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ORIGINAL ARTICLE

Influence of heavy metals on metabolic processes in cows

L. G. Slivinska[1], V. V. Vlizlo[1], A. R. Shcherbatyy[1], B. O. Lukashchuk[1], B. V. Gutyj*[1], M. P. Drach[1], M. G. Lychuk[1], I. A. Maksymovych[1], M. I. Leno[1], V. I. Rusyn[1], B. O. Chernushkin[1], V. L. Fedorovych[1], H. O. Zinko[1], O. I. Prystupa[1], V. Y. Yaremchuk[1]

[1]*Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies, Lviv, Ukraine*
**Corresponding author E-mail: bvh@ukr.net, ua-andrea@ukr.net*
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The actual problem of modern veterinary science of Ukraine in technogenic pollution regions is the study of features and mechanisms of combined action of the most common heavy metals – cadmium and lead and their influence on the body of humans and animals. The purpose of the work was to study the influence of these heavy metals on metabolic processes in cows, in particular on the activity of transferases (alanine aminotransferase, aspartate aminotransferase), total protein content, albumins, alpha-, beta- and gamma-globulins, urea, creatinine, depending on the distance to the heaps of mines in Lviv-Volyn coal basin. The researches were conducted in Lviv-Volyn coal basin (APC "Ukraine", Grybovytsya village, Bilychi village, Zabolotci village, Zastavne village of Ivanychi district of Volyn region). The study objects were cows of black-spotted breed at the age of 3–7 years with a productivity of 5000–5500 kg of milk. It was established that the content of serum total protein in cows that were in the technogenic pollution region (Grybovytsya village, Bilychi village, Zabolotci village, Zastavne village), on average was 69.6 ± 2.56; 75.5 ± 1.89; 74.5 ± 2.37 and 76.9 ± 1.31 g/L respectively, and was lower compared to parameters of cows from APC "Ukraine" (80.4 ± 0.81 g/L). Hypoproteinemia was established in 60% of cows from Grybovytsya village, 20 – from Bilychi village, 30 – from Zabolotci village, and 20% – from Zastavne village. Analysis of individual results in 12 cows (30%) found decreased albumins by 38%. It was established a decrease in the absolute amount of serum beta globulins in cows from Grybovytsya village ($P < 0.05$) and a tendency to decrease in cows from Bilychi, Zabolotci, and Zastavne villages ($P < 0.1$). It was established a decrease of serum gamma globulins in cows from Grybovytsya village ($P < 0.01$), Bilychi, and Zabolotci villages ($P < 0.05$). In 30% of cows, the percentage of albumins in the total amount of protein was in the range of 36.1–38% in other cows – from 38.1 to 44.8%. In the serum of cows from the control zone, aspartate aminotransferase activity was 1.77 ± 0.082 mmol/(L x h) (1.20–2.45). In cows, under conditions of body intoxication by heavy metals (cadmium, lead), the activity of serum aspartate aminotransferase was by 1.5 times higher ($P < 0.001$) in cows from Grybovytsya village, by 1.3 ($P < 0.001$) – from Bilychi village, by 1.2 ($P < 0.001$) – from Zabolotci village and by 1.2 times ($P < 0.01$) – from Zastavne village compared to the control group of animals. Hyperenzymemia [more than 2.14 mmol/(L x h)] was established in 31 cows of 40 (77.5%), but only in 5 cows (12.5%), aspartate aminotransferase activity was higher than 3 mmol/(L x h). It was established that in the blood serum of cows from Grybovytsya village, the activity of alanine aminotransferase was by 1.7 times ($P < 0.001$) higher compared to the control group, in cows from Bilychi village – by 1.6 ($P < 0.001$), from Zabolotci village – by 1.4 times ($P < 0.001$). The activity of this enzyme in cows from Zastavne village did not differ from the cows of the control zone. Alanine aminotransferase hyperenzymemia was established in 26 cows (65%). The serum of cows from Grybovytsya and Bilychi villages has established an increase of urea content compared to the parameter in APC "Ukraine" ($P < 0.001–0.05$) and creatinine content by 1.6 and 1.3 times, respectively.
Keywords: cadmium, lead, aspartate aminotransferase, alanine aminotransferase, total protein, albumin, globulins, creatinine, urea.

