STUDY OF RELATIONSHIPS BETWEEN MICRO ELEMENT CONTENTS OF HUMAN HAIR AND OTHER TISSUES IN CONNECTION WITH ENVIRONMENTAL CONTAMINATION AND SOME DISEASES

J. BACSO, D. BALAZS, I. UZONYI, G. LUSZTIG, I. SZIGETY.

Institute of Nuclear Research
Hungarian Academy of Sciences
Debrecen, Hungary

Abstract

It is desirable to have a non-invasive method for continuous control of intake of environmental pollutants into human body. The physiological properties of human hair ensures a continuous record of biological occurrences in hair. The measurement of toxic heavy metal concentrations in human hair made it possible to control the full intake, if the toxic metal concentration in hair reflects the full body burden of toxic metals. Autopsy samples (hair, bone, brain, kidney, liver and lung) were collected from 56 deceased. A uniform sample preparation procedure was followed. The determination of As, Cd, Cu, Hg, Pb, Se, Zn, P, S, Cl, K, Ca, Mn, Fe, Ni, Br, Rb, Sr, Zr, Mo was carried out in all samples by XRF. The data obtained was evaluated by different statistical methods and correlations and tendencies were established between trace elements in hair and organs. From the results obtained it can be concluded that hair analysis can reflect the body burden of toxic element only for the period of formation of hair involved into analysis.

1. INTRODUCTION

The motor traffic, the burning of fossil fuel, the wide use of chemicals in agriculture and housekeeping, discharges from metallurgical and chemical plants and other human activities result in releasing into the biosphere such large quantities of toxic elements and chemicals, which disturbs the ecological equilibrium of biosphere. All of these human activities have necessitated to control and/or measure the concentration of toxic pollutants not only in soil, water and air, but in itself the biological organisms, among others in the human body.

The aim of such investigations has manifold character:

1. to determine the background level of the toxic elements and chemicals in human body and in biological organisms,

2. to look for correlation between toxic elements in the same and/or different tissues, and

3. to determine relationships between toxic and bioelements in any organ.

The correlations and relationships may be in connection with health and diseases. The establishment of relation makes it possible to prevent the development of sickness caused by environmental pollutants; toxic heavy metals, etc. From this point of view it is

important to investigate the possible correlations between toxic and bio-elements in the same an 'or different tissues.

Since the intensive investigation, large scale measurements are required to determine as much as possible relations, above mentioned. It is very important to select the very suitable method for measurement of element concentrations. Whereas, many trace elements included in organs are on concentration level of mg/kg or less, and many elements should be determined in many samples, it is also important, that the selected method meet the requirements: sample preparation procedure should be simple; it should guarantee the avoidance of removal of elements from the samples or contamination with them; determination of as much as possible element concentration in one-run measurement and it is desirable that the method as far as possible to be automatically operated.

The figures obtained in such a study should be evaluated by different statistical methods in order to select the best evaluation, promising the most reliable connection between the results (data) and events (environmental pollution, physiological processes, etc.) to be investigated. In this case it is not enough to determine the mean values and standard deviations covered by the trace element concentrations, etc. Connections, tendencies should be investigated between the toxic and toxic elements, toxic and bioelements and health or diseases.

In the frame of the Co-ordinated Research Programme "On the significance of hair mineral analysis as a means for assessing internal body burdens of environmental mineral pollutants" (Research Contract No. 3668) organized by the International Atomic Energy Agency mineral concentrations (P, S, Cl, Ca, Mn, Fe, Ni, Cu*, Zn*, Hg*, As*, Se*, Br, Pb*, Rb, Sr, Zr, Mo and Cd*) were measured in hair and internal organs (bone, brain, kidney, liver, lung) in autopsy samples from 56 deceased persons. (Participants in this CRP were requested to measure elements marked by *).

2. MATERIALS AND METHOD

The tissue samples were collected in the "County Hospital József Hollos, Kecskemet, Pathological Department" (I. Szigety MD.,G. Lusztig MD., DSC.) and the "Medical High School Debrecen, Pathological Department" (B. Dezso, MD.)

The autopsy has been performed as soon as possible, but not later than 48 h after death. During the 4 years, samples were collected from 56 men. The selection criteria, followed the instruction of CRP programme descriptions. For sources were: 40-60 years aged male persons, died suddenly (mostly from heart attack or stroke, but included a few victims of accident too), seemingly free from other diseases, no having histories of extensive use of medications and/or abuse of drugs.

Tissue samples were collected from lung, liver, kidney, brain, bone and hair; keeping in view the protocol for tissue sample collection of the CRP. Some instrumental difficulties

arisen in connection with bone sampling (from iliac crest). Therefore at the very beginning of work bone sampling was not carried out in every case. Later the bone samples were taken from rib. All samples were dried at Medical High School, Debrecen by a freeze-drying technique. The samples were stored till the drying at temperature -24°C. For transportation, the samples were packed in polyethylene bags and in solid CO_2.

The instruments used in the sample preparation process, were made of stainless steel, titanium, quartz, polyethylene; and the last step of cleaning procedure has been carried out in double deionized water.

The sampling from soft tissues was performed by exsection about one cubic from a few different places of the prescribed part of the organs. The samples were placed into plastic (polyethylene) bags, marked and froze in refrigerator (-24°C). For freeze-drying the samples were divided into small (thin) pieces with carefully cleaned stainless steel scissors. After drying the samples were ground in agate mortar, homogenized and pressed into pellets (200 mg, diameter = 10 mm). The bone samples were degreased in acetone (kept in acetone for 24 h). Two pellets were pressed and measured parallel and average values were used for statistical evaluation for every each sample. For determination of concentration of elements to be analyzed in hair, a hair bunch of ≤ 5 cm length was taken from the proximal end of hair. The washing procedure was according to the IAEA recommendation: washing once in acetone, thrice in double deionized water and once more in acetone, for ten minutes in each case.

The concentration of elements to be determined were measured by X ray fluorescence technique. The schematic diagram of the measurement set up is shown in the Fig. 1. The measurements were carried out with a Si(Li) X ray spectrometer (ATOMKI product, FWHM = 165 eV at Mn-Kα). For excitation of X rays of elements in samples ring-shaped ^{55}Fe (55 GBq) and ^{125}I (0.5 GBq) radioisotope sources were used [1,2].

An automatic sample changer was developed for carry out large scale measurements. A sample holder is placed in a vacuum chamber. 50 pellets or a long sample of ~85 cm can be placed on the sample holder and put in succession in measuring position by the sample changer controller. Measurements were controlled automatically by a "Macintosh 128 K" PC (supplied by the IAEA) with a program developed for this purpose [3].

The concentration values of elements were calculated comparing the net intensities of elements to that of a suitable IAEA standard (H-8, HH-1, H-5). The net peak intensities, after correcting for background, were determined by using the ratios of Kß/Kα and Lß/Lα intensities which were calculated from spectrum library. The inter-element effects were taken into consideration as well, using a further developed version of the Comparison Standard Method for less than infinite thick biological samples. The influence coefficients were calculated by the Fundamental Parameter Method [4,5].

3. RESULTS

All results are presented in dry tissue basis in mg/kg units for toxic heavy metals in Table I and for bio-elements in Table II. In these Tables N denotes the number of samples. Both the arithmetic mean (AM) and geometric mean (GM) and their standard deviations (SD, GSD) are reported for each element in each tissue. The number in brackets below the SD values indicate the number of figures involved into the averaging which was carried out in two different ways. On the one hand, measured values having relative error 50% or more were neglected from the mean value calculations (AM $\pm$ SD), while on the other hand they were included after replacing them with zeros (AM* $\pm$ SD*). This criterion for accepting a value leads to very low concentration limits, much lower than the Limit of Detection: LOD (LOD ~ 3·SQRT(Background)), and so they practically may be replaced with zeros. The number in brackets below (SD and SD*) indicates the number of figures involved, and so does the number of samples involved into the investigation.

Comparing the figures in the Table I to the appropriate ones in literature it is seen that our results are correspondent to literature values [6]. But from the average values of elements in hair can't come to any conclusion considering the appropriate values in tissues.

Therefore an effort was made to see the point of qualitative relationship between the concentrations of element in hair and in tissues, and to try to understand, and to explain the experimental data observed.

In order to become observable the connection between the concentration of elements in hair and organs the concentration of elements in the mentioned organs were plotted versus that of in hair.

