ORIGINAL ARTICLE

STUDY ON THE CHEMICAL HETEROGENEITY OF CADMIUM AND LEAD IN THE BIOSPHERE - BIOACCUMULATION OF CADMIUM AND LEAD IN THE ORGANISM OF YOUNG RUMINANTS FROM ANTHROPOGENIC ECOSYSTEMS WITH AN INCREASED TECHNOGENIC CLARC

ПРОУЧВАНЕ НА ХИМИЧНАТА НЕЕДНОРОДНОСТ НА КАДМИЙ И ОЛОВО В БИОСФЕРАТА - БИОАКУМУЛАЦИЯ НА КАДМИЙ И ОЛОВО В ОРГАНИЗМА НА МЛАДИ ПРЕЖИВНИ ЖИВОТНИ ОТ АНТРОПОГЕННИ ЕКОСИСТЕМИ С ПОВИШЕН ТЕХНОГЕНЕН КЛАРК

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РЕЗЮМЕ

Изследвани са технологичният кларк на олово и кадмий в горе н слой на почва и фуражи в индустриално замърсен район, както и постъпленията на олово и кадмий в организма на млади агнета и ярета при синтеза на вторична биологична продукция.

За синтеза на 1 kg вторична продукция при агнета, постъпленията от фуража и питейната вода са 6,44 mg олово и 2,46 mg кадмий а в организма на яретата – съответно 21,41 mg олово и 5,29 mg кадмий.

Получената в условията на повишен техногенен кларк продукция е с по високо съдържание на олово и кадмий спрямо пределнодопустимите концинтрации (EC regulation 466/2001).

КЛЮЧОВИ ДУМИ: олово, кадмий, агнета, ярета, биоакумулация

SUMMARY

The technogenic Clarc of lead (Pb) and cadmium (Cd) from the upper soil layer and the forage plants in an industrially polluted region, so as the Pb and Cd input in the organism of young lambs and kid by the synthesis of secondary biological production have been investigated.

For the synthesis of 1 kg secondary production in the organism of lambs, the input of Pb with the food and drinking water is 6.44 mg and 2.46 mg Cd and in the kid- organism- 21.41 mg Pb and 5.29 mg Cd.

The obtained production in conditions of increased technogenic Clarc is with higher content of Pb and Cd, according the maximal admissible levels (EC- regulation 466/2001).

KEY WORDS: lead, cadmium, lambs, kids, bioaccumulation

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DETAILED ABSTRACT

The content of lead (Pb) and cadmium (Cd) in the incoming flow – substance in anthropogenic ecosystem for receiving of secondary biological production has been studied. Information about real amounts of Pb and Cd input through the forage, drinking water and air has been collected.

The analyses showed that the basic source of lead for the lambs was forage – 98,50 %, 1,39 % of the total amount being absorbed with drinking water and 0,13 % - by air. For the kids the values were 98,99 %; 0,94 % and 0,07 %, respectively. There were differences for cadmium: the basic source of that element was forage - 99,81 % for the lambs and 99,84 % for the kids, and for the drinking water the results were 0,17 % and 0,15 %. Animals breathed with air only 0,001 % of the cadmium.

By the enforce of the criteria FB (factor of bioconcentration) and Cc (Clarc of concentration) it was provided that in the secondary production from heterotrophic organism (lambs and kid) there is a lead distribution (with insignificant species – differences). According Cd – there was observed a concentration in the liver of the lambs (FB = 1.9), and in the liver of the kids – distribution (FB= 0.68). There are more significant differences in this criteria for the kidneys – FB for the lambs is 2.62 and for the kids 0.71 (distribution). In both heterotrophic species used in the experiment, cadmium dispersal was detected in the muscles, the level of dispersal in the muscles of kids being 4 times more intensive compared to that in the lamb muscles.

