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BIOLOGICAL ROLE OF MICROELEMENTS AND THEIR CONTENT IN EPIDERMAL FORMATIONS

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ANNOTATION.
It follows from the data studied that information on the content of chemical elements in animal hair, depending on the presence of melanin, should be related to the concentration of this pigment, before judging the effect of environmental factors on their content. For a long time it was assumed that, the entry of mineral substances into the hair occurs from the blood capillaries, which are supplied to the hair follicle bulbs and the epithelial layers of the skin. There have been attempts to establish a positive correlation between the content of mineral and organic substances in the blood. When comparing the reaction of blood plasma and rat hair to a change in the composition of food, it was found that plasma quickly responds to changes in the content of magnesium and calcium in the diet, slowly - to the content of phosphorus and does not react at all to changes in the level of sodium and calcium (this is explained by a clear homeostatic regulation of the content of these elements in the blood). At the same time, the hair reacts quickly to changes in sodium content, slowly to calcium, magnesium, phosphorus, and very slowly to changes in potassium concentration.
Key words: microelements, ontogeny, skin, wool, hair follicles, concentration, chemical analysis.

Relevance of the topic.

Epidermal formations, like any other tissues in terms of their mineral composition, distribution of levels of trace elements, reflect the state of the environment and the functional characteristics of this type of tissue in ontogenesis.

A systematic study of the effect of nutrition on the concentration of chemical elements in the wool of domestic animals was begun relatively long ago (Anke, M.A.Risch, M. Brohart) the concentration of other substances in the hair was also investigated, for example, vitamins, urea, proteins, glycosides, etc. From the outset, it has been noted that hair and coat have the following advantages as an object of chemical analysis as an indicator of mineral status:

A) During the period of hair growth, it seems to accumulate changes occurring in the internal environment of the body, according to which information about previous nutrition can be obtained. For this reason, hair analysis is a method traditionally used in forensic medicine.

B) The hair is easy to process, easily accessible, chemically stable**.**

The possibilities of chemical analysis of hair were periodically "rediscovered", especially in the USA, where the level of environmental pollution was studied using the analysis of human hair.

In recent years, about 250 scientific articles have been published on the chemical composition of hair and wool, but American researchers, apparently, were not aware of the existence of such a large amount of work in this area. Opinions about the ability of hair to reflect the nature of the previous nutrition of humans and animals or toxicological data range from extreme optimism to complete denial.

There are three reasons for this disagreement:

A) Limited knowledge about the origin and methods of incorporating hair into its components;

B) A too simplified idea of the possible links between excess and lack of chemical components of the diet and their content in the hair;

C) Lack of understanding of the physiological functional unity; existing between the hair follicle and the two associated glands - sebaceous and sweat.

It is now well known that keratin binds many organic substances (such as dyes), but it is less well known that it also binds mineral compounds. It has been shown, for example, that black hair is richer in calcium and phosphorus than white hair. On the same black phenotype, it was found that the melanin content varies from one organism to another, and there is a close correlation between the concentration of melanin and calcium ($r = +0.79$), magnesium ($r = +0.79$) and phosphorus ($r = + 0.64$). Sodium and potassium content is not related to melanin concentration.

The concentration of manganese, cobalt, selenium, molybdenum also correlates with the melanin content, while copper and zinc do not show such a correlation. The response of the hair to a change in the composition of food differs, therefore, by its specificity and is associated, first of all, with changes in the composition of the secretion of the sebaceous and sweat glands, which are reflected in the chemical composition of the hair. Some of the components of the secretion of these glands are easily washed off. Urea is completely washed off; sodium and potassium are removed largely during washing. Calcium, phosphorus and magnesium are washed out to a lesser extent, while the copper content does not change. Washing out of the components associated with melanin is inversely proportional to its content in the hair. The presence of sodium, potassium, lactic acid and other substances in sweat has been known for a long time. Interestingly, sweat also contains all minerals, including trace elements, and that their secretion increases with increased intake from food. The fixation of mineral substances secreted by the sweat and sebaceous glands by the hair was tested in this way in animals: in cattle, a small area of the skin was shaved, then a month later, when the hair grew back, half of the area was shaved again, and at the end of the second month the upper part of the hair of the unshaven area was cut ... This top matched the hair shaved off in the first month. It was shown that between the first and second months in the hair the content of potassium increases by 90, sodium - by 132, calcium - by 42, magnesium - by 128%. This observation explains the increase in the concentration of calcium and phosphorus from the base to the top of the hair and the reason why, in the absence of a deficiency or excess of individual elements of the feed, the concentration of chemical elements of the hair does not remain constant. The accumulation of mineral components in the hair increases if the hair follicle is at rest for a certain period. This can explain a number of changes in the mineral composition of the hair, namely: the increased content of calcium, phosphorus, which characterizes the wool of cows with low milk yield. It is associated with delayed hair regrowth due to stress, chronic infection, and insufficient nitrogen and phosphorus in the diet.

