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Investigation of the food safety of lamb meat obtained in ecologically unfavorable territories

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Introduction: This article presents data on the ecological situation of agricultural territories where small cattle are raised, focusing on the exposure dose rate, radon concentration in residential and social buildings, and the density of alpha and beta particle flux. The study also examines the levels of heavy metals (Pb, Cd, As, Hg) and radionuclides Cs-137 and Sr-90 in raw meat from ecologically unfavorable areas, as well as the effects of heat treatment on reducing the content of these harmful substances.

Methods: The research involved analyzing raw meat samples from the Abai district near the former Semipalatinsk Nuclear Test Site in Semey, Kazakhstan. The levels of heavy metals and radionuclides were measured before and after heat treatment to assess the effectiveness of cooking in reducing these contaminants. Radioecological measurements were also conducted in residential and social buildings to evaluate radon concentration and alpha and beta particle flux.

Results and discussion: The results of the study showed a significant decrease in the levels of lead, cadmium, arsenic, Cs-137, and Sr-90 in meat after heat treatment. Prolonged cooking or quenching led to the most significant reductions in toxicity and radionuclides. These findings suggest that heat treatment can be an effective method for reducing the levels of harmful substances in meat from ecologically compromised areas. Further research is needed to explore other potential strategies for mitigating the impact of environmental contamination on food safety in agricultural regions.

KEYWORDS

meat raw materials, ecology, radionuclides, heavy metals, heat treatment

1 Introduction

Kazakhstan is characterized by the presence of a high potential for agriculture, but at the same time is subject to intense man-made impacts on the environment. Intensive processes of industrial development, energy, and agricultural chemicalization are associated with the entry into the external environment of numerous xenobiotics, which enter the human body through the biogeochemical chain through food products.

It is well known that up to 70% of pollutants enter the human body with food. The main danger to the human body is the content of xenobiotics in the chemical environment in food products. These include heavy metals, pesticides, radioactive isotopes, nitrates, nitrites, etc. Among these pollutants, according to the Food and Agriculture Organization and the World Health Organization, radioactive elements and heavy metals have a pronounced carcinogenic and mutagenic effect and occupy the first place in the list of priority chemicals that are dangerous to the environment and human health.

To date, for an objective ecological assessment of the state of the territory and the degree of its transformation as a result of technogenesis, it is necessary to study the chemical composition of various natural environments, including the elemental composition of the biosubstrates of farm animals (including meat and milk), as the main human food products – one of the most important links in the human – environment chain (Rihvanov, 2009).

Food products have the ability to accumulate harmful substances from the environment and concentrate them in large quantities, therefore 20–40% of pollutants with water and 40–50% with food enter the human body from the environment.

Among the classified groups of food pollutants, there is a list of elements that are now definitely considered potentially dangerous to humans, even in trace amounts. This list, which includes Al, Cr, Fe, Co, Ni, Zn, As, Se, Mo, Cd, Sn, Sb, Hg, and Pb, contains a large number of chemical elements that circulate in the biosphere and affect it (Rihvanov, 2009).

A person with food products constantly receives one or another set of chemical elements contained in them. Some of them are a natural structural component of a product, and the other is introduced from the outside, most often as anthropogenic pollution from the environment. More than 1.3 billion tons of food are consumed and discarded in the world every year, which is one third of all products produced (Kabata-Pendias and Pendias, 1989; Sejsembaev and Smagulov, 1997; Amirbekov et al., 2013). One of the urgent tasks of the meat industry is the rational use of raw materials, the expansion of the range of meat products that meet the quality and safety requirements for a healthy diet of the population (Postanovlenie Pravitel'stva, 2005; Balmukhanov et al., 2006). The sociotechnological development of the meat industry pursues two main goals. First, meat industry enterprises and research institutes must satisfy consumer needs. Second, they should develop and produce high-quality functional products that are environmentally safe and beneficial to human health from a biomedical point of view (Henshall et al., 2014).

The group of fairly common and potentially dangerous elements for humans includes the following. V, Cr, Mn, Co, Ni, Cu, Mo, Cd, Sn, Sb, Hg, Pb, and only Cd, Sn, Hg, and Pb are considered definitely dangerous of them. It is this spectrum of elements that accumulates in the ash residue of the body of a person. Moreover, this is confirmed even by the results of rationing of such indicators as the clark of the noosphere, biosphere, and brown coal ash. In addition, food products of animal origin accumulate in themselves through water and vegetable food. The contamination of food products is caused by the direct deposition of aerosols in vegetation, which then enter the body of animals. Over time, they accumulate in organs and tissues and can also be released with metabolic products and milk. This makes it necessary to study the concentrations of heavy metals in feed and water used by animals, as well as in meat and slaughter products of cattle of different genotypes in farms located in different ecological zones.

