.214	7.64	3.336	1.76	0.769
	Average	**222.8**	**1.49**	**0.670**	**1.75**	**0.785**	**0.77**	**0.347**	**0.55**	**0.248**	**8.34**	**3.768**	**1.69**	**0.762**
	(+/-SD)	**14.4**	**0.08**	**0.071**	**0.14**	**0.059**	**0.10**	**0.059**	**0.09**	**0.052**	**0.69**	**0.516**	**0.12**	**0.095**

Table 5. Effect of trace elements administered in chelate form upon the body weights of rats

Time (day)	Animal number	Whole body (WB)	Brain weight	B/WB (%)	Lungs weight	Lu/WB (%)	Heart weight	H/WB (%)	Spleen weight	S/WB (%)	Liver weight	Li/WB (%)	Kidney weight	K/WB (%)
3	8	205	1.41	0.688	1.97	0.961	0.77	0.376	0.67	0.327	10.44	5.093	1.43	0.698
3	9	180	1.15	0.639	1.51	0.839	0.67	0.372	0.45	0.250	7.01	3.894	1.22	0.678
3	10	219	1.38	0.630	1.71	0.781	36531	0.484	0.65	0.297	8.26	3.772	1.62	0.740
3	11	195	1.57	0.805	1.52	0.779	0.79	0.405	0.54	0.277	6.35	3.256	1.44	0.738
	Average	**199.8**	**1.38**	**0.690**	**1.68**	**0.840**	**0.82**	**0.409**	**0.58**	**0.288**	**8.02**	**4.004**	**1.43**	**0.713**
	(+/-SD)	**16.4**	**0.17**	**0.081**	**0.22**	**0.085**	**0.17**	**0.052**	**0.10**	**0.032**	**1.80**	**0.777**	**0.16**	**0.031**
7	12	204	1.38	0.676	1.27	0.623	0.76	0.373	0.53	0.260	8.46	4.147	1.52	0.745
7	13	212	1.43	0.675	1.87	0.882	0.79	0.373	0.73	0.344	8.45	3.986	1.62	0.764
7	14	231	1.41	0.610	1.79	0.775	0.81	0.351	0.66	0.286	9.33	4.039	1.69	0.732
7	15	212	1.33	0.627	1.78	0.840	0.69	0.325	0.49	0.231	9.75	4.599	1.38	0.651
	Average	**214.8**	**1.39**	**0.647**	**1.68**	**0.780**	**0.76**	**0.355**	**0.60**	**0.280**	**9.00**	**4.193**	**1.55**	**0.723**
	(+/-SD)	**11.5**	**0.04**	**0.033**	**0.27**	**0.114**	**0.05**	**0.022**	**0.11**	**0.048**	**0.65**	**0.279**	**0.13**	**0.050**
14	16	221	1.52	0.688	2.40	1.086	36538	0.511	0.68	0.308	11.22	5.077	1.82	0.824
14	17	210	1.57	0.748	2.23	1.062	0.69	0.329	0.68	0.324	7.81	3.719	1.67	0.795
14	18	227	1.73	0.762	2.15	0.947	0.73	0.322	0.81	0.357	9.21	4.057	1.71	0.753
14	19	216	1.48	0.685	1.98	0.917	0.80	0.370	0.79	0.366	7.84	3.630	1.47	0.681
	Average	**218.5**	**1.58**	**0.721**	**2.19**	**1.003**	**0.84**	**0.383**	**0.74**	**0.339**	**9.02**	**4.121**	**1.67**	**0.763**
	(+/-SD)	**7.2**	**0.11**	**0.040**	**0.17**	**0.084**	**0.20**	**0.088**	**0.07**	**0.027**	**1.61**	**0.664**	**0.15**	**0.062**
17	22	218	1.49	0.683	1.64	0.752	0.78	0.358	0.51	0.234	10.20	4.679	0.80	0.367
17	23	185	1.69	0.914	1.53	0.827	0.64	0.346	0.38	0.205	8.30	4.486	0.68	0.368
	Average	**201.5**	**1.59**	**0.798**	**1.59**	**0.790**	**0.71**	**0.352**	**0.45**	**0.220**	**9.25**	**4.583**	**0.74**	**0.367**
	(+/-SD)	**23.3**	**0.14**	**0.163**	**0.08**	**0.053**	**0.10**	**0.008**	**0.09**	**0.020**	**1.34**	**0.136**	**0.08**	**0.000**
28	1	221	1.27	0.575	2.19	0.991	0.76	0.344	0.58	0.262	7.81	3.534	1.65	0.747
28	2	214	1.37	0.640	1.69	0.790	0.75	0.350	0.41	0.192	8.57	4.002	1.57	0.734
28	3	251	1.43	0.570	1.96	0.781	0.99	0.394	0.61	0.243	10.64	4.239	1.99	0.793
28	4	239	1.31	0.548	1.52	0.636	0.81	0.339	0.68	0.285	10.54	4.410	1.71	0.715
28	27	235	1.38	0.587	1.43	0.609	0.87	0.370	0.53	0.226	9.15	3.894	1.71	0.728
28	28	207	1.26	0.609	2.05	0.990	0.78	0.377	0.54	0.261	7.61	3.676	1.51	0.729
28	29	198	1.34	0.677	1.89	0.955	0.70	0.354	0.45	0.227	7.85	3.965	1.47	0.742
28	30	230	1.33	0.578	1.76	0.765	0.76	0.330	0.42	0.183	8.51	3.700	1.72	0.748
	Average	**217.5**	**1.33**	**0.613**	**1.78**	**0.830**	**0.78**	**0.358**	**0.49**	**0.224**	**8.28**	**3.809**	**1.60**	**0.737**
	(+/-SD)	**17.8**	**0.05**	**0.045**	**0.26**	**0.177**	**0.07**	**0.021**	**0.06**	**0.032**	**0.69**	**0.142**	**0.13**	**0.010**

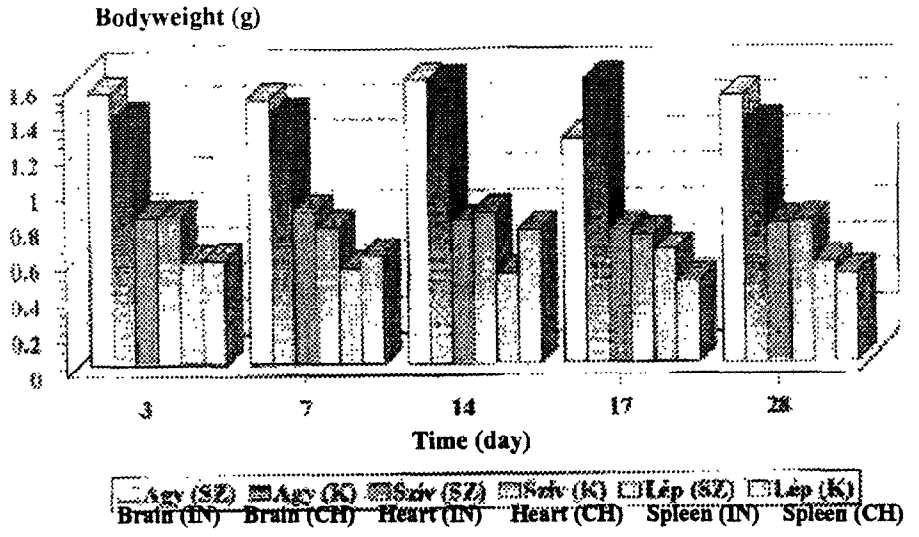

Figure 3: Effects of trace elements administered in inorganic or chelated compounds on organ weight changes of test animals

The daily excrement and urine quantities of animals kept in special metabolism cages are given in Tables 6-9, while the cumulative quantities of excrement and urine weighed on a daily basis throughout the entire study period are given in Figures 4 and 5.

The quantity of excretion per day was practically the same in both treatment groups, however in the case of animals treated with chelated compounds a smaller quantity was experienced always. Probably, as a consequence of the constipation effect of the chelate compound a significant difference ($p<0,05$) was seen in the quantity of excrement from Day 21 of the treatment.

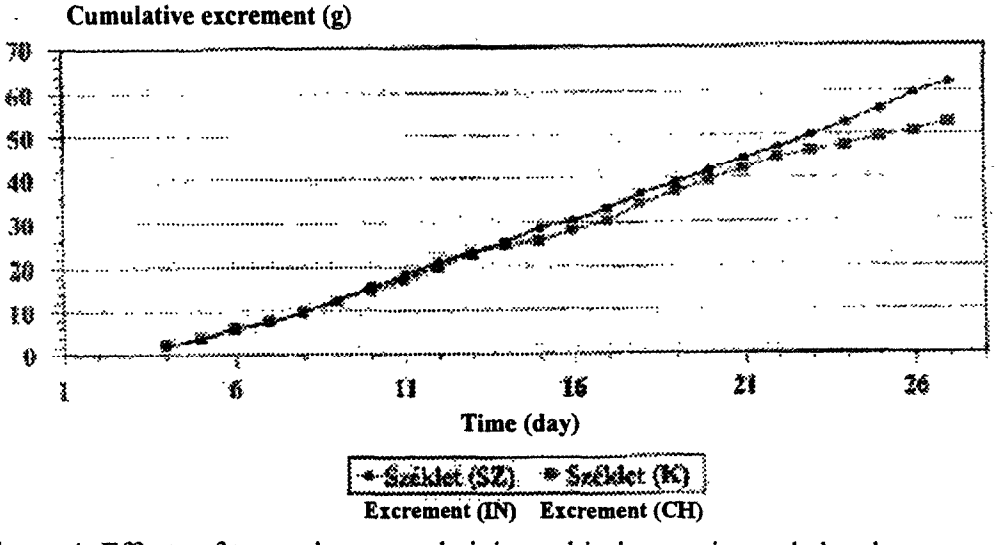

Figure 4: Effects of trace elements administered in inorganic or chelated compounds on daily excrement quantities of test animals

Table 6. Effect of trace elements administered in inorganic form upon the daily excrement quantities of rats in grams

		Number of animals										Faeces weight	
Time	Date	1		2		3		4		5		Average	(+/-)
(day)	2-Jun	Faeces	Diff.	Faeces	Diff.	Faeces	Diff.	Faeces	Diff.	Faeces	Diff.		(SD)
1	3-Jun												
2	4-Jun												
3	5-Jun												
4	6-Jun	2,80		2,29		2,41		1,56		1,61		2,13	0,54
5	7-Jun	1,35	-1,45	1,01	-1,28	1,73	-0,68	2,09	0,53	1,23	-0,38	1,48	1,32
6	8-Jun	2,88	1,53	2,18	1,17	2,42	0,69	2,72	0,63	2,71	1,48	2,58	0,89
7	9-Jun	0,52	-2,36	0,83	-1,35	2,50	0,08	1,39	-1,33	0,83	-1,88	1,21	1,54
8	10-Jun	1,73	1,21	2,09	1,26	4,42	1,92	1,86	0,47	1,59	0,76	2,34	1,08
9	11-Jun	3	1,27	3	0,91	3	-1,42	2	0,14	2	0,41	2,60	1,50
10	12-Jun	4,8	1,80	3,5	0,50	3,94	0,94	2,7	0,70	1,63	-0,37	3,31	1,54
11	13-Jun	2,34	-2,46	2,82	-0,68	2,87	-1,07	2,3	-0,40	2,56	0,93	2,58	2,05
12	14-Jun	3,37	1,03	1,56	-1,26	4,77	1,90	3,32	1,02	1,7	-0,86	2,94	1,73
13	15-Jun	1,07	-2,30	2,34	0,78	3,87	-0,90	0,76	-2,56	1,61	-0,09	1,93	2,11
14	16-Jun	4,36	3,29	2,07	-0,27	1,37	-2,50	2,39	1,63	2,17	0,56	2,47	2,00
15	17-Jun	2,53	-1,83	1,38	-0,69	3,83	2,46	4,15	1,76	3,45	1,28	3,07	2,03
16	18-Jun	1,06	-1,47	1,23	-0,15	2,37	-1,46	2,67	-1,48	1,79		1,82	1,69
17	19-Jun	2,64	1,58	0,84	-0,39	4,23	1,86	2,08	-0,59	2,88		2,53	1,55
18	20-Jun	3,37	0,73	4,75	3,91	4,3	0,07	2,01	-0,07	3,37		3,56	1,86
19	21-Jun	2,53	-0,84	1,98	-2,77	2,26	-2,04	3,02	1,01	2,19		2,40	2,15
20	22-Jun	2,84	0,31	2,4	0,42	3,79	1,53	2,95	-0,07	2,65		2,93	1,37
21	23-Jun	3,04	0,20	2,5	0,10	3,27	-0,52	2,65	-0,30	1,95		2,68	1,54
22	24-Jun	1,45	-1,59	2,8	0,30	3,28	0,01	2,69	0,04	2,1		2,46	1,63
23	25-Jun	3,51	2,06	3,62	0,82	2,08	-1,20		-2,69			3,07	2,37
24	26-Jun	2,96	-0,55	3,28	-0,34	1,88	-0,20					2,71	1,75
25	27-Jun	2,78	-0,18	2,18	-1,10	3,78	1,90					2,91	1,84
26	28-Jun	2,38	-0,40	4,46	2,28	4,98	1,20					3,94	2,01
27	29-Jun	2,91	0,53	1,44	-3,02	2,15	-2,83					2,17	2,54
28	30-Jun		-2,91		-1,44		-2,15						0,74
29	1-Jul												
30	2-Jul												

Table 7. Effect of trace elements administered in inorganic form upon the daily urine quantities of rats in ml

		No. of animals										Urine (ml)	
Time	Date	1		2		3		4		5		Average	(+/-)
(day)	2-Jun	Urine	Diff.	Urine	Diff.	Urine	Diff.	Urine	Diff.	Urine	Diff.		(SD)
1	3-Jun												
2	4-Jun												
3	5-Jun												
4	6-Jun	11,00		12,00		9,50		7,00		9,00		**9,70**	**1,92**
5	7-Jun	9,00	-2,00	12,00	0,00	6,00	-3,50	15,00	8,00	10,00	1,00	**10,40**	**3,36**
6	8-Jun	7,00	-2,00	11,00	-1,00	5,00	-1,00	9,00	-6,00	8,00	-2,00	**8,00**	**2,24**
7	9-Jun	13,00	6,00	10,00	-1,00	5,00	0,00	7,00	-2,00	8,00	0,00	**8,60**	**3,05**
8	10-Jun	11	-2,00	12	2,00	3	-2,00	6	-1,00	6	-2,00	**7,60**	**3,78**
9	11-Jun	15	4,00	14	2,00	4	1,00	6	0,00	8	2,00	**9,40**	**4,88**
10	12-Jun	28	13,00	26	12,00	7	3,00	9	3,00	15	7,00	**17,00**	**9,62**
11	13-Jun	10	-18,00	9	-17,00	4	-3,00	12,2	3,20	4	-11,00	**7,84**	**3,69**
12	14-Jun	15	5,00	8	-1,00	6	2,00	7	-5,20	7	3,00	**8,60**	**3,65**
13	15-Jun	30	15,00	9	1,00	4	-2,00	8	1,00	7	0,00	**11,60**	**10,45**
14	16-Jun	18,8	-11,20	7,9	-1,10	4,9	0,90	8,8	0,80	7,1	0,10	**9,50**	**5,40**
15	17-Jun	11,2	-7,60	12,3	4,10	3,8	-1,10	9,8	1,00	12,2	5,10	**9,86**	**3,53**
16	18-Jun	11	-0,20	8,1	-4,20	4,9	1,10	8,9	-0,90	6,9	-5,30	**7,96**	**2,27**
17	19-Jun	12,5	2,50	12,5	4,40	5,1	0,20	11,2	2,30	9,8	2,90	**10,22**	**3,07**
18	20-Jun	17,5	5,00	14,1	1,60	2,5	-2,60	7,2	-4,00	8,1	-1,70	**9,88**	**5,93**
19	21-Jun	18,8	1,30	8,2	-5,90	4,8	2,30	7,5	0,30	7,8	-0,30	**9,42**	**5,41**
20	22-Jun	16	-2,80	11,5	3,30	5,2	0,40	11,8	4,30	9,9	2,10	**10,88**	**3,89**
21	23-Jun	12,8	-3,20	13,1	1,60	4,8	-0,40	12,6	0,80	8,7	-1,20	**10,40**	**3,61**
22	24-Jun	11,2	-1,60	8,8	-4,30	3,6	-1,20	7,2	-5,40	4,8	-3,90	**7,12**	**3,05**
23	25-Jun	15,6	4,40	4,8	-4,00	3,6	0,00	8,8	1,60	6,2	1,40	**7,80**	**4,77**
24	26-Jun	8,2	-7,40	6,5	1,70	3,5	-0,10	11,9	3,10	5	-1,20	**7,02**	**3,24**
25	27-Jun	16,2	8,00	7,8	1,30	3,8	0,30	5,4	-6,50	7,2	2,20	**8,08**	**4,80**
26	28-Jun	8,2	-8,00	7,2	-0,60	1,8	-2,00		-5,40		-7,20	**5,73**	**3,44**
27	29-Jun	9,7	1,50	1,5	-5,70		-1,80			4,6		**5,27**	**4,14**
28	30-Jun	15,2	5,50	7,1	5,60			12,3		7,3	2,70	**10,48**	**3,96**
29	1-Jul		-15,20		-7,10				-12,30		-7,30		
30	2-Jul												

Table 8. Effect of trace elements administered in chelate form upon the daily excrement quantities of rats in grams

		Number of animals										Faeces weight	
Time	Date	1		2		3		4		5		Average	(+/-)
(day)	2-Jun	Faeces	Diff.	Faeces	Diff.	Faeces	Diff.	Faeces	Diff.	Faeces	Diff.		(SD)
1	3-Jun												
2	4-Jun												
3	5-Jun												
4	6-Jun	3,81		1,55		2,06		1,34		1,46		2,04	1,02
5	7-Jun	1,85	-1,96	1,51	-0,04	1,82	-0,24	1,54	0,20	1,39	-0,07	1,62	0,20
6	8-Jun	1,78	-0,07	3,01	1,50	2,13	0,31	0,94	-0,60	2,63	1,24	2,10	0,80
7	9-Jun	2,07	0,29	1,48	-1,53	1,26	-0,87	1,18	0,24	2,72	0,09	1,74	0,65
8	10-Jun	2,29	0,22	2,56	1,08	2,37	1,11	1,8	0,62	1,61	-1,11	2,13	0,40
9	11-Jun	3,5	1,21	2	-0,56	3	0,63	2	0,20	2	0,39	2,50	0,71
10	12-Jun	3,5	0,00	2,25	0,25	1,51	-1,49	2,75	0,75	2,05	0,05	2,41	0,75
11	13-Jun	2,7	-0,80	1,37	-0,88	2,35	0,84	3,75	1,00	2,63	0,58	2,56	0,85
12	14-Jun	2,97	0,27	1,41	0,04	2,61	0,26	2,85	-0,90	3,29	0,66	2,63	0,72
13	15-Jun	2,27	-0,70	2,27	0,86	3,74	1,13	2,97	0,12	2,9	-0,39	2,83	0,61
14	16-Jun	2,13	-0,14	1,74	-0,53	2,53	-1,21	1,08	-1,89	3,21	0,31	2,14	0,80
15	17-Jun	0,96	-1,17	0,44	-1,30	2,18	-0,35		-1,08		-3,21	1,19	0,89
16	18-Jun	1,99	1,03	1,75	1,31	1,97	-0,21	4,21		2,36		2,46	1,00
17	19-Jun	1,28	-0,71	2,35	0,60	2,94	0,97	2,02	-2,19	1,98	-0,38	2,11	0,60
18	20-Jun	1,45	0,17	3,79	1,44	3,11	0,17	5,81	3,79	4,98	3,00	3,83	1,69
19	21-Jun	4,08	2,63	2,57	-1,22	2,35	-0,76	2,37	-3,44	2,64	-2,34	2,80	0,73
20	22-Jun	2,25	-1,83	2,51	-0,06	3,86	1,51	2,48	0,11	3,07	0,43	2,83	0,65
21	23-Jun	2,92	0,67	1,97	-0,54	2,46	-1,40	2,25	-0,23	2,27	-0,80	2,37	0,35
22	24-Jun	2,68	-0,24	1,71	-0,26	2,93	0,47	2,7	0,45	2,83	0,56	2,57	0,49
23	25-Jun	3,3	0,62	3,57	1,86	1,7	-1,23		-2,70		-2,83	2,86	1,01
24	26-Jun	3,92	0,62		-3,57	1,88	0,18					2,90	1,44
25	27-Jun	3,77	-0,15	0,73		4,57	2,69					3,02	2,03
26	28-Jun	1,62	-2,15	3,45	2,72	2,76	-1,81					2,61	0,92
27	29-Jun	4,31	2,69	1,57	-1,88	3,3	0,54					3,06	1,39
28	30-Jun		-4,31		-1,57		-3,30						
29	1-Jul												
30	2-Jul												

Table 9. Effect of trace elements administered in chelate form upon the daily urine quantities of rats in ml

		Number of animals										Urine (ml)	
Time	Date	1		2		3		4		5		Average	(+/-)
(day)	2-Jun	Urine	Diff.	Urine	Diff.	Urine	Diff.	Urine	Diff.	Urine	Diff.		(SD)
1	3-Jun												
2	4-Jun												
3	5-Jun												
4	6-Jun	8,00		12,00		9,00		13,00		7,00		**9,80**	**2,59**
5	7-Jun	6,00	-2,00	10,00	-2,00	8,00	-1,00	10,00	-3,00	9,00	2,00	**8,60**	**1,67**
6	8-Jun	5,00	-1,00	7,00	-3,00	8,00	0,00	9,00	-1,00	10,00	1,00	**7,80**	**1,92**
7	9-Jun	5,00	0,00	8,00	1,00	5,00	-3,00	6,00	-3,00	5,00	-5,00	**5,80**	**1,30**
8	10-Jun	5	0,00	6	-2,00	7	2,00	5	-1,00	5	0,00	**5,60**	**0,89**
9	11-Jun	5	0,00	6	0,00	6	-1,00	5	0,00	5	0,00	**5,40**	**0,55**
10	12-Jun	7	2,00	9	3,00	12	6,00	12	7,00	6	1,00	**9,20**	**2,77**
11	13-Jun	4	-3,00	8	-1,00	5	-7,00	3	-9,00	6	0,00	**5,20**	**1,92**
12	14-Jun	6	2,00	10	2,00	10	5,00	6	3,00	6	0,00	**7,60**	**2,19**
13	15-Jun	5	-1,00	9	-1,00	11	1,00	11	5,00	4	-2,00	**8,00**	**3,32**
14	16-Jun	4,9	-0,10	7,2	-1,80	12,9	1,90	9,9	-1,10	8,9	4,90	**8,76**	**2,99**
15	17-Jun	3,5	-1,40	1,9	3,70	5,2	-7,70	8,4	-1,50	5	-3,90	**6,60**	**2,99**
16	18-Jun	4,9	1,40	10	-0,90	10,5	5,30	19,5	11,10	6	1,00	**10,18**	**5,75**
17	19-Jun	7,4	2,50	12,3	2,30	8	-2,50	22,5	3,00	10,2	4,20	**12,08**	**6,14**
18	20-Jun	6	-1,40	15	2,70	9	1,00	17,7	-4,80	8,5	-1,70	**11,24**	**4,90**
19	21-Jun	5,8	-0,20	8,6	-6,40	9,2	0,20	7,3	-10,40	6,8	-1,70	**7,54**	**1,37**
20	22-Jun	9,8	4,00	14,5	5,90	8,5	-0,70	17	9,70	11,9	5,10	**12,34**	**3,46**
21	23-Jun	6,8	-3,00	16,6	2,10	8,2	-0,30	18,1	1,10	9	-2,90	**11,74**	**5,21**
22	24-Jun	10,8	4,00	20,1	3,50	3,8	-4,40	14,5	-3,60	2	-7,00	**10,24**	**7,50**
23	25-Jun	5,6	-5,20	13,9	-6,20	9,3	5,50		-14,50		-2,00	**9,60**	**4,16**
24	26-Jun	5	-0,60	9,2	-4,70	8,5	-0,80	14		6,2		**8,58**	**3,47**
25	27-Jun	4,8	-0,20	13,8	4,60	5,4	-3,10	15,5	1,50	4,8	-1,40	**8,86**	**5,33**
26	28-Jun	6,8	2,00	20,5	6,70	7,1	1,70		-15,50		-4,80	**11,47**	**7,82**
27	29-Jun	1,3	-5,50	5,8	-14,70	1	-6,10					**2,70**	**2,69**
28	30-Jun	17,2	15,90	5,2	-0,60	9,2	8,20	13,1				**11,18**	**5,15**
29	1-Jul		-17,20		-5,20		-9,20		-13,10				
30	2-Jul												

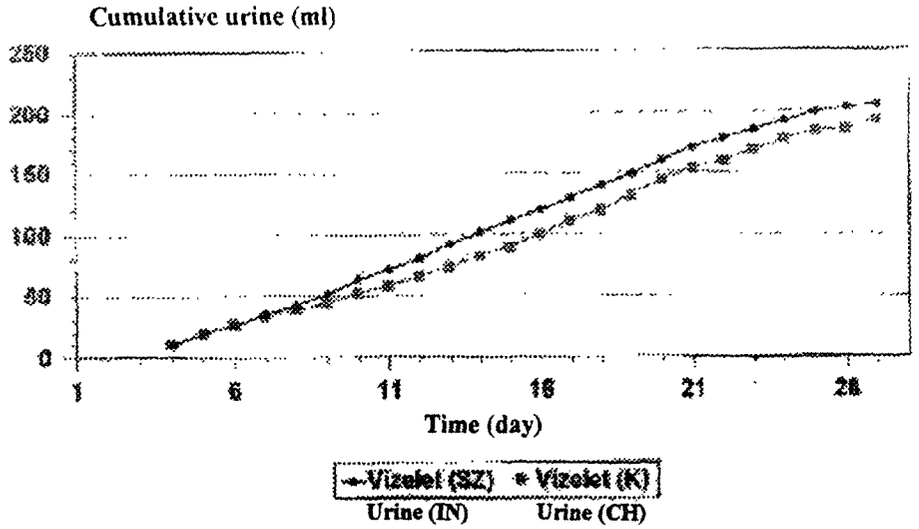

Figure 5: Effects of trace elements administered in inorganic or chelated compounds on daily urine quantities of test animals

Whole-body retention measurements per animal in each group up to Day 14 are summed up in Tables 10-17 (in this period rats received identical treatment, i.e. microelements in either inorganic or chelated compounds), while average values are shown in Figures 6-9.

As can be seen from the whole-body retention curve of cobalt (Figure 6) the quantity of Co-60 taken up from both compound forms was practically in the range of 20-40% during the study period, irrespective of the repeatedly administered isotope quantities. No significant difference in the quantities of cobalt retained in the bodies of rats was observed, although the uptake of isotope was proven more constant in the case of rats treated with chelates.

