State of health of agricultural animals on the territories affected by the radioactive contamination resulting from the ChNPP accident

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Analysis of the effect of radiation on agricultural animals as a result of the ChNPP accident is presented. The state of health of agricultural animals was determined using a complex mixture of clinico-physiological, immunological, biochemical and biophysical indices. The results of investigations from different contaminated districts of Russia, Belarus and Ukraine are described. The changes occurring in the state of separate functional systems of the body of animals were demonstrated to be mainly connected with radiation injury of the thyroid during the acute period of the accident.

The adverse effects of ionizing radiation on the bodies of farm animals manifest themselves as different pathologies. The form of the body response depends on the irradiation dose, the exposure time, the radionuclide composition of fallout and other things. An "acute period" is commonly recognized which lasts for 2 to 6 months is associated with a spectrum of the short-lived radionuclides deposited on pastures and hay lands. The first two years after an emergency should be considered as the period of short-term consequences for radiation exposure. The later period occurs as the long-term consequences when somatic effects can be partially transformated into genetic ones. The genetic effects at the micropopulation level can be registered within 4-8 years following the primary exposure to ionising radiation. For farm animals, based on their economically useful qualities and hence change of generations.

Nowadays radiobiologists are analyzing and studying the long-term consequences of three large-scale events that have resulted in radioactive contamination of large areas of the country. These are: the South Urals accident in 1957, the Chernobyl accident in 1986 and tests of nuclear weapons at the Semipalatinsk Test Site. In some places of the South Urals trace the dose from gamma-radiation over the first 12 days reached 290 rad and was accompanied by lethal cases in farm animals [1]. In animals of this region which received by an order of magnitude less dose temporary changes in the blood system were noted during 6 months. In later periods these animals were no different in all aspects, including reproductive, from the physiological norm. It should be noted that radiostrontium was the primary pollutant in this region.

The Altai territory was the most affected by the nuclear tests at the Semipalatinsk Test Site. According to the data of the diversified expedition in 1989, the reconstructed dose to man in some places amounted to about 200 rem, with the main contribution being made by the tests in 1949 [3]. There is no evidence on the death of farm animals, even though data for 1992-1993 show a deviation of some physiological values from the norm.

In the early period after the Chernobyl accident, relatively high exposure dose rates and contamination of fodder lands were reported in areas adjacent to the NPP: Khoikinsky, Braginsky and Narovlyansky districts of the Gomel region. At a distance of 10-15 km from the NPP (v.Chamkov, v.Massany, Khoikinsky district), the dose rate in the first days after the accident was as high as 300-400 mR/h and dropped to 75-100 mR/h by 10 May. The maximum dose burden from the total gamma-irradiation to small groups of animals (of around 100 heads) left in the abandoned zone could be as high as 290 rad over 4 months [2]. The accidental release of radionuclides contaminated large areas in Byelorus, the Ukraine and the Russian Federation (the Bryansk, Kaluga, Tula and other regions).

During this period the major contribution to the integrated radiation dose was made by radionuclides of zirconium, niobium, ruthenium, iodine, cesium, barium, lanthanum, cerium [4], with the short-lived radionuclides being the key dose-forming elements. Since the ^{131}I content on pasture grass on some farms of the Khoininsky district could reach 42%, dose burdens to the thyroid in the acute period ranged up to 60-80 krad.

The measurements of the intensity of gamma-radiation on the neck surface close to the thyroid in cattle evacuated from the 30-km ChNPP zone (v.Orevichi, v.Chamkov, v.Ulasy) showed that in some animals the dose rate was as high as 750 mR/h with average values of 350±45 mR/h, and decreased by a factor of 2-3 during a week.

Because of radionuclides of alkaline - earths the irradiation of the GIT mucosa amounted to about 1 krad. The highest intensity of gamma-radiation from the GIT contents was reported on the body surface in the metasternum region. It averaged 125±33 mR/h and decreased 1/10 -1/12 times during a week.

A similar pattern was observed in sheep for the relationship between the intensity of gamma-radiation from the thyroid and the metasternum region with absolute values close to those for cattle. In horses, the relationship between these values was within narrower limits due to reduced intensity in the thyroid region and increased intensity in the metasternum area. In newborn calves under 3 days, the intensity of radiation from the thyroid was half that from the thyroid of their mothers.

So, the health of farm animals could, to a large extent, be impaired by internal uptake of radionuclides rather than by external irradiation.

The reported information indicates that among the incorporated radionuclides radioiodine might be of the greatest importance for the physiological state of animals.

The specific nature of radioactive fallout from the Chernobyl NPP has defined the character and the extent to which farm animals were affected, the revealing and assessing of which were ambiguous over a long period of time. One, however, should bear in mind limited cohorts of cattle stock.