3.1. EVALUATION OF TOXIC ELEMENT CONCENTRATION DISTRIBUTION IN TISSUES VERSUS IN HAIR.

The plot of a toxic element concentration in inner organs versus that of in hair can show the connection between the toxic element concentration in organs and hair. We studied the form of distribution of element concentration element by element for all organs investigated.

Arsenic: the localization of points can be divided into three (may be four) groups:

case a: a major share of points is localized on the ordinate: good measurable amount of As ($\geq$0.2 mg/kg) was found in the tissues, but $<$0.2 mg/kg was measured in hair of persons corresponding to these points. (Hair 19/52: hair samples were investigated, and 19 samples of them have As concentration less than 0.2 mg/kg).

TABLE I. ANALYTICAL DATA FOR TOXIC HEAVY METALS IN HAIR AND TISSUE SAMPLES

ELEMENT	QUANTITY	HAIR	BONE	BRAIN	KIDNEY	LIVER	LUNG
	N	52	20	46	53	54	46
As	AM*±SD*	0.69±0.85	0.24±0.50	0.62±0.35	2.05±9.17	0.58±1.46	1.01±2.52
		(52)	(20)	40)	(49)	(49)	(39)
	AM±SD	1.08±0.83	0.95±0.60	1.38±1.74	3.46±11.8	1.19±1.93	1.64±3.07
		(33)	(5)	(18)	(29)	(24)	24)
	GM*:GSD	0.80*:2.28	0.47*:1.00	0.71*:3.42	0.69*:4.51	0.59*:3.03	0.51*:4.65
	MIN	0*	0*	0*	0*	0*	0*
	MED	0.35*0.9	0*0.65	0*0.83	0.2*0.5	0*0.43	0.1*0.5
	MAX	3.3	1.6	6.9	64	9	12.5
	LOD	1.0	5.0	2.1	2.1	2.1	2.1
Cd	AM*±SD*	5.11±3.13	0.15±0.40	3.18±3.05	99.58±81.72	7.25±6.0	4.59±5.60
		(52)	(20)	(46)	(53)	(54)	(46)
	AM±SD	5.21±3.07		3.85±2.94	101.5±81.31	7.38±5.8	6.04±5.78
		(51)	(0)	(38)	(52)	(49)	(35)
	GM*:SD	4.37*:1.86	0*:0	2.78*:2.64	71.4*:2.56	5.7*:2.60	4.0*:3.05
	MIN	0*	0*	0*	0*	0*	0*
	MED	4.65*4.80	0*	3.08*3.3	72.5*75.6	5.8*7.0	3.45*4.9
	MAX	15.4	1.5	17.0	392	25.85	32.3
	LOD	0.8	2.4	1.7	1.7	1.7	1.7
Cu	AM*±SD*	14.2±3.68	5.72±5.33	19.2±6.54	11.11±5.81	20.53±20.82	7.77±4.44
		(52)	(20)	(46)	(53)	(54)	(46)
	AM±SD	14.2±3.68	8.16±4.47	19.2±6.54	11.55±5.47	20.53±20.82	7.77±4.44
		(52)	(14)	(46)	(51)	(54)	(46)
	GM*:GSD	13.8*:1.29	7.12*:1.74	18.3*:1.35	13.3*:1.60	16.2*:1.85	6.8*:1.69
	MIN	8.5*	0*	11.5*	0*	5*	2.2*
	MED	13.6*13.6	6.5*7.3	17.2	9.65*9.65	14.9	6.6
	MAX	23.5	19.8	40.5	29.4	139.9	24.9
	LOD	1.5	17	4.0	4.0	4.0	4.0
Hg	AM*±SD*	1.03±1.91	0.15±0.46	1.34±1.74	2.57±3.63	1.15±1.57	1.64±2.2
		(52)	(20)	(40)	(49)	(49)	(40)
	AM±SD	2.33±2.30	1.02±0.85	2.06±1.79	3.49±3.84	1.70±1.65	2.26±2.3
		(23)	(3)	(26)	(36)	(33)	(29)
	GM*:GSD	1.36*:3.28	0.71*:3.17	1.37*:2.63	2.10*:2.85	1.16*:2.51	1.43*:2.74
	MIN	0*	0*	0*	0*	0*	0*
	MED	0*1.4	0*0.95	0.6*1.65	1.4*2.08	0.6*1.3	0.75*1.5
	MAX	9	1.9	6.55	16,5	8.5	8.75
	LOD	1.6	10.0	4.0	4.0	4.0	4.0

TABLE I. (cont.)

ELEMENT	QUANTITY	HAIR	BONE	BRAIN	KIDNEY	LIVER	LUNG
	N	52	20	48	53	54	48
Pb	AM*±SD*	5.92±6.36	4.94±4.01	1.44±2.69	2.97±5.13	2.31±3.99	3.13±5.59
		(52)	(20)	(46)	(53)	(54)	(46)
	AM±SD	6.55±6.36	5.81±3.70	2.77±3.22	5.08±5.88	3.57±4.50	4.96±6.39
		(47)	(17)	(24)	(31)	(35)	(29)
	GM*:GSD	4.49*:2.42	3.91*:3.49	1.71*:2.62	2.91*:2.92	2.02*:2.95	2.5*:3.56
	MIN	0*	0*	0*	0*	0*	0*
	MED	4.0*4.1	4.58*5.3	0.45*1.45	0.9*2.2	0.78*2.1	1.0*2.6
	MAX	32	13.4	13.75	23.5	22	25
	LOD	1.6	8.0	3.8	3.8	3.8	3.8
Se	AM*±SD*	0.82±1.23	0.17±0.32	0.76±1.32	2,64±2.57	0,95±1.25	0.97±1.33
		(52)	(20)	(46)	(49)	(49)	(40)
	AM±SD	1.64±1.31	0.66±0.26	1.75±1.52	2.82±2.56	1.66±1.25	1.61±1.38
		(26)	(5)	(20)	(46)	(28)	(24)
	GM*:GSD	1.08*:2.80	0.62*:1.52	1.27*:2.32	1.77*:3.06	1.21*:2,62	1.19*:2.18
	MIN	0*	0*	0*	0*	0*	0*
	MED	0.05*1.3	0*0.7	0*1.48	2*2.15	0.5*1.43	0.55*1.0
	MAX	4.6	1.0	6.35	9.8	6.15	4.85
	LOD	0.7	4.0	1.2	1.2	1.2	1.2
Zn	AM*±SD*	205±86.9	95.2±58.0	53.8±15.7	186±67	246±131	59.8±10.9
		(52)	(20)	(46)	(53)	(54)	(46)
	AM±SD	205±86.9	95.2±58.0	53.8±15.7	186±67	246±131	59.8±10.9
		(52)	(20)	(46)	(53)	(54)	(46)
	GM*:GSD	185*:1.65	81.5*1.79	51.8*:1.33	173*:1.48	217*:1,65	58.8*:1.20
	MIN	22.3*	26.6*	29.8*	60.8*	81.5*	35.4*
	MED	189	93.2	51.8	176.5	222.5	57.7
	MAX	508	283	24.4	336	739	95.9
	LOD	1.5	11.0	5.1	5.1	5.1	5.1