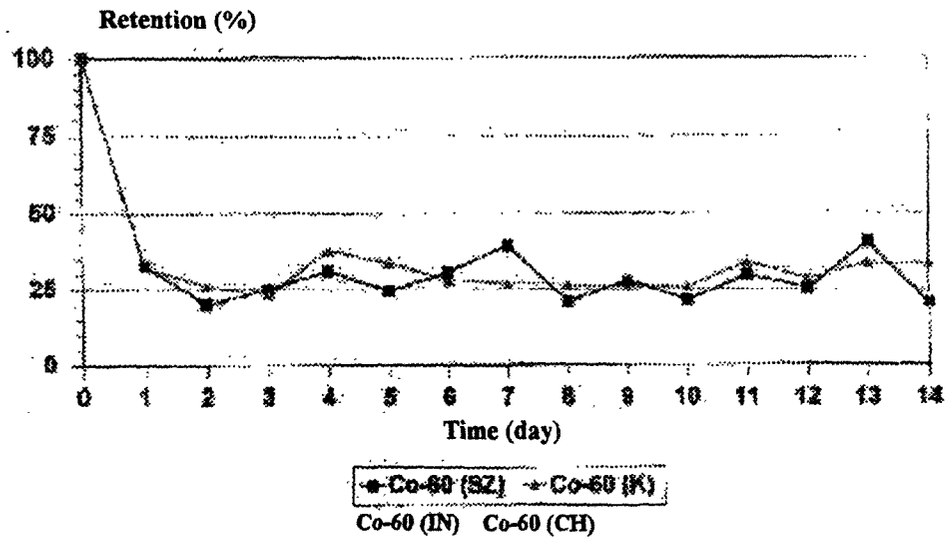

Figure 6: Whole-body retention of Co-60 administered daily in the forms of inorganic and chelated compounds in the rat

Table 10. Whole-body retention of cobalt administered in inorganic form in days 0 to 14 of the study

No. of animals	Time after exposure (day)														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	100	-	25,40	28,22	44,61	903,00	-	-	-	16,99	20,96	43,41	55,36	-	18,74
2	100	-	-	36,28	56,40	34,21	-	38,99	-	8,80	-	45,92	21,87	-	35,11
3	100	-	10,36	19,09	35,85	17,07	-	-	-	-	14,98	-	-	-	10,19
4	100	51,45	27,24	47,93	39,36	48,07	49,27	50,94	-	43,41	40,43	29,58	-	-	29,74
5	100	19,61	15,34	17,78	37,49	16,13	23,32	35,64	-	21,49	27,25	24,71	24,40	-	21,31
6	+														
7	+														
8	100	60,33	27,38	+											
9	100	15,74	33,92	+											
10	100	54,66	21,82	+											
11	100	38,89	10,49	+											
12	100	30,83	24,64	-	11,27	27,17	20,63	+							
13	100	25,93	13,44	18,87	22,38	25,92	20,04	+							
14	100	20,93	32,81	21,77	30,72	44,67	47,22	+							
15	100	-	-	9,65	32,43	38,86	22,72	+							
16	100	17,59	-	57,19	19,16	18,67	-		14,64	29,53	17,58	22,80	21,74	25,22	+
17	100	42,73	20,28	18,00	30,37	43,15	-	26,95	35,84	52,52	28,60	23,91	20,68	57,21	+
18	100	-	13,18	9,83	27,37	6,54	-	19,93	15,07	24,17	22,16	39,44	48,08	28,19	+
19	100	-	10,21	13,05	-	9,85	-	29,17	12,76	16,53	17,19	13,74	13,92	38,12	+
20	100	19,12	28,88	12,83	54,28	57,22	-	88,63	-	49,00	46,48	-	-	-	
21	100	38,56	28,27	30,77	45,47	23,85	-	34,83	28,80	12,52	13,10	44,61	24,88	35,00	-
22	100	82,60	-	-	-	-	-	82,16	-	-	-	-	-	57,89	11,45
23	100	31,52	13,01	37,22	17,65	12,45	-	31,00	13,95	19,73	17,27	11,58	25,29	-	33,26
24	100	34,47	26,71	25,85	22,42	28,75	-	38,68	-	35,40	18,03	42,03	21,03	-	27,31
25	100	38,81	9,44	7,11	18,07	10,99	-	48,00	18,02	50,92	18,28	27,40	25,36	-	11,34
26	100	18,72	13,70	17,20	17,13	14,89	-	50,26	20,89	11,05	10,16	29,59	14,56	-	7,59
27	100	-	12,19	-	-	10,07	-	11,23	-	16,28	14,81	21,03	21,40	-	11,80
28	100	15,36	31,21	37,94	52,15	24,52	-	58,84	-	46,67	-	41,11	-	-	34,53
29	100	14,38	15,98	30,80	12,86	14,73	-	10,87	17,48	30,93	16,88	28,67	17,64	-	-
30	100	14,92	13,52	23,33	23,28	19,37	-	11,61	31,83	14,46	18,31	16,94	20,08	-	11,33
Average	**100**	**32,72**	**19,97**	**24,80**	**30,99**	**24,19**	**30,53**	**39,28**	**20,93**	**27,80**	**21,32**	**29,79**	**25,08**	**40,27**	**20,28**
(+/- SD)	**0**	**18,04**	**8,20**	**13,05**	**13,76**	**14,12**	**13,79**	**22,47**	**8,25**	**14,98**	**9,55**	**11,14**	**11,44**	**14,16**	**10,43**

Table 11. Whole-body retention of iron administered in inorganic form in days 0 to 14 of the study

No. of animals	Time after exposure (day)														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	100	-	103,33	138,79	171,56	92,95	-	-	-	160,77	159,60	231,76	215,76	-	168,82
2	100	71,06	123,42	62,97	104,01	74,77	137,05	79,54	-	46,07	-	91,91	-	-	-
3	100	81,01	65,60	60,34	101,38	58,86	53,98	76,73	-	92,59	73,45	75,63	96,67	-	108,03
4	100	-	-	-	166,47	151,62	160,40	211,99	-	185,78	198,31	218,34	-	-	215,12
5	100	26,09	48,00	41,02	81,85	66,34	68,52	108,68	-	109,13	109,02	103,04	132,23	-	131,68
6	100	+													
7	100	+													
8	100	90,66	57,94	+											
9	100	22,16	51,82	+											
10	100	53,07	49,66	+											
11	100	36,56	34,02	+											
12	100	72,23	78,91	48,27	85,84	136,96	132,72	+							
13	100	38,37	44,90	49,39	86,56	97,39	82,28	+							
14	100	51,98	54,12	55,17	95,22	117,09	111,66	+							
15	100	-	-	38,17	65,28	78,48	60,49	+							
16	100	35,06	18,19	127,14	67,02	70,40	-	97,60	104,39	114,28	127,58	116,00	127,43	178,11	+
17	100	68,45	31,25	23,41	51,48	95,07	-	64,73	98,96	117,80	104,27	103,08	115,63	187,46	+
18	100	15,90	15,39	25,11	76,77	53,71	-	88,67	85,30	113,43	134,52	129,25	167,07	185,20	+
19	100	-	15,28	28,78	34,51	65,14	-	98,72	81,25	101,57	112,18	108,38	128,03	162,17	+
20	100	30,19	42,79	30,46	90,41	93,90	-	147,46	130,71	148,54	154,86	173,26	-	250,82	-
21	100	36,50	43,56	83,96	107,64	109,80	-	137,83	98,81	113,76	129,51	150,42	190,26	193,29	-
22	100	-	121,55	-	-	181,75	-	149,69	153,07	155,89	141,82	202,69	188,70	182,64	183,37
23	100	48,56	52,77	99,47	103,61	129,75	-	131,16	137,29	143,38	152,13	151,63	164,23	-	123,28
24	100	26,13	72,82	37,98	46,75	105,19	-	132,42	129,46	116,66	114,53	149,21	160,97	-	180,24
25	100	48,58	21,35	23,37	42,88	56,51	-	83,28	77,91	121,82	97,04	108,72	108,01	-	103,23
26	100	32,08	40,96	53,32	88,71	71,06	-	139,56	100,72	104,53	116,93	129,25	93,57	-	-
27	100	-	33,42	44,22	55,01	60,23	-	86,09	83,95	102,51	101,82	132,17	154,53	-	143,57
28	100	26,18	52,20	64,94	85,96	75,53	-	107,21	107,21	99,53	136,04	126,68	178,23	-	119,31
29	100	40,48	49,93	64,08	54,19	72,37	-	108,24	111,05	147,51	141,26	142,20	181,84	-	-
30	100	24,07	55,09	70,44	96,66	97,05	-	106,43	140,34	165,50	175,90	199,71	203,89	-	225,11
Average	**100**	**44,33**	**53,01**	**57,76**	**85,21**	**92,16**	**100,89**	**113,48**	**109,36**	**123,05**	**130,57**	**142,17**	**153,36**	**191,38**	**154,71**
(+/- SD)	**0**	**20,76**	**28,40**	**31,27**	**34,02**	**32,64**	**40,01**	**34,86**	**23,67**	**31,67**	**29,80**	**43,29**	**37,82**	**27,98**	**42,43**

Table 12. Whole-body retention of zinc administered in inorganic form in days 0 to 14 of the study

No. of animals	Time after exposure (day)														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	100	-	43,04	63,91	-	50,06	-	-	-	90,41	98,87	-	135,93	-	139,75
2	100	53,49	66,44	39,92	60,15	45,75	92,36	53,43	-	44,71	42,48	73,02	53,67	-	79,91
3	100	43,12	27,24	35,09	61,92	44,73	39,58	43,19	-	54,28	52,20	49,65	52,63	-	85,25
4	100	44,17	41,69	79,69	68,60	69,52	94,70	91,86	-	99,42	92,38	89,07	-	-	110,00
5	100	14,88	18,36	21,22	34,71	34,23	39,51	50,20	-	47,51	53,67	75,94	55,22	-	94,87
6	100	+													
7	100	+													
8	100	48,88	29,71	+											
9	100	20,67	40,40	+											
10	100	47,87	31,25	+											
11	100	34,74	17,57	+											
12	100	30,28	29,12	27,79	37,42	43,90	53,45	+							
13	100	23,48	23,22	23,36	34,92	37,17	42,92	+							
14	100	28,92	37,02	27,95	51,18	54,48	56,29	+							
15	100	14,46	19,44	27,67	51,14	59,03	43,99	+							
16	100	17,63	18,22	-	35,67	34,19	-	44,87	46,15	61,38	57,78	55,92	67,24	75,19	+
17	100	45,79	22,28	16,96	35,03	44,69	-	35,91	60,70	74,55	60,89	57,73	58,64	89,30	+
18	100	14,85	13,38	24,29	39,55	27,46	-	46,45	44,30	55,98	62,92	70,87	96,22	75,00	+
19	100	11,84	16,57	25,56	26,10	33,81	-	56,29	47,75	56,73	53,87	50,96	52,83	74,15	+
20	100	10,70	24,21	18,28	54,98	59,70	-	98,88	93,38	93,73	89,61	109,40	128,05	132,35	-
21	100	22,49	23,28	35,73	42,05	34,37	-	56,56	48,68	43,15	41,63	61,17	66,47	67,57	-
22	100	67,80	53,67	-	-	-	-	93,63	98,19	89,87	97,37	-	114,23	110,29	103,51
23	100	31,42	13,31	55,00	43,58	47,35	-	70,71	68,96	75,25	74,47	64,47	80,12	-	108,75
24	100	32,09	26,70	28,92	35,85	43,89	-	75,41	99,02	75,27	71,48	98,05	86,38	-	133,25
25	100	31,93	10,93	16,96	29,15	22,48	-	56,24	41,71	77,93	57,88	57,40	60,60	-	71,66
26	100	25,31	22,34	32,02	36,38	28,92	-	81,52	53,46	53,64	60,12	75,70	59,80	-	83,27
27	100	18,44	30,50	25,38	31,22	30,60	-	46,84	44,51	50,44	46,75	52,60	62,17	-	65,77
28	100	18,15	39,15	45,80	62,87	38,06	-	72,91	86,65	73,82	94,19	81,58	142,28	-	119,76
29	100	14,50	26,22	44,17	40,78	40,08	-	46,70	56,36	72,21	66,10	71,09	81,44	-	-
30	100	16,08	25,15	36,81	39,34	36,39	-	40,42	56,99	63,40	62,23	67,15	71,73	-	93,41
Average	**100**	**29,04**	**28,23**	**34,20**	**43,30**	**41,78**	**57,85**	**61,16**	**63,12**	**67,68**	**66,85**	**70,10**	**80,30**	**89,12**	**99,17**
(+/- SD)	**0**	**14,88**	**12,60**	**15,74**	**11,96**	**11,40**	**22,85**	**19,44**	**20,87**	**17,08**	**18,39**	**16,48**	**29,40**	**23,80**	**22,73**

Table 13. Whole-body retention of selenium administered in inorganic form in days 0 to 14 of the study

No of animals	Time after exposure (day)														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	100	67,01	98,42	166,94	248,84	188,36	310,68	412,31	-	361,99	529,96	570,56	405,13	-	99,23
2	100	-	-	-	-	373,30	-	538,23	-	689,54	899,79	812,63	696,61	-	172,59
3	100	56,34	97,22	122,48	152,43	136,91	195,96	261,31	-	269,75	294,08	258,23	237,67	-	-
4	100	82,23	139,56	194,38	232,16	254,84	357,10	350,19	-	372,97	490,13	433,25	346,67	-	96,33
5	100	71,53	145,87	195,45	226,63	226,92	334,00	395,09	-	407,20	539,71	469,08	400,09	-	117,56
6	100	+													
7	100	+													
8	100	114,86	126,87	+											
9	100	53,21	112,53	+											
10	100	111,77	185,06	+											
11	100	118,85	166,36	+											
12	100	78,87	165,10	182,18	224,04	262,08	339,00	+							
13	100	65,10	151,45	214,64	251,28	225,30	327,38	+							
14	100	53,33	91,19	100,59	167,95	146,59	176,73	+							
15	100	32,35	96,59	139,05	189,29	200,15	237,34	+							
16	100	47,93	58,85	36,17	136,89	151,35	-	247,52	232,17	266,99	439,21	306,94	308,09	294,84	+
17	100	66,03	113,03	181,79	227,04	269,06	-	331,97	452,37	449,07	686,73	597,28	535,07	595,52	+
18	100	41,83	86,08	135,62	177,60	189,00	-	310,44	306,10	284,11	460,22	373,08	364,57	326,88	+
19	100	39,40	61,24	102,49	96,57	147,20	-	233,54	233,06	268,76	359,48	321,69	263,61	288,83	+
20	100	44,82	105,71	163,31	197,59	201,56	-	301,60	302,65	427,11	621,15	484,90	479,51	521,46	-
21	100	52,48	91,02	143,24	209,94	271,84	-	407,77	345,04	423,77	552,42	433,39	466,32	453,60	-
22	100	97,38	179,46	265,95	634,98	-	-	603,40	699,62	778,91	-	-	867,37	880,91	286,51
23	100	90,58	134,77	227,94	336,00	309,35	-	364,06	556,00	462,52	592,89	489,27	652,79	-	212,29
24	100	70,54	-	-	-	-	-	669,97	704,81	736,68	896,76	788,91	839,77	-	318,48
25	100	81,50	77,78	186,51	252,37	243,41	-	384,58	422,40	428,11	598,61	470,74	407,81	-	157,87
26	100	48,42	64,38	125,47	172,41	156,03	-	243,34	255,80	278,52	479,83	364,49	319,16	-	143,56
27	100	66,25	125,86	152,42	191,52	187,65	-	419,59	333,13	359,66	423,03	427,05	343,79	-	148,60
28	100	25,40	114,75	280,57	275,12	337,75	-	481,27	484,48	574,21	936,42	694,34	727,81	-	362,28
29	100	32,86	103,27	191,56	192,36	258,63	-	338,61	338,73	381,71	494,23	487,63	541,28	-	-
30	100	58,03	133,41	229,89	334,08	324,30	-	379,42	460,16	521,03	673,04	651,22	548,95	-	211,30
Average	**100**	**65,52**	**116,38**	**169,94**	**233,05**	**230,98**	**284,77**	**383,71**	**408,44**	**437,13**	**577,25**	**496,56**	**487,60**	**480,29**	**193,88**
(+/- SD)	**0**	**25,19**	**35,309**	**56,644**	**106,39**	**65,824**	**70,603**	**117,1**	**152,67**	**154,04**	**178,15**	**155,38**	**185,82**	**212,43**	**87,25**

Table 14. Whole-body retention of cobalt administered in chelate form in days 0 to 14 of the study

No. of animals	Time after exposure (day)														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	100	60,77	35,90	14,32	17,08	38,03	40,05	33,02	-	13,91	28,29	20,61	28,19	48,62	48,94
2	100	24,99	23,49	24,71	19,42	-	26,37	29,70	-	18,21	34,32	43,13	16,74	19,17	60,93
3	100	23,11	12,76	22,04	25,62	14,75	44,38	17,49	-	19,02	29,61	32,97	18,42	23,60	45,08
4	100	45,93	39,52	34,41	42,30	43,03	41,42	53,89	-	34,44	17,96	36,01	27,55	35,04	52,05
5	100	-	45,15	17,13	60,12	13,98	15,19	33,65	-	44,87	25,88	18,94	18,73	22,67	46,16
6	100	+													
7	100	+													
8	100	11,72	11,11	+											
9	100	11,75	22,34	+											
10	100	24,19	-	+											
11	100	10,89	-	+											
12	100	12,15	11,27	-	52,53	-	-	+							
13	100	56,67	16,84	18,86	81,96	33,72	11,84	+							
14	100	37,86	15,57	18,26	45,64	30,20	11,03	+							
15	100	-	10,80	-	44,43	58,19	30,62	+							
16	100	50,91	-	26,07	-	64,16	-	13,51	28,35	13,68	28,75	83,86	39,20	35,37	+
17	100	18,78	-	15,61	15,74	62,67	-	12,15	15,62	13,73	18,55	30,77	48,90	24,60	+
18	100	40,26	11,57	-	23,55	28,02	-	12,52	12,09	15,05	16,90	20,93	28,92	25,50	+
19	100	47,96	44,41	19,62	37,73	74,04	-	14,68	19,57	13,97	21,47	23,44	29,83	48,19	+
20	100	20,19	16,26	-	18,32	30,21	-	11,46	-	-	16,55	13,40	18,73	12,95	-
21	100	70,54	48,73	61,35	64,65	34,08	-	52,43	12,94	24,76	55,19	57,43	33,81	51,30	-
22	100	59,70	33,23	32,98	39,67	28,83	-	48,50	32,15	31,79	35,33	60,71	72,68	51,53	-
23	100	21,31	14,13	15,36	36,30	16,88	-	11,05	-	17,89	21,82	21,04	15,04	-	11,02
24	100	25,29	19,40	16,42	15,51	15,72	-	30,12	59,90	72,99	28,51	41,11	16,20	-	24,71
25	100	16,43	-	19,15	18,14	15,15	-	13,17	22,40	21,46	17,79	22,89	35,77	-	11,57
26	100	21,50	-	27,90	20,46	22,59	-	10,89	14,05	20,53	20,75	17,09	11,63	-	14,52
27	100	39,45	43,36	11,69	79,30	54,38	-	65,76	39,53	37,77	17,33	64,18	25,39	-	42,06
28	100	40,97	13,20	15,69	-	14,91	-	19,30	28,33	15,56	22,58	16,77	-	-	17,44
29	100	26,93	46,47	28,54	22,21	20,59	-	34,32	26,39	32,05	28,61	25,65	22,62	-	19,20
30	100	13,42	-	15,39	39,92	19,87	-	13,29	26,75	-	16,82	19,10	15,44	-	-
Average	**100**	**32,08**	**25,50**	**22,77**	**37,30**	**33,36**	**27,61**	**26,54**	**26,01**	**25,65**	**25,15**	**33,50**	**28,09**	**33,21**	**32,81**
(+/- SD)	**0**	**17,64**	**14,11**	**11,10**	**20,30**	**18,44**	**13,71**	**17,06**	**13,07**	**15,13**	**9,26**	**19,31**	**14,32**	**13,74**	**18,05**

Table 15. Whole-body retention of iron administered in chelate form in days 0 to 14 of the study

No. of animals	Time after exposure (day)														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	100	76,87	58,85	36,71	58,92	75,76	83,66	88,13	-	70,58	94,75	89,05	78,79	89,65	188,56
2	100	75,69	96,94	82,18	81,63	69,45	105,70	101,04	-	159,69	161,86	164,52	142,34	63,65	102,23
3	100	31,74	24,01	54,16	55,29	51,03	69,42	60,96	-	60,99	96,72	102,42	70,10	-	119,59
4	100	92,80	56,96	107,57	137,08	144,25	136,28	145,07	-	187,01	129,69	147,25	172,69	99,99	215,85
5	100	-	95,24	35,03	131,29	30,86	45,03	84,62	-	93,15	88,33	81,18	84,22	-	87,60
6	100	+													
7	100	+													
8	100	19,37	15,99	+											
9	100	14,35	32,25	+											
10	100	36,67	31,74	+											
11	100	32,40	17,30	+											
12	100	14,47	25,02	15,32	86,76	33,95	40,23	+							
13	100	47,59	36,06	24,94	95,91	74,35	-	+							
14	100	37,09	29,97	31,31	42,25	73,47	36,04	+							
15	100	-	40,56	22,95	129,08	132,07	73,11	+							
16	100	42,68	33,19	51,40	141,52	117,42	-	75,07	89,15	60,43	91,83	-	137,83	154,42	+
17	100	39,99	31,05	47,18	54,51	111,56	-	65,48	67,89	63,03	80,81	110,29	163,85	129,99	+
18	100	48,07	24,07	22,92	61,54	70,31	-	44,53	65,46	69,89	79,68	84,38	103,12	98,62	+
19	100	124,65	78,75	50,93	127,48	299,49	-	106,36	99,91	131,64	132,65	162,88	187,72	233,80	+
20	100	32,65	-	25,26	43,89	66,84	-	51,94	49,10	64,33	80,64	79,43	95,51	111,52	-
21	100	87,80	85,67	123,80	127,81	101,31	-	101,18	-	121,92	156,53	165,40	142,60	164,12	-
22	100	64,84	72,98	70,47	138,02	116,75	-	141,59	128,98	166,94	141,51	193,06	212,00	153,72	172,88
23	100	63,82	52,36	62,48	142,10	98,29	-	95,99	115,49	130,20	130,46	170,53	198,72	-	183,45
24	100	30,30	34,67	33,94	62,50	63,98	-	67,47	100,49	112,30	78,77	101,59	93,05	-	129,07
25	100	21,01	31,47	61,65	80,68	66,87	-	78,74	100,91	110,06	93,27	129,11	136,05	-	105,81
26	100	29,79	15,73	31,01	58,63	43,17	-	53,07	76,35	57,73	70,46	89,35	71,57	-	96,55
27	100	66,95	42,76	30,98	139,18	101,99	-	119,15	104,76	103,38	87,52	145,20	130,18	-	155,90
28	100	71,05	39,63	30,66	42,88	67,93	-	69,22	64,95	73,97	104,78	83,46	89,91	-	-
29	100	56,49	82,34	46,43	72,32	56,28	-	72,09	86,67	84,37	86,21	79,59	108,49	-	74,14
30	100	16,80	-	22,60	62,23	43,98	-	-	58,93	47,17	53,90	68,88	41,02	-	-
Average	**100**	**49,07**	**45,60**	**46,74**	**90,56**	**84,22**	**73,68**	**85,35**	**86,36**	**98,44**	**102,02**	**118,29**	**124,49**	**129,95**	**135,97**
(+/- SD)	**0**	**27,60**	**25,01**	**27,23**	**37,54**	**40,56**	**34,68**	**28,53**	**23,34**	**40,57**	**29,73**	**39,31**	**44,78**	**48,71**	**45,96**

Table 16. Whole-body retention of zinc administered in chelate form in days 0 to 14 of the study

No. of animals	Time after exposure (day)														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	100	57,93	36,06	26,77	33,98	55,78	62,94	56,25	-	55,96	56,92	60,04	59,45	-	119,45
2	100	18,42	24,26	32,27	38,05	22,59	45,84	42,42	-	48,12	59,02	60,51	53,07	-	103,70
3	100	18,48	18,02	36,06	46,52	42,32	77,05	46,04	-	56,39	72,55	79,55	61,41	-	115,66
4	100	33,84	39,00	47,69	57,56	61,48	74,57	78,21	-	85,81	73,02	87,23	82,26	-	138,17
5	100	-	45,13	19,93	62,37	31,38	34,53	50,39	-	65,36	57,52	42,45	44,87	-	103,01
6	100	+													
7	100	+													
8	100	-	-	+											
9	100	-	16,61	+											
10	100	16,49	-	+											
11	100	10,85	11,09	+											
12	100	-	-	11,52	52,80	20,87	27,10	+							
13	100	55,78	20,54	25,49	62,99	53,81	38,38	+							
14	100	30,74	16,60	19,26	41,45	39,33	30,45	+							
15	100	-	12,72	15,48	66,09	66,54	54,81	+							
16	100	47,76	-	24,03	84,55	65,81	-	37,32	47,97	43,08	50,12	89,43	67,17	-	+
17	100	10,49	-	17,29	16,58	71,29	-	30,29	37,58	34,24	38,29	51,32	86,84	-	+
18	100	27,91	13,31	11,68	23,25	28,05	-	-	37,76	34,29	36,98	43,62	52,50	-	+
19	100	44,39	32,39	18,75	35,57	66,52	-	35,73	43,58	46,72	52,83	47,38	65,65	-	+
20	100	16,67	14,77	12,66	22,33	31,52	-	-	27,94	33,32	37,47	38,60	44,22	-	-
21	100	48,91	47,30	61,61	70,04	44,51	-	62,42	52,14	73,59	89,17	103,54	87,68	-	-
22	100	52,99	31,85	39,72	66,76	53,50	-	83,57	72,44	95,64	84,11	109,38	127,77	-	122,53
23	100	12,02	-	12,65	34,64	22,73	-	-	31,14	38,15	45,59	44,01	44,60	-	49,28
24	100	26,60	20,11	18,25	28,96	30,70	-	51,40	87,44	86,71	67,65	76,98	72,35	-	88,18
25	100	16,06	22,66	25,63	40,65	36,15	-	41,59	64,01	68,07	66,51	72,43	119,02	-	79,92
26	100	12,23	-	18,47	24,22	23,12	-	33,12	40,92	41,40	40,39	40,95	39,82	-	61,00
27	100	38,90	30,33	13,55	79,60	54,78	-	66,25	59,70	58,42	46,26	81,69	64,25	-	85,80
28	100	37,74	14,36	20,34	22,07	37,95	-	43,47	52,85	50,77	57,66	50,58	45,01	-	73,62
29	100	19,34	45,59	28,42	31,62	22,09	-	43,46	43,57	49,81	51,05	45,14	41,65	-	54,01
30	100	-	-	12,76	30,68	18,59	-	-	27,62	-	-	-	-	-	-
Average	**100**	**29,75**	**25,64**	**23,76**	**44,72**	**41,72**	**49,52**	**50,12**	**48,44**	**56,10**	**57,01**	**64,47**	**66,29**		**91,87**
(+/- SD)	**0**	**15,95**	**11,93**	**12,39**	**19,72**	**17,11**	**18,78**	**15,60**	**16,88**	**18,74**	**15,33**	**22,43**	**25,11**		**27,99**

Table 17. Whole-body retention of selenium administered in chelate form in days 0 to 14 of the study

No. of animals	Time after exposure (day)														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	100	65,67	115,73	207,84	263,01	308,42	364,11	414,12	-	486,82	605,98	515,61	463,68	401,17	232,90
2	100	68,60	147,76	211,33	242,28	239,33	339,44	325,66	-	503,31	595,76	369,31	355,16	-	203,18
3	100	58,03	130,51	192,61	282,41	250,53	333,48	361,47	-	367,04	528,41	426,63	399,58	174,64	175,90
4	100	55,20	141,07	252,00	320,45	307,54	346,59	369,84	-	453,46	609,35	450,99	460,49	182,49	200,06
5	100	40,79	171,29	194,05	260,49	241,27	350,64	359,55	-	414,96	628,75	398,68	357,09	174,25	210,63
6	100	+													
7	100	+													
8	100	75,03	96,54	+											
9	100	46,30	107,95	+											
10	100	59,31	94,67	+											
11	100	54,27	95,85	+											
12	100	58,62	125,00	180,71	317,04	255,22	411,60	+							
13	100	73,25	90,62	132,56	275,91	167,07	202,57	+							
14	100	49,27	97,29	143,13	192,82	177,10	270,74	+							
15	100	64,03	87,22	194,72	304,95	288,23	351,81	+							
16	100	41,07	64,17	125,13	172,08	174,58	-	266,73	321,68	295,39	434,05	377,23	383,26	393,66	+
17	100	35,58	68,95	-	151,24	150,53	-	231,73	249,80	204,47	282,57	276,67	317,20	303,90	+
18	100	119,72	234,48	219,73	414,27	350,66	-	426,11	595,38	526,46	715,15	613,11	749,45	607,62	+
19	100	53,34	109,64	145,61	237,48	238,04	-	368,96	381,35	418,06	512,97	472,97	404,37	482,62	+
20	100	64,90	107,02	155,79	284,70	234,34	-	322,96	306,28	323,02	492,29	396,55	455,73	430,08	-
21	100	51,97	115,07	134,23	220,46	190,48	-	269,88	326,12	328,26	414,57	372,54	397,25	381,48	-
22	100	63,25	93,78	166,45	267,33	214,16	-	350,41	316,08	364,92	435,47	370,02	335,93	345,68	152,37
23	100	67,74	115,67	149,71	274,82	221,65	-	265,70	350,30	393,42	510,35	429,81	458,92	-	184,85
24	100	105,35	136,30	207,98	359,84	312,03	-	489,69	540,68	510,46	700,06	566,62	651,19	-	251,02
25	100	45,22	84,37	102,74	207,24	182,53	-	210,27	289,18	274,32	387,82	351,23	467,34	-	-
26	100	45,56	70,73	100,49	198,18	165,62	-	306,76	319,43	241,93	298,05	300,02	-	-	127,51
27	100	61,75	78,52	98,78	200,28	158,77	-	210,25	257,83	237,48	338,43	308,44	258,34	-	108,41
28	100	58,27	99,22	133,45	178,53	212,34	-	296,65	328,45	306,40	417,55	317,57	343,55	-	168,76
29	100	43,08	75,31	149,22	227,63	151,05	-	266,72	323,14	298,03	399,29	336,26	334,78	-	102,84
30	100	35,91	78,42	114,71	195,73	202,37	-	239,53	238,19	233,43	315,94	287,46	299,06	-	-
Average	**100**	**59,32**	**108,33**	**161,43**	**252,05**	**224,74**	**330,11**	**317,65**	**342,93**	**359,08**	**481,14**	**396,89**	**415,39**	**352,51**	**176,54**
(+/- SD)	**0**	**18,59**	**35,61**	**42,53**	**62,99**	**56,85**	**60,05**	**75,44**	**99,32**	**100,80**	**130,31**	**91,33**	**118,40**	**136,99**	**47,04**

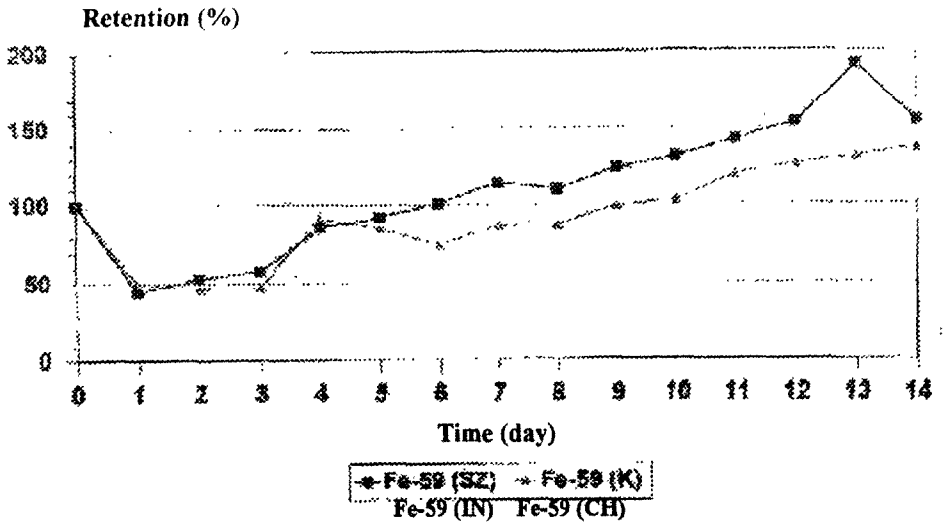

Figure 7: Whole-body retention of Fe-59 administered daily in the forms of inorganic and chelated compounds in the rat

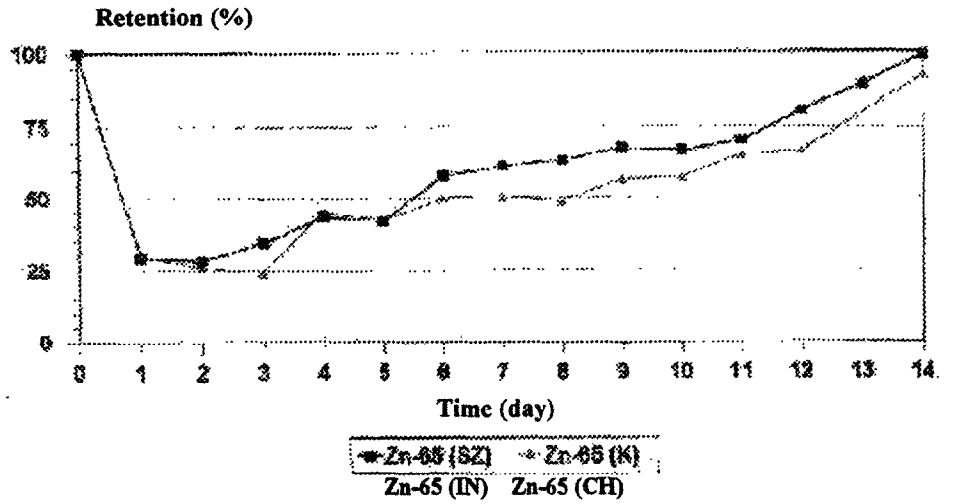

Figure 8: Whole-body retention of Zn-65 administered daily in the forms of inorganic and chelated compounds in the rat

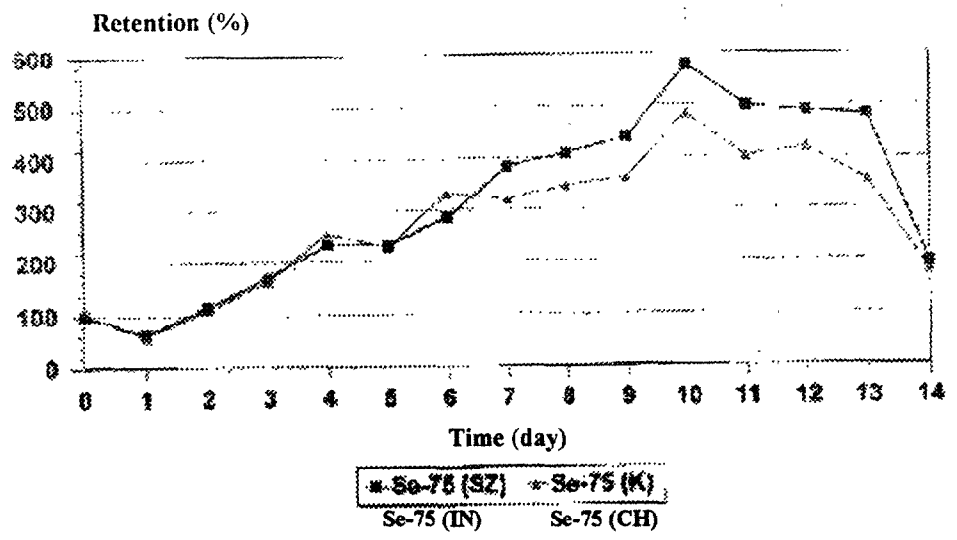

Figure 9: Whole-body retention of Se-75 administered daily in the forms of inorganic and chelated compounds in the rat

Figure 7 shows the whole-body retention of Fe-59, i.e. the quantities retained in the bodies of rats from the two different compound types. An analysis of the curves shows that 5 to 6 days following the administration of the isotope the mean values differed as the retention of iron dropped by 20-30% in the group treated with the chelate. However, this difference was not significant.