The Cc criterion assessment showed that despite the great quantities of matter passing through the cells of the heterotrophic organisms used in the experiment, the lead Cc in the lamb liver was 0,27 and 0,07 in the kid liver; in the kidneys – 0,23 and 0,05, respectively, and in the muscles – 0,14 and 0,13, respectively. The assessment of the cadmium Cc showed the same relationship – a considerably higher degree of dispersal in the studied secondary biological produce of kids: in liver – 0,06 /compared to lambs – 0,16/; in kidneys – 0,04 /0,15 in lambs/ and in muscles – 0,01 /0,04 in lambs/.

Specific differences between lambs and kids were also established concerning the lead and cadmium content in the studied tissues by BF and Cc, the kid organism showing better functioning mechanisms for limiting the amounts of the toxic chemical elements in the studied tissues by all the three indices (liver, kidneys and muscles).

INTRODUCTION

The chemical heterogeneity of the lithosphere was established by Clark at the end of 19 century and in 20 century Vernadsky proved the chemical heterogeneity in the rest of the biospheric components including in live substance /Dobrovolskiy, 1998/. The investigations were mainly conducted with the aim of establishing the levels of concentrating or dispersing in the autotrophes compared to the amounts of the studied chemical element in soil /Reylly, 1980; Kabata-Pendias and Pendias, 1984; Dobrovolskiy, 1984, 1998 etc./. The study on the chemical heterogeneity of lead and cadmium in the heterotrophic organisms was an object of less publications, including of Bulgarian authors, the investigation comprising fowl /Baykov, 1994, Baykov et al., 1995,1996,1996-a, Stantchev,1988, etc./ as well as hydrobionts /Baykov, 1999/. Most of the experiments with fowl have been conducted under modeled conditions by enriching the ration with different amounts of cadmium and lead.

For assessing the degree of bioaccumulation at the level of autotrophic organisms the criteria applied was the coefficient of biological intake /CBI/ proposed by Perelman in 1979.

CBI is the amount of the studied element in the ash of a plant biomass unit / the amount in a dried soil unit.

Due to the fact that the quantity is static, we /Baykov, 1994/ suggest to determine the ***Clarc of concentration /Cc/***, which shows the movement dynamics of the chemical elements in synthesizing the secondary biological produce:

It is expedient that the study the movement dynamics of the investigated chemical elements is combined with data about the chemical heterogeneity at the level of phytophages, using the criterion of bioconcentration factor /BF/.

In the present investigation the following objectives were set:

1. To study the lead and cadmium technogenic Clarc of the upper soil layer in an industrially polluted region.
2. To study the interrelation of the three sources of cadmium and lead for the organism: air, water and fodder.
3. To determine the cadmium and lead intake amounts for the organism by synthesizing 1000 g of secondary biological produce used as human food.
4. To determine the Cc and BF in the organism of the young small ruminants and to detect the eventual specific differences, if any.

MATERIAL AND METHODS

Studies were carried out with 2 groups of animals of equal age, sex and race, belonging to species sheep /Ovis aries/ and goat /Capra hircus/, from their birth to 70 days old /first technological age/.

The reported indices were biomass, forage consumption, health status, clinical tests.

The surface soil layer, the forages, drinking water, the muscles, the liver and the kidneys were tested for lead and cadmium content following the method of Jorchrem /1993/. The content of Cd and Pb are measured by flame atomic absorption "Perkin Elmer" 4100. For evaluating the chemical heterogeneity the following criteria were applied:

- Clarc of concentration– content of the studied element in the soil sample / mean Clarc of the soil.
- Cc – Concentration of the studied chemical element in a 1000 g of the secondary biological produce /concentration of the chemical element in the water and forage necessary for obtaining 1000 g of the tested produce.
- BF – the content of the studied chemical element in 1000 g of dry secondary biological produce / the content of the element in 1000 g of dry forage. Data from investigations conducted before the present experiment were used when determining BF, which showed that the major pasture grasses, growing on the sites where the present experiment was conducted, contained 6,63 mg of lead per a kg of dry mass and 0,72 mg of cadmium per a kg of grass dry mass.