Of the total amount of heavy metals that enter the human body with food, approximately 1/3 falls on plant food and 2/3 on animal food. Animal food products accumulate heavy metal salts (Antal and Csedo, 2004).

The information given makes it possible to develop recommendations to reduce toxic elements in food products during their manufacture, depending on technological techniques and processing modes (temperature, time). The content of macro and microelements in meat raw materials depends on various factors, in particular the conditions of production of agricultural products and other measures related to human impact on the environment, as well as the technological processing of food products.

In recent years, the issue of food safety has been particularly relevant (Kawano et al., 2008). After all, a healthy diet has not only medical importance as a factor in preserving health, its subsequent development, but also social importance as a factor determining the health of future generations.

Among the main factors that determine the competitiveness of food products in the modern world, its quality and safety are becoming increasingly important. These indicators are becoming increasingly significant, leaving behind criteria such as the price of a product and the area of its traditional consumption. The health of the population, its labor activity and, ultimately, the pace of economic development of the country depend on the quality of food (Mihajlov, 1987).

The great damage to the environment was caused by nuclear tests in the former nuclear power plant, as a result of which large areas were contaminated with radionuclides. Studies of the radiation situation at the landfill showed that the effects of secondary pollution began to manifest themselves in some areas. These include migration of radionuclides by groundwater, removal of radioactivity to the Earth's surface by thawed and stormwater, wind transport, and migration of radionuclides along the food chain. These phenomena are of extreme concern, since access to the territory of the nuclear power plant is currently open and some settlement of the landfill has already begun. On the territory of the landfill, industrial coal mining, table salt are carried out, cattle grazing and forage harvesting is carried out (Kabata-Pendias and Pendias, 1989).

This activity, in the first place, contributes to the transfer of radioactive contamination within and outside the landfill; in the second place, it is associated with an additional risk for the producers of works, for the population of the region as a whole, and for the consumers of products (Sejsembaev and Smagulov, 1997).

The intake of radionuclides into the body of farm animals and the products obtained from them should be evaluated in relation to their source of nutrition, as well as comprehensively with the study of the radioecological situation in the territories where cattle grazing and hay harvesting are carried out. The main source of radioactive and stable nuclides entering the animal body is feed, water, and air. Radioactive substances negatively affect the organoleptic and biochemical parameters of meat and meat products. All this leads to a decrease in the biological and nutritional value of meat obtained from animals, and the consumption of such products causes various diseases of people (Amirbekov et al., 2013).

During the period of operation of the test site (1949–1989), 465 nuclear explosions were carried out on this territory, including: 125 atmospheric (26 ground, 91 air, 8 high-altitude); 343 nuclear test explosions underground. There are no analogs in the world of radiation situations that have formed in the territories of Kazakhstan adjacent to the Semipalatinsk Nuclear Test Site (SNTS). However, people live in these territories and there is grazing of farm animals, forage harvesting is carried out (Kovda and Rozanov, 2013).

Therefore, the environmental and food safety of the population living in the territories adjacent to the nuclear power plant is directly related to the radiation situation on the territory of the former landfill. The nuclear weapons tests conducted for 40 years at the SNTS caused irreparable damage to human health and the environment, caused an increase in the general morbidity and mortality of the population. The long-term consequences of nuclear tests, which are transmitted from generation to generation, are increasingly detrimental.

Currently, approximately 40% of the landfill territory has been surveyed with a reliability of 25% for an area survey and 90% for a local (local) survey. Due to limited funding, area surveys are conducted on a small-scale grid. Only when areas with an increased radiation background are detected, a local survey is carried out using a large-scale grid. A comprehensive radiological assessment of them has not yet been carried out, although since the early 1990s a number of international organizations, including the International Atomic Energy Agency (IAEA), have been assessing landfills and adjacent territories. The boundaries of the polygon have not yet been fully identified and approved. The investigated area is insignificant compared to the entire SNTS territory (Balmukhanov et al., 2006).

An important problem of SNTS is also soil contamination with radionuclides, which in turn can cause contamination of water sources and animal products, and then in food (Dyusembaev et al., 2014). To date, on the territory of the SNTS, the main polluting radionuclides are Sr. and Cs, which have the longest half-life (28.5 and 30 years, respectively) among other quantitatively predominant fission products. Radioactive substances deposited on the surface of the soil can move horizontally or vertically under the influence of various processes.

Food products of plant and animal origin are the final link in the biological chain through which chemical elements, including radioactive substances, can enter directly into the human body. Therefore, determining the content of chemical elements in food and determining the degree of contamination by radioactive substances in food consumed by residents of settlements located in the zone of influence of nuclear tests is a condition necessary to complete characterization of the radiation hygienic situation in these territories (Antal and Csedo, 2004).