Introduction

Sources of heavy metals emission and their entry into the environment differ in variety, but they are mainly of technogenic origin due to urbanization and industrialization (Lavryshyn & Gutyj, 2020). The development of industry, agriculture, energy and transport, intensive mining − all this has led to the entry into the air, water, soil, plants of highly toxic mineral elements (Rodríguez et al., 2001; Lavryshyn & Gutyj, 2020; Slivinska, 2007).

As a result of industry and agriculture development, the intensity of technogenic emissions poses a threat to life in some regions of Ukraine (Hibo & Bycko, 1996; Slivinska, 2007; Gutyj et al., 2017). Scientists in past centuries have noted the dependence of animal and human pathology on adverse environmental changes.

As a result of technogenic activities, there is constant pollution of the environment with various pollutants, among which heavy metals occupy a prominent place. The presence of heavy metals in the biosphere (water, soil, plants) has a double meaning: as trace elements, they are necessary for the normal course of physiological processes, but at the same time toxic in high concentrations, which adversely affects animal health, productivity, and quality of agricultural products (Rodríguez et al., 2001; Lavryshyn & Gutyj, 2020; Slivinska, 2007; Hibo & Bycko, 1996). The body of animals is an essential link in the food chain, where mainly heavy metals get from feed, are absorbed and distributed to various organs and tissues (El-Shahat, 2009; Hibo & Bycko, 1996).

Heavy metals are dangerous pollutants that, due to toxic stress, cause various disorders of the body's functional state in animals and humans. Getting into the body in small doses over a long period and accumulating in various organs and tissues, heavy metals can cause toxicosis, which is accompanied by disturbances of biochemical processes, structure, and function of cells, in particular the permeability of the cell to the chemical components of the internal environment (Velychko, 2007; Slivinska et al., 2019; Gutyj et al., 2019).

The most significant attention of researchers (Velychko, 2007; Abramov et al., 2009; Slivinska et al., 2018; 2019; 2020) attracts the study of the combined action of heavy metals on animals' bodies as an ecopathogenic factor of the environment. The source of this action is the heaps of mines located in the Lviv-Volyn coal basin.

Due to high industrial emissions, cadmium and lead pollution of the environment are constantly increasing. 3x105 tons of Pb and 2x103 tons of Cd are annually involved in biogeochemical cycles. As a result, the contamination of soils and food products are grown on them by research elements also increases. The absorption of these elements in the digestive tract of animals depends on age, lactation, and food composition.

Cadmium and lead accumulate in the liver and then enter other organs, including the kidneys (Sahnjuk, 2009; Paranjak et al., 2007; Gutyj et al., 2016). That's why we researched the protein-synthesizing function of the liver and the filtering function of the kidneys. The study of these issues is essential because cadmium has a long half-life (over 30 years); for animals, cadmium deposition is lifelong (Sahnjuk, 2009; Gutyj et al., 2016, 2017, 2018).

Therefore, the purpose of the work was to study the influence of heavy metals (lead and cadmium) on the state of metabolic profile of cows, in particular on the content of total protein, albumins, alpha-, beta- and gamma globulins, urea, creatinine, aspartate, and alanine aminotransferase activity, depending on the distance to the heaps of mines in Lviv-Volyn coal basin.

Materials and methods

The study was conducted in Lviv-Volyn coal basin (APC "Ukraine", Grybovytsya village, Bilychi village, Zabolotci village, Zastavne village of Ivanychi district of Volyn region). The study objects were cows of black-spotted breed at the age of 3–7 years with a productivity of 5000–5500 kg of milk. The animals were examined clinically by conventional methods (Levchenko et al., 2010) and performed a laboratory blood test.

Blood was collected from 10 cows in each of the four settlements at a different distance from the territory of mines. The content determined the protein-synthesizing function of the liver in the blood serum of total protein (biuret reaction) and protein fractions (polyacrylamide gel electrophoresis); enzymatic function – by the activity of aspartate (AST) and alanine (ALT) aminotransferase (method of Raytman and Frenkel); the functional state of the kidneys was determined by the content in the serum of creatinine (Jaffe's color reaction) and urea (reaction with diacetylmonoxime) (Levchenko et al., 2010).