Zinc apparently followed a pattern very much like the absorption of iron compounds. The difference observed in the average retention in these two groups was not significant in the case of zinc, either (Figure 8).

As for selenium, the metal absorption rate in both treatment groups proved to be identical up to Day 7 (Figure 9). However, from Day 8 onward the retention curves separated as the uptake of Se-75 given in chelated form decreased slightly, while the pattern of the retention curves remained identical.

The whole-body retention of trace elements ingested in inorganic and chelated compound forms and the effects of cadmium exposure on Days 14 and 15 (Group 2.a) as well as the daily trace element contents of excrement and urine were examined through the entire period of the study (28 days) in separate treatment groups (Groups 1.a and 2.a). The results are summed up in Tables 18-25 and Figures 10-24.

The first phase (Days 0-14) of whole-body Co-60 retention curves as shown in Figure 10 was practically overlapping with the whole-body retention curve as shown in Figure 6. In the period of Days 14 to 16 an increase by approximately 20% was experienced, and this was then followed by a slightly decreasing slope, similar to that of the first phase, up to the end of the experiment.

Table 18. Individual whole-body retention and faecal and urine excretion data for trace elements administered in inorganic form

Co-60														
No. of an'ls/time	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	100	-	25,40	28,22	44,61	9,30	-	-	-	16,99	20,96	43,41	55,36	-
2	100	-	-	36,28	56,40	34,21	-	38,99	-	8,80	-	45,92	21,87	-
3	100	-	10,36	19,09	35,85	17,07	-	-	-		14,98	-	-	-
4	100	51,45	27,24	47,93	39,36	48,07	49,27	50,94	-	43,41	40,43	29,58	-	-
5	100	19,61	15,34	17,78	37,49	16,13	23,32	35,64	-	21,49	27,25	24,71	24,40	-
Whole-body (X)	**100**	**35,53**	**19,58**	**29,86**	**42,74**	**24,96**	**36,29**	**41,86**		**22,67**	**25,91**	**35,90**	**33,87**	
(+/- SD)	**0**	**22,51**	**8,07**	**12,57**	**8,31**	**15,85**	**18,34**	**8,04**		**14,79**	**10,90**	**10,36**	**18,65**	
1			63,45	66.61	63,10	82,66	40,57	55,92	-	147,17	-	85,38	70,94	77,01
2			42,88	66.47	35,57	57,77	38,50	59,35	-	133,49	-	42,69	75,78	25,33
3			97,70	53.66	45,26	58,32	52,76	59,91	-	95,17	-	64,76	64,88	11,31
4			149,73	90.33	70,01	92,76	75,99	76,95	-	164,30	-	112,93	63,71	36,78
5			129,14	86,76	53,98	72,94	53,74	71.00	-	129,49	-	61,63	85,58	66,24
Faeces (X)			**96,58**	**72,77**	**53,58**	**72,89**	**52,31**	**64.63**		**133,92**		**73,48**	**72,18**	**43,33**
(+/- SD)			**44,35**	**15,38**	**13,73**	**15,26**	**14,93**	**8.92**		**25,59**		**26,75**	**8,93**	**27,62**
1			3,47	4,73	4,30	4,11	5,14	3.76	-	4,37	-	2,89	3,12	1,29
2			2,54	2,35	1,92	2,49	3,69	1,75	-	6,27	-	2,76	2,69	-
3			2,85	3,90	1,96	2,97	1,99	1,80	-	3,58	-	3,16	2,17	-
4			5,02	5,02	2,75	4,38	3,69	3,86	-	8,60	-	4,74	4,74	-
5			2.91	4,00	3,28	4,41	3,92	4,87	-	7,86	-	4,67	5,59	5,33
Urine (X)			**3,36**	**4,00**	**2,84**	**3,67**	**3,68**	**3,21**		**6,14**		**3,65**	**3,66**	**3,31**
(+/- SD)			**0,99**	**1,04**	**0,99**	**0,89**	**1,12**	**1,38**		**2,16**		**0,98**	**1,45**	**2,86**

Table 18. (continued)

Co-60														
No. of an'ls/time	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
1	18,74	67,25	41,66	29,25	32,13	12,10	18,34	18,97	37,02	18,83	24,35	8,08	19,19	5,94
2	35,11	-	111,79	13,68	14,34	14,01	22,26	6,22	17,98	38,98	33,22	9,08	19,94	7,78
3	10,19	43,50	9,34	5,34	17,80	10,45	14,06	4,09	9,75	10,90	24,42	4,97	10,45	2,00
4	29,74	-	27,72	6,12	44,24	31,00	26,86	7,67	42,51	50,77	21,35	11,51	27,27	-
5	21,31	71,26	22,40	14,02	19,82	19,72	30,05	10,87	16,80	33,65	60,99	12,69	15,07	-
Whole-body (X)	**23,02**	**60,67**	**42,58**	**13,68**	**25,67**	**17,46**	**22,31**	**9,57**	**24,81**	**3,63**	**32,87**	**9,26**	**18,38**	**5,24**
(+/- SD)	**9,71**	**15,00**	**40,38**	**9,61**	**12,36**	**8,34**	**6,41**	**5,81**	**14,14**	**15,91**	**16,33**	**3,03**	**6,25**	**2,96**
1	252,61	282,08	40,98	44,02	236,99	79,07	96,43	-	98,55	44,44	14,65	8,79	102,08	-
2	139,76	231,47	3,37	34,53	195,15	61,28	121,73	-	70,24	40,61	11,82	19,35	70,63	-
3	171,35	227,29	29,38	0,69	178,40	53,97	102,34	-	57,85	32,18	10,52	9,11	70,38	-
4	328,90	346,76	62,43	-	-	-	-	-	-	-	-	-	-	-
5	222,80	298,39	43,51	-	-	-	-	-	-	-	-	-	-	-
Faeces (X)	**223,09**	**277,20**	**35,93**	**26,41**	**203,52**	**64,77**	**106,83**		**75,55**	**39,08**	**12,33**	**12,42**	**81,03**	
(+/- SD)	**73,64**	**49,73**	**21,73**	**22,78**	**30,17**	**12,91**	**13,23**		**20,86**	**6,27**	**2,11**	**6,01**	**18,23**	
1	13,40	24,45	2,47	1,72	8,87	2,69	4,81	-	4,05	1,52	1,02	0,51	4,94	0,99
2	3,07	11,83	2,78	2,86	11,41	2,93	4,35	-	4,50	0,87	0,88	1,10	3,12	0,24
3	3,75	13,29	2,29	1,51	6,70	3,10	6,14	-	2,49	0,94	0,45	1,12	2,02	-
4	10,73	-	3,67	-	-	-	-	-	-	-	-	-	-	-
5	6,37	-	4,42	-	-	-	-	-	-	-	-	-	-	-
Urine (X)	**7,47**	**16,52**	**3,13**	**2,03**	**8,99**	**2,91**	**5,10**		**3,68**	**1,11**	**0,78**	**0,91**	**3,36**	**0,61**
(+/- SD)	**4,48**	**6,90**	**0,90**	**0,72**	**2,36**	**0,21**	**0,93**		**1,05**	**0,36**	**0,29**	**0,35**	**1,48**	**0,53**

Table 19. Individual whole-body retention and faecal and urine excretion data for trace elements administered in inorganic form

Fe-59														
No. of an'ls/time	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	100	-	103,33	138,79	171,56	92,95	-	-	-	160,77	159,60	231,76	215,76	-
2	100	71,06	123,42	62,97	104,01	74,77	137,05	79,54	-	46,07	-	91,91	-	-
3	100	81,01	65,60	60,34	101,38	58,86	53,98	76,73	-	92,59	73,45	75,63	96,67	-
4	100	-	-	-	166,47	151,62	160,40	211,99	-	185,78	198,31	218,34	-	-
5	100	26,09	48,00	41,02	81,85	66,34	68,52	108,68	-	109,13	109,02	103,04	132,23	-
Whole-body (X)	**100**	**59,39**	**85,09**	**75,78**	**125,06**	**88,91**	**104,99**	**119,24**		**118,87**	**135,09**	**144,14**	**148,22**	
(+/- SD)	**0**	**29,26**	**34,43**	**43,13**	**41,07**	**37,29**	**51,74**	**63,50**		**55,49**	**55,00**	**74,65**	**61,13**	
1			106,57	131.07	126,36	173,07	91,00	106,44	-	320,12	-	184,14	145,07	182,63
2			40,83	98,70	41,11	76,67	39,62	79,34	-	144,99	-	52,88	86,43	35,47
3			119,42	75,80	66,29	87,83	87,81	87,35	-	136,34	-	85,14	85,58	12,35
4			311,27	279,49	182,63	223,06	209,76	192,72	-	412,32	-	263,23	112,73	108,77
5			164,85	139,73	74,60	99,47	74,94	106,35	-	195,98	-	80,53	130,70	114,47
Faeces (X)			**148,59**	**144,96**	**98,20**	**132,02**	**100,63**	**114,44**		**241,95**		**133,18**	**112,10**	**90,74**
(+/- SD)			**101,19**	**79,44**	**56,47**	**63,34**	**64,32**	**45,34**		**120,21**		**88,09**	**26,44**	**68,06**
1			2,27	3,18	1,03	4,13	4,58	2,69	-	3,38	-	2,57	2,53	1,35
2			1,46	1,26	0,63	1,40	1,65	2,03	-	7,75	-	1,27	1,05	-
3			1,83	2,50	0,71	1,41	1,68	2,14	-	3,04	-	2,00	0,54	-
4			-	6,97	0,60	4,99	2,86	3,27	-	7,05	-	3,24	1,59	-
5			2,42	2,74	1,25	2,41	2,23	1,90	-	3,03	-	2,73	0,29	0,46
Urine (X)			**2,00**	**3,33**	**0,84**	**2,87**	**2,60**	**2,41**		**4,85**		**2,36**	**1,20**	**0,90**
(+/- SD)			**0,44**	**2,16**	**0,28**	**1,63**	**1,21**	**0,57**		**2,34**		**0,75**	**0,90**	**0,63**

Table 19. (continued)

Fe-59														
Áll. sz./idő	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
1	168.82	-	434.54	432.26	233.78	180.01	200.18	169.18	253.82	256.50	425.39	-	637.58	-
2	-	-	304.57	140.05	52.62	52.39	110.46	57.77	73.68	109.30	128.55	-	96.72	-
3	108.03	-	222.80	302.44	107.40	93.79	160.19	105.13	231.29	185.53	289.67	-	493.39	-
4	215.12	-	449.68	493.43	422.13	259.51	264.81	209.72	371.11	376.45	460.64	-	1144.32	-
5	131.68	-	215.45	327.56	149.65	104.62	233.19	105.04	183.30	196.67	283.50	-	505.72	-
Egésztest (X)	**155.91**		**325.41**	**339.15**	**193.12**	**138.06**	**193.77**	**129.37**	**222.64**	**224.89**	**317.55**		**575.55**	
(+/- SD)	**46.73**		**112.26**	**135.64**	**144.12**	**82.05**	**60.64**	**59.89**	**108.20**	**99.59**	**132.06**		**376.91**	
1	91.75	-	148.98	37.60	-	79.07	474.29	-	209.47	102.92	35.80	16.70	112.86	29.56
2	32.45	-	5.97	18.69	-	61.28	377.62	-	87.73	44.86	16.11	22.53	97.73	12.90
3	43.92	-	72.65	0.34	-	53.97	249.23	-	77.83	47.51	14.26	5.82	124.81	4.51
4	117.34	-	276.64	-	-	-	-	-	-	-	-	-	-	-
5	67.18	-	112.10	-	-	-	-	-	-	-	-	-	-	-
Széklet (X)	**70.53**		**123.27**	**18.87**		**64.77**	**367.05**		**125.01**	**65.10**	**22.06**	**15.02**	**111.80**	**15.65**
(+/- SD)	**34.68**		**100.78**	**18.63**		**12.91**	**112.90**		**73.31**	**32.79**	**11.94**	**8.48**	**13.57**	**12.75**
1	1.60	17.23	1.99	1.43	2.12	2.69	18.88	20.26	-	1.58	0.82	7.35	4.43	7.99
2	0.46	8.18	3.46	-	4.54	2.93	13.45	16.84	-	0.11	1.56	-	1.58	1.14
3	-	10.51	0.00	0.68	4.90	3.10	12.10	20.78	-	0.29	0.00	-	1.13	-
4	-	-	9.07	-	-	-	-	-	-	-	-	-	-	-
5	0.00	-	0.90	-	-	-	-	-	-	-	-	-	-	-
Vizelet (X)	**0.69**	**11.97**	**3.08**	**1.05**	**3.85**	**2.91**	**14.81**	**19.29**		**0.66**	**0.79**	**7.35**	**2.38**	**4.56**
(+/- SD)	**0.83**	**4.70**	**3.59**	**0.53**	**1.51**	**0.21**	**3.59**	**2.14**		**0.80**	**0.78**	**0**	**1.79**	**4.84**

Table 20. Individual whole-body retention and faecal and urine excretion data for trace elements administered in inorganic form

Zn-65														
No. of an'ls/time	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	100	-	43,04	63,91	-	50,06	-	-	-	90,41	98,87	-	135,93	-
2	100	53,49	66,44	39.92	60,15	45,75	92,36	53,43	-	44,71	42,48	73,02	53,67	-
3	100	43,12	27,24	35,09	61,92	44,73	39,58	43,19	-	54,28	52,20	49,65	52,63	-
4	100	44,17	41,69	79,69	68,60	69,52	94,70	91,86	-	99,42	92,38	89,07	-	-
5	100	14,88	18,36	21,22	34,71	34,23	39,51	50,20	-	47,51	53,67	75,94	55,22	-
Whole-body (X)	**100**	**38,91**	**39,35**	**47,97**	**56,35**	**48,86**	**66,54**	**59,67**		**67,27**	**67,92**	**71,92**	**74,36**	
(+/- SD)	**0**	**16,69**	**18,31**	**23,49**	**14,88**	**12,93**	**31,19**	**21,88**		**25,67**	**25,76**	**16,40**	**41,06**	
1			68,68	63,30	78,66	89,40	46,99	57,30	-	155,93	-	108,70	79,42	90,23
2			35,63	49,04	31,72	43,71	33,06	51,82	-	101,25	-	47,00	65,21	21,84
3			7,74	42,65	41,49	46,61	54,88	52,66	-	75,80	-	61,14	56,20	11,50
4			123,30	77,23	74,32	82,32	76,82	75,18	-	147,71	-	107,52	52,41	38,70
5			109,01	66,27	55,77	56,28	50,56	63,47	-	103,63	-	57,90	77,05	70,64
Faeces (X)			**68,87**	**59,70**	**56,39**	**63,66**	**52,46**	**60,08**		**116,86**		**76,45**	**66,06**	**46,58**
(+/- SD)			**48,52**	**13,85**	**20,30**	**20,94**	**15,88**	**9,63**		**33,85**		**29,38**	**12,08**	**33,12**
1			0,86	0,55	0,25	0,38	0,27	0,29	-	1,18	-	0,62	1,84	0,80
2			0,45	0,60	0,12	0,00	0,46	0,02	-	3,55	-	0,59	0,43	-
3			0,16	0,44	0,05	0,45	0,76	0,64	-	0,74	-	0,67	0,87	-
4			1,24	0,44	0,74	0,11	0,17	0,39	-	1,41	-	1,62	0,87	-
5			0,52	0,30	0,32	-	0,69	0,58	-	1,17	-	1,52	0,29	0,91
Urine (X)			**0,65**	**0,46**	**0,29**	**0,23**	**0,47**	**0,38**		**1,61**		**1,00**	**0,86**	**0,86**
(+/- SD)			**0,42**	**0,12**	**0,27**	**0,21**	**0,25**	**0,25**		**1,11**		**0,52**	**0,61**	**0,08**

Table 20. (continued)

Zn-65														
No. of an'ls/time	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
1	139,75	296,36	166,75	165,50	171,07	110,88	155,63	73,16	177,07	155,47	188,75	154,50	175,10	-
2	79,91	186,40	126,14	61,53	76,69	41,93	81,74	29,36	75,83	85,77	91,43	95,67	81,15	-
3	85,25	185,69	83,06	75,49	92,37	58,25	94,36	32,34	96,90	91,27	123,22	120,83	118,78	-
4	110,00	265,60	125,50	115,77	161,53	102,99	138,00	59,63	154,98	146,68	138,87	142,98	172,66	-
5	94,87	179,25	86,68	80,42	88,24	66,90	86,54	35,79	97,81	94,32	124,55	89,77	80,88	-
Whole-body (X)	**101,95**	**222,66**	**117,63**	**99,74**	**117,98**	**76,19**	**111,25**	**46,06**	**120,52**	**114,70**	**133,36**	**120,75**	**125,71**	
(+/- SD)	**24,02**	**54,41**	**34,28**	**41,84**	**44,61**	**29,60**	**33,36**	**19,31**	**43,17**	**33,49**	**35,49**	**23,38**	**46,60**	
1	107,73	362,99	41,35	53,23	216,09	86,19	172,31	59,04	103,14	58,27	16,75	12,18	68,57	9,04
2	46,77	219,67	2,10	34,64	125,87	50,22	156,25	567,42	57,93	37,79	8,66	12,78	35,94	3,64
3	54,06	229,86	20,10	2,11	127,47	43,74	125,39	450,02	46,49	28,75	9,15	8,91	45,31	2,71
4	124,88	375,43	48,79	-	-	-	-	-	-	-	-	-	-	-
5	72,10	291,44	35,06	-	-	-	-	-	-	-	-	-	-	-
Faeces (X)	**81,11**	**295,88**	**29,48**	**29,99**	**156,48**	**60,05**	**151,32**	**358,83**	**69,18**	**41,60**	**11,52**	**11,29**	**49,94**	**5,13**
(+/- SD)	**33,97**	**72,49**	**18,59**	**25,87**	**51,63**	**22,87**	**23,85**	**266,18**	**29,95**	**15,13**	**4,54**	**2,08**	**16,80**	**3,42**
1	-	4,15	0,10	2,00	4,41	0,31	7,06	8,23	0,94	0,50	0,23	0,50	0,75	-
2	0,36	2,52	0,38	1,20	0,56	0,42	3,28	8,46	0,87	0,23	0,26	0,17	0,63	1,01
3	0,17	0,91	0,36	1,11	2,23	-	5,56	5,50	0,86	0,22	0,24	-	1,22	-
4	0,83	-	0,56	-	-	-	-	-	-	-	-	-	-	-
5	0,61	-	0,48	-	-	-	-	-	-	-	-	-	-	-
Urine (X)	**0,49**	**2,52**	**0,38**	**1,44**	**2,40**	**0,36**	**5,30**	**7,40**	**0,89**	**0,32**	**0,24**	**0,33**	**0,87**	**1,01**
(+/- SD)	**0,29**	**1,62**	**0,17**	**0,49**	**1,93**	**0,08**	**1,90**	**1,65**	**0,05**	**0,16**	**0,01**	**0,24**	**0,31**	**0**

Table 21. Individual whole-body retention and faecal and urine excretion data for trace elements administered in inorganic form

Se-75														
No. of an'ls/time	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	100	67,01	98,42	166,94	248,84	188,36	310,68	412,31	-	361,99	529,96	570,56	405,13	-
2	100	-	-	-	-	373,30	-	538,23	-	689,54	899,79	812,63	696,61	-
3	100	56,34	97,22	122,48	152,43	156,91	195,96	261,31	-	269,75	294,08	258,23	237,67	-
4	100	82,23	139,56	194,38	232,16	254,84	357,10	350,19	-	372,97	490,13	433,25	346,67	-
5	100	71,53	145,87	195,45	226,63	226,92	334,00	395,09	-	407,20	539,71	469,08	400,09	-
Whole-body (X)	**100**	**69,28**	**120,27**	**169,81**	**215,02**	**240,07**	**299,43**	**391,42**		**420,29**	**550,73**	**508,75**	**417,23**	
(+/- SD)	**0**	**10,73**	**26,05**	**34,20**	**42,78**	**83,26**	**71,54**	**100,79**		**158,88**	**219,05**	**203,84**	**170,08**	
1			12,90	15,53	26,06	26,03	11,95	18,58	-	54,78	-	22,56	18,77	48,77
2			12,98	27,35	23,09	42,70	20,23	31,06	-	132,91	-	44,47	56,89	33,63
3			22,65	107,34	14,08	12,23	11,57	15,45	-	33,31	-	21,70	20,33	9,97
4			24,82	17,38	17,54	19,63	18,31	20,25	-	40,05	-	27,64	10,09	8,84
5			21,77	13,50	23,79	25,04	18,13	21,75	-	55,19	-	18,24	29,42	46,88
Faeces (X)			**19,02**	**36,22**	**20,91**	**25,13**	**16,04**	**21,42**		**63,25**		**26,92**	**27,10**	**29,62**
(+/- SD)			**5,66**	**40,11**	**4,94**	**11,25**	**3,99**	**5,87**		**40,07**		**10,37**	**18,01**	**19,35**
1			12,22	16,24	28,72	18,15	25,70	24,18	-	25,50	-	11,33	16,51	18,59
2			38,57	42,80	43,55	35,13	48,61	43,49	-	61,33	-	47,48	51,18	-
3			13,17	11,25	11,76	8,36	10,98	11,04	-	25,99	-	17,30	14,17	-
4			18,11	20,08	22,18	18,69	26,77	19,42	-	46,25	-	25,91	18,02	-
5			14,50	23,42	22,15	17,08	16,89	29,42	-	59,82	-	26,07	35,04	51,75
Urine (X)			**19,32**	**22,76**	**25,67**	**19,48**	**25,79**	**25,51**		**43,78**		**25,62**	**26,98**	**35,17**
(+/- SD)			**10,99**	**12,09**	**11,69**	**9,70**	**14,32**	**12,11**		**17,48**		**13,71**	**15,85**	**23,45**

Table 21. (continued)

Se-75														
No. of an'ls/time	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
1	99,23	238,57	73,39	188,48	262,29	203,72	205,96	156,23	285,43	-	340,16	429,50	614,27	-
2	172,59	402,46	142,01	262,65	401,36	335,59	462,32	241,03	562,32	-	671,83	765,42	739,53	-
3	-	149,35	62,81	106,00	143,61	133,89	163,91	115,61	248,48	-	299,47	310,57	551,37	-
4	96,33	249,57	76,76	123,80	277,20	253,61	219,76	166,91	265,13	-	353,75	441,83	648,81	-
5	117,56	249,54	87,24	189,43	274,84	247,54	270,32	154,02	339,33	-	389,31	508,60	817,20	-
Whole-body (X)	**121,43**	**257,90**	**88,44**	**174,07**	**271,86**	**234,87**	**264,45**	**166,76**	**340,14**		**410,90**	**491,18**	**674,24**	
(+/- SD)	**35,38**	**91,10**	**31,19**	**62,15**	**91,31**	**73,86**	**116,95**	**45,84**	**128,83**		**149,36**	**169,09**	**104,93**	
1	11,21	19,95	4,81	4,29	13,87	27,48	26,78	-	19,77	21,56	8,47	11,01	24,19	12,32
2	17,19	36,66	6,94	8,19	43,07	74,29	85,04	-	77,26	22,98	14,66	55,00	-	19,57
3	13,46	11,04	2,93	0,07	11,04	28,19	12,08	-	9,23	11,02	5,90	16,02	-	-
4	13,14	14,44	5,28	-	-	-	-	-	-	-	-	-	-	-
5	25,38	16,13	6,06	-	-	-	-	-	-	-	-	-	-	-
Faeces (X)	**16,08**	**19,64**	**5,20**	**4,18**	**22,66**	**43,32**	**41,30**		**35,42**	**18,52**	**9,68**	**27,34**	**24,19**	**15,95**
(+/- SD)	**5,63**	**10,04**	**1,51**	**4,06**	**17,73**	**26,82**	**38,59**		**36,61**	**6,54**	**4,50**	**24,08**	**0**	**5,12**
1	6,52	18,30	5,16	0,61	10,47	16,91	27,82	217,61	25,19	15,32	6,39	20,84	4,54	18,23
2	21,27	31,03	10,06	2,89	32,08	59,34	65,07	332,00	37,19	13,20	10,17	10,21	0,84	-
3	4,06	13,08	4,46	0,94	7,75	24,00	13,90	107,34	15,83	8,77	2,00	9,29	-	-
4	11,51	-	5,16	-	-	-	-	-	-	-	-	-	-	-
5	13,86	-	6,32	-	-	-	-	-	-	-	-	-	-	-
Urine (X)	**11,45**	**20,80**	**6,23**	**1,48**	**16,77**	**33,41**	**35,60**	**218,99**	**26,07**	**12,43**	**6,19**	**13,45**	**2,69**	**18,23**
(+/- SD)	**6,73**	**9,24**	**2,24**	**1,24**	**13,33**	**22,73**	**26,46**	**112,34**	**10,71**	**3,34**	**4,09**	**6,42**	**2,61**	**0**

Table 22. Individual whole-body retention and faecal and urine excretion data for trace elements administered in chelate form