One of the urgent tasks of the meat industry is the rational use of raw materials, the expansion of the range of meat products that meet the quality and safety requirements for a healthy diet of the population (Gustavsson et al., 2011; Boliko, 2019). More than 1.3 billion tons of food are consumed and thrown away in the world every year, which is one third of all products produced (Oraz et al., 2019; Senanayake et al., 2021; Toldra et al., 2021).

The sociotechnological development of the meat industry pursues two main goals. First, meat industry enterprises and research institutes must satisfy consumer needs. Secondly, they should develop and produce high-quality functional products that are environmentally safe and beneficial to human health from a biomedical point of view (Uzakov et al., 2020).

The main task of the safety and quality of meat products is to identify possible inconsistencies and prevent their occurrence at all stages of production. An important method of solving this problem is the analysis of the types and consequences of potential inconsistencies (analysis of failure modes and effects – FMEA) (Alruqi et al., 2021). The FMEA methodology allows one to assess the risks and possible damage caused by potential design and technological process inconsistencies at the earliest stage of design and creation of the finished product (Teng et al., 2006; Segismundo and Miguel, 2008; Lipol and Haq, 2011; Goo et al., 2019).

The method covers all stages of product production. FMEA is a set of systematic actions carried out in order to:

- identify and quantify non-conformities in products and processes, as well as the consequences of these nonconformities;
- compile a differentiated list of types and causes of nonconformities for planning corrective and preventive actions;
- identify corrective and preventive actions that can eliminate or reduce the likelihood of nonconformities;
- document data based on the results of the analysis (Kmenta and Ishii, 2004; Xiao et al., 2011; Soufhwee et al., 2013).

The purpose of this study is to determine the food safety of meat and the features of the accumulation of heavy metals in the meat raw materials of small cattle; monitoring of the territories affected by the activities of the SNTS, where the grazing of agricultural animals is carried out; analysis of the possibility of reducing the concentrations of heavy metal salts and radionuclides in meat using certain types of heat treatment.

2 Materials and methods

Based on retrospective data, the territories included in our investigation are characterized as unfavorable on the environment and belong to the territories with the highest radiation risk due to radioactive fallout during atomic weapons tests (Dyusembaev and Iminova, 2012).

To perform radiometric control in the territories studied, instruments and measuring devices were used, which are annually verified by state. The dose rate of gamma radiation, beta particle flux density, and alpha particle flux density were determined according to the current GOST 26305-84, 26306-84, 26307-84. The equivalent equilibrium volumetric activity of radon and thoron (EEVA) was also measured in open areas and in the air of residential buildings of the studied territories.

Studies of the radioecological situation of the territory, as well as sampling of meat, were carried out on the territory of the Abai district, near the Atomic Lake, on the wintering grounds of Bekejan1, Bekejan2, Sarapan, Shynyrau, Berezka, Ilyich's Testaments, Zharyk, Usen and Obaly nearby.

As the object of the study, sheep meat, a Kazakh short-tailed coarse wool breed, was chosen, grown in pastures of the Abai district near the Atomic Lake. All selected samples have passed the appropriate sample preparation procedure. The sampling and preparation of the meat sample for further instrumental analysis were carried out according to the approved guidelines for carrying out these procedures. The meat sampling for the study was carried out in a complex with the study of the radioecological situation, synchronously in time.

As containers and packaging for samples of products obtained from animals with radiation damage, it is recommended to use polyethylene products that absorb less radioactive substances. Before placing the samples in the container, the inner surface of them must be rinsed, wiped with a gauze swab moistened with a 2 N solution of nitric or hydrochloric acid. This reduces the sorption of isotopes by walls and eliminates extraneous activity (ST RK 1623-2007 Radiacionnyj kontrol, 2007).

Studies of organoleptic and physicochemical parameters of meat of small cattle raised in territories exposed to radiation, as well as microbiological analysis and analysis for the content of antibiotics, pesticides were carried out on the basis of the Testing Laboratory Abai regional branch of the RSE on PCV "Republican Veterinary Laboratory" of the Committee for Veterinary Control and Supervision of the Ministry of Agriculture of the Republic of Kazakhstan." Studies were also conducted there to determine heavy metals and radionuclides in meat raw materials.