RESULTS AND DISCUSSIONS

When determining the technogenic Clarc of the soil horizon 0-20 cm, we accept as a basis the data of

Dobrovolskiy /1998/, that the mean content of lead in soil is 16 mg/kg. In our experiment the mean content from 6 measurements on the first site was 118 mg/kg or the Clarc was 7,37 while in the second site it was 131, i.e. the Clarc was 8,18. The mean content of Cd in the surface soil layer is 0,13 mg/kg while in our experiment the reults were 3,44 and 3,00, respectively, that means the technogenic Clarc was 26,46 and 23,08.

Table 1: Pb and Cd content in the uptake substance flow

Index			Amount	Pb	Cd
1.	Air	Lambs	408,9 m^3/life	0,097 m^3/life	0,0024 m^3/life
		Kids	451,2 m^3/life	0,108 m^3/life	0,0027 m^3/life
2.	Drinking water	Lambs	248,75 l/life	1,18 m^3/life	0,057 m^3/life
		Kids	274,50 l/life	1,51 m^3/life	0,059 m^3/life
3.	Ration				
3.1.	Milk	Lambs	67,70 l/life	9,61 m^3/life	0,35 m^3/life
		Kids	72,83 l/life	10,34 m^3/life	0,36 m^3/life
3.2.	Green grass	Lambs	1,47 kg/life	0,97 m^3/life	0,35 m^3/life
		Kids	1,83 kg/life	1,21 m^3/life	0,36 m^3/life
3.2.	Hay	Lambs	16,3 kg/life	67,81 m^3/life	25,43 m^3/life
		Kids	20,0 kg/life	139.65 m^3/life	34,07 m^3/life
3.3.	Grain	Lambs	11,07 kg/life	5,48 m^3/life	6,62 m^3/life
		Kids	14,08 kg/life	8,72 m^3/life	4,93 m^3/life
	Forage - total	Lambs	96,24 kg/life	83,87 m^3/life	32,51 m^3/life
		Kids	108,71 kg/life	158,30 m^3/life	39,49 m^3/life
	Forage total + water + air	Lambs		85,14	32,57
		Kids		159,92	39,55
	Mean weight Torso + liver + kidney	Lambs	13,213 kg	6,44 kg	2,46 kg
		Kids	7,469 kg	21,41 kg	5,29 kg

Table 1 shows data about the lead and cadmium content in the flow of the substance entering the anthropogenic ecosystem for obtaining the secondary biological produce.

Due to the fact that it is the first time information is presented about the real intake amount of lead and cadmium, showing the amounts of both toxic elements not only in forage and water but also the quantity contained in air, we set the task of determining the objectiveness of the doctrine that the basic source of toxic chemical elements is the lithosphere. In our case the experiments have been conducted in a region with an increased lead and cadmium Clarc, however, the analyses showed that the basic source of lead for the lambs was forage – 98,50 %, 1,39 % of the total amount being absorbed with drinking water and 0,13 % - by air. For the kids the values were 98,99 %; 0,94 % and 0,07 %, respectively. There were differences for cadmium: the basic source of that element was forage - 99,81 % for the lambs and 99,84 % for the kids, and for the drinking water the results were 0,17 % and 0,15 %. Animals breathed with air only 0,001 % of the cadmium. The conducted studies give a reason to exclude air when assessing the lead and cadmium content in the input flow in the anthropogenic ecosystem for obtaining secondary biological produce.

Data in Table 1 show that the lead input in the animal organism for obtaining 1 kg of secondary biological produce /mean torso weight + liver + kidney/ is 6,44 for the lambs and 21,41 mg for the kids. The respective values for cadmium are 2,46 and 5,29. These data give the reason to underline the specific differences concerning the lead and cadmium amounts entering the organism. For 1 kg of biomass 3,32 times higher lead amounts and 2,15 times higher cadmium amounts enter the organism of the kids compared to lambs. One of the reasons for that is the low level of bioconversion of the biogenic chemical elements and the energy from the feed in the organism of the kids.