Co-60														
No. of an'ls/time	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	100	60,77	35,90	14,32	17,08	38,03	40,05	33,02	-	13,91	28,29	20,61	28,19	48,62
2	100	24,99	23,49	24,71	19,42	-	26,37	29,70	-	18,21	34,32	43,13	26,74	19,17
3	100	23,11	12,76	22,04	25,62	14,75	44,38	17,49	-	19,02	29,61	32,97	18,42	23,60
4	100	45,93	39,52	34,41	42,30	43,03	41,42	53,89	-	34,44	17,96	36,01	27,55	35,04
5	100	-	45,15	17,13	60,12	13,98	15,19	33,65	-	44,87	25,88	18,94	18,73	22,67
Whole-body (X)	**100**	**38,70**	**31,37**	**22,52**	**32,91**	**27,45**	**33,48**	**33,55**		**26,09**	**27,21**	**30,33**	**23,92**	**29,82**
(+/- SD)	**0**	**17,99**	**13,09**	**7,79**	**18,12**	**15,24**	**12,35**	**13,10**		**13,07**	**6,01**	**10,33**	**4,91**	**12,08**
1			92,99	90,64	59,19	58,37	69,54	70,74	-	138,03	-	88,78	83,21	33,11
2			66,39	68,83	49,04	73,56	50,48	59,66	-	104,59	-	59,27	71,08	33,20
3			55,76	78,18	58,32	65,29	55,73	74,57	-	129,55	-	81,59	93,28	27,90
4			104,24	79,07	60,95	85,52	66,71	82,27	-	169,33	-	98,83	116,22	-
5			136,53	73,87	55,10	78,75	69,97	65,50	-	143,19	-	81,10	90,01	-
Faeces (X)			**91,18**	**78,12**	**56,52**	**71,70**	**62,48**	**70,55**		**136,94**		**81,92**	**90,76**	**31,41**
(+/- SD)			**32,01**	**8,10**	**4,69**	**9,86**	**8,85**	**8,63**		**23,40**		**14,55**	**16,58**	**3,04**
1			4,33	5,51	2,62	4,08	4,03	2,77	-	3,21	-	4,33	4,10	-
2			2,73	2,93	3,37	3,04	3,52	3,23	-	5,96	-	3,32	4,59	-
3			3,65	3,86	3,22	5,05	4,21	3,36	-	7,49	-	5,51	4,98	3,64
4			3,95	5,54	3,17	5,29	2,23	2,36	-	8,71	-	4,75	5,79	-
5			5,80	3,49	2,76	3,46	1,60	2,32	-	3,62	-	3,30	3,34	4,55
Urine (X)			**4,09**	**4,27**	**3,03**	**4,18**	**3,12**	**2,81**		**5,80**		**4,24**	**4,56**	**4,10**
(+/- SD)			**1,12**	**1,20**	**0,32**	**0,98**	**1,15**	**0,48**		**2,39**		**0,95**	**0,92**	**0,64**

Table 22. (continued)

Co-60														
No. of an'ls/time	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
1	48,94	45,50	59,14	23,59	17,79	17,30	29,64	10,65	10,46	14,76	18,07	8,30	14,83	-
2	60,93	88,49	36,16	9,80	11,96	19,63	27,37	21,33	11,66	27,71	41,07	10,48	16,33	-
3	45,08	71,61	42,76	40,68	33,85	17,71	22,99	10,04	48,95	56,86	17,96	10,73	32,29	-
4	52,05	41,25	51,79	19,02	25,49	26,67	34,89	9,84	21,21	39,63	21,20	14,17	24,57	-
5	46,16	47,05	45,11	13,78	25,30	22,73	31,18	10,97	23,21	25,40	25,94	10,55	42,87	-
Whole-body (X)	**50,63**	**58,78**	**46,99**	**21,37**	**22,88**	**20,81**	**29,21**	**12,57**	**23,12**	**32,87**	**24,85**	**10,85**	**26,18**	
(+/- SD)	**6,36**	**20,42**	**8,79**	**11,99**	**8,34**	**3,92**	**4,43**	**4,92**	**15,51**	**16,06**	**9,63**	**2,11**	**11,67**	
1	285,30	251,14	32,89	27,59	238,03	71,45	171,01	-	75,28	43,41	11,56	1,82	105,44	2,87
2	182,27	233,31	32,36	29,20	170,33	59,80	121,96	-	60,62	26,94	6,41	17,26	59,76	4,30
3	303,08	220,98	40,13	28,83	232,92	65,05	151,09	-	59,68	-	13,71	4,11	77,66	12,65
4	303,89	461,65	38,31	-	-	-	-	-	-	-	-	-	-	-
5	346,79	333,98	37,50	-	-	-	-	-	-	-	-	-	-	-
Faeces (X)	**284,27**	**300,21**	**36,24**	**28,54**	**213,76**	**65,43**	**148,02**		**65,19**	**35,17**	**10,56**	**7,73**	**80,95**	**6,61**
(+/- SD)	**61,35**	**100,45**	**3,44**	**0,84**	**37,70**	**5,83**	**24,67**		**8,75**	**11,65**	**3,75**	**8,33**	**23,01**	**5,28**
1	4,28	19,23	3,49	1,54	9,82	4,41	11,28	24,71	4,10	0,81	0,69	1,28	1,81	0,40
2	14,47	21,35	2,58	1,54	15,15	3,97	10,10	25,00	3,40	2,11	0,98	0,54	3,30	0,60
3	6,02	28,83	2,49	-	9,70	7,32	14,64	26,02	2,95	1,75	0,59	0,10	-	0,45
4	15,46	-	3,11	-	-	-	-	-	-	-	-	-	-	-
5	6,50	-	2,43	-	-	-	-	-	-	-	-	-	-	-
Urine (X)	**9,35**	**23,14**	**2,82**	**1,54**	**11,56**	**5,23**	**12,01**	**25,24**	**3,49**	**1,56**	**0,76**	**0,64**	**2,56**	**0,48**
(+/- SD)	**5,21**	**5,04**	**0,46**	**0,00**	**3,11**	**1,82**	**2,36**	**0,69**	**0,58**	**0,67**	**0,20**	**0,60**	**1,05**	**0,10**

Table 23. Individual whole-body retention and faecal and urine excretion data for trace elements administered in chelate form

Fe-59														
No. of an'ls/time	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	100	76,87	58,85	36,71	58,92	75,76	83,66	88,13	-	70,58	94,75	89,05	78,79	89,65
2	100	75,69	96,94	82,18	81,63	69,45	105,70	101,04	-	159,69	161,86	164,52	142,34	63,65
3	100	31,74	24,01	54,16	55,29	51,03	69,42	60,96	-	60,99	96,72	102,42	70,10	-
4	100	92,80	56,96	107,57	137,08	144,25	136,28	145,07	-	187,01	129,69	147,25	172,69	99,99
5	100	-	95,24	35,03	131,29	30,86	45,03	84,62	-	93,15	88,33	81,18	84,22	-
Whole-body (X)	**100**	**69,27**	**66,40**	**63,13**	**92,84**	**74,27**	**88,02**	**95,97**		**114,28**	**114,27**	**116,88**	**109,63**	**84,43**
(+/- SD)	**0**	**26,21**	**30,44**	**31,25**	**39,12**	**42,86**	**34,84**	**31,04**		**56,01**	**31,08**	**36,91**	**45,29**	**18,73**
1			82,70	102,97	53,10	65,94	94,58	83,86	-	117,37	-	94,15	90,73	29,58
2			154,18	161,04	93,62	156,96	103,20	135,93	-	201,05	-	113,13	136,00	82,18
3			43,32	76,99	63,99	61,53	64,95	75,52	-	115,81	-	75,95	90,09	26,58
4			200,97	153,42	105,77	176,92	97,59	157,06	-	257,94	-	161,47	204,35	-
5			153,47	105,45	69,30	102,31	95,53	95,88	-	155,05	-	111,91	107,56	-
Faeces (X)			**126,93**	**119,97**	**77,16**	**112,73**	**91,17**	**109,65**		**169,44**		**111,32**	**125,74**	**46,12**
(+/- SD)			**63,00**	**35,89**	**21,81**	**52,43**	**15,03**	**35,21**		**60,47**		**31,88**	**47,73**	**31,27**
1			2,95	3,50	55,00	1,46	1,87	1,81	-	0,49	-	1,99	1,32	-
2			3,17	2,83	1,13	1,41	2,66	2,56	-		-	3,13	3,32	-
3			1,85	2,21	0,64	1,35	0,71	1,47	-	1,67	-	1,57	0,43	1,50
4			5,06	4,00	0,70	5,46	3,05	3,40	-	3,44	-	4,36	2,49	-
5			3,33	0,89	0,52	0,69	0,97	0,97	-	1,54	-	3,01	51,00	1,97
Urine (X)			**3,27**	**2,68**	**0,70**	**2,07**	**1,85**	**2,04**		**1,78**		**2,81**	**1,61**	**1,74**
(+/- SD)			**1,15**	**1,21**	**0,25**	**1,92**	**1,02**	**0,95**		**1,23**		**1,09**	**1,26**	**0,33**

Table 23. (continued)

Fe-59														
No. of an'ls/time	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
1	188,56	132,56	224,78	201,29	100,44	67,00	143,48	90,77	139,31	118,03	168,53	-	354,69	-
2	102,23	348,30	309,13	315,29	154,19	143,83	274,47	217,79	229,28	249,81	205,03	-	596,16	-
3	119,59	154,14	249,51	176,01	83,87	68,91	119,99	75,24	153,56	158,81	174,99	-	347,66	-
4	215,85	210,14	418,05	342,15	177,53	154,78	275,51	136,72	241,77	253,62	281,28	-	302,54	-
5	87,60	129,67	301,68	175,82	87,95	67,31	165,24	75,07	116,46	126,95	200,48	-	327,26	-
Whole-body (X)	**142,76**	**194,96**	**300,63**	**242,11**	**120,80**	**100,37**	**195,74**	**119,12**	**176,08**	**181,44**	**206,06**		**385,66**	
(+/- SD)	**56,26**	**91,61**	**74,54**	**80,30**	**42,40**	**44,85**	**74,10**	**60,65**	**56,03**	**65,93**	**44,90**		**119,41**	
1	26,13	-	53,92	13,02	-	65,56	251,29	-	100,19	45,63	15,17	3,42	21,90	4,55
2	35,76	-	170,95	27,75	-	100,33	472,07	-	131,73	68,38	13,53	47,74	49,62	12,18
3	31,43	-	50,09	17,02	-	56,28	241,98	-	28,68	-	17,46	2,37	26,90	13,38
4	101,67	-	109,21	-	-	-	-	-	-	-	-	-	-	-
5	61,29	-	65,56	-	-	-	-	-	-	-	-	-	-	-
Faeces (X)	**51,26**		**89,95**	**19,27**		**74,06**	**321,78**		**86,86**	**57,01**	**15,39**	**17,84**	**32,81**	**10,04**
(+/- SD)	**31,25**		**51,02**	**7,62**		**23,22**	**130,24**		**52,80**	**16,08**	**1,97**	**25,89**	**14,77**	**4,79**
1	1,10	26,05	2,64	0,31	3,02	3,64	14,78	8,45	2,01	0,64	1,00	1,52	1,55	2,27
2	-	87,15	1,26	1,05	19,22	1,22	17,98	0,00	5,04	1,72	1,12	-	1,15	0,76
3	1,30	15,48	1,68	0,06	-	1,08	15,57	5,02	-	0,40	0,24	-	-	2,03
4	3,02	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	1,85	-	-	-	-	-	-	-	-	-	-	-
Urine (X)	**1,81**	**42,89**	**1,86**	**0,47**	**11,12**	**1,98**	**16,11**	**4,49**	**3,53**	**0,92**	**0,79**	**1,52**	**1,35**	**1,69**
(+/- SD)	**1,06**	**38,69**	**0,58**	**0,51**	**11,45**	**1,44**	**1,67**	**4,25**	**2,15**	**0,70**	**0,48**	**0**	**0,28**	**0,81**

Table 24. Individual whole-body retention and faecal and urine excretion data for trace elements administered in chelate form

Zn-65														
No. of an'ls/time	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	100	57,93	36,06	26,77	33,98	55,78	62,94	56,25	-	55,96	56,92	60,04	59,45	-
2	100	18,42	24,26	32,27	38,05	22,59	45,84	42,42	-	48,12	59,02	60,51	53,07	-
3	100	18,48	18,02	36,06	46,52	42,32	77,05	46,04	-	56,39	72,55	79,55	61,41	-
4	100	33,84	39,00	47,69	57,56	61,48	74,57	78,21	-	85,81	73,02	87,23	82,26	-
5	100	-	45,13	19,93	62,37	31,38	34,53	50,39	-	65,36	57,52	42,45	44,87	-
Average	**100**	**32,17**	**32,49**	**32,55**	**47,70**	**42,71**	**58,99**	**54,66**		**62,33**	**63,81**	**65,96**	**60,21**	
(+/- SD)	**0**	**18,64**	**11,09**	**10,42**	**12,20**	**16,25**	**18,41**	**14,14**		**14,47**	**8,23**	**17,71**	**13,91**	
1			86,36	69,82	63,47	52,19	71,36	71,20	-	113,19	-	88,66	78,85	34,55
2			75,65	60,11	46,07	71,33	56,08	61,46	-	96,48	-	68,19	70,63	34,12
3			50,00	71,00	61,20	61,28	59,37	82,73	-	116,07	-	86,53	94,68	30,33
4			133,30	74,83	65,34	88,56	63,37	84,41	-	157,16	-	110,83	122,65	-
5			111,63	59,26	51,30	62,46	66,83	58,80	-	114,80	-	79,02	73,84	-
Faeces (X)			**91,39**	**67,00**	**58,08**	**67,16**	**63,40**	**71,72**		**119,54**		**86,65**	**88,13**	**33,00**
(+/- SD)			**32,22**	**6,94**	**8,80**	**13,75**	**6,02**	**11,78**		**22,48**		**15,71**	**21,39**	**2,32**
1			1,29	0,44	0,17	-	0,15	0,26	-	0,37	-	0,70	1,11	-
2			0,53	0,29	-	0,49	0,30	0,44	-	0,28	-	0,58	1,08	-
3			0,85	0,43	0,17	0,34	0,33	0,85	-	0,36	-	0,92	0,79	0,08
4			0,88	0,42	0,16	1,07	0,84	0,53	-	0,93	-	0,80	1,61	-
5			0,95	0,00	-	-	0,16	0,23	-	-	-	0,17	0,29	0,19
Average			**0,90**	**0,32**	**0,17**	**0,63**	**0,36**	**0,46**		**0,49**		**0,63**	**0,98**	**0,13**
(+/- SD)			**0,27**	**0,18**	**0,01**	**0,39**	**0,28**	**0,25**		**0,30**		**0,29**	**0,49**	**0,08**

Table 24. (continued)

Zn-65														
No. of an'ls/tim	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
1	119,45	89,32	129,69	109,66	121,29	86,13	137,28	56,79	134,17	122,69	141,21	134,03	135,77	-
2	103,70	127,51	84,36	83,46	94,15	69,82	102,98	89,70	96,87	103,92	132,28	89,01	88,04	-
3	115,66	118,76	128,21	98,97	107,89	78,95	123,66	48,84	148,72	141,19	121,10	109,31	127,27	-
4	138,17	121,31	147,29	136,29	160,69	100,94	150,89	56,83	161,31	153,23	158,11	171,78	141,39	-
5	103,01	84,17	99,46	84,33	94,24	63,61	97,11	37,30	98,88	87,52	97,02	108,82	124,61	-
Whole-body (X)	**116,00**	**108,21**	**117,80**	**102,54**	**115,65**	**79,89**	**122,38**	**57,89**	**127,99**	**121,71**	**129,94**	**122,59**	**123,42**	
(+/- SD)	**14,35**	**19,94**	**25,37**	**21,78**	**27,57**	**14,57**	**22,65**	**19,49**	**29,13**	**26,74**	**22,85**	**31,80**	**20,88**	
1	54,04	307,89	22,21	24,50	170,33	57,41	186,81	486,89	36,66	41,00	10,82	2,48	55,33	5,09
2	29,55	250,79	28,46	32,46	145,01	60,66	152,39	480,56	59,04	29,73	4,85	15,30	43,59	5,75
3	68,87	255,00	28,49	40,57	176,91	64,74	171,46	492,87	58,32	-	12,27	3,25	54,97	11,50
4	66,27	460,13	27,73	-	-	-	-	-	-	-	-	-	-	-
5	62,47	266,55	20,96	-	-	-	-	-	-	-	-	-	-	-
Faeces (X)	**56,22**	**308,07**	**25,57**	**32,51**	**164,08**	**60,93**	**170,22**	**486,77**	**60,34**	**35,37**	**9,31**	**7,01**	**51,30**	**7,45**
(+/- SD)	**15,92**	**87,95**	**3,68**	**8,03**	**16,84**	**3,68**	**17,24**	**6,16**	**2,90**	**7,97**	**3,93**	**7,19**	**6,68**	**3,53**
1	0,17	9,65	0,60	0,28	1,40	0,75	4,69	9,30	1,50	0,19	0,07	0,16	-	0,53
2	0,40	4,69	0,70	0,48	-	-	4,79	8,85	1,13	1,26	0,15	0,51	0,37	0,66
3	0,53	8,40	0,56	-	0,90	0,12	-	8,71	0,54	0,26	0,17	-	-	0,88
4	-	-	0,96	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-0,10	-	-	-	-	-	-	-	-	-	-	-
Urine (X)	**0,37**	**7,58**	**0,55**	**0,38**	**1,15**	**0,44**	**4,74**	**8,95**	**1,06**	**0,23**	**0,13**	**0,33**	**0,37**	**0,69**
(+/- SD)	**0,19**	**2,58**	**0,39**	**0,14**	**0,35**	**0,45**	**0,07**	**0,31**	**0,49**	**0,04**	**0,05**	**0**	**0**	**0,18**

Table 25. Individual whole-body retention and faecal and urine excretion data for trace elements administered in chelate form

Se-75														
o. of an'ls/ti	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	100	65,67	115,73	207,84	263,01	308,42	364,11	414,12	-	486,82	605,98	515,61	463,68	401,17
2	100	68,60	147,76	211,33	242,28	239,33	339,44	325,66	-	503,31	595,76	369,31	355,16	-
3	100	58,03	130,51	192,61	282,41	250,53	333,48	361,47	-	367,04	528,41	426,63	399,58	174,64
4	100	55,20	141,07	252,00	320,45	307,54	346,59	369,84	-	453,46	609,35	450,99	460,49	182,49
5	100	40,79	171,29	194,05	260,49	241,27	350,64	359,55	-	414,96	628,75	398,68	357,09	174,25
hole-body (	**100**	**57,66**	**141,27**	**211,56**	**273,73**	**269,42**	**346,85**	**366,13**		**445,12**	**593,65**	**432,25**	**407,20**	**233,14**
(+/- SD)	**0**	**10,89**	**20,69**	**24,06**	**29,74**	**35,46**	**11,68**	**31,70**		**55,23**	**38,37**	**55,72**	**53,17**	**112,09**
1			10,01	25,41	20,12	16,83	17,66	15,46	-	27,84	-	18,94	14,64	13,82
2			9,85	18,09	21,21	19,04	16,31	14,86	-	30,95	-	20,17	20,72	15,69
3			9,57	16,37	23,18	18,73	18,62	26,01	-	50,12	-	24,17	35,15	15,96
4			19,00	13,07	14,68	12,19	11,62	18,35	-	35,13	-	21,80	29,93	-
5			22,00	15,76	10,87	17,68	22,09	19,79	-	25,68	-	22,88	22,91	-
Faeces (X)			**14,09**	**17,74**	**18,01**	**16,89**	**17,26**	**18,89**		**33,94**		**21,59**	**24,67**	**15,16**
(+/- SD)			**5,95**	**4,65**	**5,09**	**2,77**	**3,81**	**4,47**		**9,72**		**2,09**	**8,01**	**1,17**
1			19,53	14,67	17,56	14,56	25,72	17,47	-	27,40	-	30,91	25,00	-
2			16,35	23,18	31,87	14,15	21,52	24,98	-	35,11	-	23,02	26,74	-
3			13,71	22,36	25,52	17,50	23,16	16,55	-	39,47	-	24,64	22,22	23,97
4			22,42	19,92	20,00	17,60	13,58	12,47	-	38,54	-	26,45	28,85	-
5			36,75	19,24	24,60	21,64	12,16	19,48	-	25,85	-	20,88	27,64	42,03
Urine (X)			**21,75**	**19,87**	**23,91**	**17,09**	**19,23**	**18,19**		**33,27**		**25,18**	**26,09**	**33,00**
(+/- SD)			**9,00**	**3,34**	**5,53**	**3,01**	**6,01**	**4,57**		**6,31**		**3,80**	**2,58**	**12,77**

Table 25. (continued)

Se-75														
No. of an'ls/tim	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
1	232,90	83,27	134,60	168,55	330,04	232,53	331,83	201,87	377,08	-	462,91	549,51	629,69	-
2	203,18	126,14	86,95	149,63	275,31	247,79	277,35	370,00	299,23	-	395,79	309,24	621,17	-
3	175,90	119,85	11,98	157,27	246,85	231,28	261,06	167,38	309,13	-	398,07	429,53	553,32	-
4	200,06	101,09	87,75	198,25	282,55	259,20	277,01	196,83	326,62	-	440,76	530,64	457,72	-
5	210,63	98,13	110,82	178,54	245,53	197,71	240,80	179,05	335,02	-	437,73	434,29	640,36	-
hole-body+A1 (	**204,53**	**105,70**	**106,42**	**170,45**	**276,06**	**233,70**	**277,61**	**223,03**	**329,42**		**427,05**	**450,64**	**580,45**	
(+/- SD)	**20,51**	**17,32**	**19,82**	**19,03**	**34,43**	**23,19**	**33,80**	**83,31**	**30,14**		**29,18**	**96,02**	**76,60**	
1	78,42	7,94	21,14	5,07	18,36	12,72	22,03	182,51	26,47	15,54	6,97	9,06	10,25	4,80
2	52,55	7,79	33,47	3,18	20,48	17,35	30,97	311,73	21,71	9,78	5,80	38,91	27,43	-3,50
3	83,54	4,94	20,55	3,37	17,16	7,73	5,95	205,68	11,40	-	7,23	19,99	13,39	7,64
4	79,40	11,30	21,76	-	-	-	-	-	-	-	-	-	-	-
5	107,06	8,89	31,07	-	-	-	-	-	-	-	-	-	-	-
Faeces (X)	**80,19**	**8,17**	**25,60**	**3,87**	**18,67**	**12,60**	**19,65**	**233,31**	**19,86**	**12,66**	**6,67**	**22,66**	**17,02**	**2,98**
(+/- SD)	**19,37**	**2,29**	**6,16**	**1,04**	**1,68**	**4,81**	**12,68**	**68,90**	**7,70**	**4,07**	**0,76**	**15,10**	**9,15**	**5,79**
1	4,38	0,66	2,36	0,81	11,23	19,79	34,38	263,77	11,67	7,53	3,14	7,70	8,22	2,63
2	6,19	0,62	3,37	2,16	18,12	13,42	26,51	463,67	27,94	9,06	7,03	16,19	17,08	-2,89
3	4,48	0,07	2,94	-	13,93	30,16	36,00	374,98	24,18	14,06	4,97	15,87	-	3,09
4	9,15	-	2,11	-	-	-	-	-	-	-	-	-	-	-
5	6,15	-	2,78	-	-	-	-	-	-	-	-	-	-	-
Urine (X)	**6,07**	**0,45**	**2,71**	**1,48**	**14,42**	**21,12**	**32,30**	**367,47**	**21,26**	**10,22**	**5,05**	**13,25**	**4,43**	**0,94**
(+/- SD)	**1,93**	**0,33**	**0,49**	**0,96**	**3,47**	**8,45**	**5,07**	**100,16**	**8,52**	**3,42**	**1,95**	**4,81**	**17,89**	**3,33**

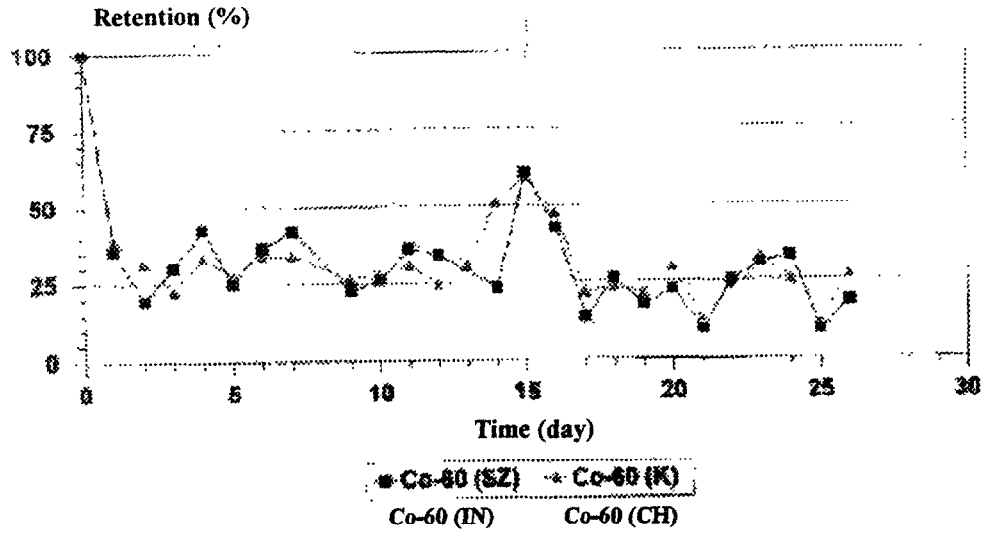

Figure 10: Whole-body retention of Co-60 administered daily in the forms of inorganic and chelated compounds through the entire study period in the rat

The results of excretion activity measurements are given in Figures 11-12. It is demonstrated that Co-60 is removed from the rat bodies through the faeces, practically. The cumulative quantities of excrement tested on a daily basis were identical up to Day 20, irrespective of the form of the ingested compound, however, after that day the quantity of cobalt excreted with the faeces increased by nearly 20% in the group treated with the chelate compound. A similar tendency was seen in the case of cobalt leaving in the urine.

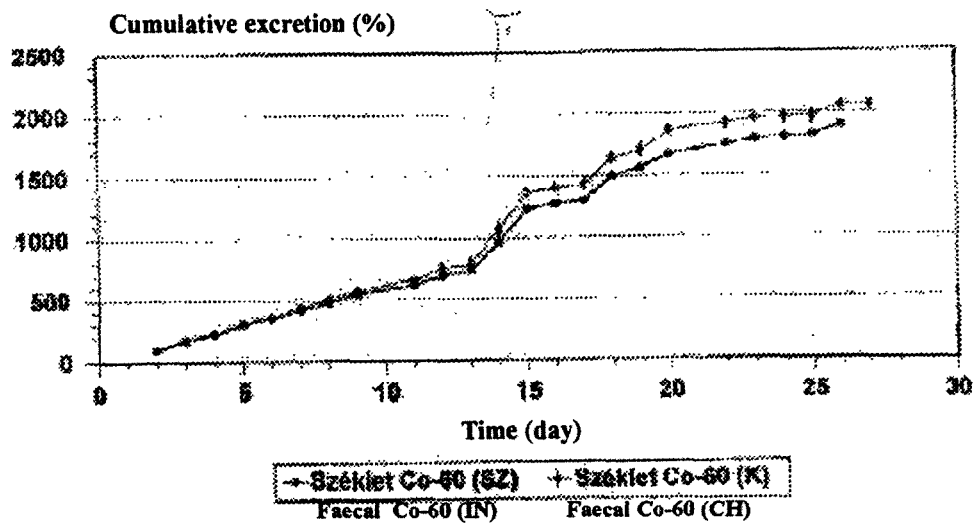

Figure 11: Cumulative faecal excretion of rats treated with Co-60 daily in the forms of inorganic and chelated compounds through the entire study period

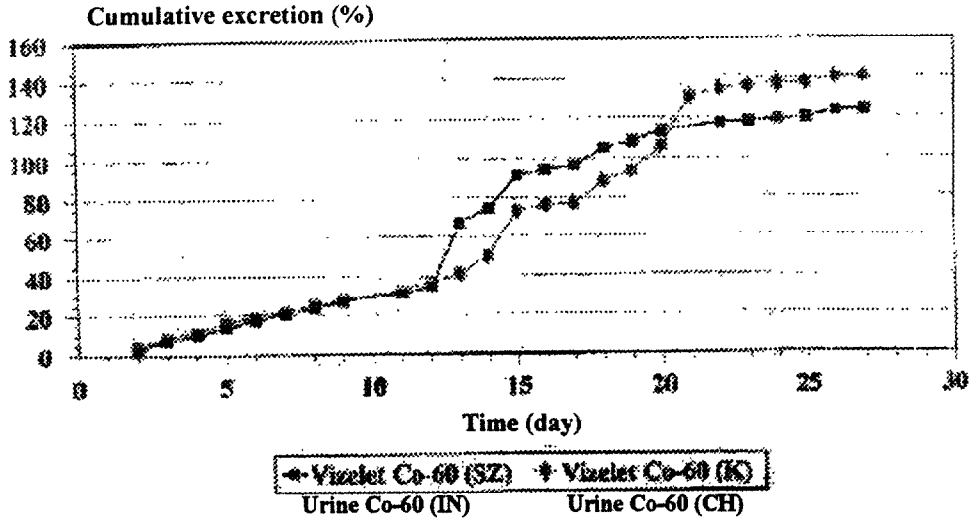

Figure 12: Cumulative urinary excretion of rats treated with Co-60 daily in the forms of inorganic and chelated compounds through the entire study period

An analysis of the slope of whole-body iron retention curves (Figure 13) has revealed that the F-59 quantities retained in test animals, receiving either form of treatment, were identical up to Day 14 of the experiment, and were somewhere in the range of 100%. Following the iron retention pattern observed during Days 14 to 17, the quantities of Fe-59 retained in the body dropped again, but showed intensive increase in the last phase of the study.