Organoleptic research methods provide for the determination of: appearance and color; consistency; odor; condition of fat; condition of tendons. Each selected sample from the wintering is analyzed separately. The appearance and color of the carcass are determined by external examination. The type and color of the muscles on the cut are determined in the deep layers of muscle tissue on a fresh cut of meat. In this case, the presence of stickiness is established by feeling and moistening the surface of the meat on the cut by applying a piece of filter paper to the cut. Determining consistency in a fresh cut of the carcass or test sample, a slight pressure of the finger forms a hole and monitors its alignment. Organoleptically, the determination of odor establishes the odor of the surface layer of the test sample. Then an incision is made with a clean knife and the smell is immediately detected in the deep layers. Determination of the state of fat The state of fat is determined in the carcass at the time of sampling, the color, smell and consistency of fat are determined. Determination of the tendons' condition The tendons' condition is determined in the carcass at the time of sampling. When the tendons are felt, their elasticity, density, and condition of the articular surfaces are established. To determine the transparency and flavor of the broth, you need to prepare for the tests. To obtain a homogeneous sample, each sample is separately passed through a meat grinder with a grate hole diameter of 2 mm, and the minced meat is thoroughly mixed. Twenty gram of the resulting minced meat is weighed on laboratory scales with an error of no more than 0.2 g and placed in a conical flask with a capacity of 100 cm^3, 60 cm^3 of distilled water is poured, thoroughly mixed, covered with a watch glass and put in a boiling water bath. During the tests, the smell of meat broth is determined during heating to 80–85°C at the time of the appearance of vapors coming from the slightly open flask. To determine the transparency of 20 cm^3 of broth, pour it into a measuring cylinder with a capacity of 25 cm^3, having a diameter of 20 mm, and set the degree of its transparency visually. A quantitative potentiometric method based on the measurement of electromotive force was used to determine the pH level in the meat. The pH value is measured using laboratory pH meters and portable express meters. The laboratory pH meter consists of a reference electrode with a known potential value and an indicator (glass) electrode, the potential of which is determined by the concentration of hydrogen in the test solution. The pH value is measured by dipping two electrodes in the test solution and setting the pH value on the scale of the device. When using a portable pH meter, the electrodes are inserted into muscle tissue to a depth of 2–3 cm, excluding contact with adipose tissue (ST RK 1731-2007 Meat and meat products, 2007).

During the analysis for the presence of antibiotics of microorganisms and bacteria, including pathogenic ones, in the meat raw materials studied, a microbiological method was used. Microbiological methods include smear bacterioscopy, quantitative accounting of microbes in terms of 1 g of meat, conducting a reductase test, determining the activity of the catalase enzyme produced by microorganisms. To perform the test, the surface of the muscles studied is sterilized with a red hot spatula or burned with a swab soaked in alcohol, pieces 2.0 × 1.5 × 2.5 cm are cut with sterile scissors, and the surfaces of the slices are applied to a slide (three prints on two slides). The preparations are air-dried, fixed, stained, and microscoped (GOST 23392-2016 Meat, 2016).

According to the requirements for the analysis of meat quality, the most relevant studies are to determine the following heavy metal ions, Pb, Hg, Cd, and As.

The content of toxic metals (Pb, Cd, As, Hg) was determined by the inversion voltammetric method on the TA 07 "Talap" voltammetric analyzer for toxic elements. The inversion voltammetric method refers to electrochemical methods of analysis. The electrochemical method is based on electrolysis, a chemical reaction that occurs under the influence of an electric current on electrodes placed in an electrolyte solution (Gorbunov et al., 2003; GOST 31628-2012 Food products and food raw materials, 2012; GOST 33426-2015 Meat and meat products, 2015).

The inversion method of analysis is based on the preliminary electrochemical accumulation (concentration) of the detectable component on the electrode and subsequent dissolution of the resulting concentrate within a short period of time by a current of positive polarity.

In inversion voltammetry, during the measurement stage, a voltammogram is recorded, i.e., a current measurement depending on the potential of the electrode. In the presence of metal ions, current peaks appear on the voltammogram, which show the quantitative content of the elements.

Analyses were also carried out for the content of toxic metals and radionuclides in the raw materials of the meat, but after heat treatment in the form of cooking in water for 2.5 h, frying at high temperature, prolonged stewing without adding water for 2.5 h at a temperature of 90–95°C.

Nine wintering grounds (farms) were selected for the study, 5 exposure dose rate measurements were carried out at each wintering to determine the average value, as well as the selection of sheep meat for analysis.

3 Results and discussion

The safety of meat depends on various factors, in particular on the conditions of production of agricultural products and an environmentally friendly environment, as well as the technological processing of food products. Therefore, the quality and safety of meat is directly dependent on the condition of the territories on which cattle were grazed. Meat samples were taken at the same points where environmental measurements were carried out and samples of environmental components were taken (Antipova and Soskova, 2000).

According to the results of the study of the gamma radiation dose rate, the minimum value of exposure dose rate (EDR) of 0.15 mSv/h was registered at the addresses of Shynyrau Winter Quarters, the maximum is the Sarapan Winter Quarters, where the EDR is at the level of 0.26 mSv/h, which exceeds the level of the safe value of the EDR for the human body (up to 0.2 mSv/h), but does not exceed the permissible limit dose rate (0.5 mSv/h). The range of values ranges from 0.15 mSv/h to 0.26 mSv/h, the average value is 0.18 mSv/h.

