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Comparative Analysis Of Heavy Metal Sorption Characteristics On Laboratory Animal Models.

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ABSTRACT

Heavy metals have a high ability to diverse chemical, physicochemical and biological reactions. Many of them have a mixed valency and participate in redox processes. Therefore, one cannot talk about the unambiguous role of metals in ecosystems, so we set the goal to assess the level of accumulation of heavy metals in biological tissues when creating the experimental intoxication. During the research, it was found that out of all the studied metals lead and zinc were the most intensively accumulated by tissues with an increase in the overall percentage of the deposit in the tissues for 66.34% and 61.22% compared to the group of the intact animals. Analysis of the element distribution in the organism revealed a common pattern of distribution with the maximum percentage of accumulation in bone tissue 42.15% and 43.41%, respectively. The level of cadmium accumulation was 60.05% in comparison to the group of intact animals. Like in the group with lead intoxication maximum values of the accumulation were observed in bone tissue accounted for 43.18%.
Keywords: heavy metals, intoxication, bioaccumulation, muscle tissue, bone tissue, cutaneous covering

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INTRODUCTION

In the era of the scientific and technical revolution any living organism, especially human one, is prone to daily exposure of many harmful toxins including heavy metals. It is necessary to note that toxic heavy metals with cumulative properties are particularly dangerous for the health of both people and animals. At concentrations above the allowable, they cause intoxication [1].

Nowadays it is needless to say that toxic metals are supposed to only be cadmium, lead, mercury, and antimony. Effects of a significant part of heavy metals in biological systems are variable. It is true that there are not harmful substances but harmful concentrations exist [2, 3].

Many heavy metals show high toxicity in trace amounts and concentrate in living organisms. Unlike organic pollutants, which decompose in the natural environment, metals can only be reallocated between natural environments [4].

It should also be noted that microorganisms are resistant to almost all heavy metals. And so they are able to quickly adapt to such conditions of existence. Due to these abilities, microorganisms serve as marks of changes in the environment [5,6].

Therefore, one cannot talk about the unambiguous role of metals in ecosystems, so we set the goal to assess the level of accumulation of heavy metals in biological tissues when creating the experimental intoxication.

MATERIALS AND METHODS, EXPERIMENTAL

The research was executed at the experimental biological clinic (vivarium) of Orenburg State University on model-specific groups of laboratory white rats Wistar. Distributing the animals into groups, we followed the generally accepted principles of analogue selection: similar age (four-month rat); physiological state, which was estimated in two aspects: nutrition and behavior that were within the physiological norm of animals; live weight (200-250 grams); gender of a laboratory animal was no matter. An important advantage of white rats as laboratory animals is that they are fairly resistant to infectious diseases and give great offspring. The weight of the albino rats is small, and it is not difficult to breed them in the conditions of the Vivarium, and it allows conducting mass experiments on them.

$CuSO_4$ (single concentration introduction was 10 mg/kg of body weight), $ZnSO_4$, $Zn(CH_3COO)_2$, $ZnCl_2$ (75 mg/kg), $FeSO_4$ (150 mg/kg), $CdSO_4$ (1 mg/kg)m and $Pb(NO_3)_2$ (150 mg/kg) were used as xenobiotic factors of effects on the body of experimental animals in the experiment. Injections of metal aqueous solutions were produced once, individually (forcibly), fasting.

The influence of heavy metals on the body of laboratory animals was assessed by examining biological specimens obtained at different stages of the experiment (background research, 7th, 14th and 21st day of experiment). Treatment to animals and performing procedures in the experiment were carried out in accordance with the requirements and recommendations of Russian rules (order of Ministry of the health of the USSR № 755 from 12.08.1977) and The Guide for the Care and Use of Laboratory Animals (National Academy Press Washington, D.C. 1996). To perform the studies, we selected 120 rats, formed 6 groups of them identical by sex, age, and weight [9].

The degree of effect was assessed by means of a deviation of the received data in dynamics compared to reference values. To obtain reliably meaningful values, at every point of the study 5 heads of the studied animals were subjected to slaughter, after that we took material from them for further research. As a control of reference values, we used a group of intact animals treated in identical conditions with control groups of the experimental intoxication with heavy metals (comparative biological research method).

The method of atomic-absorption spectral analysis is characterized by high absolute and relative sensitivity. The method is based on a property of atoms of chemical elements, formed when sprayed ash solutions into the acetylene-air flame, to absorb light of a specific wavelength. The device with the type AAS-1 (GDR) with a set of spectral lamps was used as an atomic-absorption spectrophotometer [10].

Preparation to the analysis requires warming a light source up before measuring not less than 30 minutes and preparing the solution of 10% nitric acid.

As biomaterials, we selected cutaneous covering, bone and muscle tissue. Sample preparation was performed as follows: 5 grams of biomaterial were bio-ashed, and then the ash deposition was dissolved in 10% nitric acid.

The spectrophotometer was configured to do analysis and in 30 minutes after switching on the device scanned photometrically at first standard solutions, then experimental ones. The average value of the series of measurements was considered as the result of the analysis for each element.

RESULTS AND DISCUSSION

We analyzed the characteristics of different biological tissues to bioaccumulate cations of the studied heavy metals (for this purpose, we studied the following biological materials: bones, muscles and the skin of laboratory animals) and, using atomic-absorption spectrophotometry, we measured concentrations of zinc, copper, iron, cadmium, and lead (table 1) in the tissues.