The sebaceous glands cover the hair with a lipid layer that prevents the entry of minerals dissolved in sweat into it. This assumption is supported by a negative correlation between the content of lipids and minerals in hair ($r = -0.66$). The amount of lipids depends on the level of nutrition and gender. A low nutritional level leads to a decrease in the amount of lipids in the composition of bovine hair, but increases it in the hair of cows. These differences are caused by hormonal factors. Poor nutrition inhibits the secretion of both male and female sex hormones. However, testosterone increases the secretion of the sebaceous glands, while estrogens have the opposite effect on them. The relationship between the mineral composition of epidermal formations and the supply of the body with microelements is not always direct, but is influenced by a number of external and internal influences that make it difficult to use the mineral composition of wool as an indicator of the macro and microelement status of the body. The supply of the body with iron and cobalt is characterized by the level of hemoglobin in the blood and vitamin B12 in the blood plasma much better than the content of these elements in the outer covers. The largest amount of data on the ability of individual mineral components serves as an indicator of the microelement status of the organism, obtained in relation to copper, manganese, zinc, selenium, molybdenum, iodine and potassium. Less is known about the indicative ability of such elements as mercury and lead in hair. As for chromium, fluorine, tin, vanadium, silicon, nickel, antimony and arsenic, the data are very scarce due to analytical difficulties. The trace elements, the vital necessity of which for the body has already been proven (the so-called "classic" trace elements) include iron, iodine, copper, zinc, cobalt, molybdenum, selenium and chromium, and 5 more elements were added to them - vanadium, tin, silicon, nickel ... Arsenic and lead and cadmium ("new" trace elements) The state of knowledge of the biological role of these elements and the indicative value of their content in epidermal formations is convenient to consider for each separately.

Manganese (Mn)

Scientists at the University of Wisconsin [11,12] established the vital need for manganese in animals 80 years ago. The lack of this element in ruminants leads to a weak manifestation of signs of heat while maintaining a normal ovulation process and an increased number of abortions and resorption of fetuses. The offspring of mothers lacking manganese have a lower live weight and reduced vitality at birth. Manganese is necessary for the biosynthesis of mucopolysaccharides and lipids, and therefore its deficiency causes a disruption in the formation of mucus and cartilage tissue, especially during the prenatal period. Mothers lacking manganese bring forth more male offspring, which is apparently explained by the predominant fertilization of the egg with more mobile sperm carrying the Y-chromosome. The external manifestation of manganese deficiency is the thickening and deformation of the tubular bones and the violation of osteogenesis in general. These lesions are especially noticeable in mammals at the hock joints, experiencing the greatest stress, during the milk period. With the transition to a feed rich in manganese, cartilage growth is normalized. In the offspring of mothers lacking manganese, the nervous system is often affected, which is reflected in paralysis during the first 10 days of life, which are treatable with manganese. In poultry, a lack of manganese leads to perosis (slipping tendon), which can be treated with this element. The animal's need for manganese is significantly influenced by the presence of its physiological antagonists in the feed, the most important of which is iron. The manganese requirement of cattle, horses, sheep, goats and poultry is, as a rule, 60 mg / kg feed. For pigs, 30 mg / kg is sufficient. However, with a high concentration of iron, even 100 mg of manganese per kg of feed may not be sufficient.