Thus, the values of the EDR of gamma radiation in the wintering grounds of the Abai district, near the Atomic Lake, do not exceed the standard values, only in the territory of the Sarapan wintering area, the level of the EDR exceeds the "normal radiation background" by 0.6 mSv/h.

According to the hygienic standard approved by the decree of the Government of the Republic of Kazakhstan, in operating buildings, the average annual equivalent equilibrium volume activity of the daughter products of radon and thoron in the air of residential premises should not exceed 200 Bq/mL.

The maximum values of radon EEVA recorded in residential premises are 150 Bq/mL (Bekejan2), which corresponds to the norm. The spread of radon EEVA values in residential premises ranges from 9 Bq/mL to 150 Bq/mL, the mean value is 46.42 Bq/mL.

The volume and results of the studies of the density of the flow of alpha and beta particles in the open air in the studied areas are shown in Table 1.

As can be seen from the graph, the levels of alpha and beta radiation are relatively uniform, with rare minor deviations from the average value.

Therefore, as a result of the evaluation of the radiation indicators of the current ecological situation in the territories of the Abai district wintering grounds (which included: EDR, radon EEVA, alpha and beta particle flux density), it was found that the radioecological situation is within the established standards.

Therefore, the quality and safety of meat is directly dependent on the condition of the territories on which cattle were grazed. Meat samples were taken at the same points where environmental measurements were carried out and samples of environmental components were taken.

The safety of meat depends on various factors, in particular on the conditions of production of agricultural products and an environmentally friendly environment, as well as the technological processing of food products.

Organoleptic, physicochemical parameters, small-bred meat in areas exposed to radiation, microbiological analysis, as well as analysis for the content of antibiotics, pesticides were studied (see Table 2).

Organoleptic, physicochemical parameters, meat of small cattle raised in areas exposed to radiation, microbiological analysis, as well as analysis for the content of antibiotics and pesticides were studied. According to the results of the study, the meat is fresh, the organoleptic parameters correspond to this type of meat, the color is red, the consistency is dense, elastic, the pit formation is quickly leveled when pressed. The smell is specific to this type of meat, fresh and of good quality. The fat does not have a smell of burning or rancidity. One of the parameters that changes its value and the control that can be used to judge the quality of meat is the pH parameter. The conducted study of the pH level showed a value of 5.7. The pH value of fresh meat is in the range of 5.6.0.6.2 and is designated as normal. The presence of antibiotics, microorganisms and bacteria, including pathogenic ones, was not detected in the meat samples.

The studies were carried out on the basis of the testing laboratory of the Semey regional branch of the RSE at the Republican Regional Laboratory of the Committee for Veterinary Control and Supervision of the Ministry of Agriculture of the Republic of Kazakhstan. The laboratory is accredited by the National Accreditation Center LLP.

The content of such chemical elements as copper, zinc, molybdenum, and vanadium was determined in the laboratory of the Research Institute of Radiation Medicine and Ecology of the Semey Medical University. The studies were carried out by inductively coupled plasma mass spectrometry at a high-resolution THERMO installation, which made it possible to eliminate interference by using medium-and high-resolution, the sensitivity of which is sufficient to determine the small contents of most elements in the samples, almost at the threshold of determination. The completeness of the opening of the samples was provided by the installation of the MARS-6 autoclave, the same company. The results obtained from the study of the meat of sheep of the Kazakh short-tailed coarse-wool breed, grown in territories exposed to prolonged radiation exposure, for the content of toxic elements in the meat are presented in Table 3.

The maximum value of lead Pb in the Abai district is 0.457 mg/kg, observed during the winter of the Obala, which does not exceed the standard values for the lead content in meat products. The minimum content is 0.143 mg/kg at the frying point. The average value is 0.286 mg/kg, which does not exceed the standard values for the lead content in meat of 0.5 mg/kg.

The Cd content in the meat samples studied in the wintering grounds does not exceed the normatively established values, and the maximum value was recorded in the sample from the wintering of the Obala and is 0.0341 mg/kg, the minimum at the point of Bekejan1 and is 0.0243 mg/kg, the average value for the area is 0.03 mg/kg with a normative value of not more than 0.05 mg/kg.

The minimum value of arsenic is 0.0535 mg/kg, recorded in a sample from the Usen wintering, the average value for the region is 0.0662 mg/kg, the maximum value is observed at the Birch wintering and is 0.0755 mg/kg, which is lower than the normatively established values of no more than 0.1 mg/kg.

The minimum value of the Hg content in the meat samples studied is 0.0015 mg/kg, the sample from the Sarapan wintering, the average value for the region is 0.0129 mg/kg, and the maximum value is observed in the meat sample from the Usen point and is 0.021 mg/kg, which does not exceed the standard values for the content of Hg in meat products.