In the Chernobyl affected area in the first 10-day period of May 1986 in a small portion of animals at the above doses of gamma- and beta-radiation the clinical symptoms included swollen submaxillary space in both young and adult animals, bloodstained diarrhea in calves, reduced number of leukocytes (up to lower normal ranges) in the peripheral blood in adult stock. No lethal out comes induced by radiation were reported.

Most of the cattle evacuated from the 30-km ChNPP zone did not differ from the clinically healthy animals. The examination of the physiological state of cattle, horses and sheep in December 1986 through March 1987 didn't signal any health hazards. Clinical examinations of cattle identified isolated short-lasting cases of deviation of the body temperature, pulse rate and respiration. No deviations from the physiological norm were revealed in horses. In sheep, the early studies reported symptoms of respiratory disease (cough, rale, harsh breathing, inspiratory dyspnea) in 38.7% of animals, in some animals dictyokayues was diagnosed. By the end of the studies 11.2% of sheep still showed some symptoms of respiratory disease.

Quantitative changes in the formed elements and other hematological parameters were insignificant in individual animals. The number of leukocytes in all species varied within the physiological norm. The differential blood count showed some increase in juvenile neutrophils; 1% of cases revealed lymphocytes alterations manifested as the occurrence of binuclear forms, as well as fragmentary neutrophyls. No significant deviations were noted in them out and concentration of hemoglobin.

Some functional changes were registered in the level of thyroid hormones in cattle which turned to normal level by the end of the study. In horses the physiological state of the thyroid remained within the norm.

The immediate consequences of the radiation exposure after the Chernobyl accident in values of the immune status were less pronounced, which correlated well with the dose burdens. These were always sublethal and did not exceed 50-60 rad to the whole body of cattle. The indices of the betalytic, bactericidal and lysozymic activities in these animals did not differ from those in intact cattle and only the titer of normal antibodies was 1.5-2 times higher. The value of the immunomicrobiological test in these cows was increased 1.4-1.9 times.

The consequences of radiotoxic effect of ^{131}I in individual cattle herds and sheep flocks became evident in 1987-1988. These appeared in the form of hypo- and athyreosis with signs of myxedema and thyrotoxicosis. Animals developed folded and callous skin, the hair became dishevelled.

The examination of cows within the 30-km ChNPP zone subjected to chronic, thyrotoxic action of radioiodine over two months has demonstrated that beta-irradiation of the thyroid tissue resulted in injuries of different severity [3]. The local dose burdens of 30-40 krad or more to the thyroid led to the arrest of the excretory function of the follicles and athyreosis accompanied by relevant clinical symptoms in cows. Dose burdens of 10-12 krad caused a partial loss of the thyroid functional activity and hypothyreosis. Thyroids exposed to a cumulative dose of 2-3 krad in clinically healthy cows outside the abandoned zone did not differ from that in intact animals.

Post mortem examinations reported pulmonary congestive plethora and pronounced edema of subcutaneous fat in cattle with the most severely affected thyroid. The thyroid weight in these animals was considerably reduced (up to 6.5±0.6 g), only 26.0% of the control weight (25.0 g), i.e. the reduction factor was 3.8.

Macroscopically, the thyroid lobes in the affected cattle were significantly smaller in volume, thinned and indurated. In incision, the tissue was penetrated by whitish firm veins - bands with poor patches between these of loci of greyish-pink semitransparent parenchyma tissue.

Since the functional activity of the radiation affected thyroid requires a long time to recover, animals with hypo- and especially athyreosis need to be removed from agroindustrial production. These cannot be used for reproduction either. It is advisable to use these animals for meat because in lactating cows both milkyields and lactation time are reduced. Labour in these cattle is often complicated by the prolapse of the uterus and rectum [4].

Biochemical tests of blood plasma in horses and sheep revealed rather high amounts of uric acid (4-fold) and slightly increased createnine concentrations in sheep, whereas in horses this parameter was somewhat lower.

The cholesterol content in the blood of cows was within or above the upper limit.

In horses, the cholesterol concentration was higher than in animals from the Kaluga region.

A more stable increase in the cholesterol concentration was found in the blood of sheep.

The changes revealed were reversible in nature and when animals were fed "clean" feed they returned to normal, except for the cholesterol content.

The farm animals that were kept for a long time on less contaminated territories of the Bryansk and Kaluga regions have demonstrated insignificant variations in the biochemical values [5].

A comparative assessment of the molecular-cellular indicators in sheep, cattle and horses that were kept for a long time in the contaminated area did not reveal considerable changes in the overall protein content in cells of white blood and platelets.

The photometric index of the thrombocytic-lymphocytic mixture was reduced by 40% in horses and by 25% in sheep, whereas this index in exposed cattle did not differ from the index control cattle. Slightly reduced in all animals was the value of the thrombocytic osmotic reaction.

A variation in the stimulation rate of adenylate cyclase in platelets of animals with signs of affected thyroid have been identified [6].