Determination of manganese in wool requires careful cleaning, as dust, excrement and soil tend to contain more manganese than the wool itself. The lipid film surrounding the hair retains these impurities, and therefore it is necessary to first remove grease, best of all, by extraction with ether or acetone, followed by rinsing with bidi-stilled water. Comparison of the indicator capacity of various organs and tissues in goats [2], it was shown that manganese deficiency is most noticeably reflected in the content of this element in the liver. It is followed by white hair, kidneys, heart muscle and ovary, while other organs and tissues, such as bone, plasma, blood, lungs, due to better homeostatic control, react much weaker to manganese deficiency. Thus, the analysis of wool is quite suitable for determining the supply of the organism with this element. This is also evidenced by experiments with radioactive manganese (Mn52). Its inclusion in the composition of wool occurs within a few hours after giving through the mouth, and after two days, the radioactivity of the wool disappears again. This indicates that wool, like any other body tissue, is actively involved in the exchange of manganese. The plumage of a bird is also actively involved in the exchange of manganese and can serve as a depot of this element for a short time. 9 hours after giving Mn52 by mouth, 18% of the absorbed manganese is present in the plumage, from which it moves to other organs (skeleton, ovaries, liver) over the next few hours. The manganese content in the coat reflects not only its deficiency in the body, but also its normal level and excess. Hair from different parts of the body reflects the level of manganese in the body in different ways. Therefore, the hair on the bangs is usually 1.5 times poorer in manganese than the hair growing on the side, and therefore the latter is more suitable for characterizing the manganese status of the body. Along with topographic differences, the manganese content in wool depends on a number of physiological characteristics, which include the age and color of the wool, the health of the animal, pregnancy, lactation, and the height of the sample cut. Thus, the wool on the withers is usually richer in manganese than the wool on the side, light wool is usually poorer in this element than dark, and wool and hair of brown and red colors are usually the richest in manganese. Thus, it was shown that in humans, blond hair contains 1.6 mg / kg and red hair - 3.2 mg / kg (13). Because of periodic molting, the coat of animals is heterogeneous. Before molting, the supply of nutrients to the hair follicle is reduced. The hair gradually separates from the follicle and dies off, remaining, however, depending on the circumstances, for a long time in the hair sheath. Young hair appears next to the dead hair. During the summer, the integumentary hair grows old, and with the onset of autumn, in addition to the integumentary hair, young downy hair appears in animals. Accordingly, the content of trace elements in the hair undergoes periodic changes. At the same time, the highest content of manganese was noted in the cover hair in spring during the molting period and the lowest in autumn (14). Dead hair is always richer in manganese than living cover hair, since the manganese absorbed by it is excluded from metabolism. In this regard, it is not recommended to take wool samples to assess the supply of manganese to the body during molting. In sick or emaciated animals, in which there is no replacement of dead hair, as a rule, the amount of manganese in the wool also exceeds the physiological norm. There were no statistically significant differences in the level of manganese in wool associated with age in animals [15, 16]. The influence of age is rather indirect because young animals, which are on a dairy diet poor in this element, contain less manganese in their wool than adults do. With depigmentation of hair, the content of manganese in it also decreases. Another factor influencing the level of manganese in the coat is the origin of the animals, as has been demonstrated in cattle (2) and in pigs. It was also shown that the peripheral part of the hair differs from the basal part by a high content of this element. In pigs, these differences are statistically significant. It follows that the wool for analysis should be cut as close to the skin as possible. The threshold concentration of manganese, which characterizes the provision of the animal organism with this element, should be considered its content in the liver, 8 mg / kg, and in black wool, equal to 6 mg / kg. There is a statistically significant relationship between these two values ($L < 0.05$), characterized by the correlation coefficient - r = 0.83 and the regression equation - y = 2.45 + 0.64x. a positive relationship was also noted between the content of manganese in the liver, kidneys and brain. A significant correlation was also established between the manganese content in the wool of cows and red clover growing on soils of various geological origins. The highest concentration of the element was found in wool and clover on soils formed by the weathering products of syenite, granite, and porphyry, and the lowest concentration on loess and limestone soils. The content of manganese in red clover in prosperous territories ranged from 57 to 71 mg / kg dry weight, and in disadvantaged areas - 22 to 34 mg / kg. These values corresponded to the level of manganese in the wool, amounting to 15-19 and 4-5 mg / kg, respectively. Among animals with low levels of manganese in the coat, a large number of cases of manganese deficiency have been found. The cattle kept on pasture were usually superior to the animals kept in the stall in terms of the manganese content in the wool, which corresponded well to the higher concentration of this element in green fodder [17, 18, and 19]. As for sheep, for this species of animals, such data are much less, since their wool is difficult to clean, especially in fine-wooled sheep, and in coarse-wooled sheep and goats, the analysis results are significantly influenced by the ratio in the fleece of down and guard hairs, which varies greatly from age and season of the year, and depending on the method of sampling. Under these conditions, it is especially important to adhere to standard wool sampling conditions. The wool of one-two-month-old Karakul lambs [12] meets such requirements, for example. The phenomena of manganese deficiency, expressed by impaired reproductive function and skeletal development, were observed, as a rule, in animals with a manganese content of less than 8 mg / kg in the liver and less than 5 mg / kg of manganese in wool [2]. The ability of sheep wool to reflect the level of manganese in the diet was also noted by New Zealand [13, 14] and Hungarian authors. A similar relationship was found in wild ruminants, minks, and in humans [2]. In men and women, the content in the liver of 5.5-7.5 mg / kg and in the hair 1-2 mg / kg of manganese corresponds to the physiological norm. Age and gender do not significantly affect the metal content in the hair, in contrast to its level in other organs and tissues. In case of insufficient protein nutrition, the level of manganese in the hair also increases due to slower growth. The inclusion of protein in the diet leads to a rapid normalization of the level of manganese in the hair - 4.4-1.4 mg / kg, respectively [15].