The research was performed following the rules for the performance of zootechnical experiments to select and keep animal analogs in groups, the technology of harvesting, use, and accounting of consumed feed.

All manipulations with animals were carried out under the European Convention for the Protection of Vertebrate Animals, used for Experimental and Scientific Purposes (Official Journal of the European Union L276/33, 2010).

The mathematical processing of the research results was worked out statistically using a program package Statistica 6.0 software (Stat Soft, Tulsa, USA). Differences between the mean values were considered statistically significant at $P < 0.05$ (ANOVA, taking into account the Bonferroni Correction).

Results

According to the results of our studies (Table 1, 2), the content of serum total protein in cows from the zone of technogenic pollution (Grybovytsya village, Bilychi village, Zabolotci village, Zastavne village) was lower than the parameters in cows from APC "Ukraine". Hypoproteinemia was established in 60% of cows from Grybovytsya village, 20 – from Bilychi village, 30 – from Zabolotci village, and 20% from Zastavne village.

Since the total protein content is the sum of all its fractions, we determined their quantitative ratio in the serum of cows. Analysis of the blood serum proteinogram in cows from villages located in the technogenic pollution region showed that the average proportion of albumins did not differ from animals from APC "Ukraine".

Analysis of individual results in 12 cows (30%) revealed a decrease in albumin by 38%, which is considered the minimum norm. Cows had at least 36% albumin.

Therefore, we analyzed the level of albumins in absolute values, which showed ($P < 0.001$) their lower content compared to clinically healthy cows (Table 2). Hypoalbuminemia was established in 12 cows (6 from Grybovytsya village, 2 – Bilychi village, 2 – Zabolotci village, and two from Zastavne village), which is 30% of the studied animals. The cause of hypoalbuminemia is liver damage in cows with anemia because albumins are synthesized only in the liver.

Table 1. Parameters of protein metabolism in the blood of cows from control zone and research settlements

Name of settlements	Total protein, g/L	Albumins, in percent	Globulins, in percent		
			α-	β-	γ-
APC "Ukraine"					
Lim	74.0–85.2	36.8–44.1	12.5–18.9	14.1–20.5	25.0–33.0
M ± m	80.4 ± 0.81	39.9 ± 0.57	14.6 ± 0.46	17.1 ± 0.38	28.4 ± 0.39
Grybovytsya village					
Lim	60.1–81.2	36.8–44.1	12.0–18.9	14.1–20.5	27.0–28.9
M ± m	69.6 ± 2.56	39.8 ± 0.64	14.6 ± 0.63	17.3 ± 0.63	28.1 ± 0.21
P <	0.001	0.5	–	0.5	0.5
Bilychi village					
Lim	62.3–82.5	36.4–42.4	13.5–18.0	13.6–19.0	24.3–29.1
M ± m	75.5 ± 1.89	39.3 ± 0.67	15.8 ± 0.55	17.0 ± 0.54	28.0 ± 0.44
P <	0.05	0.5	0.1	0.5	0.5
Zabolotci village					
Lim	59.8–82.1	36.1–44.8	12.9–18.7	14.1–19.3	25.2–28.9
M ± m	74.5 ± 2.37	40.1 ± 0.76	16.0 ± 0.59	16.8 ± 0.60	27.1 ± 0.47
P <	0.05	0.5	0.1	0.5	0.05
Zastavne village					
Lim	70.1–82.3	36.8–40.6	13.9–18.9	14.1–18.5	27.3–33.0
M ± m	76.9 ± 1.31	38.7 ± 0.47	15.7 ± 0.52	16.7 ± 0.40	28.9 ± 0.49
P <	0.05	0.1	0.1	0.5	0.5

Note: P < – compared to APC "Ukraine".

It is also essential to determine the globulin fractions of blood protein. The level of alpha globulins in the blood of cows did not differ between the animals of the experimental settlements (Table 2).
It was established a decrease in the absolute amount of beta globulins in the blood serum of cows from Grybovytsya village ($P < 0.05$) and only a tendency to decrease in cows from Bilychi, Zabolotci, and Zastavne villages ($P < 0.1$), which is caused by toxic liver damage (Table 3).