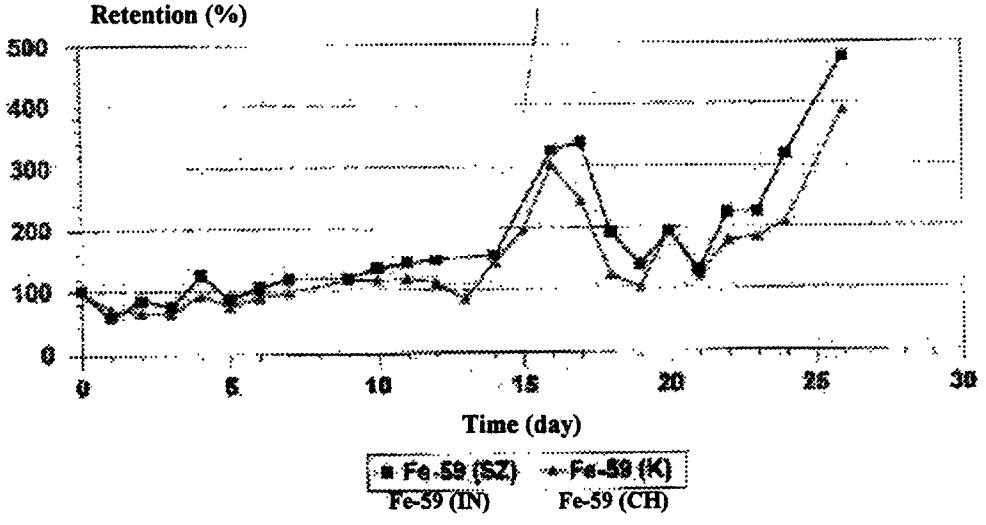

Figure 13: Whole-body retention of Fe-59 administered daily in the forms of inorganic and chelated compounds through the entire study period in the rat

An analysis of the curves representing cumulative excretion (Figures 14 and 15) has revealed that ingested iron, irrespective of the chemical form used, was excreted from the body with the droppings. The quantities of iron excreted with urine increased on Day

15 in the group treated with the chelated compound, which can be interpreted as a sign of better absorption in the gastrointestinal tract for this compound type.

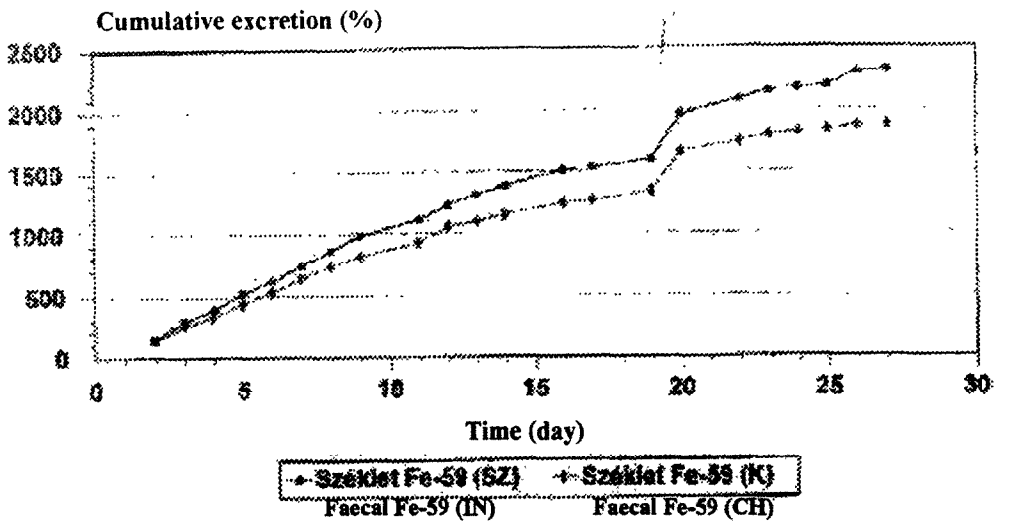

Figure 14: Cumulative faecal excretion of rats treated with Fe-59 daily in the forms of inorganic and chelated compounds through the entire study period

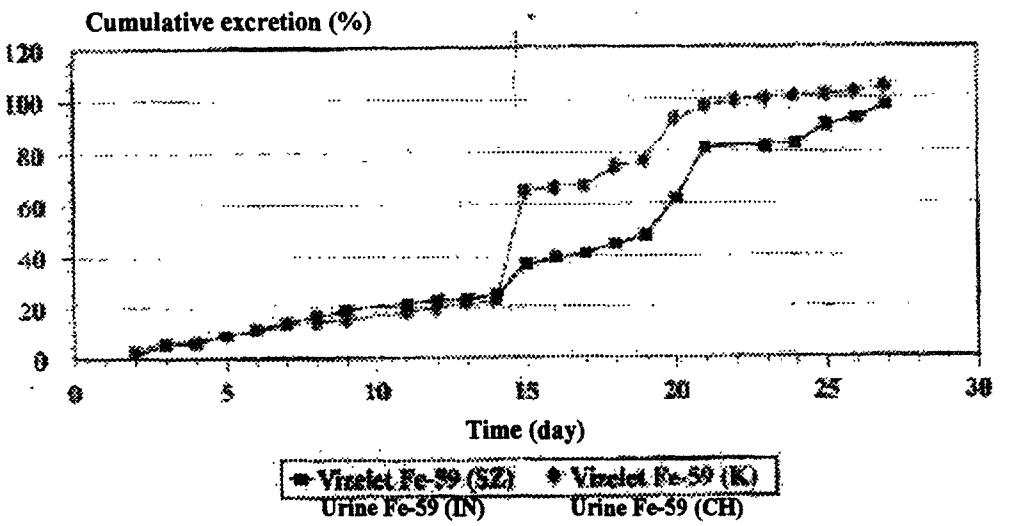

Figure 15: Cumulative urinary excretion of rats treated with Fe-59 daily in the forms of inorganic and chelated compounds through the entire study period

Figure 16 illustrates the whole-body retention of Zn-65. In Days 0 to 14 the quantities of zinc retained in the body were identical, irrespective of the chemical formulation used. In Days 14 to 16 a slight increase was observed in both treatment groups and the quantities of retained Zn-65 varied in the range of 100-120%.

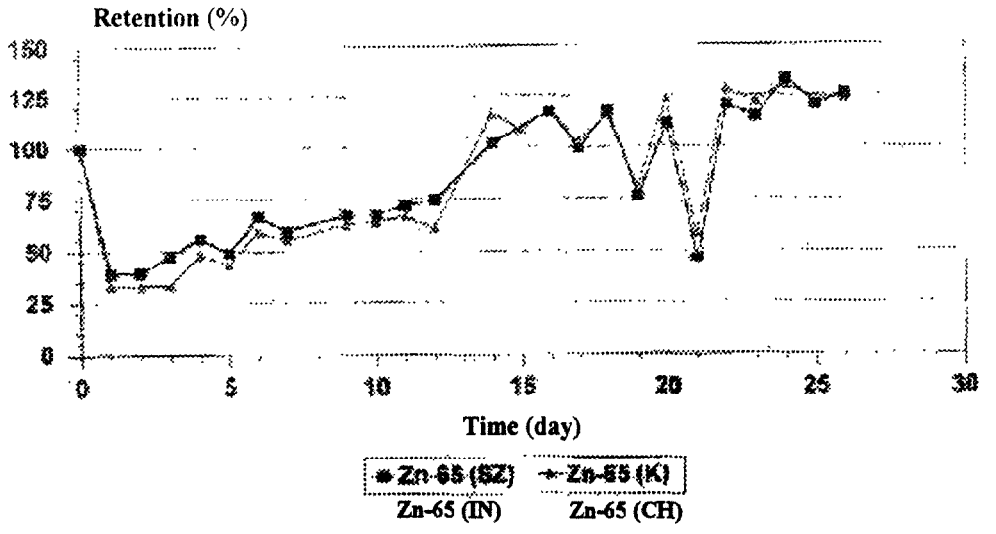

Figure 16: Whole-body retention of Zn-65 administered daily in the forms of inorganic and chelated compounds through the entire study period in the rat

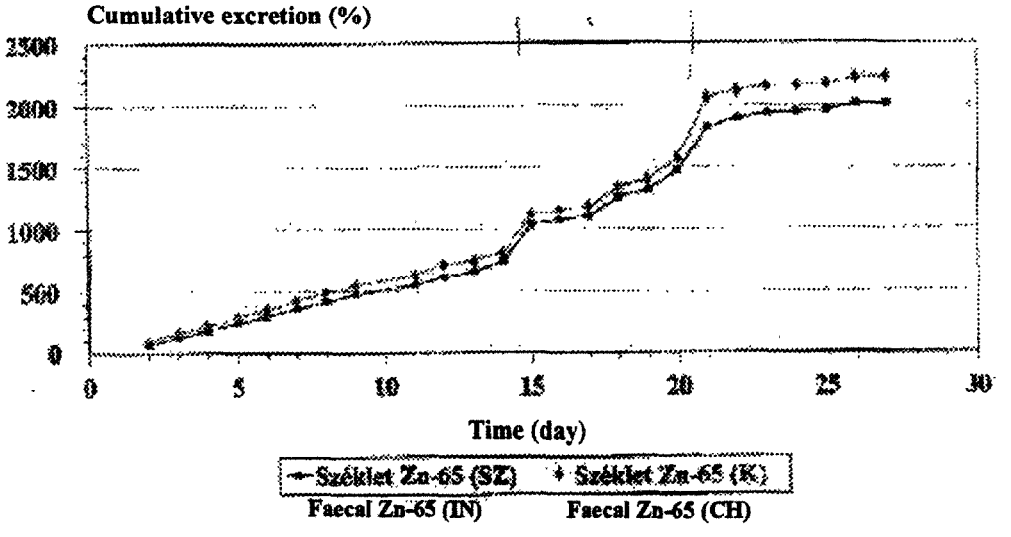

Figure 17: Cumulative faecal excretion of rats treated with Zn-65 daily in the forms of inorganic and chelated compounds through the entire study period

To conclude, zinc is almost entirely discharged with the faeces from the body (Figures 17 and 18). The slopes of curves representing cumulative faecal excretion were identical in both treatment groups.

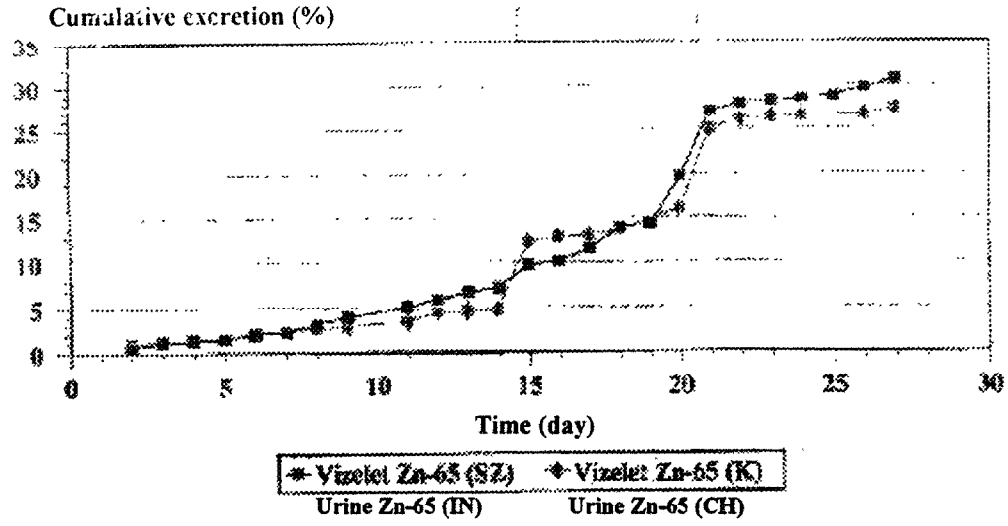

Figure 18: Cumulative urinary excretion of rats treated with Zn-65 daily in the forms of inorganic and chelated compounds through the entire study period

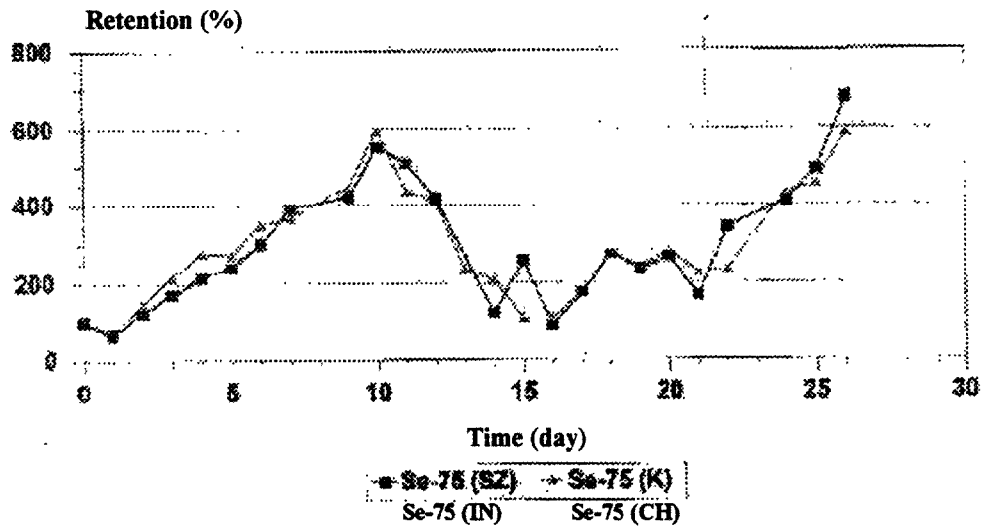

Figure 19: Whole-body retention of Se-75 administered daily in the forms of inorganic and chelated compounds through the entire study period in the rat

The slopes of the curves representing the whole-body retention of selenium were practically identical with the Se-75 retention data shown in Figure 9 up to Day 14 of the experiment. Despite repeated daily administration of Se-75 the quantities of metal retained in the bodies of rats stabilised around 200% (in both chemical forms), then – starting from Day 23 – an intensive growth was observed again.

The curves representing cumulative excretion (Figures 20, 21) demonstrate that selenium is discharged from the body in equal portions through urine and faeces, respectively. Taking into account the quantity of Se-75 discharged with urine also, no significant difference can be observed between the two treatment groups.

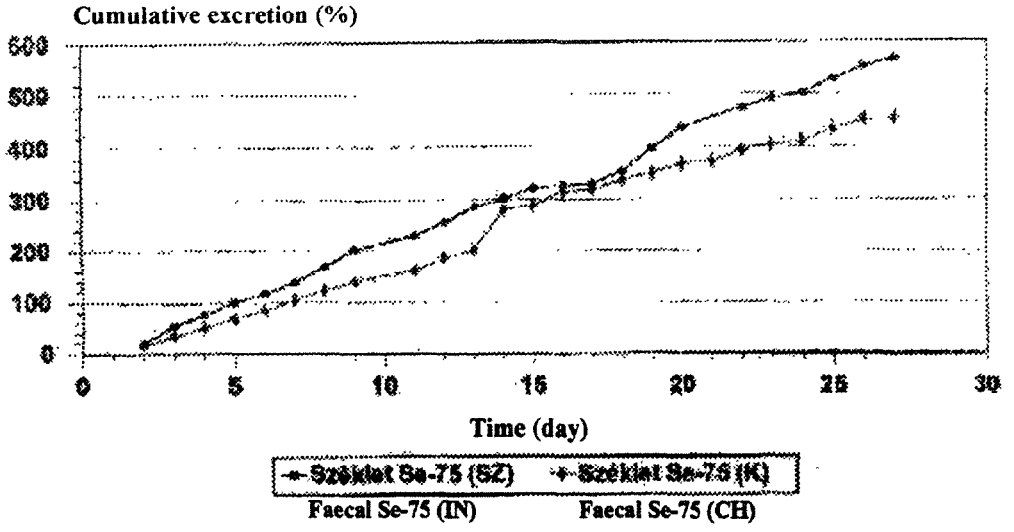

Figure 20: Cumulative faecal excretion of rats treated with Se-75 daily in the forms of inorganic and chelated compounds through the entire study period

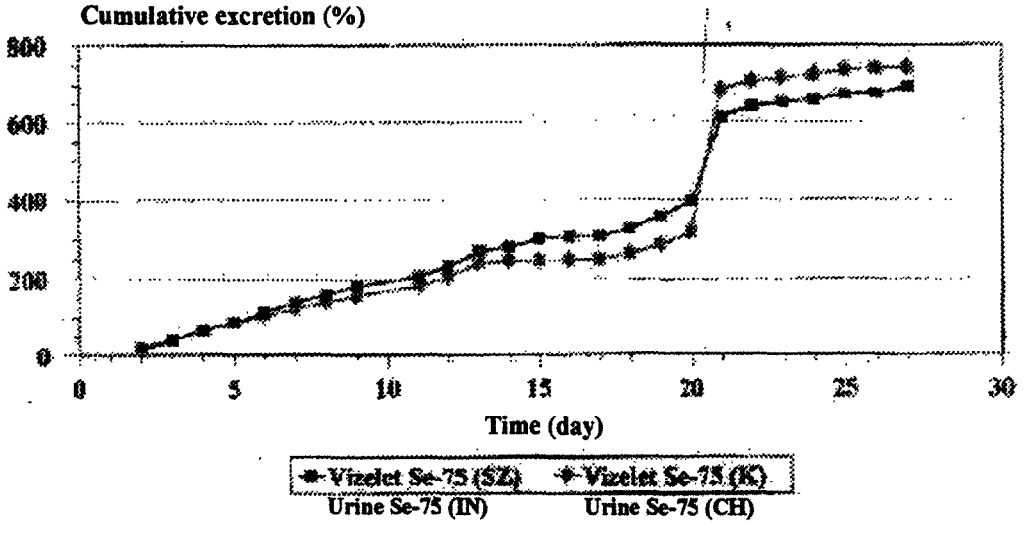

Figure 21: Cumulative urinary excretion of rats treated with Se-75 daily in the forms of inorganic and chelated compounds through the entire study period

With a view to the short, 12.8-hour half-life of radioactive copper, the activity of this trace element could be measured only up to Day 3 of the experiment. Even so, copper remained in the bodies of test animals as an inactive element and could enter into interaction with the other metal ions.

Whole-body and excretion measurement results are given in Table 26 and Figures 22-24.

As a conclusion from the retention values given in Figure 22, Cu-64 was absorbed in the same way whether given in inorganic or chelated form (approx. 60-70%), and is discharged from the rats in a parallel pattern (Figures 23 and 24).

Table 26. Individual whole-body retention and faecal and urine excretion data for trace elements administered in inorganic and chelate forms

Inorganic Cu-64					
o. of an'l/tim	**0**	**1**	**2**	**3**	**4**
1	100	-	55,77	87,53	-
2	100	78,50	-	81,45	122,59
3	100	53,47	43,72	53,54	77,44
4	100	81,12	77,96	107,86	133,34
5	100	40,24	58,51	57,19	92,10
Whole-b. (X)	100	**63,33**	**58,99**	**77,51**	**106,37**
(+/- SD)	**0**	**19,80**	**14,19**	**22,50**	**26,02**
1			52,15	44,78	69,00
2			36,13	71,18	42,18
3			73,82	45,95	53,43
4			91,04	88,96	80,09
5			84,25	85,66	72,45
Faeces (X)			**67,48**	**67,31**	**63,43**
(+/- SD)			**22,88**	**21,12**	**15,34**
1			0,93	0,85	-
2			0,63	1,86	-
3			0,06	0,92	0,85
4			2,53	2,74	-
5			1,43	0,58	-
Urine (X)			**1,12**	**1,39**	**0,85**
(+/- SD)			**0,94**	**0,90**	**0**

Chelated Cu-64					
No. of an'l/tim	**0**	**1**	**2**	**3**	**4**
1	100	75,88	66,35	67,43	46,46
2	100	46,44	60,24	67,60	78,30
3	100	41,30	52,10	67,30	56,97
4	100	67,42	76,80	107,00	120,70
5	100	18,13	80,00	50,90	49,70
Whole-b.H1 (X	**100**	**49,83**	**67,10**	**72,05**	**70,43**
(+/- SD)	**0**	**22,79**	**11,54**	**20,81**	**30,72**
1			73,06	88,66	80,91
2			73,43	80,72	63,54
3			43,89	91,68	73,46
4			118,32	98,74	82,56
5			98,63	77,61	62,12
Faeces (X)			**81,46**	**87,48**	**72,52**
(+/- SD)			**28,28**	**8,50**	**9,50**
1			1,90	39,00	0,93
2			0,05	3,34	-
3			0,52	-	-
4			1,21	4,37	-
5			1,27	-	-
Urine (X)			**0,99**	**2,70**	**0,93**
(+/- SD)			**0,72**	**2,07**	**0**

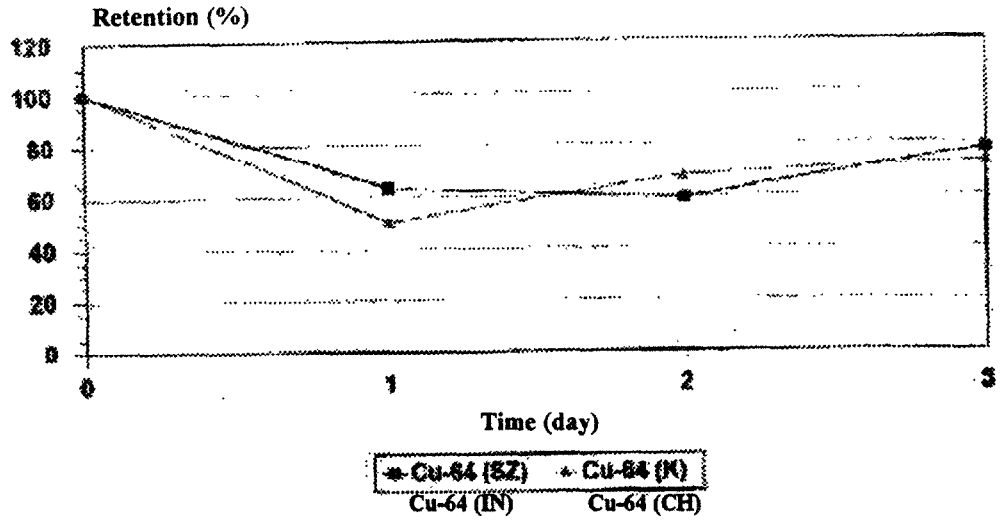

Figure 22: Whole-body retention of Cu-64 administered daily in the forms of inorganic and chelated compounds through the entire study period in the rat

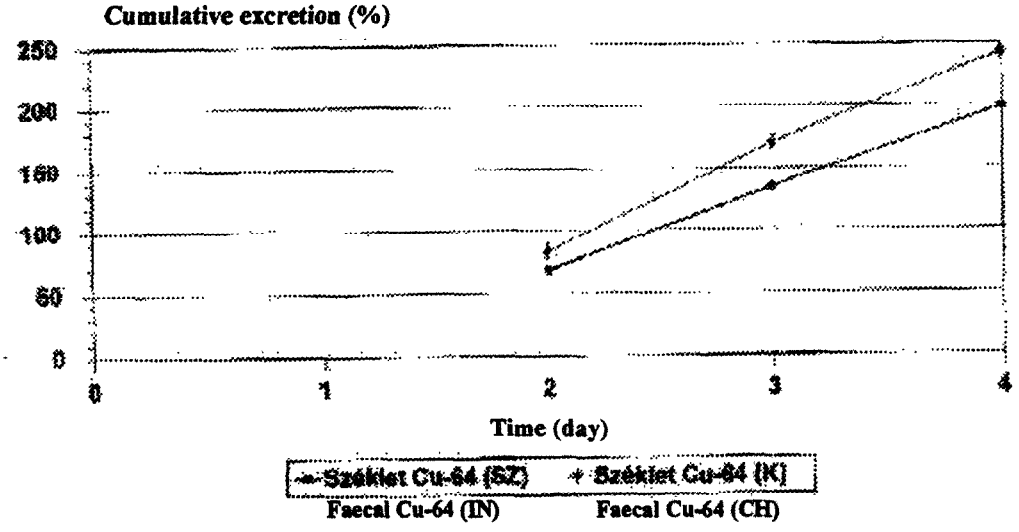

Figure 23: Cumulative faecal excretion of rats treated with Cu-64 daily in the forms of inorganic and chelated compounds through the entire study period

The possible discharge of trace elements from the body was examined in treatment Groups 1.b and 2.b following cadmium exposure (Days 14 and 15), as of Day 16. In Group 1.b tap water (TW), while in Group 2.b humic acid (HA) was applied as decorporating compound (agent).

The exponential curves representing the excretion of different metal ions are given in Figures 25-28.

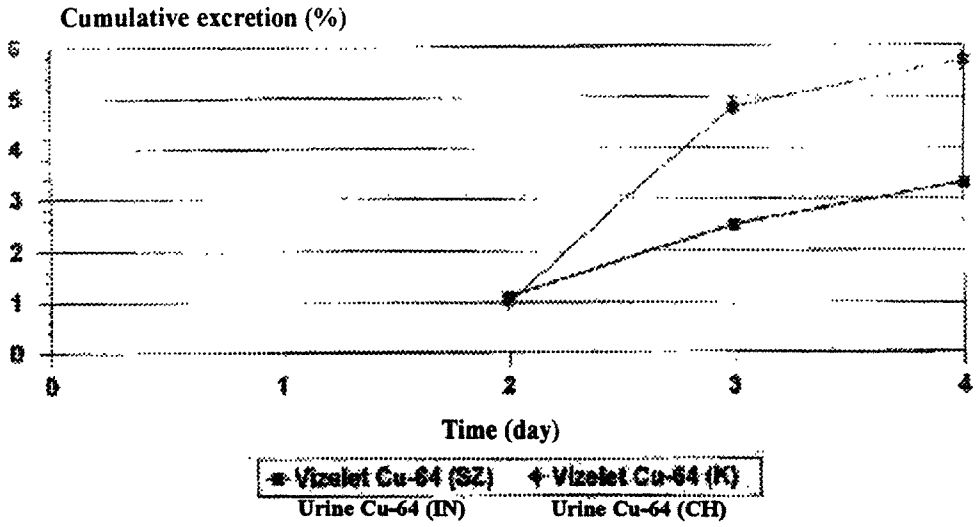

Figure 24: Cumulative urinary excretion of rats treated with Cu-64 daily in the forms of inorganic and chelated compounds through the entire study period

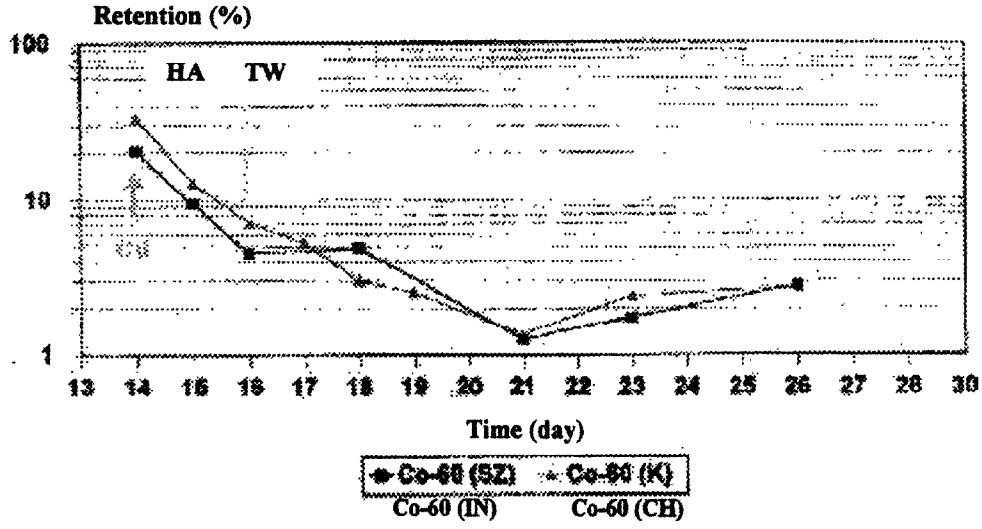

Figure 25: Whole-body retention of Co-60 administered daily up to Day 14 in the forms of inorganic and chelated compounds. The animals in both groups received Cd-115 on Days 14 and 15, then up to the end of the experiment tap water (TW) in the inorganic group (IN) and undoted humic acid (HA) in the chelate group (CH).

Following the administration of cadmium Co-60 was discharged intensively from the body in both treatment groups. The quantity of cobalt retained in the whole body dropped from 20-30% of whole-body load (on Day 14) to only 5-8%. This quantity, irrespective of the mode of treatment, was discharged evenly from the body.

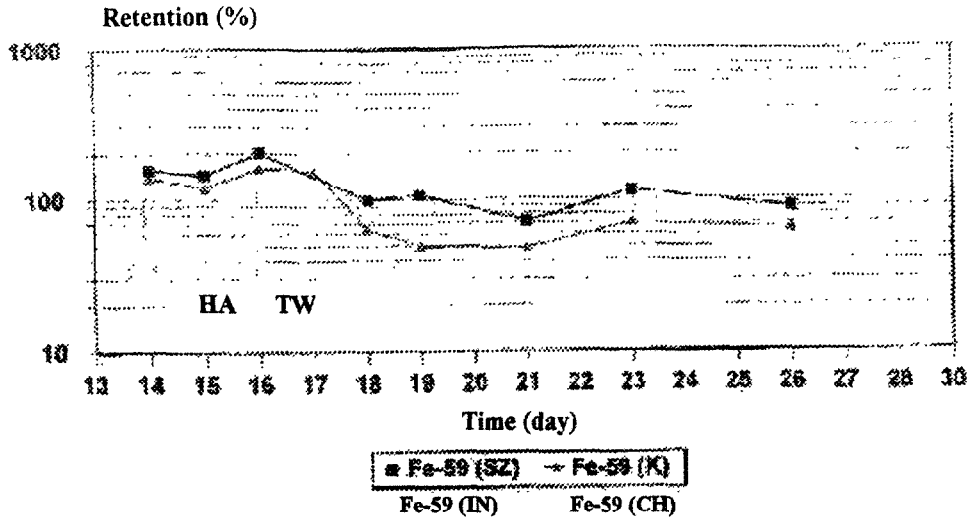

Figure 26: Whole-body retention of Fe-59 administered daily up to Day 14 in the forms of inorganic and chelated compounds. The animals in both groups received Cd-115 on Days 14 and 15, then up to the end of the experiment tap water (TW) in the inorganic group (IN) and undoted humic acid (HA) in the chelate group (CH).