TABLE II. ANALYTICAL DATA FOR BIOELEMENTS IN HAIR AND TISSUE SAMPLES

ELEMENT	QUANTITY	HAIR	BONE	BRAIN	KIDNEY	LIVER	LUNG
	N	52	20	46	53	54	46
Br	AM*±SD*	9.83±23.2	6.18±13.5	8.90±17.1	31.2±32.6	13.8±23.8	43.1±70.5
		(52)	(20)	(45)	(53)	(54)	(46)
	AM±SD	10.43±23.8	8.24±14.9	9.77±17.6	31.2±32.6	13.8±23.8	43.1±70.5
		(49)	(15)	(41)	(53)	(54)	(46)
	GM*:GSD	3.88*:3.96	3.54*:3.43	3.79*:4.39	23.2*:2.00	6.29*:3.25	26.5*:2.29
	MIN	0*	0*	0*	4.3*	0.55*	6*
	MED	3.5*3.8	2.55*2.9	3.4*4.1	20.3	6.08	23.4
	MAX	159	58.35	94.0	178.5	126	412.5
	LOD	0.6	3.0	1.0	1.0	1.0	1.0
Ca	AM*±SD*	512±383	86990±63080	419±367	843±816	281±179	777±423
		(52)	(20)	(46)	(53)	(54)	(46)
	AM±SD	512±383	86990±63080	419±367	843±816	281±179	777±423
		(52)	(20)	(46)	(53)	(54)	(46)
	GM*:GSD	411*:1.91	53100*:3.42	342*:1.82	687*:1.76	238*:1.76	698*:1.56
	MIN	99.9*	4780*	93*	286.5*	85*	328*
	MED	376	116300	319	649.5	227	687
	MAX	1620	174000	2440	5736	921	2697
	LOD	30	70	30-60	30-60	30-60	30-60
Cl	AM*±SD*	1664±1415	2572±1199	8094±2320	11140±2640	5652±1799	13430±3432
		(52)	(20)	(46)	(53)	(54)	(46)
	AM±SD	1664±1415	2572±119	8094±2320	11140±2640	5652±1799	13430±3432
		(52)	(20)	(46)	(53)	(54)	(46)
	GM*:GSD	1064*:3.01	2302*:1.64	7747*:1.36	10834*:1.27	5407*:1.34	13020*:1.29
	MIN	19*	880*	3420*	5215*	3160*	8225*
	MED	1090	2465	8065	10650	5420	13550
	MAX	5580	5340	13540	18690	13340	22360
	LOD	130	400	200	200	200	200
Fe	AM*±SD*	49.5±26.3	386±378	246±84.6	360±179	920±828	1301±968
		(52)	(20)	(46)	(53)	(54)	(46)
	AM±SD	49.5±26.3	386±378	246±84.6	360±179	920±828	130±968
		(52)	(20)	(46)	(53)	(54)	(46)
	GM*:GSD	43.8*:1.63	250*:2.64	234*:1.36	327*:1.56	650*:2.39	1082*:1.79
	MIN	17.5*	53.8*	124*	108.5*	86.5*	392.5*
	MED	40.8	278	228	325	625	1027
	MAX	124	1310	579	1278	4260	5480
	LOD	5.0	60	11	11	11	11

TABLE II. (cont.)

ELEMENT	QUANTITY	HAIR	BONE	BRAIN	KIDNEY	LIVER	LUNG
	N	52	20	46	53	54	46
K	AM*±SD*	213±195	3109±975	11600±1859	9691±2083	9419±2288	8888±1655
		(52)	(20)	(45)	(53)	(54)	(46)
	AM±SD	2123±195	3109±975	11600±1859	9691±2083	9419±2288	8888±1655
		(52)	(20)	(45)	(53)	(54)	(46)
	GM*:GSD	139.7*:2.73	2971*:1.36	11343*:1.19	9465*:1.25	9150*:1.28	8737*:1.21
	MIN	9.9*	1640*	7900*	5875*	5700*	5412*
	MED	162	3143	11750	9385	9400	8830
	MAX	971	5350	15450	13800	14900	12700
	LOD	25	200	30	30	30	30
Mn	AM*±SD	4.47±5.94	17.0±17.2	6.41±5.98	6.54±7.72	9.20±9.22	7.15±6.64
		(52)	(20)	(46)	(53)	(54)	(46)
	AM±SD	5.96±6.19	22.7±16.2	7.97±5.65	8.46±7.80	9.93±9.19	7.83±6.55
		(39)	(15)	(37)	(41)	(50)	(42)
	GM*:GSD	3.91*:2.57	18.3*:1.98	5.18*:3.42	4.79*:3.57	6.13*:3.16	4.30*:4.05
	MIN	0*	0*	0*	0*	0*	0*
	MED	2.8*3.4	13.3*17.2	5.23*7.5	3.4*6.2	6.53*8.45	5.5*6.7
	MAX	24.6	61	23.0	32.2	48.0	26.5
	LOD	5.0	100	14	14	14	14
Mo	AM*±SD*	0.11±0.31	0±0	0.27±0.43	0.93±0.90	2.06±0.99	0.38±0.55
		(52)	(20)	(40)	(49)	(49)	(40)
	AM±SD	0.56±0.50		0.59±0.46	0.97±0.90	2.06±0.99	0.61±0.60
		(10)	0	(18)	(47)	(49)	(25)
	GM*:GSD	0.39*:2.46	0*:0	0.44*:2.24	0.60*:3.05	1.80*:1.77	0.42*:2.49
	MIN	0*	0*	0*	0*	0.4*	0*
	MED	0*0.35	0*	0*0.43	0.8*0.9	1.95	0.2*0.4
	MAX	1.5	0	1.7	3.6	4.7	2.5
	LOD	0.9	1.0	0.9	0.9	0.9	0.9
Ni	AM*±SD*	1.68±2.53	1.15±2.95	2.93±5.22	3.86±5.47	2.60±3.55	6.13±12.7
		(52)	(20)	(40)	(49)	(49)	(40)
	AM±SD	3.11±2±73	5.74±4.48	5.09±6.07	5.41±5.80	3.54±3.72	8.17±14.2
		(28)	(4)	(23)	(35)	(36)	(30)
	GM*:GSD	2.27*:2.28	4.28*:2.64	2.37*:4.50	3.35*:2.72	1.95*:3.74	3.56*:3.62
	MIN	0*	0*	0*	0*	0*	0*
	MED	0.8*2.1	0*4.95	0.45*3.6	1.95*2.80	1.0*2.6	1.7*4.1
	MAX	11.7	11.9	27.0	24.0	16.5	62
	LOD	2.4	30	7	7	7	7

TABLE II. (cont)

ELEMENT	QUANTITY	HAIR	BONE	BRAIN	KIDNEY	LIVER	LUNG
	N	52	20	46	53	54	46
P	AM*±SD*	841±474	38590±26320	15170±1170	9836±1738	11240±2834	7959±1913
		(52)	(20)	(46)	(53)	(54)	(46)
	AM±SD	857±464	38590±26320	15170±1170	9836±1738	11240±2834	7959±1913
		(51)	(20)	(46)	(53)	(54)	(46)
	GM*:GSD	690*:2.16	25460*:3.07	15128*:1.08	9690*:1.19	10934*:1.26	7742*:1.27
	MIN	0*	2230*	13300*	6660*	7000*	3955*
	MED	885*900	51980	15030	9570	10830	7690
	MAX	1980	75750	17940	14000	22800	13570
	LOD	1200	3600	1100	1100	1100	1100
Rb	AM*±SD*	0.36±0.76	2.29±2.08	6.74±2.59	9.03±4.18	10.52±4.52	8.91±3.94
		(52)	(20)	(46)	(53)	(54)	(46)
	AM±SD	0.97±1.0	2.69±2.00	6.74±2.59	9.03±4.18	10.52±4.52	8.91±3.94
		(19)	(17)	(46)	(53)	(54)	(46)
	GM*:GSD	0.65*:2.53	1.90*:2.75	6.23*:1.51	8.12*:1.62	9.51*:1.61	7.90*:1.78
	MIN	0*	0*	2.2*	2.35*	2.35*	0.5*
	MED	0*0.60	2.05*2.4	8.45	8.55	9.88	8.05
	MAX	4.1	8.2	12.8	26.3	22.15	18.5
	LOD	0.5	1.8	0.9	0.9	0.9	0.9
S	AM*±SD*	53090±4505	8000±6187	6430±630	8891±1077	7700±1365	8249±1054
		(52)	(20)	(46)	(53)	(54)	(46)
	AM±SD	53090±4505	8000±6187	6430±630	8891±1077	7700±1365	8249±1054
		(52)	(20)	(46)	(53)	(54)	(46)
	GM*:GSD	52890*:1.09	5475*:2.61	6401*:1.10	8827*:1.13	7572*:1.21	8187*:1.13
	MIN	45000*	1300*	5095*	6310*	4585*	6695*
	MED	52050	6760	6300	8855	7710	8058
	MAX	64300	20400	8055	11340	10390	11030
	LOD	140	700	450	450	450	450
Sr	AM*±SD*	1.98±1.47	32.8±28.1	0.49±0.90	1.09±1.63	0.48±0.85	1.38±1.39
		(52)	(20)	(46)	(53)	(54)	(46)
	AM±SD	2.09±1.43	32.8±28.1	0.97±1.08	1.60±1.76	0.92±1.00	1.63±1.37
		(49)	(20)	(23)	(36)	(28)	(39)
	GM*:GSD	1.58*:2.31	18*:3.8	0.55*:3.14	0.85*:3.43	0.57*:2.82	1.09*:2.88
	MIN	0*	1.1*	0*	0*	0*	0*
	MED	1.7*1.8	29.6	0.03*0.6	0.4*0.8	0.1*0.7	1.2*1.4
	MAX	6.4	83.5	4.4	6.45	4	5.9
	LOD	0.4	1.5	0.8	0.8	0.8	0.8

TABLE II. (cont.)