Table 2. The content of total protein and its fractions in the blood of cows from control zone and research settlements

Name of settlements	Total protein, g/L	Albumins, g/L	Globulins, g/L		
			α-	β-	γ-
APC "Ukraine"					
Lim	74.0–85.2	30.3–36.5	10.7–16.9	11.8–17.5	22.0–30.5
M ± m	80.4 ± 0.81	32.4 ± 0.46	11.43 ± 0.43	13.8 ± 0.37	22.9 ± 0.45
Grybovytsya village					
Lim	60.1–81.2	22.1–32.5	8.0–12.2	8.5–14.8	16.4–23.5
M ± m	69.6 ± 2.56	27.8 ± 1.03	10.1 ± 0.45	12.1 ± 0.73	19.6 ± 0.77
P <	0.001	0.001	0.1	0.05	0.01
Bilychi village					
Lim	62.3–82.5	24.4–33.5	8.7–15.3	10.9–14.1	17.4–22.9
M ± m	75.5 ± 1.89	29.6 ± 0.89	12.0 ± 0.65	12.8 ± 0.38	21.1 ± 0.58
P <	0.05	0.05	0.1	0.1	0.05
Zabolotci village					
Lim	59.8–82.1	24.0–32.6	8.9–14.9	9.1–15.2	16.3–23.0
M ± m	74.5 ± 2.37	29.8 ± 0.91	11.9 ± 0.67	12.5 ± 0.62	20.2 ± 0.75
P <	0.05	0.05	0.5	0.1	0.05
Zastavne village					
Lim	70.1–82.3	26.2–33.3	9.9–14.7	11.2–14.5	20.3–23.5
M ± m	76.9 ± 1.31	29.8 ± 0.74	12.1 ± 0.50	12.9 ± 0.32	22.2 ± 0.36
P <	0.05	0.05	0.1	0.1	0.1

Note: P < – compared to APC "Ukraine".

The gamma globulin fraction of the protein contains a primary mass of antibodies that provide humoral protection of the organism. It should be noted that the proportion of gamma globulins in the serum of cows from the control zone and experimental settlements did not differ in relative values (excluding cows from Zabolotci village). However, in absolute terms was established their significant decrease in the blood serum of cows from Grybovytsya village ($P < 0.01$), from Bilychi and Zabolotci villages ($P < 0.05$). The decrease in the content of gamma globulins in the blood serum of cows from experimental settlements was due to the suppression of the immune system.

Thus, hypoproteinemia, which was established in some cows of all settlements, is explained by two reasons: a decrease in the synthesis of albumins in hepatocytes and gamma globulins by immunocompetent systems. No significant changes in albumins were found; only in 30% of cows, their share in the total amount of protein was in the range of 36.1–38% in other cows – from 38.1 to 44.8%.

In addition to protein and its fractions, parameters of hepatocytes state are the activity of aminotransferases (Shcherbatyy et al., 2017; Lukashchuk et al., 2020). In cows, under conditions of body intoxication by heavy metals (cadmium, lead), the activity of serum aspartate aminotransferase was by 1.5 times higher ($P < 0.001$) in cows from Grybovytsya village, by 1.3 ($P < 0.001$) – from Bilychi village, by 1.2 ($P < 0.001$) – from Zabolotci village and by 1.2 times ($P < 0.01$) – from Zastavne village compared to the control group of animals (Table 3). Hyperenzymemia [more than 2.14 mmol/(L x h)] was established in 31 cows of 40 (77.5%), but only in 5 cows (12.5%), aspartate aminotransferase activity was higher than 3 mmol/(L x h). Increased aspartate aminotransferase activity in the serum of cows under conditions of intoxication by cadmium and lead salts is due to hepatocytes damage and enzyme elimination into the bloodstream.