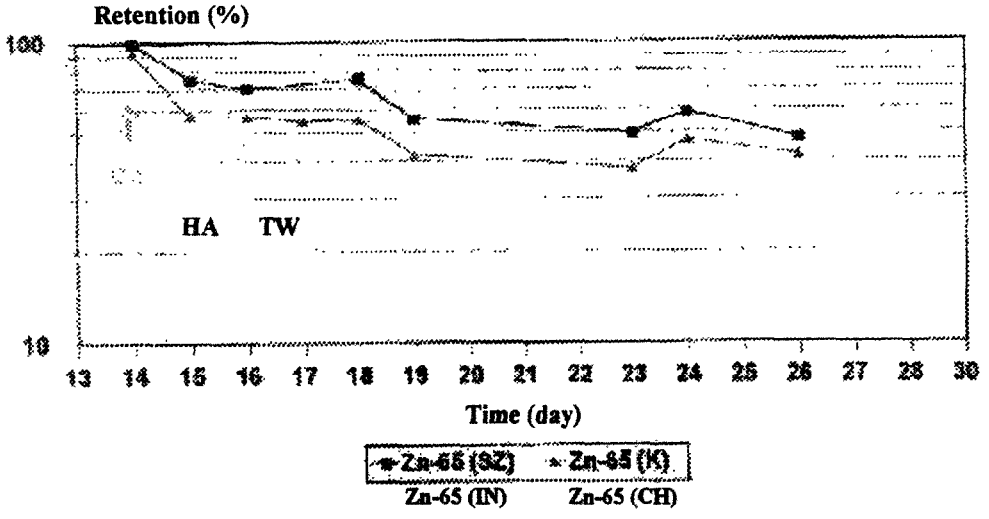

Figure 27: Whole-body retention of Zn-65 administered daily up to Day 14 in the forms of inorganic and chelated compounds. The animals in both groups received Cd-115 on Days 14 and 15, then up to the end of the experiment tap water (TW) in the inorganic group (IN) and undoted humic acid (HA) in the chelate group (CH).

An analysis of the Fe-59 discharge curves given in Figure 26 revealed that the quantity of iron discharged increased by nearly 20-30% in the animals treated with undoted humic acid. The kinetics of excretion showed a similar pattern in both treatment forms.

A tendency similar to that of iron retention was observed in the case of Zn-65 (Figure 27). Following the cadmium exposure on Day 14 the discharging of both the inorganic and the chelated zinc compound accelerated by approximately 20-30%. Obviously, as a result of HA treatment the quantity of excreted zinc increased, however the two curves have parallel-running slopes and are characterised by identical discharge kinetics.

The excretion of chelated selenium significantly increased (by 50%) as a result of cadmium exposure, and HA treatment up to the end of the experiment resulted only in

minimum reduction in retention (Figure 28). In the case of selenium administered in the form of inorganic compound no retention-reducing (antagonistic) effect of cadmium could be observed.

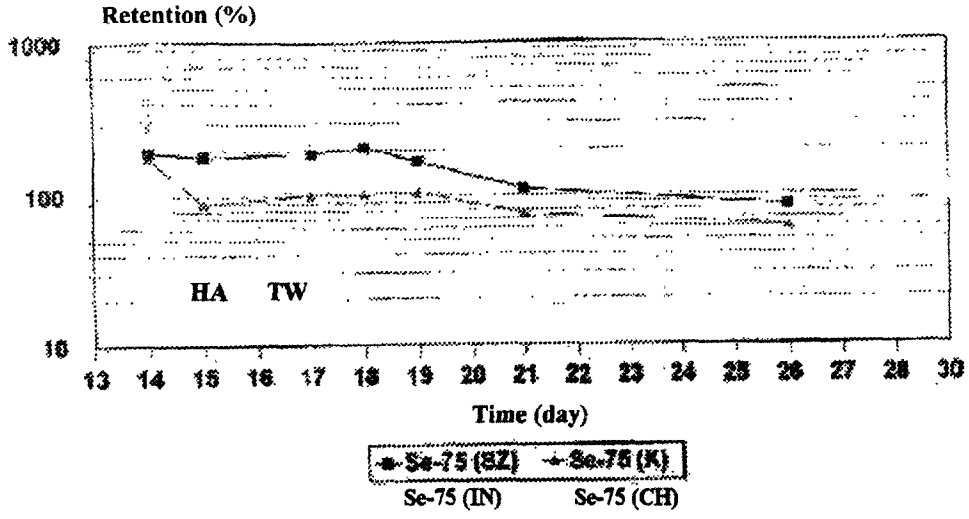

Figure 28: Whole-body retention of Se-75 administered daily up to Day 14 in the forms of inorganic and chelated compounds. The animals in both groups received Cd-115 on Days 14 and 15, then up to the end of the experiment tap water (TW) in the inorganic group (IN) and undoted humic acid (HA) in the chelate group (CH).

As a result of tap water treatment higher quantities of selenium (by approximately 25-30%) was retained in the bodies of experimental animals. In this case also the slopes of excretion curves can be regarded as identical.

Figures 29 and 30 show the whole-body retention of various chemical forms of cadmium and the efficacy of the treatments pursued.

It was found that discharge patterns for Cd-115 differ only upon administration (Days 14 and 15 of the experiment) in the groups receiving different modes of treatment (Figure 29). The treatments used as of Day 16 did not influence either the retention quantities or the rate of discharge.

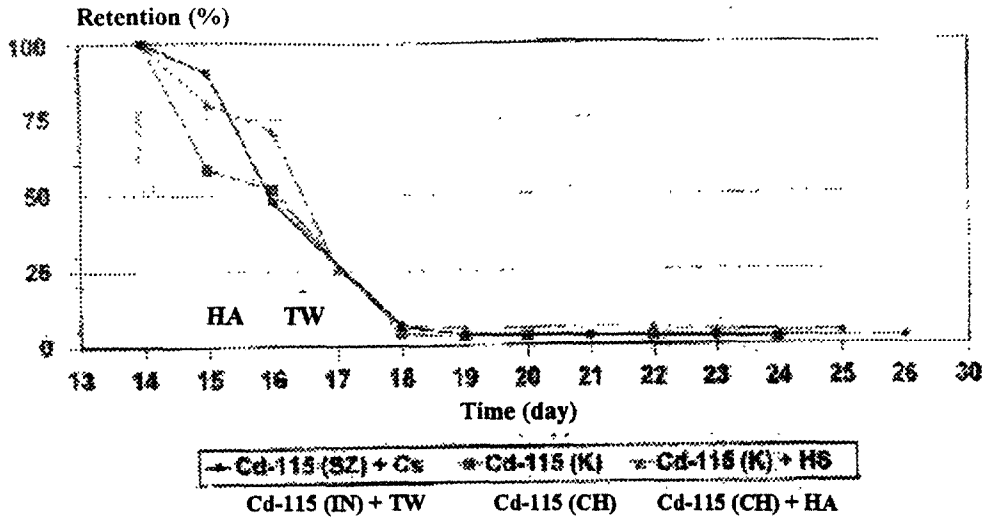

Figure 29: Whole-body retention of cadmium in rats receiving trace elements in the forms of inorganic and chelated compounds up to Day 14 and exposed to Cd-115 on Days 14 and 15. As of Day 16 up to the end of the experiment the animals were given tap water (TW) in the inorganic group (IN) and either undoted humic acid (HA) or trace elements in chelate forms in the chelate group (CH).

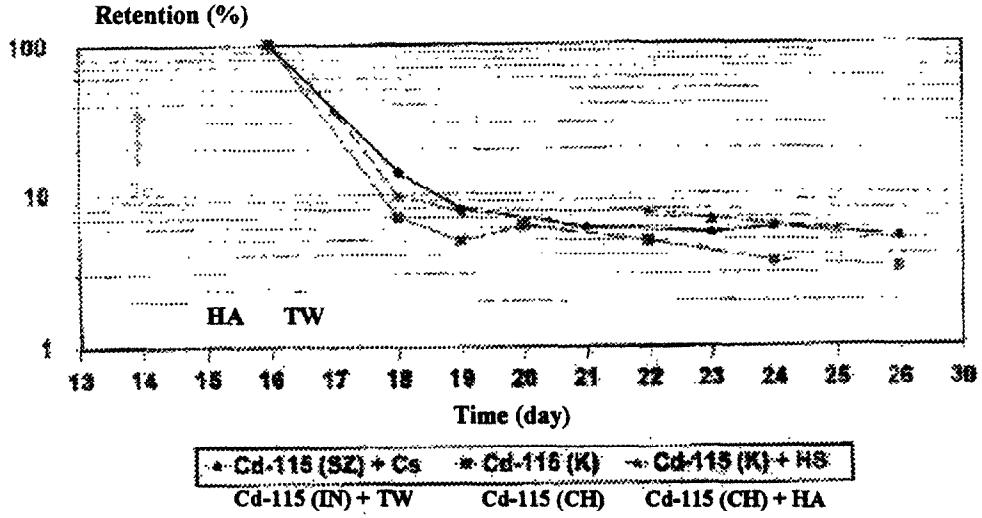

Figure 30: Whole-body retention of cadmium in rats receiving trace elements in the forms of inorganic and chelated compounds up to Day 14 and exposed to Cd-115 on Days 14 and 15. As of Day 16 up to the end of the experiment the animals were given tap water (TW) in the inorganic group (IN) and either undoted humic acid (HA) or trace elements in chelate forms in the chelate group (CH).

The isotope quantity retained at the end of the cadmium treatment was taken as 100% in the above Figure.

In respect of the exponential curves shown in Figure 30, cadmium quantities retained in the organisms of rats at the end of the cadmium treatment in each group were regarded as

100%, i e. "initial whole-body load", and the data measured up to the termination of the experiment were expressed as a percentage of that baseline value.

As suggested by these results, the discharging of cadmium can be described as the sum of a binominal exponential function. In the first phase of excretion (days 1-3) 3-5% of the initial whole-body load was retained in the rats in all the three treatment groups. Further treatments did not change considerably the kinetics of discharge. Curve parameters and the biological half-time values of Cd-115 were summed up in Table 27. It must be noted that due to major errors in interpolating component no. 2 when biological half-time values were calculated the groups cannot be reasonably compared. As exponential coefficients demonstrate it, more than 95% of cadmium retained in the body was discharged extremely fast, with 0.3-0.5 days half-time. No significant difference could be observed between the treatment groups.

Table 27: Summary of retention curve° parameters and biological half-times

Test	Parameter (5)		Biological half-time (day)	
groups	A	B	T_1	T_2
Cd-115 (IN) + TW	97.8	2.2	0.57	79.6
Cd-115 (CH)	94.4	5.6	0.38	11.9
Cd-115 (CH) + HA	96.7	3.3	0.53	24.9

° The parameters were computed using the following equation:

$$Y = A*\exp(-b*t) + B*\exp(-d*t)$$

As shown by the analysis of excretion products, cadmium was discharged from animal bodies in all treatment groups in the same way, with the droppings. During the period of 1-3 days following exposure 80-90% of the administered quantity (initial whole-body load) was detected in the faeces. The radioactivity as measured in urine was insignificant.

Due to the 53-hour half-life of the cadmium isotope, this element could be traced for only a couple of days because of the limits of measurement technology used, however the toxic effect of this metal had to be still reckoned with.

In these experiments the effects of pregnancy on the absorption and discharge of trace elements administered daily in inorganic and chelated forms were examined. Treatments were stopped immediately when delivery started. The animals were also exposed to 1000 microgram of cadmium on Day 18 of their pregnancies in the form of inorganic or chelated compounds.

Changes in the whole-body activity of dams are summed up in Tables 28 and 29 and also in Figures 31 to 34.

In the case of Co-60 (Figure 31) it is clear that from Day 13 intensive cobalt uptake took place, which reached its peak by the time of delivery in both treatment groups.

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Table 28. Specific and mean retention of trace elements administered in inorganic form in pregnant animals

Time (day)	1				2				3			
No of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	137,34	-	188,59	196,54	-	-	-	221,58	231,28	380,95	387,19	333,04
2	101,41	110,89	129,20	155,96	140,94	194,09	203,11	170,81	87,67	160,19	175,02	281,22
3	-	171,38	158,10	199,08	-	-	-	260,58	149,52	268,62	237,44	370,36
4	113,79	150,29	-	196,28	149,85	240,86	323,31	206,99	164,62	233,34	-	333,74
5	69,03	169,73	135,79	-	67,44	180,61	143,82	256,53	348,00	366,77	319,36	369,82
Average	**105,39**	**150,57**	**152,92**	**186,96**	**119,41**	**205,19**	**223,41**	**223,30**	**196,22**	**281,97**	**279,75**	**337,64**
(+/- SD)	**28,46**	**28,14**	**26,81**	**20,71**	**45,23**	**31,62**	**91,45**	**37,14**	**99,03**	**92,68**	**92,86**	**36,49**

Time (day)	4				5				6			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	143,17	405,46	296,12	357,38	246,59	-	497,06	466,99	97,45	519,13	413,49	476,75
2	100,43	183,45	182,78	274,43	123,94	186,51	213,46	274,87	68,79	213,06	198,60	387,29
3	104,61	286,23	244,48	422,33	113,69	329,95	263,30	479,71	93,40	445,60	309,36	-
4	107,19	253,56	386,30	368,32	160,25	337,82	497,99	447,24	113,06	359,08	519,65	552,82
5	70,59	207,05	215,53	387,12	104,33	300,91	290,38	447,77	86,94	348,59	294,10	584,43
Average	**105,20**	**267,15**	**265,04**	**361,91**	**149,76**	**288,80**	**352,44**	**423,32**	**91,93**	**377,09**	**347,04**	**500,32**
(+/- SD)	**25,82**	**87,03**	**79,55**	**54,78**	**58,13**	**70,02**	**135,29**	**84,11**	**16,12**	**115,01**	**122,95**	**87,87**

Time (day)	7				8				9			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	-	-	425,36	616,82	140,77	637,57	433,50	546,04	128,89	-	526,36	619,30
2	-	227,72	194,33	469,03	70,79	229,08	228,45	459,35	54,50	235,44	223,66	421,88
3	-	683,05	503,55	698,65	237,01	541,65	423,57	644,81	152,86	586,68	461,33	709,11
4	-	590,28	563,63	636,75	153,44	458,56	597,67	566,66	124,63	513,09	655,67	592,25
5		508,39	389,19	701,33	164,84	374,00	339,81	624,74	98,64	424,22	313,87	518,84
Average		**502,36**	**415,21**	**624,52**	**153,37**	**448,17**	**404,60**	**568,32**	**111,90**	**439,86**	**436,18**	**572,28**
(+/- SD)		**196,50**	**140,89**	**94,58**	**59,38**	**156,70**	**135,74**	**73,15**	**37,42**	**151,61**	**171,08**	**108,18**

Time (day)	11				12				13			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	-	-	-	353,14	-	-	1708,21	327,80	607,73	-	1842,89	263,06
2	-	-	-	237,64	251,09	760,38	713,63	269,62	113,01	-	761,90	201,82
3	-	-	-	431,14	369,36	1759,07	1190,91	386,84	309,41	-	1331,56	303,32
4	-	-	-	315,38	431,09	1674,06	-	335,41	225,20	-	-	240,14
5				400,61	358,05	1691,51	1262,84	483,93	181,32	-	1291,59	256,44
Average				**347,58**	**352,40**	**1471,25**	**1218,90**	**360,72**	**287,33**		**1306,99**	**252,96**
(+/- SD)				**75,74**	**74,78**	**475,34**	**407,20**	**80,45**	**192,76**		**441,64**	**36,84**

Time (day)	14				15				16			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	-	-	1526,95	298,42	524,30	-	1332,57	413,27	223,60	1530,34	1283,79	298,70
2	-	-	663,05	227,60	148,46	1172,13	505,13	311,93	144,50	268,60	503,50	227,40
3	-	-	880,29	392,28	343,02	2544,09	964,15	452,26	154,57	1174,15	898,62	407,04
4	-	-	1932,27	348,01	553,34	2508,21	1808,36	403,63	156,83	1188,58	1416,26	318,20
5			1155,50	358,97	550,62	2112,76	1208,66	500,38	273,00	1052,12	1174,25	418,74
Average			**1231,61**	**325,06**	**423,95**	**2084,30**	**1163,77**	**416,29**	**190,50**	**1042,76**	**1055,28**	**334,02**
(+/- SD)			**507,60**	**64,03**	**176,99**	**638,74**	**479,50**	**69,69**	**55,78**	**467,88**	**362,52**	**79,65**

Table 28. (continued)

Time (day)	17				18				19			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	-	-	-	-	190,28	1267,78	773,28	439,79	196,20	1079,62	950,51	342,56
2	97,38	476,51	446,76	259,28	38,09	484,04	317,30	374,94	45,35	284,46	373,68	281,56
3	-	-	-	-	90,77	1473,57	759,99	575,35	95,50	677,94	658,16	388,79
4	258,23	1213,29	1399,64	337,30	131,29	1453,25	1099,54	507,96	96,79	578,93	983,47	324,48
5	201,53	654,80	769,63	333,44	155,29	654,92	541,20	413,99	71,40	470,37	597,60	338,67
Average	**185,71**	**781,53**	**872,01**	**310,00**	**121,14**	**1066,71**	**698,26**	**462,40**	**101,05**	**618,26**	**712,68**	**335,21**
(+/- SD)	**81,58**	**384,40**	**484,62**	**43,97**	**58,88**	**464,88**	**291,66**	**79,59**	**57,20**	**296,33**	**255,45**	**38,51**

Time (day)	20				21				22			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	-	-	1294,50	-	247,85	-	1440,52	-	-	-	656,28	350,75
2	55,12	521,49	595,19	-	47,80	663,39	662,07	-	22,82	-	302,47	326,52
3	44,53	1035,60	960,43	-	114,53	1156,67	1082,89	-	76,26	-	545,84	448,39
4	188,57	1095,26	-	-	174,91	1005,14	-	-	65,84	-	806,65	362,78
5	179,08	881,09	1007,84	-	212,26	1222,03	1116,44	-	13,84	-	474,77	395,37
Average	**141,83**	**883,36**	**964,49**		**159,47**	**1011,81**	**1075,48**		**44,69**		**557,20**	**376,76**
(+/- SD)	**60,82**	**257,57**	**287,05**		**79,57**	**249,41**	**319,32**		**30,95**		**189,64**	**47,10**

Time (day)	23				25				28			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	76,31	-	503,22	-	-	-	-	350,75	-	-	465,63	-
2	17,44	-	225,21	-	22,82	-	296,53	326,52	15,35	347,23	291,86	-
3	55,81	-	344,18	-	76,26	-	544,40	448,39	64,69	-	394,60	-
4	63,79	-	555,20	-	65,84	-	-	362,78	44,86	571,10	-	-
5	44,57	-	378,84	-	53,87	-	464,78	395,37	37,06	507,57	375,12	-
Average	**51,58**		**401,33**		**54,70**		**435,24**	**376,76**	**40,49**	**475,30**	**381,80**	
(+/- SD)	**22,32**		**131,19**		**23,14**		**126,55**	**47,10**	**20,40**	**115,37**	**71,47**	

Time (day)	29				30				32			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	67,73	-	464,47	331,74	50,41	-	407,93	-	70,46	-	425,43	421,77
2	-	-	-	-	-	-	-	-	-	-	-	-
3	49,45	553,91	340,25	392,80	45,11	777,43	313,68	-	41,28	644,09	287,15	447,47
4	44,75	359,18	543,20	336,13	30,21	590,10	-	-	50,09	489,69	487,96	331,98
5	40,58	386,95	310,11	302,11	40,92	615,72	351,24	-	33,75	377,23	291,84	383,09
Average	**50,63**	**433,34**	**414,51**	**340,69**	**41,66**	**661,08**	**357,61**		**48,90**	**503,67**	**373,09**	**396,08**
(+/- SD)	**11,96**	**105,33**	**108,74**	**37,88**	**8,57**	**101,57**	**47,45**		**15,85**	**133,98**	**99,87**	**50,26**

Time (day)	35				36			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	109,24	862,16	358,05	373,95	90,57	626,64	281,59	491,43
2	-	-	-	-	-	-	-	-
3	55,06	612,30	281,72	515,42	46,72	601,27	316,46	666,75
4	57,63	495,13	507,23	368,55	47,68	553,13	520,73	561,95
5	59,72	399,53	251,18	424,68	64,74	404,72	289,16	523,96
Average	**70,41**	**592,28**	**349,54**	**420,65**	**62,42**	**546,44**	**351,98**	**561,02**
(+/- SD)	**25,96**	**199,86**	**114,33**	**68,05**	**20,51**	**99,28**	**113,49**	**76,15**

Table 29. Specific and mean retention of trace elements administered in chelate form in pregnant animals

Time (day)	1				2				3			
No of an	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	-	181,51	196,07	210,78	-	194,89	220,39	220,54	252,37	210,78	275,79	328,96
2	93,33	109,35	135,35	193,97	102,90	133,69	137,88	194,39	171,54	150,59	198,19	293,88
3	134,47	121,66	121,52	137,57	65,56	139,45	104,46	131,66	70,03	139,15	130,38	196,17
4	201,83	176,97	202,03	247,03	174,97	179,97	211,60	257,00	-	278,51	579,75	344,97
5	114,42	128,75	132,68	198,74	171,72	212,72	167,45	205,31	137,27	146,05	172,06	315,25
Average	**136,01**	**143,65**	**157,53**	**197,62**	**128,79**	**172,14**	**168,35**	**201,78**	**157,80**	**185,01**	**271,23**	**295,85**
(+/- SD)	**46,99**	**33,26**	**38,31**	**39,48**	**53,68**	**34,54**	**48,96**	**45,79**	**75,84**	**59,61**	**180,43**	**58,79**

Time (day)	4				5				6			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	-	282,59	355,90	365,73	-	511,25	510,34	413,81	-	354,26	497,13	412,08
2	96,26	159,49	185,89	333,49	141,54	189,04	211,22	365,25	135,31	206,13	237,09	367,23
3	0,66	274,50	233,34	205,21	270,07	313,11	334,83	257,33	135,91	332,14	309,12	254,97
4	143,64	210,90	287,38	395,50	228,98	283,72	350,77	423,46	171,55	280,33	371,30	437,87
5	112,56	176,61	160,08	310,88	161,33	259,64	225,30	363,48	133,37	275,64	256,48	381,01
Average	**134,28**	**220,82**	**244,52**	**322,36**	**200,48**	**311,35**	**326,49**	**364,66**	**144,04**	**289,70**	**334,22**	**370,63**
(+/- SD)	**38,91**	**55,93**	**78,95**	**72,97**	**59,61**	**120,79**	**120,40**	**65,95**	**18,38**	**57,53**	**104,91**	**70,24**

Time (day)	7				8				9			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	390,27	475,53	489,99	570,25	461,04	484,81	452,71	480,64	-	-	744,61	649,59
2	4,00	280,79	269,82	574,12	147,30	233,46	267,95	496,07	228,71	322,99	348,15	516,04
3	251,49	336,17	367,02	352,03	370,03	422,53	396,29	361,08	183,83	435,06	332,28	357,14
4	264,17	338,45	464,03	652,52	291,39	362,61	440,06	548,55	209,94	466,88	487,12	633,07
5	98,97	311,79	248,16	558,31	154,48	304,33	274,09	539,28	227,72	459,37	327,92	592,84
Average	**228,71**	**348,55**	**367,80**	**541,45**	**284,85**	**361,55**	**366,22**	**485,12**	**212,55**	**421,07**	**448,02**	**549,73**
(+/- SD)	**114,92**	**74,71**	**109,66**	**112,25**	**136,25**	**98,23**	**89,42**	**74,97**	**21,00**	**66,79**	**178,39**	**119,38**

Time (day)	11				12				13			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	-	1538,31	1860,01	-	-	1592,28	1750,81	349,51	-	-	1793,46	218,80
2	-	1051,51	1231,66	-	445,02	1025,74	1021,97	292,48	295,67	-	1030,00	211,56
3	-	1214,91	1260,63	-	441,85	1012,65	854,46	203,48	401,54	-	1148,80	179,13
4	-	1218,49	1541,49	-	645,34	1323,89	1434,86	371,49	429,23	-	1532,63	274,75
5	-	1202,41	1148,97	-	380,98	693,00	855,90	302,31	287,21	-	929,27	244,18
Average		**1245,13**	**1408,55**		**478,30**	**1129,51**	**1183,60**	**303,85**	**353,41**		**1286,83**	**225,69**
(+/- SD)		**178,11**	**292,42**		**115,19**	**341,65**	**395,82**	**64,93**	**72,53**		**363,99**	**35,93**

Time (day)	14				15				16			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	-	1963,67	1416,48	287,54	969,79	1264,16	1407,43	450,74	410,16	974,94	1142,62	321,56
2	-	1833,73	889,99	206,24	361,23	745,35	887,78	427,74	129,34	609,74	765,06	267,75
3	-	2141,87	1172,52	225,48	707,53	864,97	1044,01	263,06	305,00	736,29	837,40	218,59
4	-	1702,10	1362,30	300,35	453,67	871,81	1223,24	460,89	253,30	817,70	1267,70	390,18
5	-	2029,41	775,79	234,72	292,62	954,41	701,65	363,51	137,00	770,00	684,72	276,07
Average		**1934,15**	**1123,01**	**250,87**	**556,97**	**940,14**	**1052,82**	**393,19**	**246,96**	**781,73**	**939,50**	**294,83**
(+/- SD)		**171,05**	**283,57**	**40,90**	**279,27**	**195,87**	**276,33**	**82,01**	**118,29**	**132,67**	**252,36**	**64,62**

Table 29. (continued)

Time (day)	17				18				19			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	157,21	1065,69	685,02	503,23	-	1076,14	1045,92	362,41	162,59	1097,68	1054,44	427,15
2	119,51	811,81	572,15	509,21	200,95	605,17	785,14	326,91	101,75	595,91	774,05	429,34
3	169,80	564,98	476,31	368,27	279,57	792,65	697,74	251,06	147,09	571,78	679,90	287,63
4	128,23	502,99	550,08	388,11	-	-	-	-	116,66	437,69	772,71	350,80
5	81,77	998,97	502,54	467,49	130,14	972,44	729,04	374,85	93,85	789,06	674,47	380,21
Average	**131,31**	**788,89**	**557,22**	**447,26**	**203,56**	**861,60**	**814,46**	**328,81**	**124,39**	**698,42**	**791,11**	**374,94**
(+/- SD)	**34,48**	**251,57**	**80,84**	**65,42**	**74,75**	**207,22**	**158,49**	**55,67**	**29,49**	**256,00**	**154,88**	**59,03**

Time (day)	20				21				22			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	-	1976,01	2105,52	-	389,03	3424,93	2515,42	-	113,97	1739,20	621,97	373,11
2	201,88	722,61	882,00	-	185,98	866,73	955,80	-	84,86	945,15	417,22	328,66
3	314,18	1282,68	1080,97	-	347,70	1754,43	1437,12	-	184,38	1811,76	656,99	443,46
4	256,59	885,55	1180,86	-	268,43	1216,20	1354,17	-	79,09	1161,50	593,36	375,46
5	149,60	1500,17	1266,32	-	148,54	1198,86	1028,67	-	68,77	1178,33	419,78	266,35
Average	**230,56**	**1273,41**	**1303,13**		**267,94**	**1692,23**	**1458,24**		**106,21**	**1367,19**	**541,86**	**357,41**
(+/- SD)	**70,82**	**499,74**	**470,86**		**102,47**	**1019,51**	**625,67**		**46,81**	**384,75**	**114,86**	**65,38**

Time (day)	23				25				28			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	68,96	-	556,02	562,56	113,97	1739,20	621,97	373,11	75,19	613,69	684,52	-
2	60,75	-	331,62	503,34	84,86	945,15	417,22	328,66	52,28	419,48	406,76	655,56
3	125,65	-	477,47	533,26	184,38	1811,76	656,99	443,46	-	-	-	-
4	75,36	-	469,94	667,26	79,09	1161,50	593,36	375,46	67,83	426,96	597,41	640,04
5	32,57	-	389,77	430,75	68,77	1178,33	419,78	266,35	35,07	497,09	395,24	572,68
Average	**72,66**		**444,96**	**539,43**	**106,21**	**1367,19**	**541,86**	**357,41**	**57,59**	**489,31**	**520,98**	**622,76**
(+/- SD)	**33,83**		**86,47**	**86,64**	**46,81**	**384,75**	**114,86**	**65,38**	**17,80**	**89,99**	**143,11**	**44,06**

Time (day)	29				30				32			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	49,71	441,69	520,66	347,85	47,09	809,16	536,72	-	41,54	608,73	465,58	420,02
2	55,68	299,54	290,65	307,80	35,85	429,32	278,94	-	31,70	379,04	275,93	288,20
3	-	-	-	-	-	-	-	-	-	-	-	-
4	66,23	368,96	383,98	353,49	55,13	600,29	389,76	-	42,93	400,48	474,46	408,42
5	42,57	386,88	328,19	368,05	20,48	568,33	350,93	-	40,77	499,82	279,54	346,21
Average	**53,55**	**374,27**	**380,87**	**344,30**	**39,64**	**601,78**	**389,09**		**39,24**	**472,02**	**373,88**	**365,71**
(+/- SD)	**10,01**	**58,64**	**100,77**	**25,78**	**15,02**	**156,91**	**108,60**		**5,10**	**105,24**	**111,08**	**61,00**

Time (day)	35				36			
No. of an.	Co-60	Fe-59	Zn-65	Se-75	Co-60	Fe-59	Zn-65	Se-75
1	139,94	575,85	427,46	385,85	68,48	523,15	449,12	591,81
2	105,88	290,53	243,82	415,72	76,53	329,11	238,33	517,87
3	-	-	-	-	-	-	-	-
4	114,32	511,06	398,76	444,41	99,61	381,64	420,79	594,44
5	93,11	454,10	296,10	387,19	61,14	570,00	274,56	548,19
Average	**113,31**	**457,89**	**341,53**	**408,29**	**76,44**	**450,97**	**345,70**	**563,07**
(+/- SD)	**19,78**	**122,16**	**86,16**	**27,74**	**16,68**	**114,07**	**104,76**	**36,85**

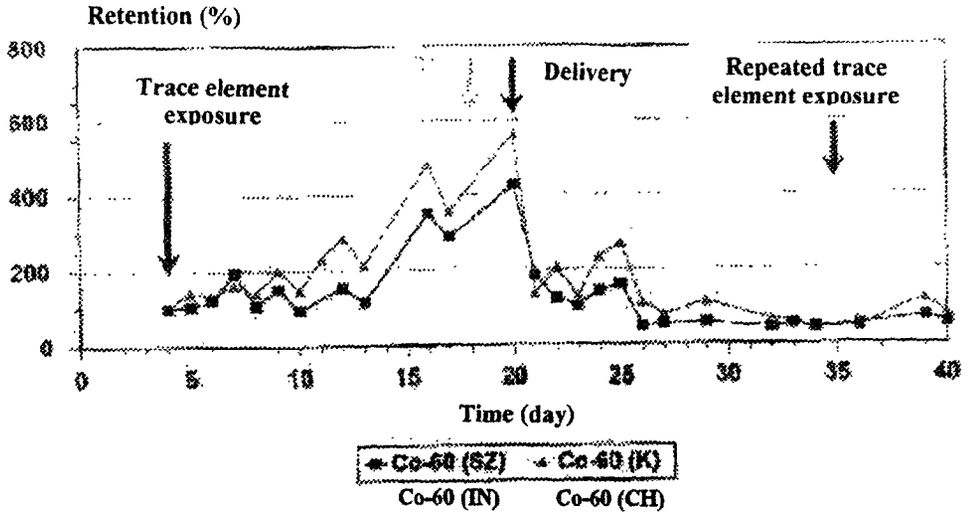

Figure 31: Whole-body retention of Co-60 administered in the forms of inorganic and chelated compounds in dams. As of Day 4 of pregnancy up to the date of delivery trace elements were administered in identical doses, daily. Trace element treatment was repeated two weeks after delivery.