TABLE 1 Volume and results of measurements of alpha and beta particle flux density in the environment.

No.	Open air	Spread of values	Average value
1	Alpha particle flux density	(Particles/min*cm^2)	(Particles/min*cm^2)
2	Beta particle flux density	2–27	11.5

TABLE 2 The results of studies of the meat of small cattle grown in the Abai district.

No.	Name of the study	Regulatory document	Results
1	Appearance and color of the carcass surface	GOST 7269-2015	Slightly moist, do not leave a wet spot on the filter paper. The color is red, corresponds to this type of meat
2	Muscles on the incision		
3	Consistency		Dense, elastic. The forming fossa is quickly leveled when pressed.
4	Smell		Specific, characteristic for this type of meat, fresh and good-quality
5	Fat condition		Fat has no smell of salting or rancidity, white color, dense consistency
6	Condition of tendons		No tendons
7	Transparency and smell of broth		Transparent with a pronounced smell of fresh and good-quality meat
8	Freshness	GOST 7269-2015, GOST 23392-2016	Fresh
9	pH	GOST R 51478-99	5.7
10	Pesticides (mg/kg, hexachlorocyclohexane), (α,β,γ isomers), DDT and its metabolites	MU 2142-80	Not detected
11	Quantity of Mesophilic Aerobic and Facultative Anaerobic Microorganisms, CFU, no more	GOST 10444.15-94	$6.0*10^3$
12	Bacteria of the *E. coli* group (coliforms), 0.01 g.	GOST 31474-2012	Not detected
13	Pathogenic, including salmonella	GOST 31659-2012	Not detected
14	*L. monocytogenes*	GOST 32031-2012	Not detected
15	Antibiotics, tetracycline group	GOST 31903-2012	Not detected
16	Antibiotics, bacitracin	MU 3049-84	Not detected

TABLE 3 The content of toxic elements in meat samples of the Abai district, mg/kg.

		Pb	Cd	As	Hg	Cu	Zn
Normative values, no more than		0.5	0.05	0.1	0.03	5.0	2.0
Zimovki	Sample number						
Sarapan	0.0814	0.43	0.0324	0.0695	0.0015	2.34	10.4
Berezka	0.0815	0.256	0.0308	0.0755	0.017	3.48	15.2
Bekejan 2	0.0816	0.204	0.0247	0.0715	0.017	2.21	25.8
Shynyrau	0.0817	0.193	0.0283	0.062	0.0125	3.26	17.7
Zavet Ilyich	0.0818	0.356	0.0336	0.075	0.008	2.24	13.5
Bekejan 1	0.0819	0.384	0.0243	0.069	0.0058	3.71	8.9
Obaly	0.0820	0.457	0.0341	0.0585	0.018	1.23	11.1
Usen	0.0821	0.155	0.0285	0.0535	0.021	2.78	17.5
Zharyk	0.0822	0.143	0.0334	0.0615	0.016	1.69	28.6

Thus, SanPiN 2.3.2.1078-01 "Hygienic requirements for the safety and nutritional value of food products" abolished the norms of such toxic elements in meat as copper and zinc.

Figures 1–4 clearly show that in all the meat samples studied, the content of toxic elements Pb, Cd, As, and Hg are below the standard values.

Thus, in the meat raw materials of sheep of the Kazakh short-tailed coarse-wool breed, grown in territories exposed to prolonged radiation exposure, there are toxic elements such as lead, cadmium, arsenic, and mercury, but their content is lower than the normalized values.

A study of the radionuclide content in meat raw materials was conducted in the Abai district of the East Kazakhstan region; the results are presented in Table 4.

Therefore, during the investigation, the content of radionuclides in meat was revealed, whose content does not exceed the normatively established values.