Simultaneously the modification of the erythrocytic membrane permeability for Ca^{2+} was revealed in the absence of changes in hematological parameters [7].

It is well known that exposure to lethal or sublethal radiation doses inhibits the natural resistance of the body of animals which in turn can result in enhanced sensitivity to exogenous infection. In this case of particular threat will be both conventionally pathogenic microflora and causative agents of asymptomatic infections, including in particular leptospirosis, which can at lowered resistance induce clinically pronounced forms of disease.

The estimation of the humoral and cellular factors of natural resistance has shown that 7 months after the accident no inhibition of the blood bactericidal properties was observed in relation to intestinal bacteria (Salmonella and Bacillus coli), as well as no decrease in betalytic and lysozymic blood indices in sheep, horses and cattle compared to the control.

Similar data were obtained during the last 5-year period of observation of animals kept in contaminated areas.

Bactericidal and betalytic characteristics of blood in examined animals were within the physiological norm; no variations in blast-cell transformation of leukocytes were revealed.

Bacteriological tests have shown that the level of upper respiratory tract dissemination in non-calving young cows did not differ from the average values for healthy animals. Similar results were found for the GIT autoflora. Thus, microflora of non-calving young cows and horses in both quantitative and qualitative terms did not show pronounced deviations, whereas in sheep the relationship between different groups of microorganisms was susceptible to dysbacteriosis. The improvement of the feeding and keeping of the animals returned the microbial pattern to normal.

So, the indicators of natural resistance of the body were within the physiological norm. Changes in these indicators are usually connected with the conditions for feeding and keeping of animals, as well as other factors of non-radiation nature. The analysis of the veterinary data on noncontagious diseases in cattle of the Vetkovsky and Braginsky districts of the Gomel region (1988) has demonstrated that the sickness rate in young cattle amounted to 80% in the Vetkovsky and 70% in the Braginsky districts, of which more than a half were gastro-intestinal disturbances, others were respiratory diseases. A similar structure of diseases is usually observed on "clean" territories. However, the death rate of sick animals was relatively low (6.4-14.9%).

In studies into the epizootic situation for liptospirosis in the Kaluga and Bryansk regions it has been found that areas contaminated by radionuclides are not different from "clean" areas in the number of positive reactions of animals to liptospirosis. For instance, farms in the Novozybkovsky, Krasnogorsky and Gordeyevsky districts of the Bryansk region reported a decrease from 37 to 7% for the period 1985-1990 in the number of positive reactions. At the same time in Pogarsky "clean" district the number of animals with a positive reaction amounted to 24-82% of the number of animals examined. The same picture was observed in the Kaluga region. In the Ulyanovsky and Zhizdrinsky districts, in areas with the contamination density from 5 to 15 Ci/km^2 ^{137}Cs the number of positively reacting animals decreased, whereas in the Dzerzhinsky, Lyudinovsky and Zhukovsky districts this value increased from 27 to 78%.

Consequently, in both early and long times after the accident, the animals kept in the contaminated areas did not show a significant inhibition of factors of natural resistance of the body. The bactericidal, lysozymic and betalytic blood activities were within the norm. No decrease in the blast-cell transformation of leukocytes, no drop in the level of normal antibodies or dysbacteriosis were reported. There were no reports of deteriorating epizootic situation regarding visceral and contagious diseases or liptospirosis exacerbation. The effectiveness of veterinary-prophylactic measures was adequate.

In recent years the health of farm animals in terms of chemical and laboratory values remains at the level of the long-term averages. But there were some variations towards deterioration and subsequent improvement. At the same time, the drop in milk yields and calf crop in 1990 on some farms might be related to some or other extent to the rejuvenation of productive stock born in 1986, i.e. the year of intensive radiation effect on the body of cows and newborn calves. Nonbalanced mineral exchange, periodic growth of gynecologic diseases can impair the physiological state of animals in terms of hematological, biochemical, immunological and other indicators. An increase in the number of animals with positive response (Ridu) to leukosis was observed. The integration and analysis of the generated data suggest that radiation exposure on farms with the contamination levels of 30 to 40 Ci/km^2 has not gone without leaving a trace. Most probably, these are the results of the distant consequences of the radiation factor superimposed by other factors of zooveterenary character. It is not improbable that contamination levels such as 370-740 kBq/m^2 (10-20 Ci/km^2) affect the animal health. It is, however, even more difficult to isolate the effect of the radiation factor in these events.

The analysis of the long-term data suggests that radiation exposure on local territories with the contamination levels of about 1480 kBq/m^2 (40 Ci/km^2) superimposed by additional environmental factors does sometimes have impact on the health of animals. Identification of such cases presents a real challenge. Therefore, a promising and urgent task is to develop methodological approaches to a comprehensive assessment of the state of animal health in situations of combined technogenous effects.

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