ELEMENT	QUANTITY	HAIR	BONE	BRAIN	KIDNEY	LIVER	LUNG
	N	52	20	46	53	54	46
Zr	AM*±SD*	0.47±1.65	0.17±0.35	0.20±0.41	0.40±0.73	0.13±0.29	0.64±0.76
		(46)	(20)	(40)	(49)	(48)	(40)
	AM±SD	1.19±2.51	0.58±0.42	0.50±0.53	0.89±0.88	0.40±0.40	0.92±0.75
		(18)	(6)	(16)	(22)	(15)	(28)
	GM*:GSD	0.50*:3.25	0.44*:2.40	0.30*:2.85	0.57*:2.73	0.29*:2.16	0.63*:2.59
	MIN	0*	0*	0*	0*	0*	0*
	MED	0*0.5	0*0.5	0*0.3	0*0.5	0*0.25	0.4*0.7
	MAX	11.0	1.3	1.7	3.15	1.6	2.55
	LOD	0.3	1.0	0.6	0.6	0.6	0.6

case b: the second part of the concentration values measured is localized on the axis of abscissas: the element investigated has a well measurable concentration in hair, but not does in organs (bone 15/20; brain 22/40; kidney 20/49; liver 25/49; lung 35/39)

case c: the third part of points has localization in the X-Y-field ($x > 0.2$ and $y > 0.2$): the concentration of element investigated in both samples: (hair and organ) has higher concentration, than the "minimal evaluable value" (under the applied circumstances) (0.2 mg/kg). The distribution of these points (c case) on x-y field refers to connection of element concentration in hair and organs. The Fig. 2. demonstrates the three possible cases for As in hair and brain. In principle an other case may exist, too: when both tissue (hair and organ) investigated have very low value of toxic element <0.2 mg/kg (explanation see later Fig. 10). The distribution of experimental figures into groups (a, b and c cases) is well performed for As in bone, brain, kidney, liver and lung (in all tissues investigated) Fig. 3.

The presentation of main results obtained for other elements (Cd, Cu, Hg, Pb and Zn) follows shortly.

Cadmium

case a: hair 1/51, this does mean that on the axis of ordinate only one point can be located.

case b: bone 17/20; brain 8/46; kidney 1/53; liver 5/49.

case c: bone 3 points are in x-y field; brain, lung: there are many point in the x-y field, but a relationship does not appear to be; kidney, liver: there

are many points in the x-y field, which are separated into two groups. (Fig. 4) It is worth investigating what specific health parameter is in connection with the grouping.

Mercury

case a: is realized in all organs (bone, brain, kidney, liver and lung)

case b: seems to be realized almost in all organs, see Fig. 5.

case c: bone is questionable, in the other organs it is realized, but connection does not seem to exist.

Lead

case a: is realized in all organs (see Fig. 6). However it should be noticed that the Pb concentration of events placed on ordinate (a cases) covers a much less range for each organ than events which are placed in the x-y field (c case). Events belong to b and c cases cover about the same range presenting an individual form.

Copper All the events (except 6 of bone: b case) belong to c case, see Fig. 7. The events of bone suggest to exist a positive correlation, while that of kidney a negative correlation.

Zinc All the events belong to c case, see Fig. 8. The Zn in bone appears to show a negative correlation in contrast with Cu in bone. In the other organs any relationship ca not be observed.

Selenium

case a: is realized in brain, kidney, liver and lung.

case b: seems to be realized in bone, brain and liver(?), lung(?).

case c: is realized in each organs, see Fig. 9. The Fig. 9 shows the results of NAA too, for liver measurement, carried out by Dr. Kinova (Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria).

4. DISCUSSION

From the figures found it is difficult to state, that the first question of this CRP can be answered but it is also at least so difficult to establish, that we did not find any evaluable information in connection with the aim of the CRP. It is seen from the pictures (Figs 2 - 9) that correlation can be established between element concentration measured in organs and hair investigated, but how to interpret these results requires a very careful investigation of the figures. First of all on the basis of the average grow speed of hair it

can be stated that the figures found in hair cover the events of about the last 5 months (the first 5 cm hair was investigated which were taken from head skin) considering the exposure to toxic metals. In spite of this it is also difficult to state that by the figures found in organs only just this period would be represented in their toxic metal concentration accumulated in them. The period covered by these figures depend on that, how long time can remain the toxic metal investigated in the tissue of organs. What varies from organ to organ and from toxic metal to toxic metal. Therefore at evaluation of our results we have to investigate what kind of correlations can be expected depending on the period of exposition to the sampling time. It is clear that the correlation expected between the toxic metal concentration measured in organs and hair strongly depend on that, the sampling performed, was carried out before, during or after (and how long after) the deceased was exposed to environment contaminated by toxic metals.

The range of element concentrations determined in organs and hair is in good agreement with that in literature [6,7]. The main characters of concentration distribution in organs vs. hair are also in good agreement. The main difference in which alters our method from that of Aalbers is the sensitivity of analytical method used. But if their results found to be below our detection limit, were presented on the appropriate axis of coordinate, the results found by Aalbers and us would be in perfect agreement. In all cases it is possible to compare:

Cu: in liver vs. hair, in kidney vs. hair
Cd: in liver vs. hair, in kidney vs hair
Zn: in liver and kidney vs. hair
Pb: in rib vs. hair.

The alone difference in the two measurements is the range of Cd in hair: it covers the range of 0 - 2 ppm in the population from Netherlands and it does 0 - 12 ppm in the Hungarian population.

In the light of the foregoing it can be seen that the toxic heavy metal concentration measured in hair could reflect that of in organs if those infiltration into hair and organs and remaining there were happen on the same route and in the same time. Since this condition is not fulfilled at random sampling, the answer for the main question of CRP under general circumstances is negative. But a series of new very evaluable information is revealed.

A short descriptive evaluation of observations is as follows:

Arsenic It appears that the accumulation of As in tissues is very similar, (see Fig. 3) the lowest is in bone. No correlation can be revealed.

Cadmium The accumulation in different tissues is very different. The concentration is lowest in bone, highest in kidney cortex. No correlation can be revealed in bone, brain and lung. Correlation appears to be between the Cd concentration in kidney and hair and may be between in liver and in hair.

The grouping in these organs should be noted (especially in kidney). The physiological reason of this observation should be investigated (Fig. 4).

Mercury See: *Arsenic*.

Lead The Pb concentration is about on the same level in each organ. It is worth mentioning that the distributions are very similar and their form may refer to a continuously increasing Pb contamination from motor traffic (the Pb concentrations placed on ordinate, a case, is lower than that of c case).

Copper The events belong to c case. An arising tendency appears to be in bone vs. hair and a decreasing one in kidney.

Zinc The events belong to c case. A decreasing tendency appears to be in bone vs. hair.

Selenium The localization of events refer to different type of distribution cases. Our liver measurement is repeated by Dr. KINOVA with NAA. The results are very similar but not in every case.

We continue the evaluation of results looking for correlations between toxic metals in the same and/or different organ(s), and do it in toxic-bio-element combination.