Copper

The same group of a student of the University of Wisconsin [16] showed the vital necessity of copper in 1928. The widespread occurrence of copper deficiency among farm animals has generated great interest in the biological role of this element in the animal body [8, 9]. It was initially shown that copper is essential for the normal process of hematopoiesis. It was further found that copper deficiency causes endemic ataxia in newborns, causing great damage to sheep and goat breeding in large areas around the world. This disease is caused by myelin aplasia in the central nervous system. The effect of copper deficiency on reproductive function is expressed by increased embryonic mortality in ruminants with impaired function of copper-containing cytochrome oxidase, the terminal carrier of electrons in the respiratory chain.

In sheep and cows, a lengthening of the sexual cycle was noted, returning to normal after the addition of copper. Another characteristic sign of copper deficiency is damage to the connective tissue of the vessel walls and bone collagen. These phenomena are caused by a decrease in the activity of specific lysyl oxidases, which contain copper and are necessary for the formation of desmosin and isodesmosin, amino acids involved in the maturation of elastin and collagen and determining their strength. Damage to the walls of blood vessels and the heart leads to cases of sudden death in cattle, pigs and poultry [11]. Depigmentation of dark wool is a sensitive indicator of copper deficiency in rabbits and sheep, earlier than anemia. As early as 2 days after the onset of copper deficiency, the conversion of tyrosine to melanin is disrupted in dark-colored fine-wooled sheep and a pigment-free keratin is formed [17]. Similar phenomena were noted in Karakul sheep [18]. Bovine wool is less responsive to copper deficiency than sheep wool. It is important to note that the brown shade of the coat in black-and-white cattle may not be the result of a copper deficiency, but a consequence of crossing it with jerseys. Copper is also required for the synthesis of keratin. In sheep that are deficient in this element, wool grows more slowly, exhibiting weak crimp and thinned areas. It also increases the content of a number of amino acids such as glycine, alanine, serine, glutamic acid. Recently, it has been shown that there is a genetic disease in humans and mice associated with impaired transport of copper by metallothionein through the intestinal wall, called Menkes disease. To establish the body's need for copper, feed analysis is of subordinate importance, since a large number of physiological antagonists (sulfur, calcium, cadmium, silver, molybdenum, zinc, and iron) influences the metabolism of this element. The brain better than other organs and tissues reflects the supply of the body with copper and surpasses even the liver in this respect. The fact is that with copper deficiency caused by an excess of cadmium, the synthesis of metallothionein increases in the liver, which, along with cadmium, also accumulates copper, zinc and mercury, which are thus excluded from metabolism. Other organs and tissues reflecting the copper status of the organism are, after the liver, blood plasma (serum), guard hair, and heart muscle (in the given sequence). The copper content in the wool of goats reflects the deficiency of this element in the feed (<2 mg / kg) only 2 months after the animals were transferred to a copper-poor diet. In females, the level of copper in the coat decreases faster than in males, which is apparently explained by the influence of pregnancy, which causes an additional decrease in copper reserves. The additional supply of copper to adult animals is reflected in the content of this element in wool. However, as long as the liver copes with the function of depositing this element, wool reflects an increase in the copper content in the diet only to a limited extent. In the case of an inverse relationship between the content of copper in internal organs, as well as in pasture plants and its level in wool, work [13] indicates. These observations are also confirmed in the work of Nazarov [2011], where it was established that the hair coat of 15-20 day old Karakul lambs experiencing pronounced copper deficiency during the prenatal period contains an increased amount of copper in comparison with lambs from the reference province. The author explains this phenomenon by the increased release of copper from the body under the influence of the increased consumption of molybdenum and sulfates by animals, and the inclusion of copper in wool is considered as one of the ways to remove it from the body. Copper is also different from manganese in relation to its association with hair color. The dependence of the copper level in wool on the melanin content has not been established (29). The indications of the presence of such a connection, in particular, the higher content of copper in black wool as compared to white (30), are apparently based on analytical errors. On the other hand, linear and pedigree differences in copper content are possible in white and black animals. In particular, the coat of albinos and albinoids is always poorer in copper than the coat of