The quantities of Co-60 retained in dams following delivery dropped to almost half, then between days 23 and 25, i.e. 1-2 days following delivery, Co retention got stabilised between 50-100% following a period of slight increase. Repeated doses of cobalt administered prior to the termination of the experiment showed 30-50% absorption only when given in the chelated form.

Whole-body iron retention data are given in Figure 32.

It has been found that in the last third of pregnancy iron uptake intensified in both groups. The approximately 500% value measured on Day 14 of pregnancy quadrupled by the date of delivery. The massive discharge following delivery implies intensive iron absorption by foetus. The repeated trace element exposure given by the end of the experiment did not result in increased Fe-59 retention. No significant difference could be observed between the two treated groups.

It is clear from the curves representing whole-body retention of zinc (Figure 33) that the quantities of Zn-65 ingested from either compound form were practically identical. Similarly to iron, intensive trace element (zinc) uptake was found in the last week of pregnancy. After delivery, dams gradually released zinc, however at a slower rate than in the case of iron discharge. One week after delivery Zn-65 quantities deposited in the dams stabilised in the range of 350-400%, and this was not affected by the repeated trace element exposure.

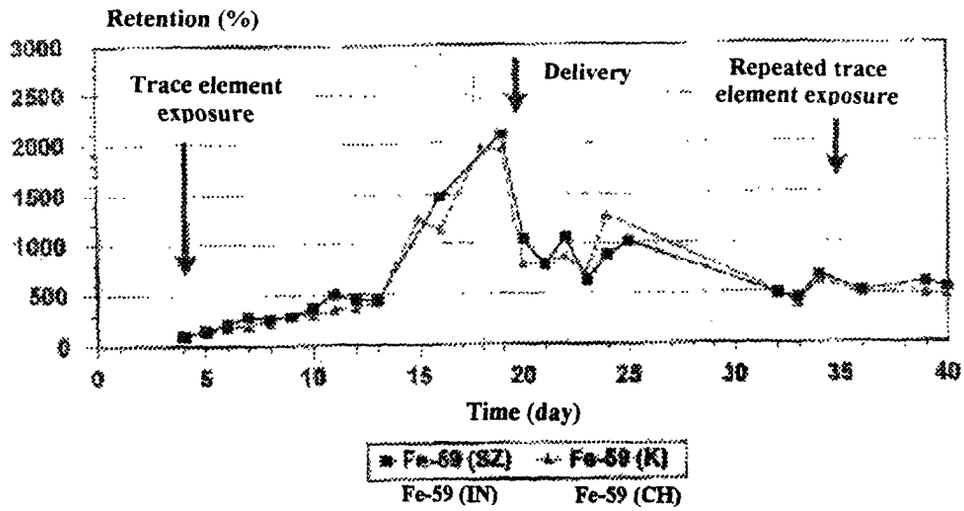

Figure 32: Whole-body retention of Fe-59 administered in the forms of inorganic and chelated compounds in dams. As of Day 4 of pregnancy up to the date of delivery trace elements were administered in identical doses, daily. Trace element treatment was repeated two weeks after delivery.

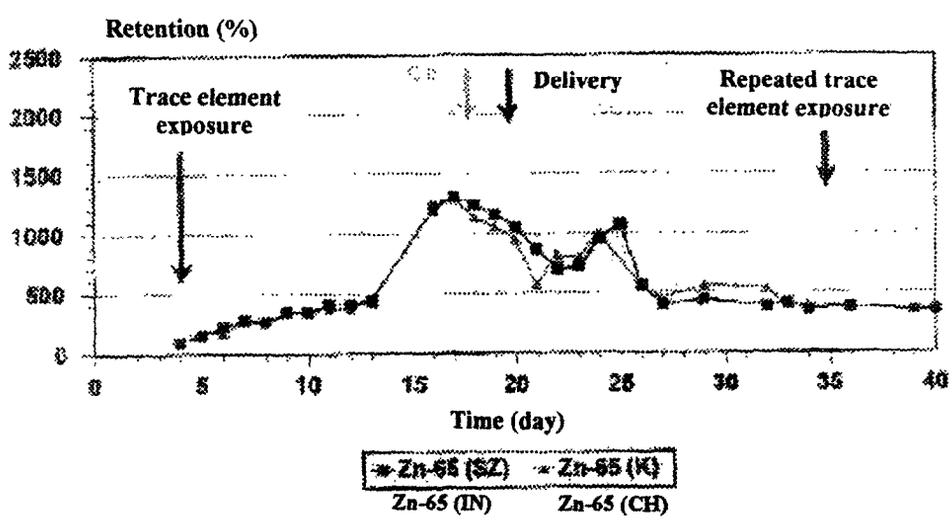

Figure 33: Whole-body retention of Zn-65 administered in the forms of inorganic and chelated compounds in dams. As of Day 4 of pregnancy up to the date of delivery trace elements were administered in identical doses, daily. Trace element treatment was repeated two weeks after delivery.

Contrary to the other trace elements, the absorption and discharge attributes of Se-75 did not differ from those in normal animals (see Figure 9). The organism got saturated on days 11-12 following administration, then – following a discharge period of 4-5 days – again some uptake could be observed. A few days following delivery the quantities of selenium retained in the bodies of dams stabilised around 350%. This volume increased slightly following repeated exposure to selenium.

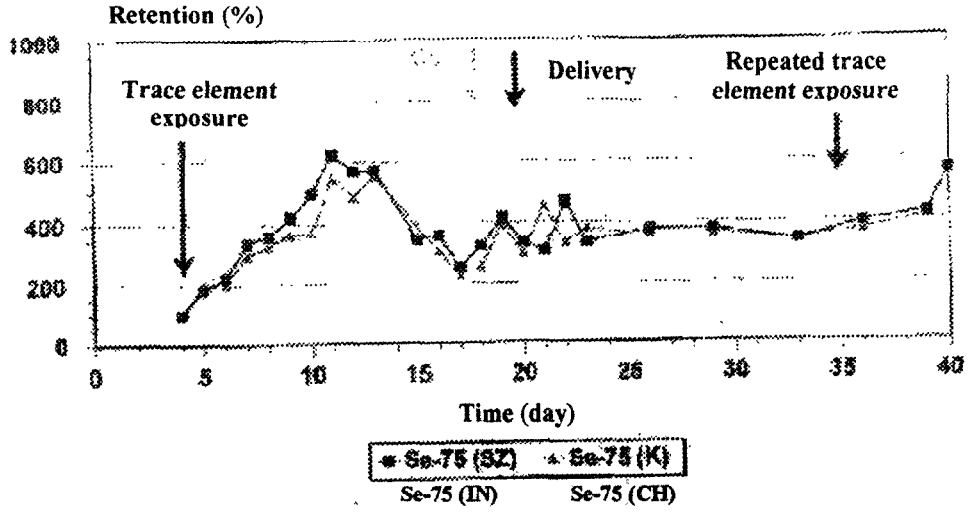

Figure 34: Whole-body retention of Se-75 administered in the forms of inorganic and chelated compounds in dams. As of Day 4 of pregnancy up to the date of delivery trace elements were administered in identical doses, daily. Trace element treatment was repeated two weeks after delivery.

The cadmium uptake in pregnant rats is shown in Figure 35. Cd-115 administered on Days 18 and 19 of their pregnancies in inorganic and chelated compound forms (in 2 x 1500 microgram doses) was released from the organism speedily in either treatment forms.

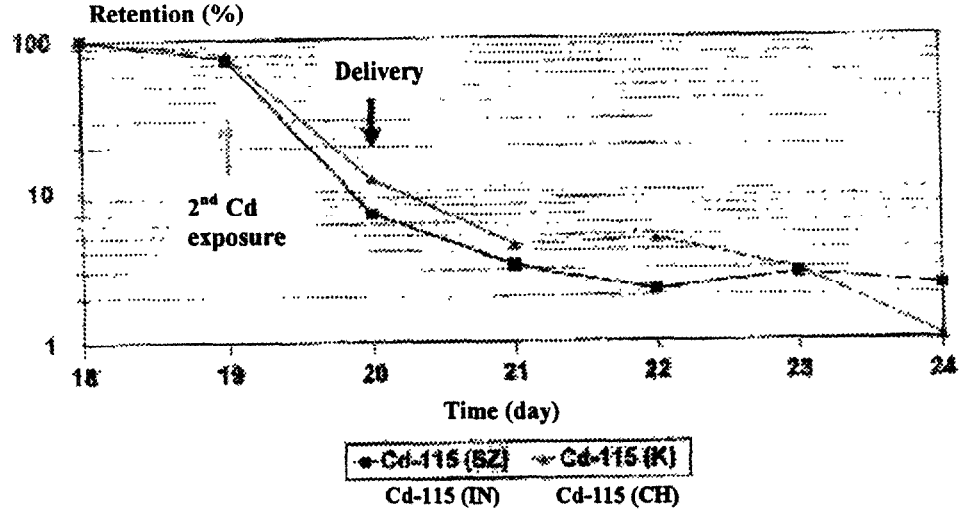

Figure 35: Whole-body retention of Cd-115 administered in the forms of inorganic and chelated compounds on Days 18 and 19 of the pregnancy in rats.

On the second day following the first administration (Day 18) deposited cadmium quantities represented 7% in the inorganic group and 11.8% in the chelate group. Following delivery (Day 20) cadmium administered in the inorganic compound form

remained at the retention range of 2-3%. A more intensive discharge was observed in the chelate group over the same period of time.

Litter was weighed in both treatment groups (inorganic and chelate), immediately after delivery. The average litter number was 11 puppies in both groups. The individual weight of newborn rats in the group treated with inorganic compounds was 5.79 ± 1.33 g, while in the chelate-given group it was 6.15 ± 0.63 g. The average litter weight in the same groups was 64.2 ± 14.6 g and 71.7 ± 16 g, respectively.

The litters of dams treated according to various methods were either left with the dams (active dam – active newborn), or were replaced with inactive newborns (active dam –inactive newborn). The newborn rats freed this way were given to inactive dams (inactive dam – active newborn).

The results are given in Figures 36 to 47.

The trace element retention values of active dams and own litter, i.e. active newborn rats (AD-AN) are summed up in Figures 36 to 39.

It has been found that the whole-body loads (of all the four elements) in newborn rats following delivery further increased due to trace element uptake from dam's milk. Trace element retention gradually dropped following a 3 to 5 day period after birth.

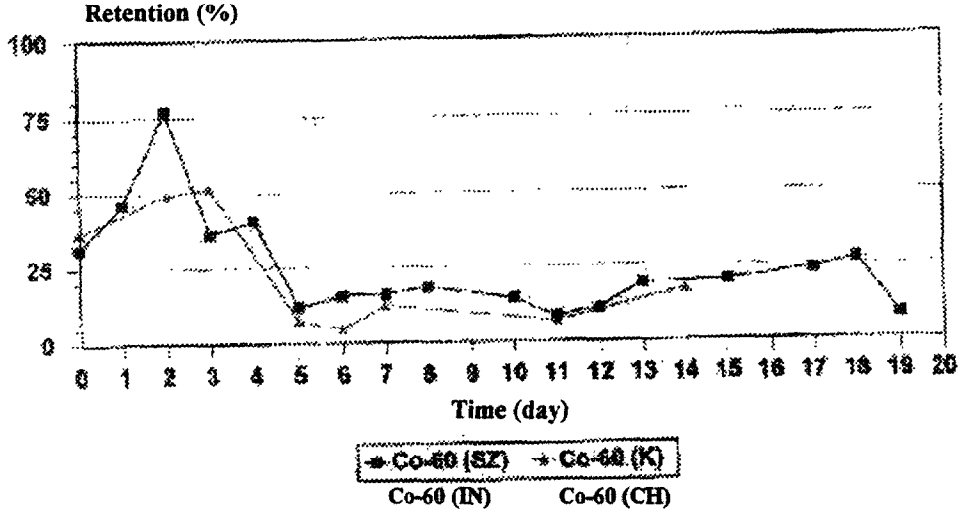

Figure 36: Whole-body retention of Co-60 administered in the forms of inorganic and chelated compounds in newborn rats, in the case of active dam – active newborn

It is worth noting that in both treatment modes the trace element load of newborn rats stabilised, the discharge of individual elements was characterised by very long biological half-time.

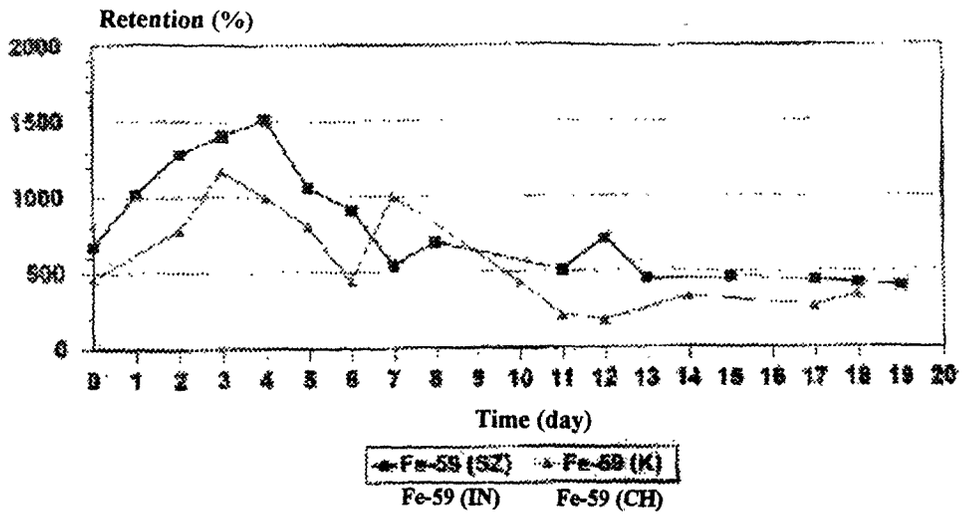

Figure 37: Whole-body retention of Fe-59 administered in the forms of inorganic and chelated compounds in newborn rats, in the case of active dam – active newborn

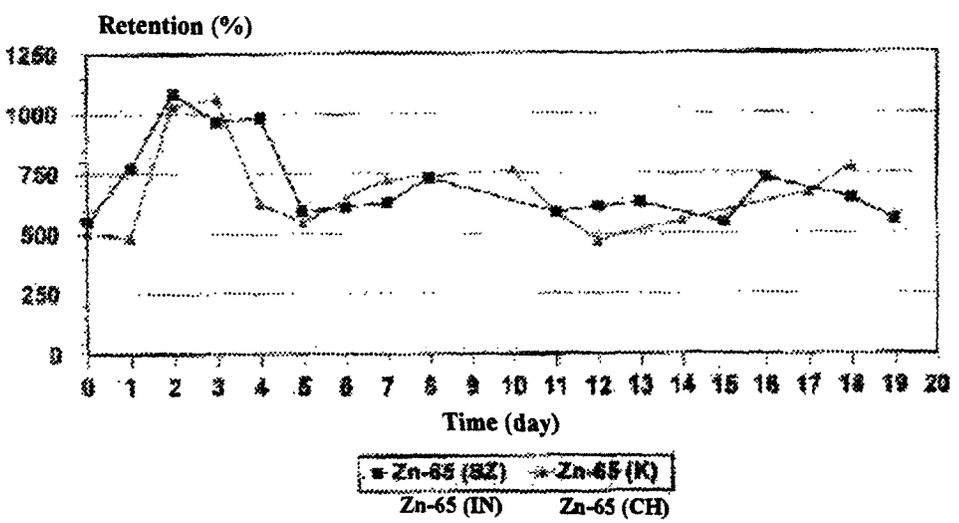

Figure 38: Whole-body retention of Zn-65 administered in the forms of inorganic and chelated compounds in newborn rats, in the case of active dam – active newborn

By transferring active newborn rats to inactive dams (ID-AN) we attempted to provide a model for the discharge mechanism of trace elements absorbed in the embryonic state. In the case of each element the whole-body load upon delivery as applicable to the dam was regarded as 100% and all further retention values were compared to this baseline. Results are given in Figures 40 to 43.

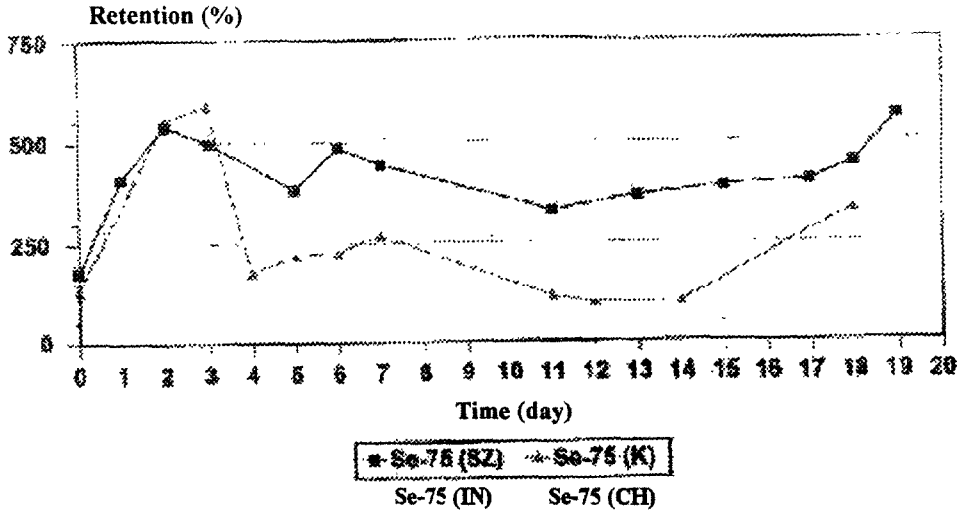

Figure 39: Whole-body retention of Se-75 administered in the forms of inorganic and chelated compounds in newborn rats, in the case of active dam – active newborn

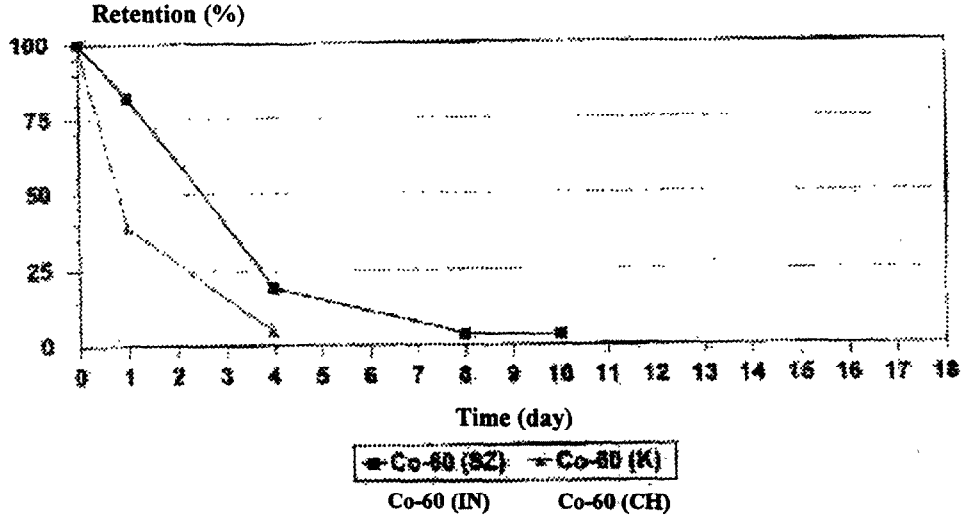

Figure 40: Excretion of Co-60 administered in the forms of inorganic and chelated compounds from newborn rats, in the case of inactive dam – active newborn

Co-60 was discharged from the organisms of newborn rats extremely rapidly, irrespective of the treatment mode used. On Day 4 following delivery only 5-15% of the original whole-body load could be detected in the animals. The excretion of inorganic cobalt from the animals could be described using a binominal exponential function, while that given in chelated form by using a monominal exponential.

As for iron (Figure 41) whole-body load upon birth was in the range of 500-700%. No difference could be seen in the kinetics of Fe-59 discharge, however, it has been concluded that the chelate form was excreted more slowly from the bodies of newborn rats.

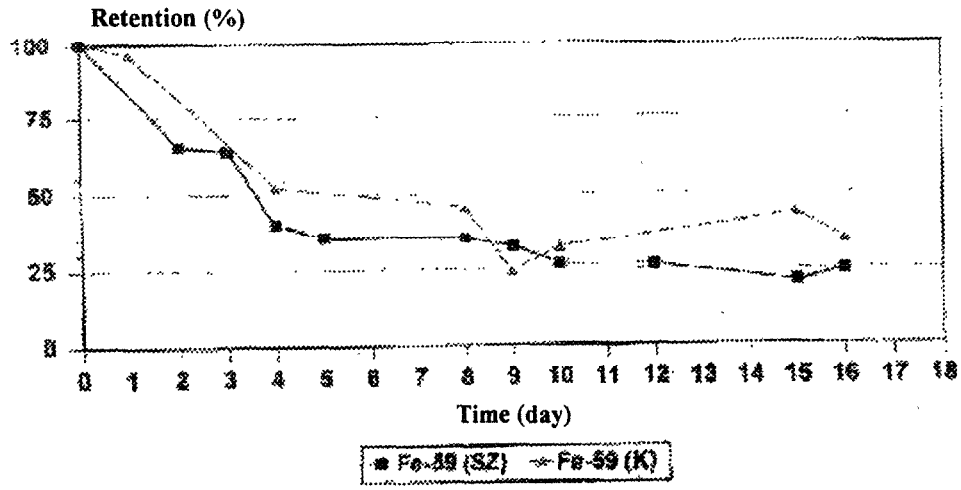

Figure 41: Excretion of Fe-59 administered in the forms of inorganic and chelated compounds from newborn rats, in the case of inactive dam – active newborn

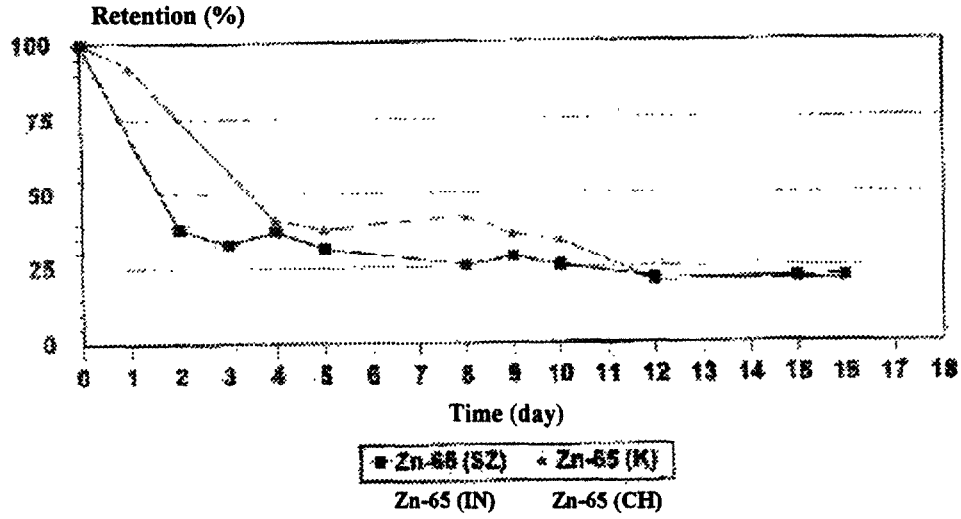

Figure 42: Excretion of Zn-65 administered in the forms of inorganic and chelated compounds from newborn rats, in the case of inactive dam – active newborn

In the case of both zinc compounds (Figure 42) the whole-body load of newborn rats expressed in relation to their dams reached approximately 500% (see Figure 38). A comparison of the rate of discharge and the quantity of zinc ingested still in the foetus stage has revealed that in the group using the chelate form the volume as well as the speed of discharged Zn-65 decreased (see Days 0 to 4 in the Figure). On days 4-5 following birth quantities of zinc retained in the body stabilised with very long biological half-time.

Excretion kinetics resembling that of zinc could be observed in the case of selenium also (Figure 43).

No difference could be seen in the initial whole-body loads of newborn rats (150-200%) between the two treatment groups (see Figure 39). In the chelate group Se-75 retention was higher, however in the first phase of clearing out (Days 0-4) the rate of discharge increased.

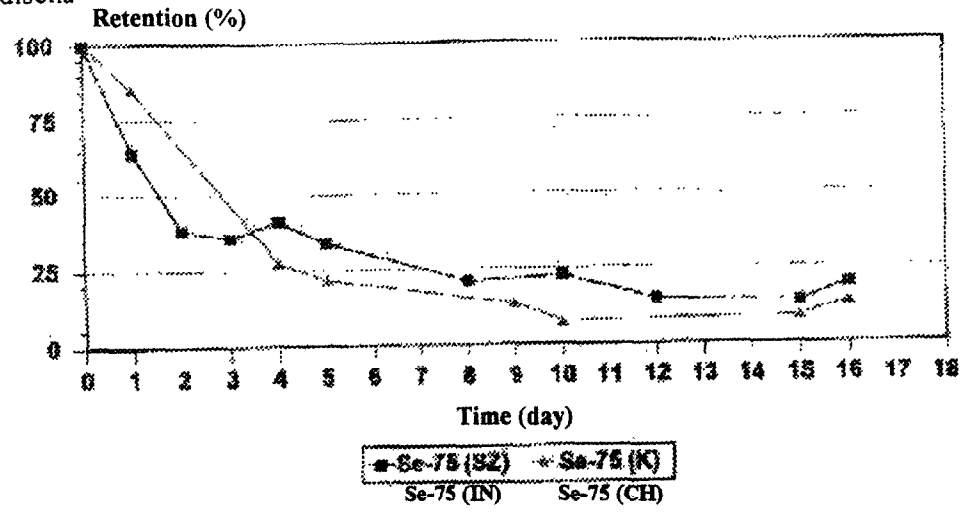

Figure 43: Excretion of Se-75 administered in the forms of inorganic and chelated compounds from newborn rats, in the case of inactive dam – active newborn

Trace element translocation through breast milk into the newborn rats was examined on inactive newborn rats given to active dams (AD-IN). As for the elements analysed, the whole-body loads of inactive newborn animals measured on their first days were regarded as 100%. The results have been summed up in Figures 44 to 47.

As for Co-60, no further isotope was ingested by the newborn rats, thus it is highly probable that no noteworthy amount of metal was transported through breast milk. The chelated form was released from the bodies of suckling rats extremely fast compared to the inorganic cobalt form, which was discharged much more slowly and at higher retention values (Figure 44).

Figure 45 shows the iron uptake by inactive newborn animals. It has been found that during the sucking period, iron was transported at an intensive rate into the bodies of newborn animals through the milk of dams that had received iron in inorganic compound form. In the case of the chelate-receiving group iron uptake was minimal during the sucking phase, as it practically stabilised at the initial activity level.

In the case of zinc administered to dams in inorganic form intensive uptake (nearly quadruple) was observed by inactive newborn rats at the beginning (1-4 days) of the sucking phase (Figure 46). Following a decrease in activity, during the following week the ingestion of Zn-65 with milk showed a constantly increasing pattern. On the other hand the whole-body zinc load of suckling rats increased evenly and gradually through milk from dams that had received zinc in the chelate form.