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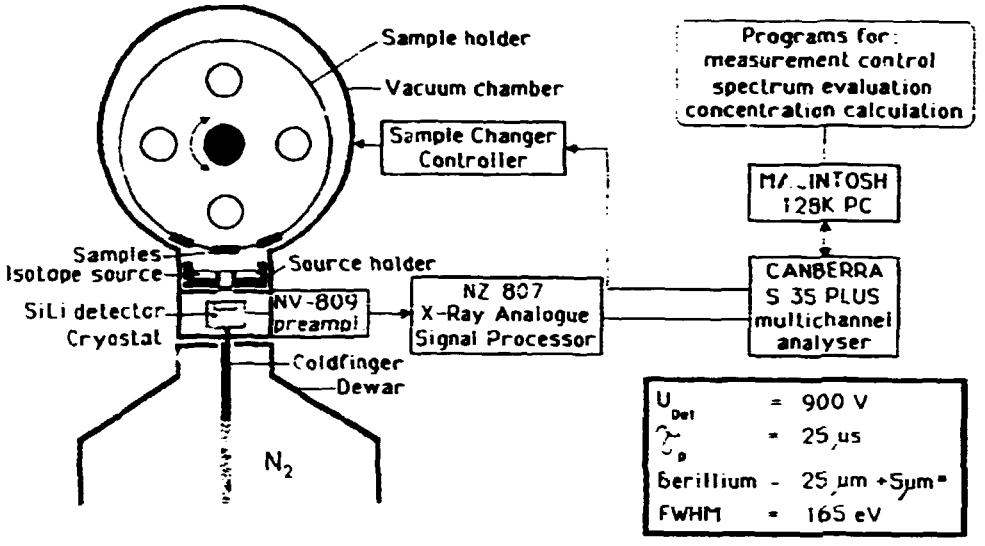

Figure 1. Experimental setup of measurement

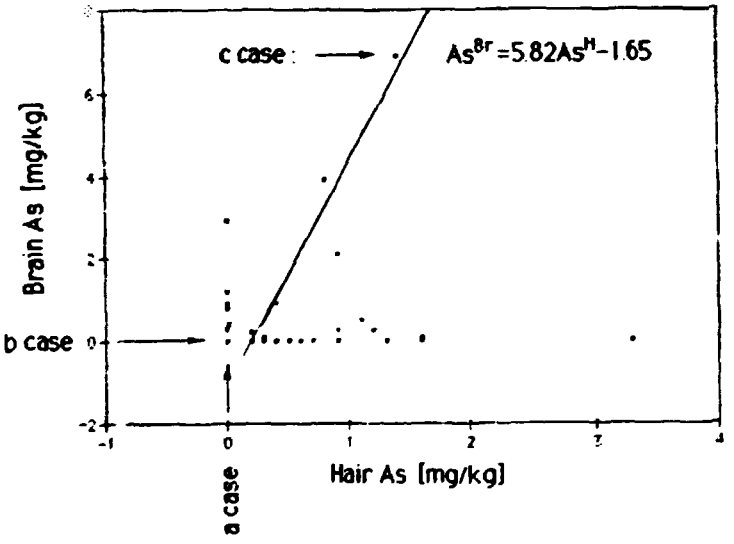

Figure 2. **The possible toxic metal concentration distribution in organs vs hair at random sampling. The sampling was carried out; case a: about five months after the finishing of exposition; case b: in the first some months of exposition; case c: during exposition (see also figure 10)**

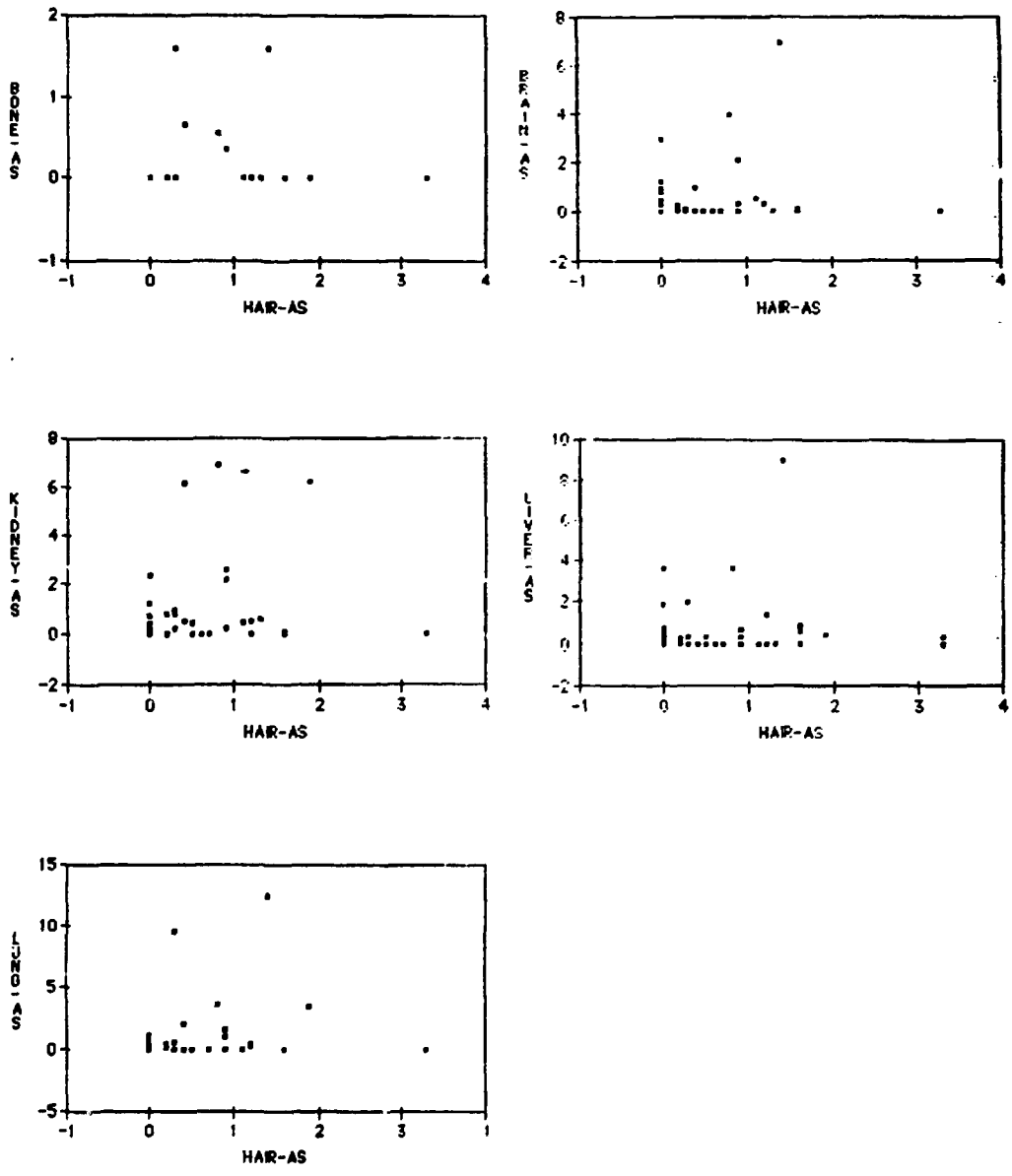

Figure 3. Distribution of As concentration in tissues vs hair (mg/kg)