Despite that the study of aspartate aminotransferase activity indicates the diagnosis of liver diseases in cattle, we also found an increase in alanine aminotransferase activity. Thus, in the serum of cows from Grybovytsya village, the activity of alanine aminotransferase was by 1.7 times ($P < 0.001$) higher compared to the control group, in cows from Bilychi village – by 1.6 ($P < 0.001$), from Zabolotci village – by 1.4 times ($P < 0.001$). The activity of this enzyme in cows from Zastavne village did not differ from the cows of the control zone. According to data (Sahnjuk, 2009), the maximum activity of alanine aminotransferase is 1.03 mmol/(L x h). Given the above, it can be argued that alanine aminotransferase hyperenzymemia was established in 26 cows (65%).

Table 3. The activity of liver enzymes in the blood of cows from control zone and experimental settlements

Name of settlements	Biometric parameter	Aspartate aminotransferase, mmol/(L x h)	Alanine aminotransferase, mmol/(L x h)
APC "Ukraine"	Lim	1.20–2.45	0.36–1.24
	M ± m	1.77 ± 0.082	0.83 ± 0.062
Grybovytsya village	Lim	2.29–3.27	0.96–1.85
	M ± m	2.73 ± 0.142	1.43 ± 0.101
	P <	0.001	0.001
Bilychi village	Lim	2.18–2.95	0.80–1.82
	M ± m	2.34 ± 0.070	1.32 ± 0.098
	P <	0.001	0.001
Zabolotci village	Lim	2.04–2.28	0.95–1.28
	M±m	2.16 ± 0.025	1.13 ± 0.031
	P <	0.001	0.001
Zastavne village	Lim	1.91–2.29	0.74–1.18
	M ± m	2.10 ± 0.050	0.92 ± 0.042
	P <	0.01	0.1

Note: P < – compared to APC "Ukraine".

Therefore, taking into account the individual parameters of aspartate and alanine aminotransferase activity, it can be noted that the lesion of hepatocytes has a chronic course. The pathological process disrupts the structure of plasmatic and mitochondrial membranes. The activity of enzymes is characteristic of the dystrophic process or chronic course of hepatitis.

The content of serum urea in cows from the control zone (APC "Ukraine") was in the range from 3.2 to 5.5 mmol/L and averaged 4.4 ± 0.14 mmol/L (Table 4). According to the literature (Sahnjuk, 2009), the content of urea is in the range from 2.0 to 6.0 mmol/L, which is considered the physiological limit for highly productive cows. In the blood serum of cows from Grybovytsya and Bilychi villages, was established an increase in the content of urea compared to the parameter of animals from APC "Ukraine" ($P < 0.001$–0.05), which is the result of impaired renal excretory function. Confirmation of our assumption is indicated by an increase in cows of the same groups by 1.6 and 1.3 times the content of serum creatinine in cows (Table 4), which is an indicator of glomerular filtration dysfunction kidneys.

In the serum of cows from the control zone, creatinine content ranged from 82.0 to 149.0 μmol/L (115.8 ± 5.11 μmol/L). According to the literature (Sahnjuk, 2009), the normal creatinine level for cattle is 70-140 μmol/L. In healthy animals, creatinine is entirely filtered by the glomerular apparatus of the nephron and is almost not reabsorbed in the tubules, so its level in the serum depends on the degree of glomerular filtration.

Table 4. Parameters of the functional state of the kidneys in cows from control zone and research settlements

Name of settlements	Biometric parameter	Urea, mmol/L	Creatinine, μmol/L
APC "Ukraine"	Lim	3.2–5.5	82.0–149.0
	M ± m	4.4 ± 0.14	115.8 ± 5.11
Grybovytsya village	Lim	4.5–7.4	152.0–208.0
	M ± m	5.8 ± 0.32	182.4 ± 5.59
	P<	0.001	0.001
Bilychi village	Lim	4.3–6.7	106.0–195.0
	M ± m	5.2 ± 0.28	148.1 ± 9.11
	P <	0.05	0.01
Zabolotci village	Lim	4.1–5.5	92.0–165.0
	M ± m	4.7 ± 0.15	130.3 ± 7.99
	P <	0.1	0.1
Zastavne village	Lim	3.8–5.2	95.0–142.0
	M ± m	4.5 ± 0.14	120.0 ± 5.30
	P <	0.5	0.5

Note: P < – compared to APC "Ukraine".