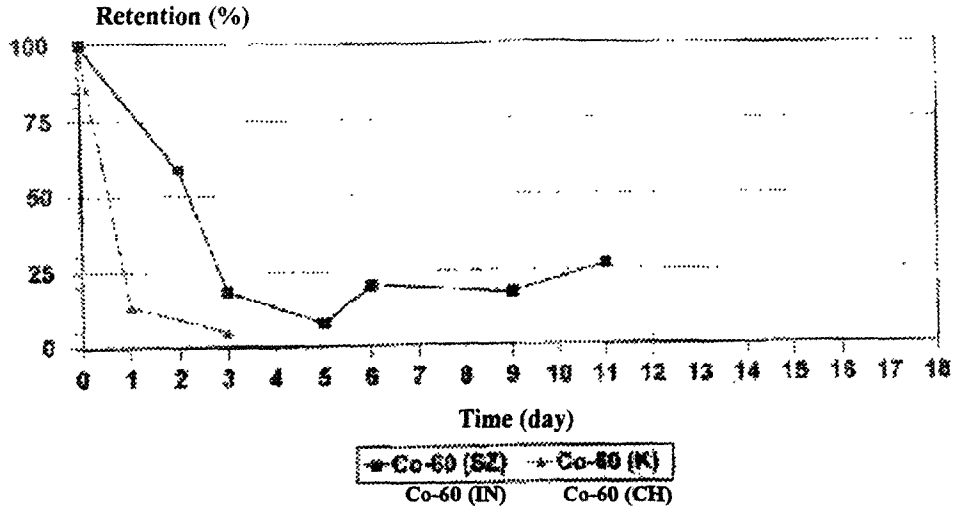

Figure 44: Excretion of Co-60 administered in the forms of inorganic and chelated compounds from newborn rats, in the case of active dam – inactive newborn

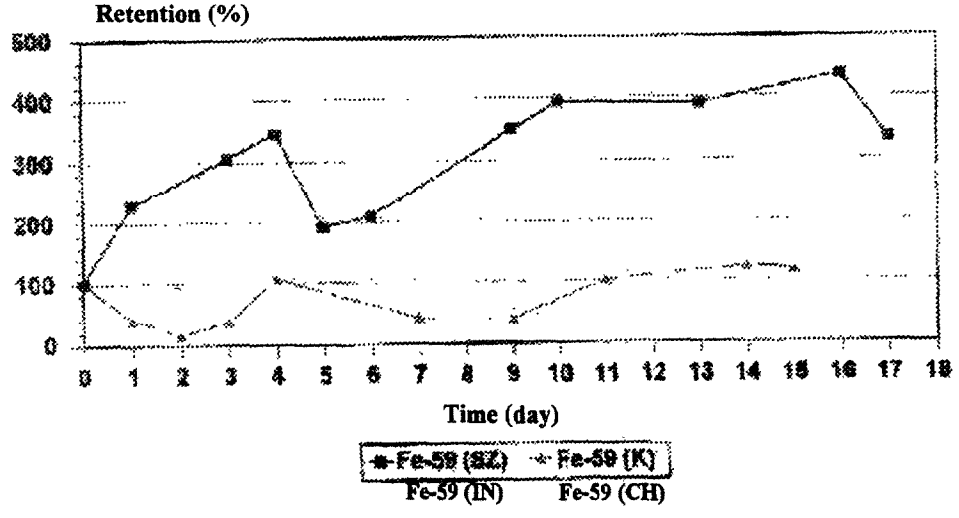

Figure 45: Excretion of Fe-59 administered in the forms of inorganic and chelated compounds from newborn rats, in the case of active dam – inactive newborn

Selenium uptake from breast milk was significant in either compound forms (Figure 47). In the two treated groups the Se-75 uptake by suckling rats increased evenly. By the end of the sucking period whole-body load increased by tenfold compared to the initial load in the group that had received inorganic selenium, while it increased up to 6-7 times the initial value in the case of selenium administered in chelated form.

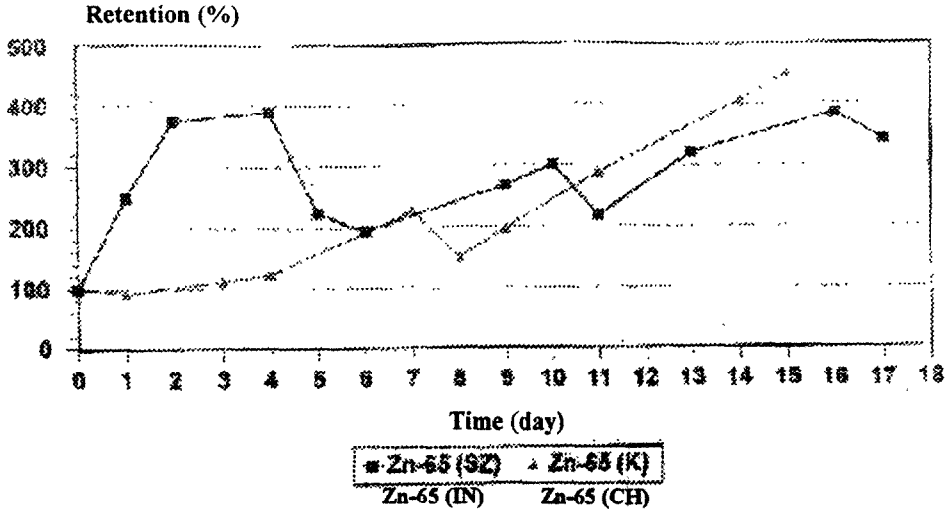

Figure 46: Excretion of Zn-65 administered in the forms of inorganic and chelated compounds from newborn rats, in the case of active dam – inactive newborn

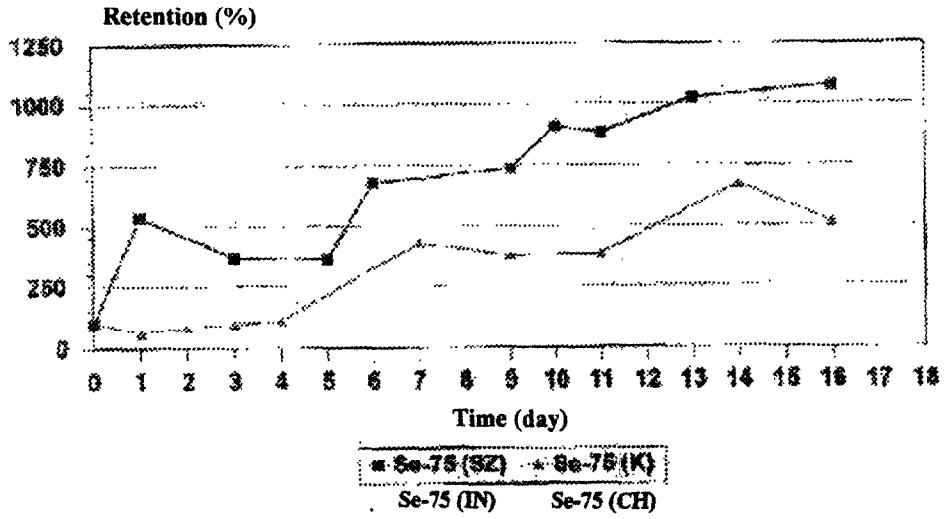

Figure 47: Excretion of Se-75 administered in the forms of inorganic and chelated compounds from newborn rats, in the case of active dam – inactive newborn

Furthermore, we examined whether the slope of retention curves for the entire litter (because of the changes in the litter number from time to time) would change if the retention data were expressed relative to bodyweight gram of newborn rats. The results are summed up for active dam and active newborns in Figures 48-51.

As for cobalt (Figure 48) it has been concluded that 1.5-1.8 times more trace elements were transported into the organisms of foetus from dams that had received chelated compounds. Their cobalt levels at the time of birth did not increase further, but after passing through a few days (3-5) of steady excretion phase they stabilised as components of very long biological half-time.

In the case of Co-60 administered in inorganic form the whole-body load upon birth (0.4 R %/g) increased by approximately twofold (during the first two days of sucking), then following an intensive discharge phase, stabilised, similarly to the pattern described in the case of the chelated compound form.

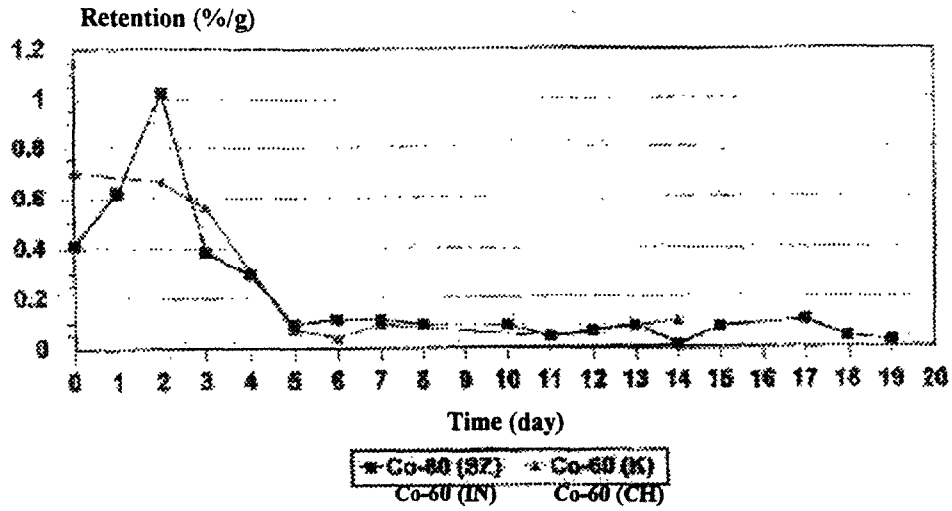

Figure 48: Whole-body retention of Co-60 administered in the forms of inorganic and chelated compounds per bodyweight grams in the active newborn rats of active dams

Post-delivery iron loads of newborn rats (Figure 49) were practically identical in both forms of administration. In the first sucking phase of four days, the iron uptake of newborn animals increased further in the case of both treatment modes, however this change was more intensive in the case of iron administered in inorganic form. Further iron discharge kinetics were identical with that described in the case of cobalt.

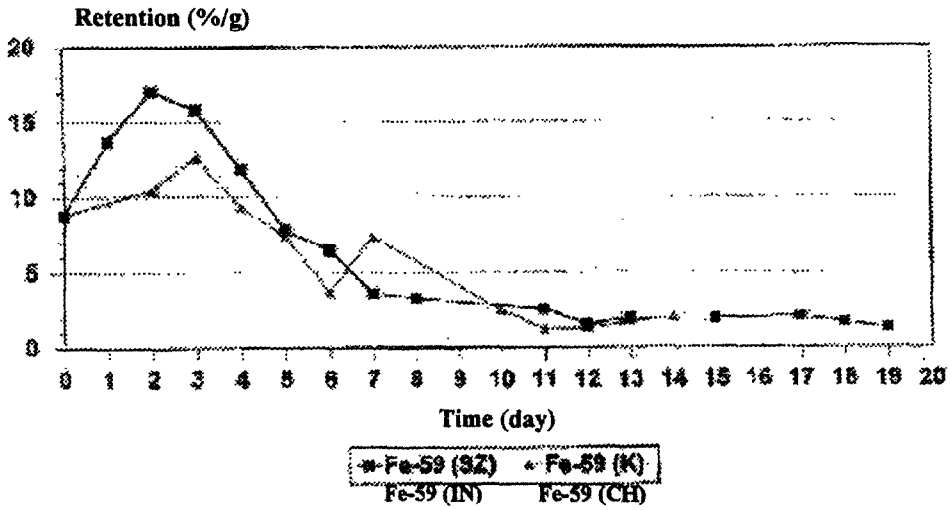

Figure 49: Whole-body retention of Fe-59 administered in the forms of inorganic and chelated compounds per bodyweight grams in the active newborn rats of active dams

Figure 50 shows the zinc load of newborn animals relative to their bodyweight grams. The conclusion to draw in this case is that in the case of dams treated with the chelate compounds the zinc absorption by foetus exceeded that of the animals treated with the inorganic form by 1.3-1.5 times. With the ingestion of breast milk the zinc load of newborn rats increased further in both cases, however this lasted longer in the cases in which the chelate form had been used (for 2 and 3 days). Regardless of the form of treatment intensive zinc excretion was observed; this stabilised after 5-6 days of sucking and was discharged with very long half-time. In the case of zinc administered in the chelate form the metal load of newborn animals was higher at every measurement date.

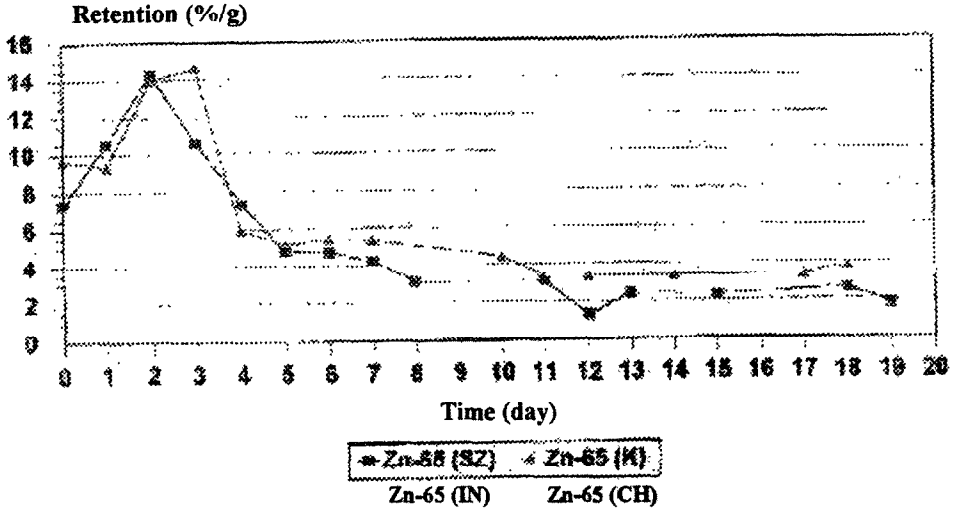

Figure 50: Whole-body retention of Zn-65 administered in the forms of inorganic and chelated compounds per bodyweight grams in the active newborn rats of active dams

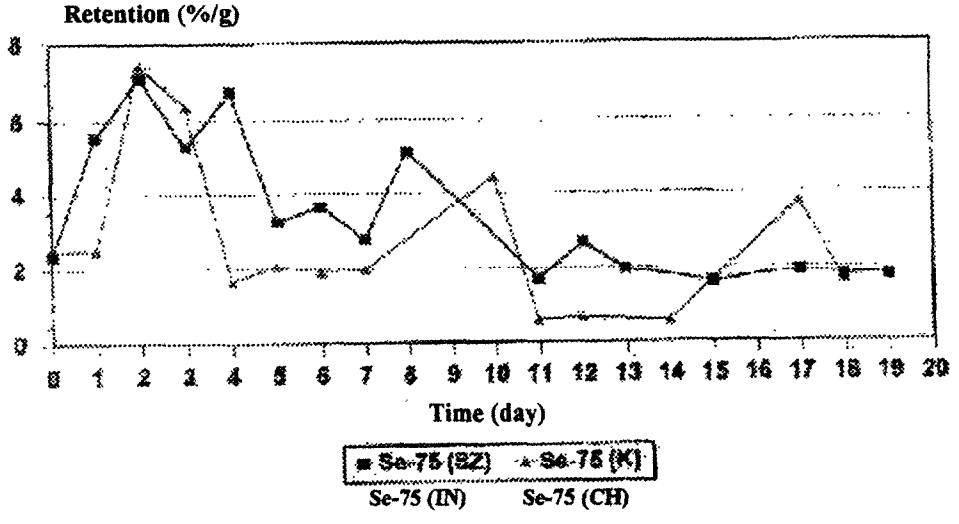

Figure 51: Whole-body retention of Se-75 administered in the forms of inorganic and chelated compounds per bodyweight grams in the active newborn rats of active dams.

In the cases of selenium administered in inorganic and chelated form (Figure 51) the selenium uptake by foetus was the same in both groups, approximately 2-2.5% of the whole-body load of dams upon delivery. This load increased by approximately 3.5 times by Day 4 of the sucking period in both cases, then dropped significantly. Selenium ingestion from breast milk was later characterised by varied metal uptake and discharge.

Similarly to active dam – active newborns, we also traced the trace element ingestion from milk also in such a way that the newborn rats of inactive dams fed on normal food were relocated to live with active dams. Taking into account the data relating to the entire litter (Figures 44-47) the whole-body loads of inactive newborn rats as taken on their first day was regarded as 100%.

The results are summed up in Figures 52-55.

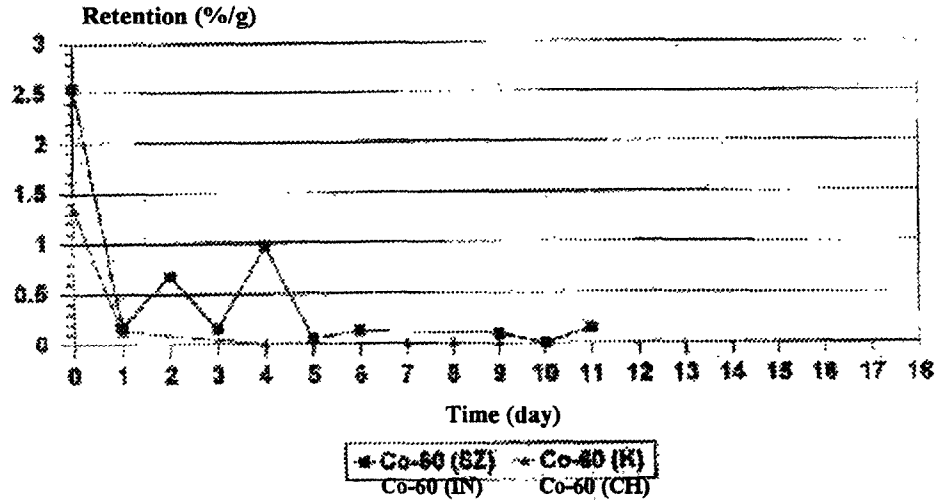

Figure 52: Whole-body retention of Co-60 ingested in the forms of inorganic and chelated compounds from breast milk relative to bodyweight grams

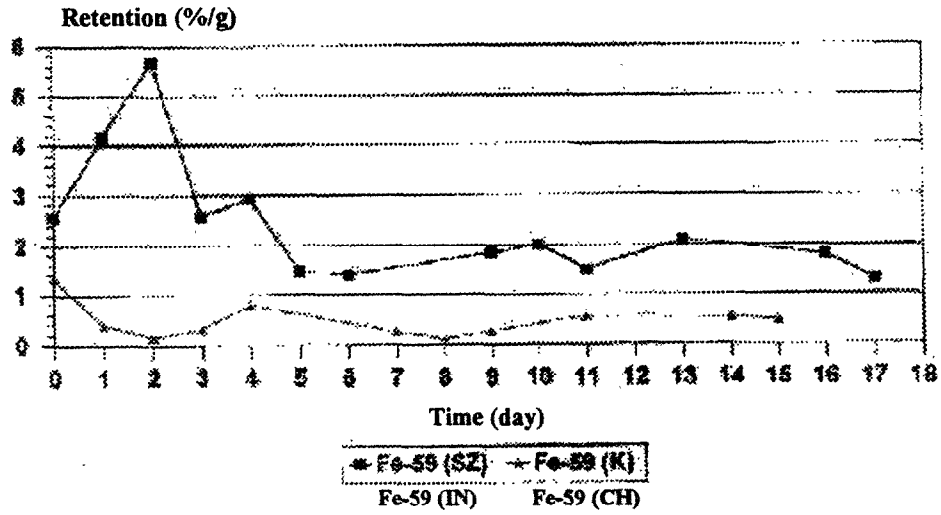

Figure 53: Whole-body retention of Fe-59 ingested in the forms of inorganic and chelated compounds from breast milk relative to bodyweight grams

Figure 52 shows the cobalt uptake by inactive newborn animals. As has been shown, the newborn animals ingested from dams that had been treated with inorganic compounds nearly double quantity on the first day of sucking. Later, irrespective of the treatment mode, no considerable cobalt transport through breast milk occurred. The chelate form was released from the bodies of sucking rats extremely fast (in approx. 4 days).

In the case of iron administered in inorganic form (Figure 53), iron levels transported with milk increased to approximately double the initial value. A reverse tendency was observed in the case of iron administered in chelate form. Following the slight decrease compared to initial whole-body load, iron level stabilised at approx. 50% of that initial value.

The pattern observed in the case of zinc (Figure 54) was similar to that of iron. In the case of dams that had received zinc in inorganic form the whole-body loads of sucking animals nearly doubled on days 3-4 of the sucking period, and then stabilised at a lower level following the first week.

The transport of zinc administered in chelated form through milk was really minimal, as zinc level practically stayed at the initial value.

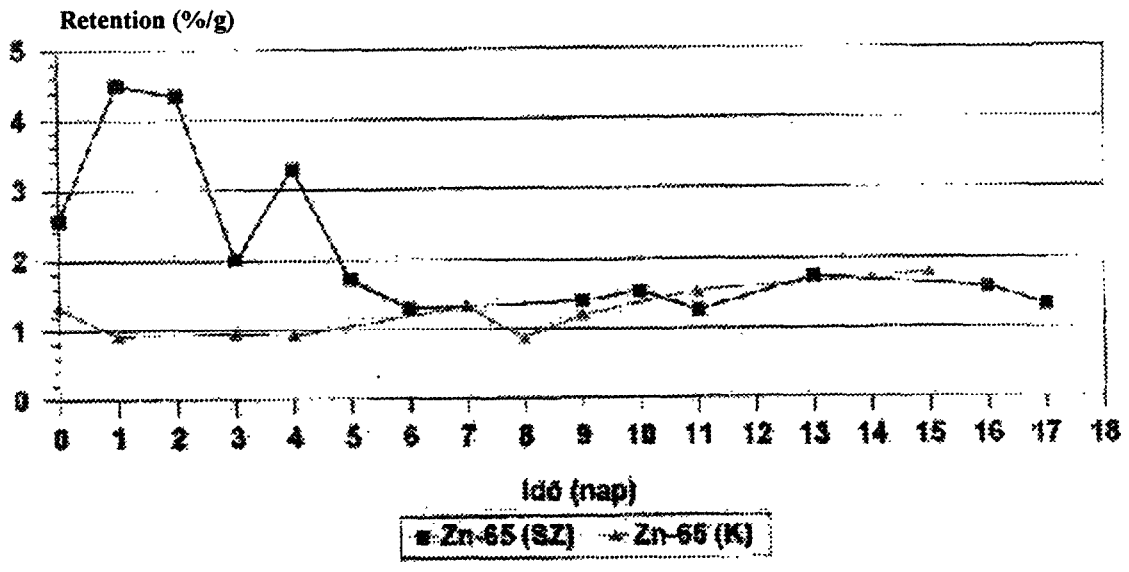

Figure 54: Whole-body retention of Zn-65 ingested in the forms of inorganic and chelated compounds from breast milk relative to bodyweight grams

Selenium ingestion from breast milk is shown in Figure 55. As seen in the Figure, selenium in the inorganic form was more intensively transported with milk, following some days of sucking, and selenium level increased by sevenfold compared to initial

whole-body load. Milk transport got stabilised by the end of the first week at a value equal to twice or even three times the initial activity.

In the case of selenium administered in the organic form no increase was observed in days 4-5 of the sucking period, i.e. no selenium was transported. The increase in selenium uptake in the 8-10 day period following this phase was minimal.

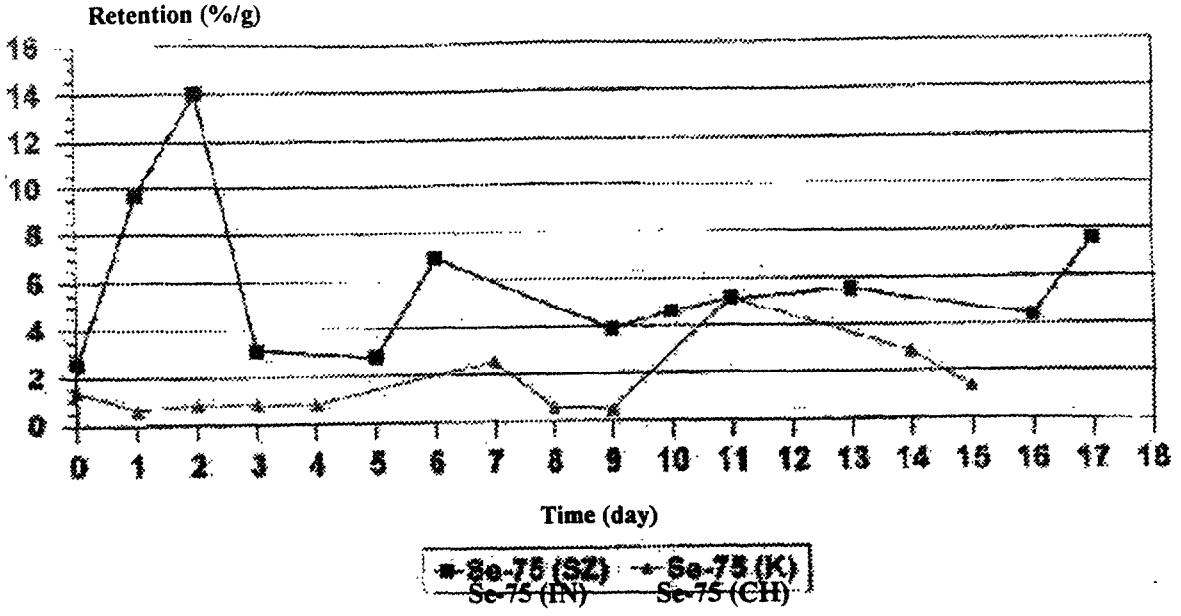

Figure 55: Whole-body retention of Se-75 ingested in the forms of inorganic and chelated compounds from breast milk relative to bodyweight grams

Having assessed the embryonic uptake of trace elements administered in inorganic and chelated forms, it has been found that in the case of active dams and active newborn rats the processes of metal uptake and excretion were similar both relative to the entire litter and relative to the bodyweight grams of animals. However, the values expressed as of bodyweight grams represent trace element turnover more accurately.

A comparison of the Figures representing the trace element transport through milk has also revealed that the values levelled to bodyweight gram demonstrate most clearly the kinetics of the uptake and excretion of a given element.

Conclusions and proposals

1. In fact the **whole-body weight of the rats** in either treatment groups **changed in the same extent**, however the mean weight gain of animals treated with the chelated compound proved to be more intensive and more steady as of Day 10 of the treatment.
2. No change occurred in either the **organ weights of rats**, or the percentage of organ weight to whole-body weight upon the effect of trace elements administered in inorganic and chelated forms.
3. **No significant difference was observed in the quantities of daily excretion**, although as a result of treatment with chelated compound the cumulative excretion quantity was always smaller. Most probably the reason for this phenomenon was that the faeces passes through the gastrointestinal tract more slowly because of the pro-constipation effect of chelate type compounds.
4. The measurement results clearly show that **individual trace elements,** administered either in the form of inorganic compound or in that of chelated compound were absorbed through the gastrointestinal systems of rats **in the same extent.** The fact that the whole-body loads of test animals were nearly identical does not mean that the deposition and translocation of trace elements administered in various forms may not differ.
5. **Cadmium exposure** on Day 14 **did not affect the quantities of excreted trace elements**. A comparison of the groups treated with tap water and undoted humic acid (HA) revealed that the kinetics of excretion was the same, however, **HA treatment increased the discharge of iron, zinc and selenium by 20-30%.**
6. It has been established that cadmium retention differed among the groups treated differently only in the 2-3 day period following exposure. **The highest excreted metal level was observed in the group treated with the chelated compound.**
7. Results of the excretion analysis have demonstrated that the trace elements in either compound type are **discharged from the body in the same way.** Nearly 100% of cobalt, iron and zinc is excreted in the faeces, while in the case of selenium the ratio of faeces/urine excretion was approx. 50-50%.

   It must be noted here that **iron in the chelated form was absorbed better** through the gastrointestinal tract of rats, as evidenced by the higher rate of iron discharge through urine.
8. **In general,** with regard to the trace elements examined **it has been found that** the retained portion of **metals administered in the chelated compound form were excreted in a more even, constant pattern.**
9. **No significant difference** could be demonstrated between the inorganic and chelated treatment modes with regard to **metal absorption** and discharge mechanisms **in the case of pregnant animals, either.**
10. It has been established that **trace element content accumulated during embryonic life increased** further after birth due to **trace element ingestion from breast milk.** Following a sucking period of 3 to 5 days trace element retention gradually decreased, then stabilised at a certain level. Taking into

consideration the results applied to the entire litter only in the case of selenium was any difference in retention (following a period of growth) observed between the two types of treatment modes.

11. The **elimination of trace elements** absorbed during embryonic life **can be described using identical exponential curves** in both study groups, except for cobalt. **In the chelate group trace element retention** could be observed in the initial phase of excretion. Chelated cobalt was discharged from sucking rats extremely fast.
12. In the case of **iron, zinc and selenium** levels applied for the entire litter it has been found **that following the first week of sucking** trace element ingestion from milk **gradually increased**. When, however, measured results were expressed **as of bodyweight grams** of newborn rats, this increase was not demonstrated, and **the quantities of trace elements remained stable**.
13. The **cadmium** load of **newborn** animals was in fact **insignificant** with respect to both treatment modes.
14. These **results** obtained in accordance with our study design have clearly **demonstrated that our experimental system is perfectly suitable for conducting such experiments** even in cases when **several** activated **metal ions have to be analysed** simultaneously in the subjects (e.g. rats) and synergistic as well as antagonistic effects need to be reckoned with due to the simultaneous administration of metal ions.
15. **For the better applicability of the trace element content of chelated compound types** in veterinary medicine, **we propose** that **additional research** be performed to:

- study the **behaviour**, deposition, translocation and elimination properties of **trace elements taken up into the body through various compound forms**,
- study **biological changes caused by trace element deficiency** and the ways of preventing and eliminating them,
- **clarify the synergistic and antagonistic effects of trace elements administered simultaneously**, which would result in an optimal trace element composition in the feeding of animals,
- **study the trace element turnover during pregnancy and breast feeding**, based on these results relating to pregnant animals, as a result of which an **optimal nutrient composition** in animal feed might be determined.

On behalf of the authors:

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