normally pigmented animals. At the same time, in a piebald animal sample of wool from black and white areas, they do not differ in the content of this element. It can be assumed that copper, preferring sulfur-containing ligands, is bound to a much greater extent by keratin than nitrogen and oxygen-containing melanin ligands [12]. The differences in the copper content between black and red wool in cattle are apparently associated not so much with color as with the type of wool. Thus, for example, the copper-rich wool of the German mountain motley cattle is coarser and longer, as well as richer in ash components, than the shorter and thinner wool of the black-and-white cattle. In Hungarian red-motley cattle, it has been established that the amount of copper increases from light yellow to dark red [11]. Under normal copper status, it contains 5 mg / kg copper. A slight effect of coloration on the copper content has also been shown on human hair [2]. Sex differences have little effect on the copper content in wool and hair and become noticeable only in conditions of a deficiency of this element. At the same time, smaller values were found in females, which consume additional copper for the reproduction of offspring. Available sex differences are 4-4.3 mg / kg in goat hair and 13-14 and 15-18 mg / kg in human hair, respectively. In the bristles of pigs, there were no sex differences in the copper content (13 mg / kg). In wild geese, on the other hand, the feather of females is richer in copper than that of males. Thus, in other habitats, 14-27 mg / kg of copper were found in the feather geese, and 10-18 mg / kg of copper in the gander [12]. As the norm for people of both sexes, you can take the copper content in the hair equal to 15 mg / kg. In cattle, seasonality has practically no effect on the copper content in wool, which varies by no more than 1 mg / kg. Based on these data, seasonality can be disregarded when sampling wool to determine the copper status of animals, although the molting period should nevertheless be considered unfavorable for this purpose. The age of the animals does not affect the level of copper in the coat. Therefore, in calves of one line, it fluctuated within 10-10, 7 mg / kg for 2 to 45 weeks and in the other - within 9.8-11.0 mg / kg. There were no significant fluctuations in copper levels in adult cows from 3 to 10 years of age. In Karakul lambs, wool at birth is richer in copper than in adult sheep, however, from one year old to 6 years of age, no statistically significant changes in the copper content were observed in them [13]. In humans, the copper content in the hair exhibits a certain age-related dynamics. The largest amount of this element is found in the hair of girls 6-10 years old (21 + 14 mg / kg) and adolescents 11-10 years old (37 + 23 mg / kg). Subsequently, the level of copper in the hair fluctuates around the value of 15 mg / kg, which can be taken as a conditional physiological norm [14]. In poultry, age also has a marked effect on copper levels in the plumage. So in chickens, the content of this metal when hatched from an egg was 24 mg / kg and decreased by 70 days of life by more than 3 times (7.3 mg / kg) and did not change more with age [15]. As evidenced by most of the studies cited, the level of copper in the outer integument of young animals is usually higher than in adults, in which it remains at a more or less constant level, reflecting the specificity of the species. The copper content in wool is under genetic control. So in the works [2] it was shown that the offspring of one bull-producer had on average 45% more copper in the wool (8 mg / kg) than the offspring of 11 other bulls (4.8-6.0 mg / kg). Linear differences in the content of copper in blood and liver were also found for sheep, in which, unfortunately, the level of this element in wool was not analyzed [16]. These observations suggest that differences in analytical results may be due to genetic causes. Breed differences in copper content were found in hooves of pigs, where the content of this element ranged from 6.9 in Cornwall piglets to 15 in Durok animals and 16 mg / kg in Hercegalom [17]. Pregnancy of cows is reflected in the level of copper in their wool only in the last month of pregnancy (about 1.3 mg / kg). In earlier periods and in the second month of lactation, the content of this metal in wool does not differ from the norm. In this regard, the wool of cows at the end of pregnancy and in the first month of lactation is less suitable for indicator studies [2]. Limited human material has shown that the level of copper in hair changes with various diseases. It is decreased in Menkes disease [17, 18] and increases in infectious hepatitis (46 + 29 mg / kg) and hyperthyroidism (43 + 12 mg / kg) [10]. In cattle, the content of copper in the brain (better an indicator of copper status) should be taken as the norm, equal to 9 mg / kg. With such an amount of copper, the content of this element in the liver is 35 mg / kg, the content in the blood serum is 0.65 mg / l, and in the black guard hair is 6.0 mg / kg. At a higher level of copper in the brain, the enrichment of this element and other listed tissues occurs, with a highly reliable correlation