Thus, under the influence of heavy metals on cows' bodies in the technogenic pollution region, there is a decrease in the content of serum total protein, hypoalbuminemia, hyperenzymemia (aspartate and alanine aminotransferase), increased urea and creatinine content. As they move away from the source of pollution, the signs of liver and kidney dysfunction decrease in cows from Zabolotci and Zastavne villages, the creatinine and urea content probably did not differ from parameters in the control group of cows.

Discussion

The growing anthropogenic impact on ecosystems has led to environmental pollution by heavy metals, which poses several fundamental problems to world science in preventing the spread, accumulation, and control of their content in the soil, water, feed, animal body, and livestock products (Kalyn et al., 2020; Bashchenko et al., 2020; Honcharova et al., 2021; Vasylyev et al., 2021; Borshch et al., 2021; Butsiak et al., 2021; Kalaitan et al., 2021; Saranchuk et al., 2021).

Pollution of agricultural lands by heavy metals usually occurs due to atmospheric emissions from enterprises, waste from livestock farms, and mineral fertilizers and pesticides. Organic fertilizers – manure and compost also contain a significant amount of heavy metals. As a result of the introduction of organic matter into the soil, the concentration of such chemical elements as lead, cadmium, copper, zinc, iron, and manganese increases. Given the slow removal of heavy metals from the soil, with a long-term supply of even relatively small amounts of cadmium, its concentration can reach very high levels over time.

Cadmium is considered a dangerous pollutant because, due to toxic stress, it causes various disorders of the functional state in animal's body.

The peculiarity of the harmful effects of cadmium on the animal body is its rapid assimilation and slow excretion, which leads to the accumulation of metal in tissues. Cadmium hurts some biochemical processes and physiological functions in the animal body (Waisberg et al., 2003; Alonso et al., 2004). It accumulates mainly in the liver and kidneys. In particular, in the kidneys, it causes nephron dysfunction, which inhibits the reabsorption of amino acids, glucose, phosphorus, and oligopeptides in bone tissue which disrupts the processes of calcification (Gutyj et al., 2018).

It is believed that the distribution of cadmium between organs and tissues depends on the routes of its administration. After oral administration, the kidneys contain approximately two times more cadmium than the liver, and the intravenous infusion revealed the opposite ratio. The predominant accumulation of cadmium in the liver after the intravenous infusion is due to the increased ability of liver tissue to synthesize metallothionein – a protein containing 33% cysteine and binds six metal ions per molecule. There is a correlation between the concentration of cadmium in the liver and kidneys and the level of metallothioneins in the blood and urine of experimental animals.

Immunohistochemical studies of the kidneys of rats with cadmium intoxication revealed intense fluorescence in capillaries and capsules of the glomerulus and in proximal tubules, which indicate the deposition of immune complexes in vessels and mesangial of the glomeruli and basal membrane of the tubules. In the kidneys of a control group of animals, slight illumination in proximal tubules was detected.

The intravenous or intraperitoneal administration of cadmium damages primarily the liver and other organs (Hwang and Wang, 2001; Gupta et al., 2004). Cadmium toxicity is associated with the ability of an element to cause a peroxidase reaction of hepatocyte membrane lipids (Watjen and Beyersman, 2004). Besides, the activity of certain enzymes, in particular glutathione peroxidase, glutathione reductase, glucose-6-phosphatase, is reduced, which may be a test for early diagnosis of liver tissue damage (El-Shahat et al., 2009).

The effect of cadmium on the body of animals is manifested by chronic and acute intoxications, which are accompanied by metabolic disorders, violation of physiological functions, decreased resistance, productivity, and ability to reproduce.

It is known that cadmium ions can react with functional groups of protein molecules, in particular sulfhydryl groups, cause oxidative stress and inhibit some biocatalytic processes.