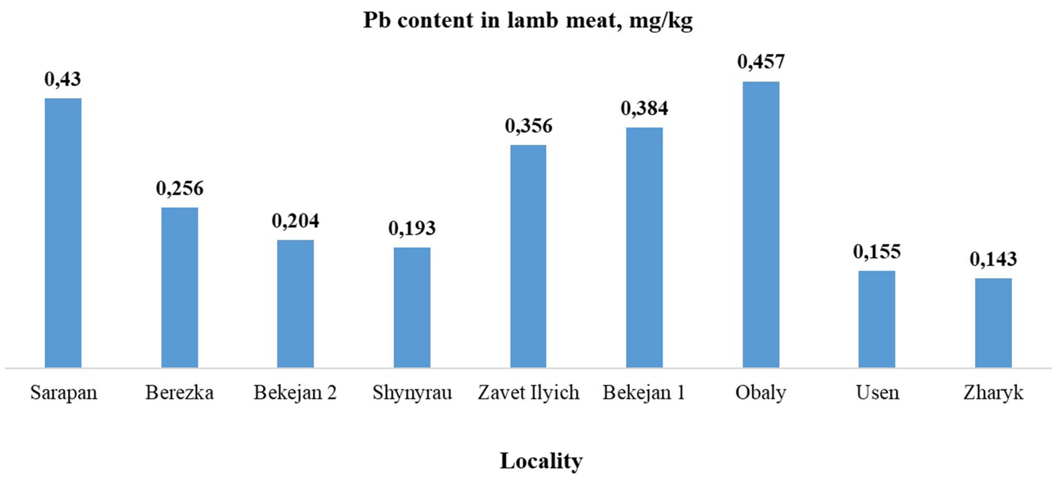

FIGURE 1
Pb content in lamb meat, mg/kg.

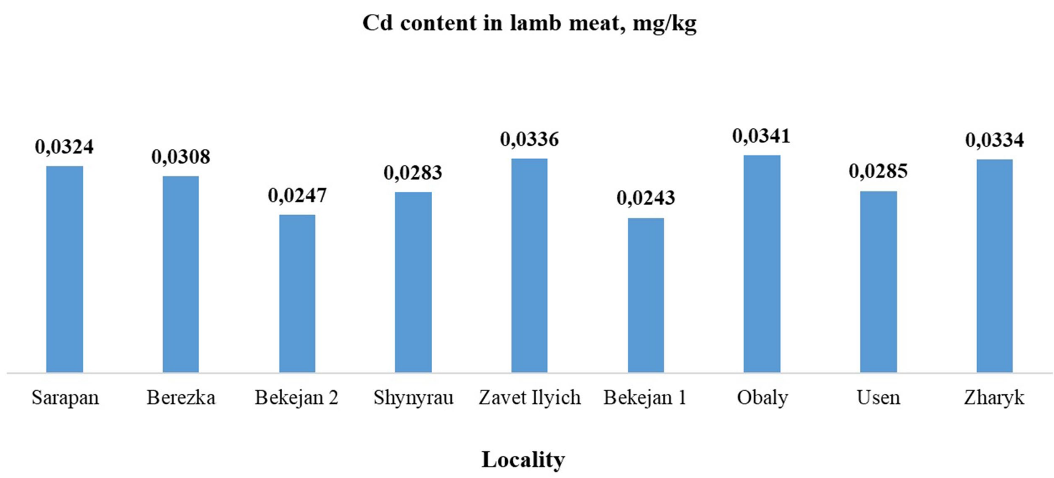

FIGURE 2
Cd content in lamb meat, mg/kg.

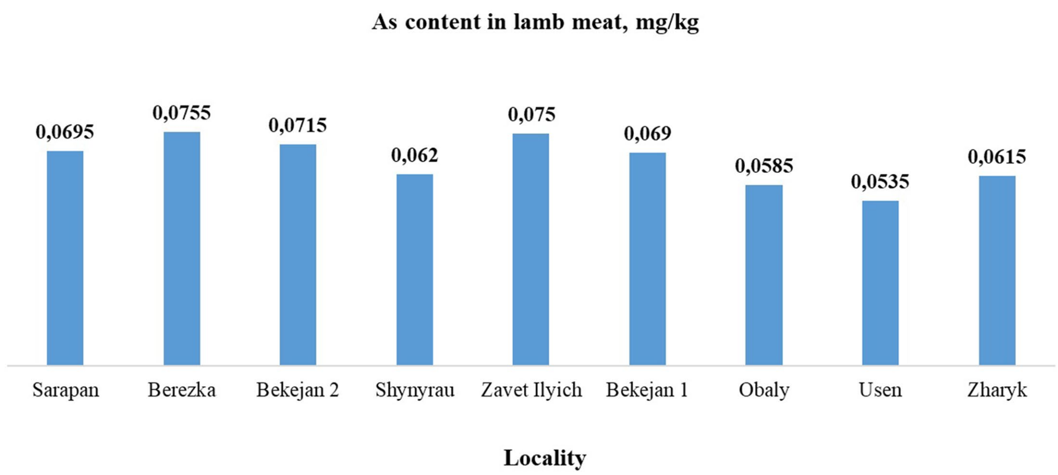

FIGURE 3
As content in lamb meat, mg/kg.