coefficient (r), which is 0.91, 0.84 and 0.80, respectively. The kidneys and skeleton do not show this correlation with the brain. If the content of copper in the brain is in the range of 6-9, in the liver - 15-35 mg / kg, in the serum - 0.6-0.65 mg / l and black outer hair - 5-6 mg / kg, then one can expect growth retardation of young animals. When the copper content falls below 6 mg / kg in the brain, clinical phenomena of copper deficiency are observed. Unlike manganese, it was not possible to establish a correlation between the level of copper in wool and red clover, since various physiological antagonists of this element of techno genic origin, such as sulfur dioxide, molybdenum and cadmium, have a great influence on the copper content in animals, especially in the vicinity of industrial enterprises. At the same time, there was a good agreement between the number of wool samples with low copper levels and its content in clover in each province studied. The largest number of samples of wool, poor in copper, was found in cows from provinces with swampy and sandy soils (6.4 and 7 mg / kg), where a reduced content of copper in red clover was also noted. In areas not polluted by industrial emissions, a better match was found between the level of copper in wool and red clover. In areas polluted by industrial emissions, there is, as a rule, a decrease in the copper content in cattle wool by 16-29% [11]. Many researchers [12, 13, 14, 15, 16, 17 and 18] note the existence of a relationship between the level of copper in cattle wool and its provision with this element. Sheep wool can also serve as an indicator of their copper nutrition. For this species of animals, as well as for cattle, a correlation has been established between the content of copper in the brain, liver, blood serum and wool [2]. Critical values for this element should be considered its content in the brain less than 4 mg / kg, at which the liver contains 7, blood serum 0.3, and wool 3.7 mg / kg of this element. These figures were obtained from adult sheep from biogeochemical provinces where clinical signs of copper deficiency were observed - endemic ataxia of lambs. Under normal conditions of copper nutrition in the body of sheep found on dry tissue: brain 18 + 7.1; liver 220 + 25.1; blood serum 0.84 + 0.46; wool 10 + 8.2; kidney 15 + 5 mg / kg. The content of copper in the brain is equal to 6.0-9.0; in the liver - 16, in the blood serum - 0.66 and in the wool - 5.2 mg / kg should be considered close to the lower threshold [12, 2]. Similar concentrations were found in the wool of one-year-old sheep in Hungary - 4.2-5.4 mg / kg. The results obtained in the USA [10], -25-147 and in New Zealand [13, 14] - 22-81 mg / kg differ from the data presented. The reason for this discrepancy is unclear. Contamination of wool with copper is not excluded. In wild artiodactyls - mouflons, deer, moose - similar copper content in wool was found - 6.6, 7.1, 12 mg / kg, respectively. For moose in Alaska, the reported value corresponded to good copper status. With a copper deficiency in their wool, only 5.2 mg / kg of this element was found [11]. The copper content in the covering hair of the mink is 8 + 1.4 [2], and that of rabbits is 9.1 + 3.2 mg / kg. Under conditions of copper deficiency in these animals, the copper content in wool also significantly decreases and amounts to 5.6 + 2.3 mg / kg. In pigs, the copper content in the bristles is 10-14 mg / kg on different rations. When copper is included in the diet in an amount of 250 mg / kg of feed, the content of this element in the bristle increases by only 2-3 times, reaching 33 + 9.1 (grain ration) and 32 + 71 mg / kg (root crops) on different rations. At the same time, the copper content in the liver increases by almost 20 times. Thus, the content of copper in the bristles, as well as in the wool of ruminants, reflects the level of this element in the body only within certain limits, since the liver, accumulating this element over a wide range, performs its buffer function in relation to it [15].Normally, the hair of a person over 20 years old contains 15 mg / kg of copper regardless of gender. Such figures were obtained in the cities of Freiburg and Jena in the GDR [2]. Similar values (18 mg / kg) were found in 204 adult New Yorkers (34). In Bushmen, the content of copper in hair was 10 mg / kg, while in lactating women the level of this element decreased to 8 mg / kg [13]. The same authors found 9.9 mg / kg of copper in the hair of lactating women of the Bantu tribe, which is also significantly inferior to the data found in Europeans. The authors note that these values, apparently, are not associated with copper deficiency in the body of the examined people, since they did not have anemic conditions characteristic of copper deficiency. In the hair of adult residents of Chandigarh (India), an even lower content of copper was found - 7.1 mg / kg, while in Thailand and Denver (USA), 13 and 14 mg / kg were found in persons comparable to them [14, 15]. Workers engaged in the smelting and processing of non-ferrous metals, without exception, contain high concentrations of copper in the hair, which exceeds the norm for representatives of certain professions by 4-10 times.