Literature data on the relationship between induced liver cell damage by cadmium and the activity of LPO processes are also often contradictory. Some researchers believe that these phenomena are independent, and the main destructive effect of the metal is associated only with a violation of the energy metabolism of hepatocytes (Antonio et al., 1998; El-Shahat et al., 2009; Al-Azemi et al., 2010). However, the vast majority of researchers believe that cadmium significantly enhances the processes of lipid peroxidation and reduces the activity of antioxidant enzymes: glutathione peroxidase, superoxide dismutase, catalase (El-Shahat et al., 2009; Al-Attar, 2011). Cadmium has been shown to activate LPO in parenchymal organs and kidney and brain tissues (El-Refaiy and Eissa, 2012). Administration of 3.3 mg/kg (0.05 DL_{50}) of cadmium chloride for 30 days changed the prooxidant-antioxidant status of rat liver. Besides, there was a sharp increase in the content of diene conjugates; under these conditions, glutathione peroxidase activity was significantly reduced. Inhibition of catalase, superoxide dismutase, and glutathione peroxidase activity and the content of vitamin E and ascorbic acid in the liver under the influence of cadmium has been found in other scientific studies (Gupta et al., 2004).

The determining component of toxic cadmium action is the suppression of the functional state of mitochondria, which leads to depletion of energy resources and the corresponding disruption of several vital processes. Cadmium, penetrating cells, interacts with mercapto groups that play an essential role in enzymatic energy supply systems. This metal, by binding to phospholipids and nucleic acids, separates the process of oxidative phosphorylation. Under conditions of environmental pollution, Cd cations can cause adverse biological effects even in small concentrations.

One of the heavy metals that are widespread in the biosphere is lead. Despite the decline in industrial production in recent years, the level of lead emissions into the biosphere remains high, posing a threat to human and animal health. Organic lead compounds are bioavailable, toxic, affect protein synthesis, the energy balance of cells, and their genetic apparatus. This element is not subject to destruction and biotransformation but is only redistributed between the individual components of the ecosystem.

Lead is one of the most toxic heavy metals, capable of blocking reactive (sulfhydryl, carboxyl, and phosphate) groups of biopolymers, including proteins, nucleic acids, and enzymes. It has been included in the list of priority pollutants by some international organizations, including the WHO.

When a large amount of lead salts enters the body of animals, it has a pronounced membrane-toxic effect, which results in the activation of blood clotting with the formation of blood clots and disruption of microcirculation of internal organs.

The nature of lead distribution and the degree of its accumulation in the animal body depends on the affinity for various structures and biochemical components of tissues and organs, the strength of the formed complexes, the rate of their elimination.

In the blood of animals, lead is unevenly distributed; namely, 96-98% of it is fixed in erythrocytes, and 2-4% binds to plasma proteins. After the lead enters the body of animals, it accumulates most in the bones, then in the blood, liver, and kidneys, and its concentration in the skeleton is tens or even hundreds of times higher than in other organs.

Lead toxic to the liver (Gutyj et al., 2019), inhibits the synthesis of heme precursors, inhibiting the activity of heme synthetase – an enzyme that regulates the incorporation of iron into the porphyrin ring, disrupts tissue respiration.

The changes in the protein-synthesizing function of the liver and filtration function of the kidneys established by us are not critical for the organism of cows. This is because cadmium and lead enter the body with feed in small quantities and their metabolism, an important role belongs to low molecular weight proteins – metallothioneins, which contain a significant number of free sulfhydryl groups (Davis & Cousins, 2002; Sabolic et al ., 2002; Gutyj et al., 2019). Each molecule of metallothionein can attach 7 molecules of cadmium. Only cadmium not bound to metallothioneins is toxic to the body. A prolonged intake of moderate amounts of cadmium allows cells to convert it into a bound form, which is a very stable compound and can be broken down in small amounts only in the renal tubules, which explains the greater sensitivity of the kidneys to cadmium action.

Like cadmium, lead is toxic to the kidneys, but when both metals enter the body simultaneously, their toxic effect on renal canals is significantly reduced (Slivinska, 2007; Alonso et al., 2004). These reasons can explain the slight changes in liver and kidney function due to cadmium and lead.

Conclusion

The protein metabolism in cows from the polluted zone is characterized by hypoproteinemia (32.5% of cows), hypoalbuminemia (30%), hypogammaglobulinemia; 77.5% of cows had increased aspartate aminotransferase activity and 66.5% − alanine aminotransferase activity. We observed that the concentration of urea and creatinine is increased in the blood serum of cows from the settlements located within 3-5 km from the mines.

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