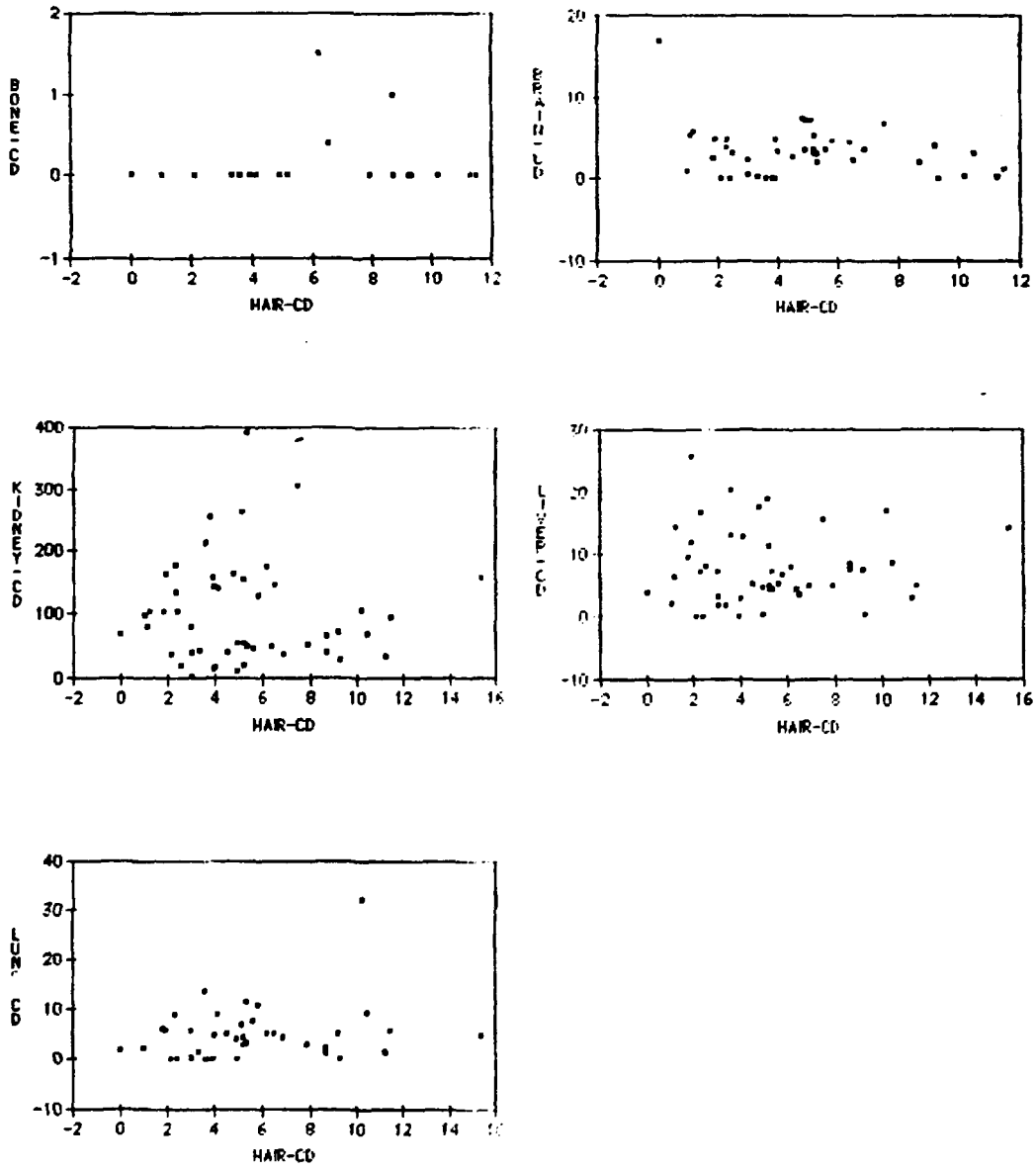

Figure 4. Distribution of Cd concentration in tissues vs hair (mg/kg)

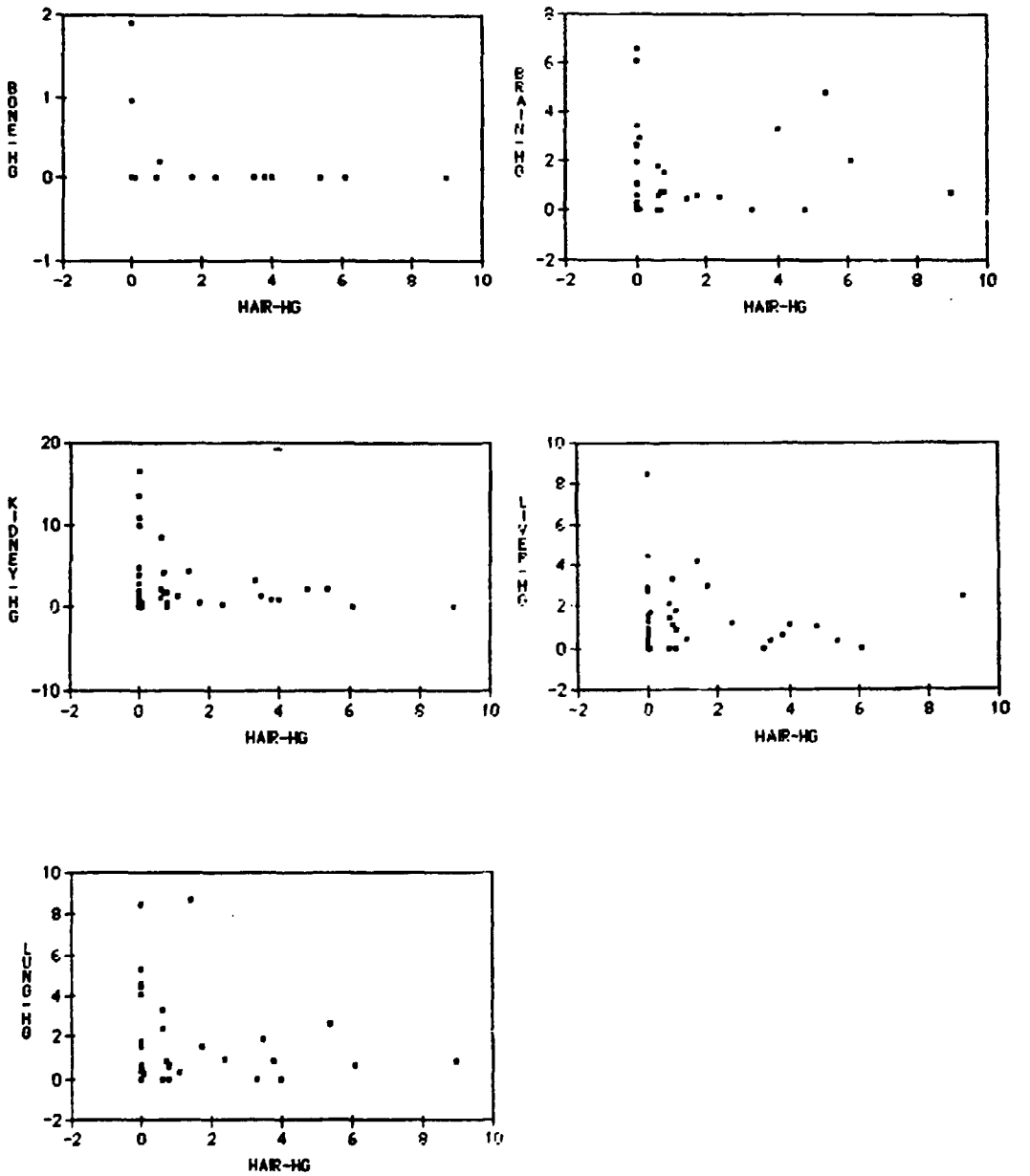

Figure 5. Distribution of Hg concentration in tissues vs hair (mg/kg)

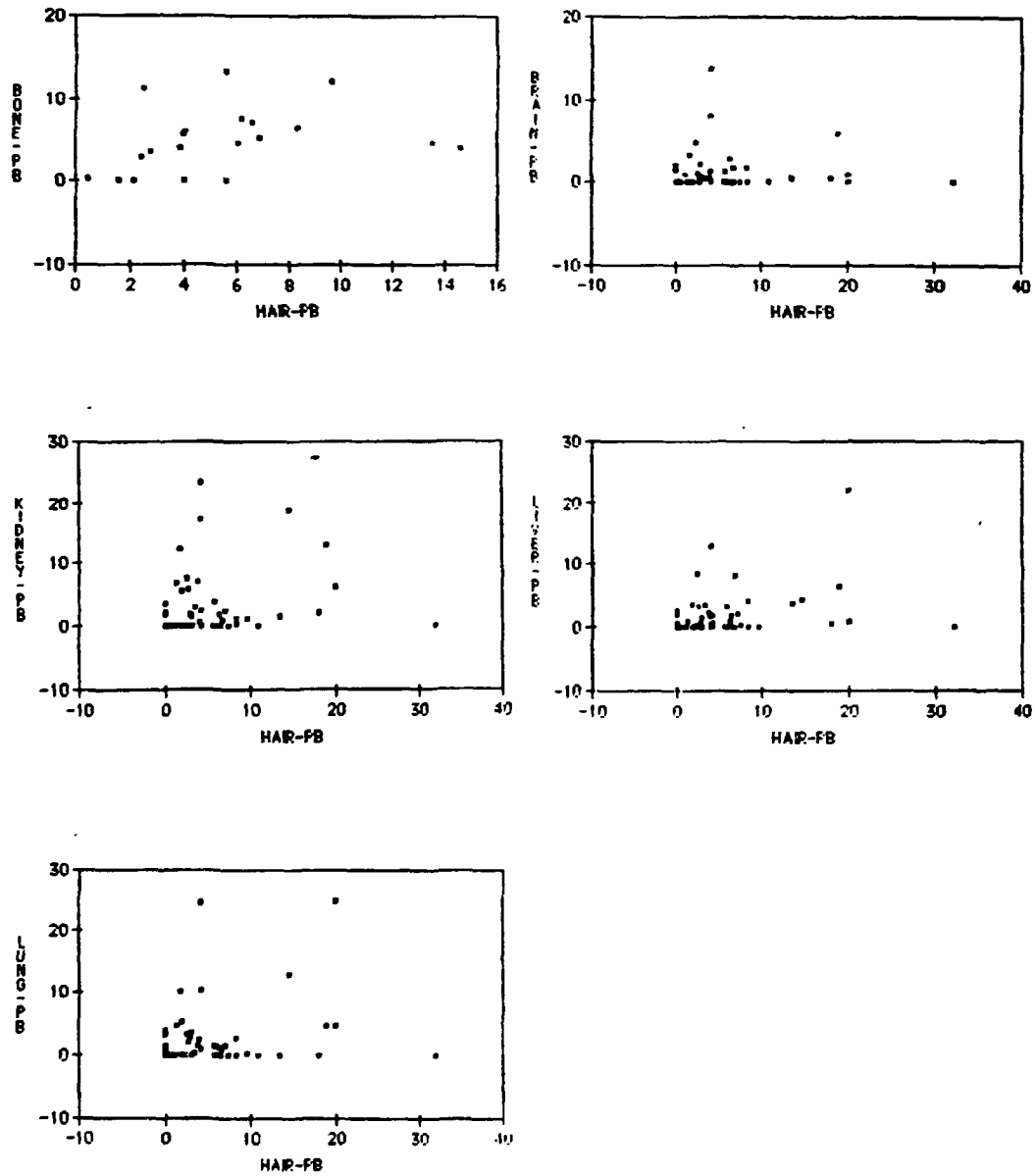

Figure 6. Distribution of Pb concentration in tissues vs hair (mg/kg)