Zinc

Research on the biological role of this element is intensively developing, because one of the indicators of its biological role is the detection of more than 200 enzymes of all known classes, which contain zinc. A non-specific sign of zinc deficiency is growth retardation and impaired protein synthesis. Epithelial cells of the prostate and seminal fluid are especially rich in zinc. Zinc deficiency, especially during the prenatal period, can lead to a decrease in the gonads in males and irreversible atrophy of the embryonic epithelium. Prolonged deficiency of this element reduces sexual function, although it does not reduce sexual instinct, leads to a decrease in sperm production. In the Middle East, cases of hypogonadism and underdevelopment of secondary sexual characteristics in young men have been repeatedly described, cured by giving zinc salts. Intrauterine zinc deficiency causes malformations in the fetus and can lead to miscarriage or obstructed labor. Milk of all animal species is rich in zinc and, as a rule, helps to cure the phenomena of zinc deficiency in offspring. Zinc has a positive effect on wound healing. One of the manifestations of zinc deficiency in humans can be dwarf growth associated with a delay in the growth of tubular bones, impaired ossification of the skull and other parts of the skeleton. In animals and humans, genetic defects are known that lead to zinc deficiency. In humans, this disease is known as acrodermatitis enteropathy. An autosomal recessive disorder appears after weaning. It is characterized by lesions of the skin epithelium, areas of the mucous membrane and intestines close to it, hair and nails. At first, purely empirically, in this disease, drugs were used that form complex compounds with zinc and promote its absorption through the intestinal wall, for example, orthoxyquinoline derivatives. Then zinc compounds were used with full success. Heals all symptoms of the disease and restores normal hair growth. The lesion of the intestinal tract observed in this disease has a close resemblance to another human disease - celiac disease (Guy-Herter Heibner's disease), in which the level of zinc in the blood serum is also reduced, especially in forms resistant to a gluten-free diet. (0.37 + - 0.075 versus 0.95 + - 0.125 mg / l zinc is normal). Giving zinc to sick children has been shown to be effective in this disease. Zinc plays a decisive role in human parenteral nutrition, which is often accompanied by symptoms of zinc deficiency, similar to acrodermatitis enteropathy. Thus, in 37 adults who received parenteral nutrition and became ill with signs of zinc deficiency, complete cure and restoration of hair growth was achieved. It turned out that with parenteral nutrition, the excretion of zinc in the urine increases, as a result of which a deficiency of this element occurs in the body. The level of zinc in the body also decreases with a hereditary disease known as sickle cell anemia, which accompanies the phenomena of zinc deficiency. The level of zinc in the hair of persons affected by this disease is significantly reduced. A quite definite dynamics of zinc is established in human hair, regardless of the sex of the hair of 3-5 year old children, it contains a smaller amount of this element than at a later age (185 + - 43; 15 years - 234 + - 57; 11-25 years - 237 + -64; 65 years old - 239 mg / kg). A significant decrease in the content of zinc in the body is excellent for Adem's disease associated with the lethal gene A 46 m with enteropathy acrodermatitis in humans. In the hair of a two-year-old child with this disease, almost half the amount of zinc was found in the normal range (100 mg / kg). After a month of zinc treatment, its content in the hair approached the norm and amounted to 168 mg / kg. Summarizing the data on the level of zinc in the epidermal structures, it should be said that because of pronounced homeostatic regulation, its level in the hair, in the wool, in the range fluctuates only within limited limits and reflects the zinc status of the body more slowly than its content in the blood serum. Human hair reflects well the pollution of the external environment with zinc. Young hair is somewhat richer in zinc than old hair. Especially rich in zinc in young hair with milk nutrition.