Table 1: Heavy metal cation bioaccumulative characteristics of various biological tissues

Groups	Background observation	In 7 days	In 14 days	In 21 days
Metal concentration in cutaneous covering				
$K_{0(zinc)}$	0,76±0,03	0,75±0,06	0,76±0,02	0,75±0,01
$K_{1(zinc)}$	0,75±0,04	1,32±0,03***	1,20±0,03**	1,12±0,02*
$K_{0(copper)}$	0,26±0,05	0,23±0,02	0,22±0,01	0,22±0,03
$K_{2(copper)}$	0,37±0,01*	0,41±0,08**	0,4±0,02*	0,58±0,05*
$K_{0(iron)}$	5,74±0,005	5,77±0,004	5,64±0,002	5,56±0,003
$K_{3(iron)}$	5,65±0,008	6,58±0,003	6,48±0,005	6,78±0,004
$K_{0(cadmium)}$	0,86±0,04	0,80±0,05	0,78±0,02	0,75±0,03
$K_{4(cadmium)}$	0,82±0,03	1,28±0,04***	1,20±0,02**	1,09±0,01*
$K_{0(lead)}$	0,34±0,02	0,36±0,03	0,30±0,02	0,36±0,04
$K_{5(lead)}$	0,37±0,01	1,80±0,07*****	1,81±0,04***	1,68±0,03***
Metal concentration in muscle tissue				
$K_{0(zinc)}$	0,45±0,02	0,45±0,01	0,43±0,03	0,44±0,032
$K_{1(zinc)}$	0,45±0,03	1,04±0,06****	0,89±0,04**	0,82±0,024***
$K_{0(copper)}$	0,24±0,01	0,23±0,03	0,22±0,05	0,22±0,06
$K_{2(copper)}$	0,35±0,005	0,4±0,01*	0,45±0,02*	0,48±0,004*
$K_{0(iron)}$	5,68±0,003	5,65±0,004	5,66±0,002	5,63±0,003
$K_{3(iron)}$	5,63±0,003	5,89±0,005	6,64±0,004	6,72±0,002*
$K_{0(cadmium)}$	0,47±0,02	0,46±0,01	0,40±0,03	0,43±0,04
$K_{4(cadmium)}$	0,37±0,03	1,01±0,05***	0,80±0,02***	0,79±0,04**
$K_{0(lead)}$	0,85±0,02	0,99±0,04	0,94±0,03	0,95±0,033
$K_{5(lead)}$	0,83±0,03	2,29±0,08***	2,20±0,04****	1,87±0,02**
Metal concentration in bone tissue				
$K_{0(zinc)}$	0,40±0,03	0,39±0,02	0,39±0,04	0,40±0,024
$K_{1(zinc)}$	0,35±0,02	1,78±0,06****	1,69±0,05*****	1,63±0,08***
$K_{0(copper)}$	0,21±0,01	0,23±0,003	0,22±0,01	0,22±0,002
$K_{2(copper)}$	0,23±0,01	0,58±0,03**	0,60±0,02**	0,64±0,04***
$K_{0(iron)}$	5,64±0,006	5,65±0,005	5,65±0,003	5,58±0,004
$K_{3(iron)}$	5,68±0,003	6,37±0,004	6,13±0,006	6,06±0,005
$K_{0(cadmium)}$	0,39±0,03	0,35±0,02	0,49±0,04	0,40±0,042
$K_{4(cadmium)}$	0,32±0,02	1,74±0,06****	1,79±0,05****	1,63±0,08****
$K_{0(lead)}$	1,03±0,03	1,03±0,05	1,04±0,04	0,96±0,043

$K_{5(lead)}$	1,04±0,06	2,98±0,07**	2,76±0,08**	2,73±0,05**
*p < 0,5; **p < 0,05; ***p < 0,005				

During the research, it was found that out of all the studied metals lead is most intensively accumulated by the tissues with an increase in the total percentage of the deposit in the tissues at 66.34% compared to the group of the intact animals. The most distinct sorption characteristics were revealed in bone tissue (42.15%).

The level of cadmium accumulation was 60.05% compared to the group of the intact animals. Like in the group of lead intoxication, maximum values were observed in the accumulation of bone which accounted for 43.18%.

It should also be noted that in addition to the xenobiotic elements, the body intensively sorbs zinc in excess of the control values of the intact animal group in 61.22%, with maximum sorption of this element in bones (43.41%).

The obtained experimental data indicate high levels of xenobiotic pressure on the animal organism with the introduction of excessive concentrations of heavy metals into the body. It should be noted that the highest sorption characteristics are discovered for lead, zinc, and cadmium, the content of the last exceeded the same value of the intact animals with a high level of reliability (more than 60%) in the body of laboratory animals on the 21st day of the experiment. It should also be noted that the highest sorption characteristics for these elements were recorded in bones which accounts for more than 40% of the metal content.

CONCLUSION

From the literature review, it is known that the mutual antagonism between these elements is a consequence of their isomorphic replacement in biological systems. Namely, increased consumption of one of these elements can cause a deficit of another, owing to its replacement in some functional sites of binding [1, 2, 4, 11]. Considering the percentage of copper sorption, it should be noted that this element is also actively sorbed by the studied tissues (over 60%) compared to the group of the intact animals. It's remarkable that the percentage of this element sorption is negligible in relation to other heavy metals in an absolute value, in our opinion, it may be due to the low dose of injection and sorption characteristics of intestinal microbiota which this element also is biogenic for.

The absolute maximum value of content was detected in biological samples of the experimental intoxication with iron, with on the 21st day of the experiment, the total percentage of iron in the tissues of animals of this group exceeded the value of the intact group in 14.26%, which, in our opinion, could be determined, like in the case with copper, by the sorption characteristics of microbiota which this element is vital for. It should be noted that, unlike other elements, iron was uniformly distributed between the studied tissues with the highest values of the content in the cutaneous covering and muscle tissue.

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