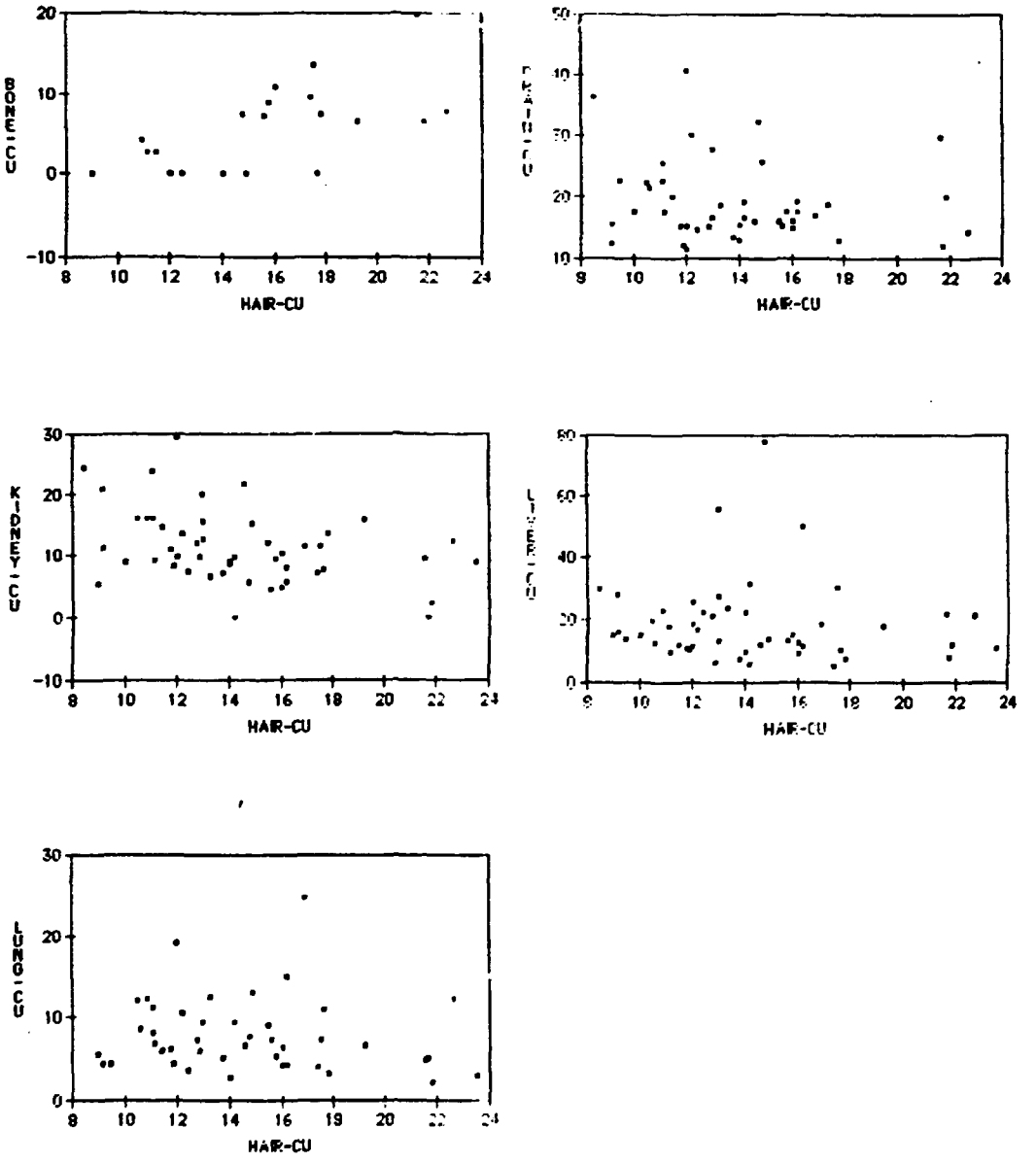

Figure 7. Distribution of Cu concentration in tissues vs hair (mg/kg)

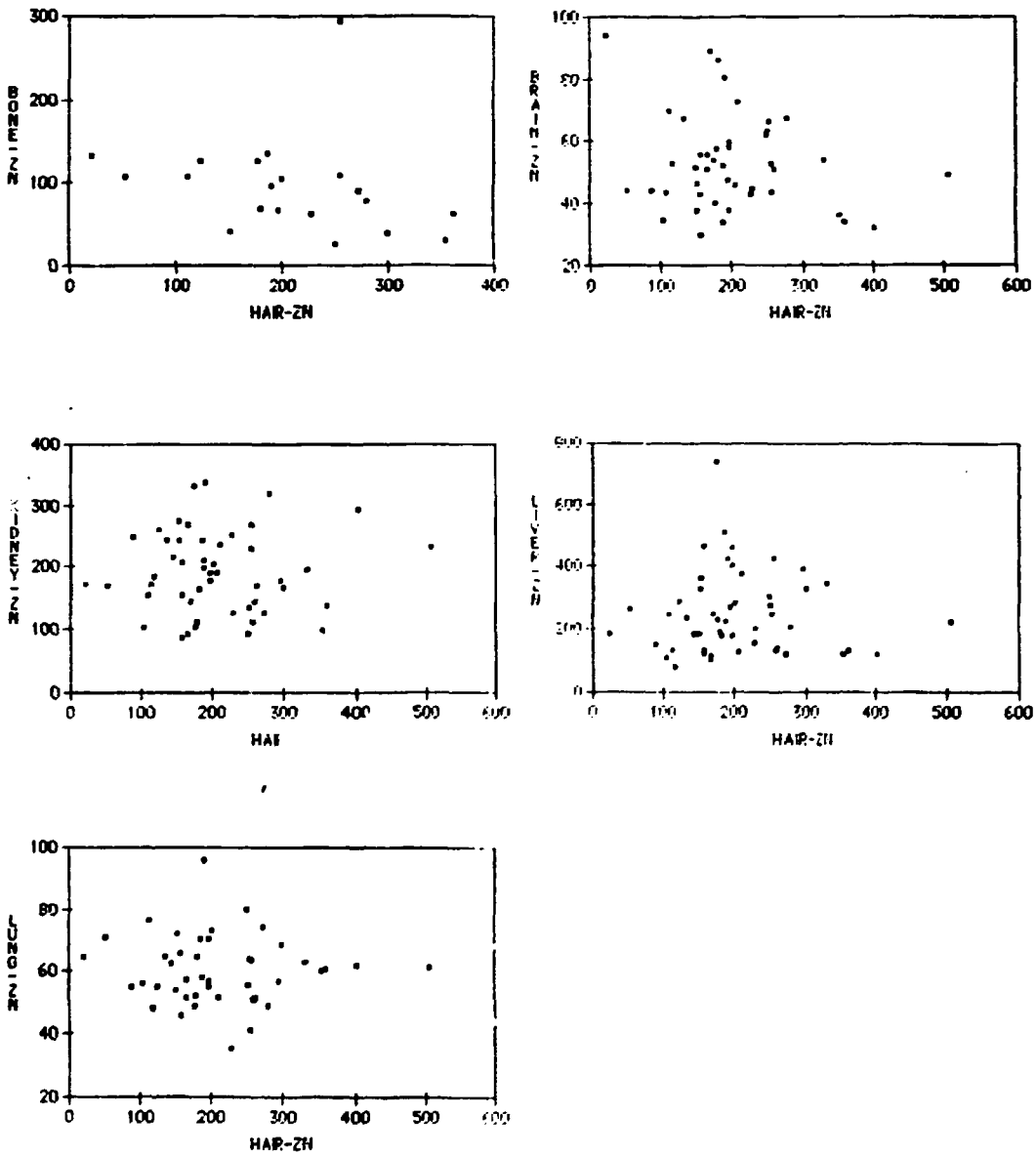

Figure 8. Distribution of Zn concentration in tissues vs hair (mg/kg)