Nickel

Divalent nickel ions are essential for the existence of animals. In a diet deficient in nickel in animal cells, swelling of mitochondria, expansion of the perinuclear space, and a number of other phenomena associated with membrane dysfunction are found. Nickel toxicity is very low and there are homeostatic mechanisms in the body that regulate its concentration levels. The usual content of this element in tissues is 1-5 μg / kg. Known macroglobulin in the blood, which is a carrier of nickel-nickel plasmin. In blood serum, it is also found in low molecular weight complexes and compounds with serum albumin. Due to the ubiquitous prevalence of nickel (soil, plants, etc.), it is difficult to compose a diet in which this element would be completely absent, which forms the active center of a very important enzyme - urease, which cleaves urea to form two NH_3 molecules, and CO_2. This enzyme with MB. 105000 contains two-nickel atoms. It is possible that this ion plays the role of a biological Lewis acid (like Zn), although it is possible that an forms a strong complex with ammonia, the product of the cleavage of urea. It is possible that this ion is part of the enzymatic systems of glutamine metabolism, in particular, catalyzing its hydrolysis with the formation of ammonia.

Lead

Hair and hair analysis has been used repeatedly, as noted, in toxicological studies. Especially many works are known on the study of the content of lead in hair and wool. **The results of these studies are shown in Table 1.2.** Gender and age do not affect the lead content of the coat and hair, but there is less lead in the lower part of the hair than in the upper part. The lead content in hair increases as a result of contamination from external sources, as follows from Table 1.2, the lead content in uncontaminated hair does not exceed 10 mg / kg. Such a concentration of lead was found in rural areas with insignificant lead pollution from transport and industrial emissions. Hence, it follows that the content of lead in the head hair, which did not exceed I0 mg / kg, indicates a low pollution of the environment with this element. In the urban population not associated with the processing of lead, its content in the head hair reaches Z2-2I7 mg / kg. Similar results were also obtained for small mammals (rats) in rural and urban habitats and amounts to 11 and 133 mg / kg, respectively.

Table 1.2

Lead content in human head hair

Country, gender, locality	**χ**	**б**
Ireland, children, countryside	3,1	-
India, men, countryside	5,0	4,3
USA, countryside	7,6	5,0
Canada, countryside	9,1	-
India, students	9,4	7,4
USA, women, men	11,0	3,0
USA, printers	15,0	12,0
USA, young women	20,0	-
United States, male lead contact	32,0	29,0
Canada, men, lead contact	45,0	-
USA, children, lead contact	217,0	213,0

In healthy dogs, the concentration of lead in the coat ranges from 10 to 30 mg / kg, and in dogs poisoned with lead, from 30 to 180 mg / kg. In the wool of a moose from Alaska, 0.5-26 mg / kg of lead was found [16], and in the wool of sheep - 9 mg / kg [10]. In cattle from an area with a low level of lead, its content fluctuated within I-4 mg / kg, and from an area contaminated with this element, within 60-96 mg / kg [18].

It clearly follows from the data presented that the content of lead in hair and wool reflects well the level of this element in the body and in the environment.

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