Table 2: Biometric indices and Pb and Cd content in secondary biological produce

		Index	Weight (kg)	Pb content (mg/kg)	Cd content (mg/kg)
1.	Biomass after slaughtering	1.1 Lambs	23,99		
		1.2. Kids	15,25		
2.	Biomass of dressed torso	2.1. Lambs	12,55		
		2.2. Kids	7,21		
3.	Liver	3.1. Lambs	0,624	1,77 / 5,91	0,40 / 1,37
		Clarc of concentration		0,27	0,16
		Factor of Bioaccumulation		0,89	1,90
		3.2. Kids	0,227	1,59 / 5,42	0,14 / 0,49
		Clarc of concentration		0,07	0,06
		Factor of Bioaccumulation		0,81	0,68
4.	Kidney	4.1. Lambs	0,039	1,51 / 7,87	0,36 / 1,89
		Clarc of concentration		0,23	0,15
		Factor of Bioaccumulation		0,82	2,62
		4.2. Kids	0,032	1,10 / 5,61	0,10 / 0,51
		Clarc of concentration		0,05	0,04
		Factor of Bioaccumulation		0,85	0,71
5.	Muscles	5.1. Lambs	7,53	0,92 / 3,15	0,10 / 0,35
		Clarc of concentration		0,14	0,04
		Factor of Bioaccumulation		0,47	0,49
		5.2. Kids	4,33	0,83 / 3,00	0,03 / 0,09
		Clarc of concentration		0,13	0,01
		Factor of Bioaccumulation		0,45	0,125

Table 2 presents the results of the biometrical studies and the lead and cadmium amounts in the muscles, liver and kidneys of lambs and kids raised in a region with an increased technogenic Clarc of the mentioned toxic elements. The numerator shows the content of the studied element in the fresh weight and the denominator – in a kg of dry weight. The highest lead and cadmium content is in the liver and the lowest in the muscles. The hygienic assessment according to the EU norms – Regulation 466/200, on the basis of which Regulation №12/2002 was adopted by the Bulgarian Ministry of Health, shows that the high technogenic Clarc of both toxic elements affects the quality of the secondary biological produce obtained. The ultimate permissible levels for lead in liver and kidneys are 0,5 mg per a kg of biomass, while the detected amounts were 1,77 mg/kg of liver in lambs and 1,59 mg/kg of liver for kids, i.e. respectively 3,54 and 3,18 times higher than the permissible levels. High contents of lead were also established in kidneys – 3,02 times higher than the permissible levels for the lambs and 2,2 times higher for the kids. The highest values were detected in the muscles. At a permissible level of 0,1 mg/kg the established amounts of 0,92 mg for the lambs and 0,83 mg for the kids, were respectively 9,2 and 8,3 times higher than the ultimate permissible levels. The hygienic assessment of the secondary biological produce concerning the lead content showed approximately similar values, while the assessment of the cadmium content showed specific differences. The cadmium content in the liver of both lambs and kids was below the permissible level, which is 0,5. Considerably lower content of the toxic element was found in the kidneys of the kids, too. At a permissible level of 1, the established values were 0,36 for the lambs and 0,10 for the kids. The cadmium ultimate permissible concentration in lamb muscles is 0,05, while the established value was twice higher, and, in kids it was below the permissible level. It should be mentioned that the cadmium content in the lamb liver was 2,9 times higher compared to kids, in the kidneys – 3,6 times higher and in the muscles – 3,3 times higher.

The clinical tests of the animals showed no deviations from the normal indices of temperature, pulse, breathing, mucous membrane status. No symptoms of acute or chronic intoxication were detected.