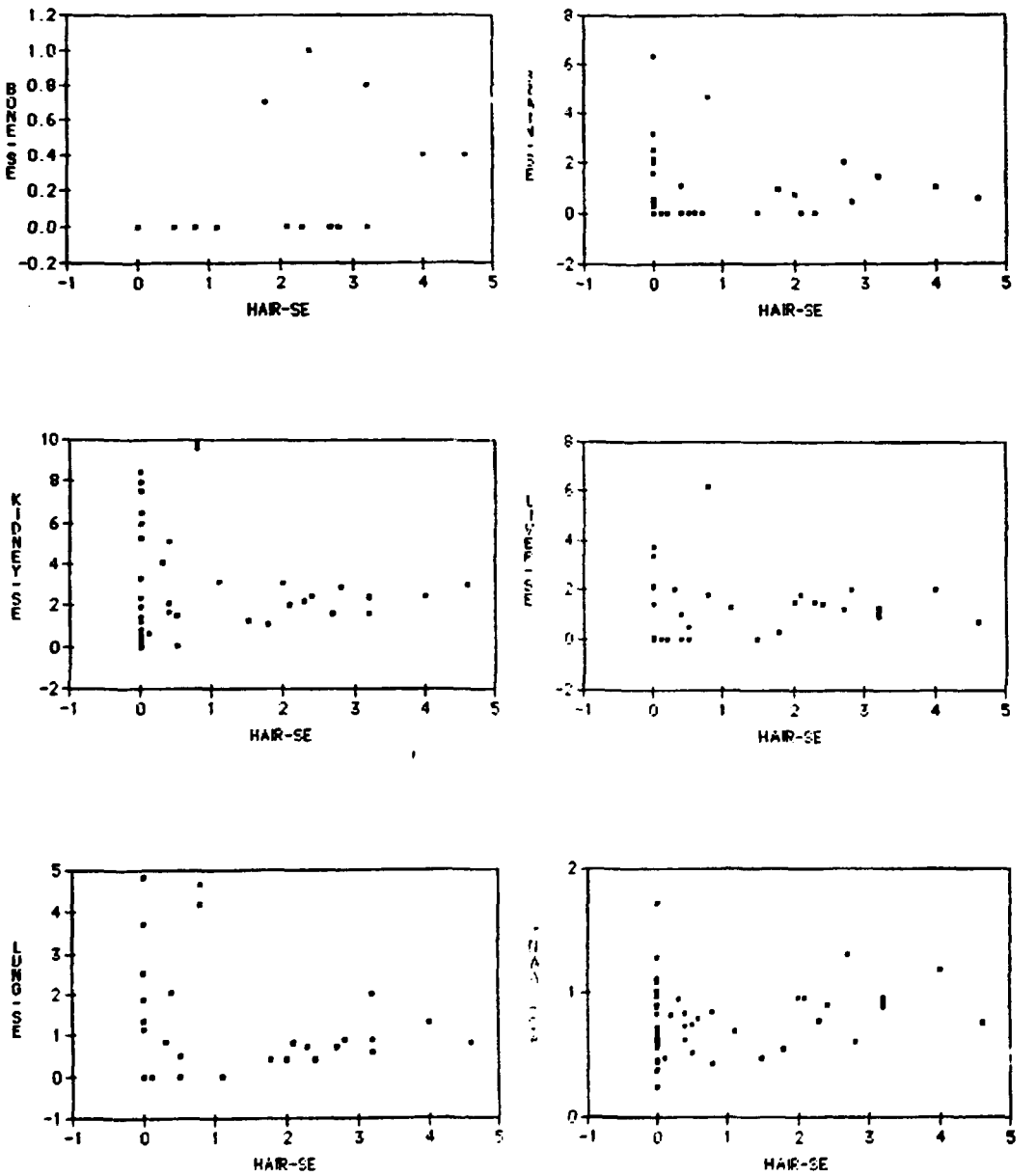

Figure 9. **Distribution of Se concentration in tissues vs hair (mg/kg) Our liver measurement was repeated with NAA by Kinova. The last fragment of our picture shows the NAA measurement of liver by Kinova (Inst. Nucl. Res. & Nucl. Eng., Sofia, Bulgaria)**

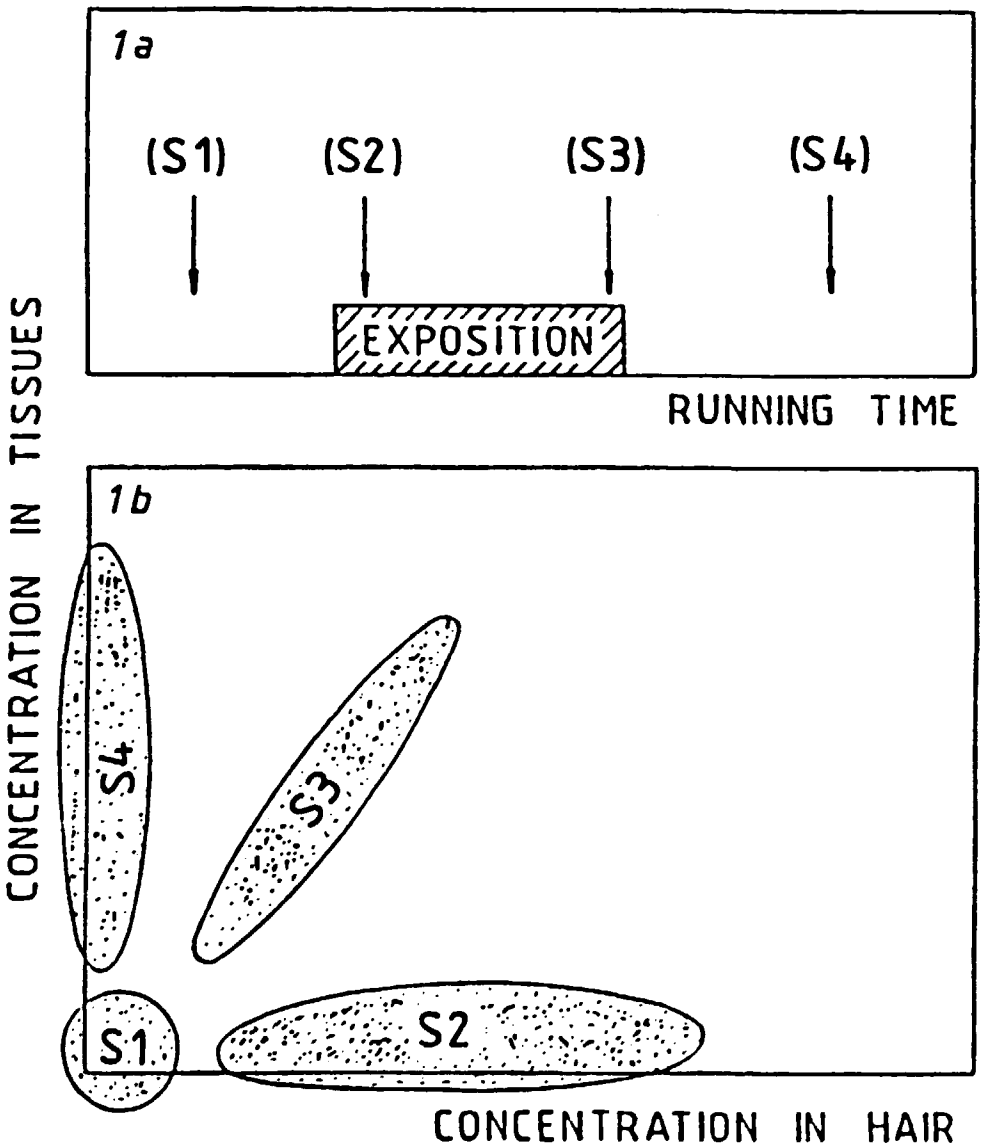

Figure 10. **The expected distribution of toxic heavy metal concentrations measured in tissues and hair depending on the relation of sampling time to exposition**