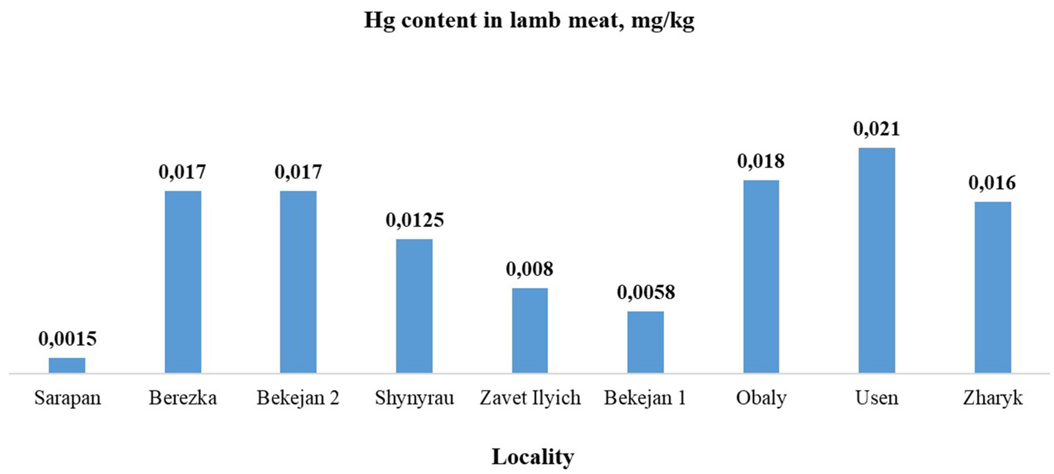

FIGURE 4
Hg content in lamb meat, mg/kg.

TABLE 4 Radionuclide content in meat raw materials of Abai district of East Kazakhstan region, Bq/kg.

Locality	Sample number	Radionuclide content in meat, Bq/kg	
		Cs-137	Sr-90
Normative values		200	50
The Precepts of Ilyich	0.0814	0	0
Birch	0.0815	0	0
Bekejan 2	0.0816	0	0
Shynyrau	0.0817	0	0.1852
Sarapan	0.0818	8.204	0
Bekejan 1	0.0819	2.726	0
Obaly	0.0820	3.116	0
Usen	0.0821	0.2107	0
Zharyk	0.0822	0	0
The average value for the district		3.564	0.02

TABLE 5 Changes in the content of heavy metals in meat raw materials during its processing.

Toxic element	Average value before treatment, mg/kg	Content after heat treatment, mg/kg		
		Cooking 2.5 h	Roasting (15 min)	Extinguishing (2.5 h)
Pb	0.29	0.12 ± 0.04	0.32 ± 0.09	0.18 ± 0.05
Cd	0.03	0.013 ± 0.004	0.021 ± 0.006	0.02 ± 0.006
As	0.066	0.054 ± 0.022	0.050 ± 0.020	0.035 ± 0.012

TABLE 6 Changes in the content of radionuclides in meat raw materials during its processing.

Radionuclide	Average value before treatment, mg/kg	Content after heat treatment, mg/kg		
		Cooking 1.5 h	Roasting (15 min)	Extinguishing (45 min)
Cs-137	3.564	1.075	1.343	1.488
Sr-90	0.02	0.012	0.084	0.014

The content of heavy metals and radionuclides in meat was also studied, but after heat treatment (cooking, stewing, and frying). The results are shown in Tables 5, 6, and on the basis of the conducted studies, it was found that as a result of heat treatment, the level of toxicity in the finished product decreases.

Earlier studies conducted by scientists Trakhtenberg and Korshun were devoted to the question of the effect of various types of heat treatment on reducing the level of toxicity in meat raw materials. In their work, it was found that when frying meat products, the heavy metal content decreases by about 25% or more, depending on the degree of meat grinding (Trahtenberg and Korshun, 1990).

4 Conclusion

1 As a result of the assessment of the radiation indicators of the current ecological situation in the territories of the Abai district wintering grounds (which included: EDR, radon EEVA, alpha and beta particle flux density), it was found that the radioecological situation is within the established norms.
2 Raw meat from sheep raised in areas exposed to prolonged radiation exposure contains toxic elements such as lead, cadmium, arsenic, and mercury, as well as radionuclides, but its content is below the normalized values.
3 The study of the content of heavy metals and radionuclides in meat, after heat treatment (cooking, stewing, and frying), showed a decrease in their content in the finished product.
4 The greatest decrease in the level of lead and cadmium in meat is observed during prolonged cooking in broth, the arsenic content in the meat decreased the most after a long process of stewing the meat.

In general, it can be concluded that by using various technological methods of processing biological raw materials, it is possible to ensure sufficient food safety of finished meat products.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

ZA: Conceptualization, Investigation, Methodology, Visualization, Writing – original draft, Software, Validation. KuA: Writing – review & editing, Conceptualization, Supervision. SG: Conceptualization, Writing – review & editing, Investigation. AM: Writing – review & editing, Methodology. YY: Writing – review & editing, Methodology, Supervision. SK: Writing – review & editing, Methodology. YB: Investigation, Writing – review & editing. AS: Methodology, Writing – review & editing, Validation. AL: Investigation, Visualization, Writing – original draft. KaA: Methodology, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

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