For assessing the chemical heterogeneity we used two criteria: static /BF/ that displays the real degree of concentrating or dispersing of the studied chemical element, and, dynamic /Cc/ displaying the amount of the matter passing through the organism for synthesizing 1 kg of secondary biological produce. The assessment by the BF criterion showed that at the level of the heterotrophic organisms – sheep and goats – there was a dispersal of lead in the secondary biological produce used as human food – liver, kidneys and muscles, the specific differences being insignificant. The assessment of the cadmium bioaccumulation proved there were differences between the species. The Clarc of the lamb liver is 1,90 /concentrating/, while in the liver of kids it was 0,68. The differences were still greater when analyzing data about the kidneys: concentrating up to the Clarc of 2,62 in lambs and dispersing in kids /BF = 0,71/. In both heterotrophic species used in the experiment, cadmium dispersal was detected in the muscles, the level of dispersal in the muscles of kids being 4 times more intensive compared to that in the lamb muscles.

The Cc criterion assessment showed that despite the great quantities of matter passing through the cells of the heterotrophic organisms used in the experiment, the lead Cc in the lamb liver was 0,27 and 0,07 in the kid liver; in the kidneys – 0,23 and 0,05, respectively, and in the muscles – 0,14 and 0,13, respectively. The assessment of the cadmium Cc showed the same relationship – a considerably higher degree of dispersal in the studied secondary biological produce of kids: in liver – 0,06 /compared to lambs – 0,16/; in kidneys – 0,04 /0,15 in lambs/ and in muscles – 0,01 /0,04 in lambs/. The results obtained give the reason to conclude that the investigated heterotrophic species possess regulatory mechanisms for limiting the unfavourable effect of the increased cadmium and lead concentrations, resulting from the technogenically increased Clarc in soil. The indicator for that was the dynamic Cc criterion, proving undoubtedly the dispersal in liver, kidneys and muscles. Comparing BF and Cc it is worth mentioning that those regulatory mechanisms in lambs do not allow avoiding the bioaccumulation of cadmium in liver and kidneys, i.e. the classical doctrine of the increasing content of the toxic elements and compounds along the ecological nutrition chain is preserved in that case. Special attention should be paid to the efficiency of the regulatory mechanisms of kids which use significantly greater quantities of matter /forage and water/ for synthesizing secondary biological produce, however, for both indices BF and Cc the differences to lambs are obvious. It can be admitted that the case refers to substrate induction of the regulating mechanisms, a fact established in our previous investigations for activating the tryptophan pyrolase and other enzymes at increased uptake of the quantities of the substrate in the organism.

Conclusions:

The lead and cadmium balance in the three basic components of the incoming flow: air, water and soil, gives a reason to admit that even in regions of increased technogenic Clarc, air can be eliminated as a source of the studied chemical elements due to the low content of the toxic factor.

Under the concrete conditions of the increased technogenic Clarc, the secondary biological produce used as human food, contains lead and cadmium levels, which in liver and kidneys are significantly above the ultimate permissible concentrations adopted by the EU. Concerning the amounts of the studied elements in the basic foodstuff, i.e. the muscles, the conclusion is analogous with an exception of the muscles of kids, the latter complying with the hygienic regulations about the cadmium permissible levels. It must be pointed out that the criterion permissible levels according to the EU norms is hygienic, not ecological, and it does not provide information for establishing the mobility of substances in the anthropogenic ecosystem at the level of heterotrophic organisms.

The classical criterion in biogeochemistry – the bioaccumulating factor - for assessing the chemical heterogeneity along the trophic chain, showed that there were specific differences: for the lambs lead concentrating in liver and kidneys and dispersing in the muscles were detected, while for the kids dispersing was established in all the three studied tissues.

The dynamic criterion Clarc of concentration gives the reason to conclude that under the conditions of input substance metabolism – disintegration and synthesis – despite the significant amounts of the cadmium and lead intake the Clarc of concentration is far below one.

Specific differences between lambs and kids were also established concerning the lead and cadmium content in the studied tissues by BF and Cc, the kid organism showing better functioning mechanisms for limiting the amounts of the toxic chemical elements in the studied tissues by all the three indices.

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