IRSTI 34.23.23

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Cytogenetic abnormalities in sheep kept in the territory of Almaty region contaminated with non-utilized and banned pesticides

Abstract. *On the territory of the Almaty region, there are warehouses with banned and non-utilized pesticides, the active substances, and metabolites of which pollute the pastures of farm animals located nearby. Blood samples of 27 sheep from three monitoring points of the Almaty region were analyzed for the presence of genomic mutations and chromosomal aberrations. Cell cultivation and preparation of slides were carried out by standard cytogenetic techniques.*
The frequency of occurrence of genomic mutations in the blood system of experimental groups of animals exceeded the same indicator in the control group by an average of 1.98 times, and chromosomal aberrations - by 4.1 times. The proportion of hypodiploid cells accounted for 70% of the total number of genomic mutations. Polyploidy accounted for up to 27.9%, and hyperdiploidy was found in single cells. The calculation of indicators of general cytogenetic instability showed that hyperdiploidy and chromosomal aberrations are the main components of this indicator, which, on average in the three monitoring sites, exceeded the control data by 4.14 times. Statistical data processing allows us to conclude about the genotoxic effect of prohibited and non-utilized pesticides on the body of sheep, which have a clastogenic, aneugenic, and mutagenic effect.
Key words: *sheep, pesticides, peripheral blood lymphocytes, chromosome aberrations, genomic mutations, cytogenetics*

DOI: 10.32523/2616-7034-2021-135-2-48-62

Introduction

Modern Kazakhstan has great potential for the development of agriculture, as one of the aspects of the country's economic growth, being a major producer of agricultural products [1].

The development of this sector of the economy is impossible without the use of chemical plant and animal protection products. To increase the economic effect of agriculture for many millennia, mankind has used pesticides, the chemical composition of which varies in accordance with scientific achievements. Initially, the role of pesticides was mainly played by compounds of mercury and arsenic, with the help of which rice crops were protected [2], now they are mainly complex complexes of chemical compounds.

Analyzing the indicators of crop production in the Almaty region, it can be argued that the volume of pesticides applied in all categories [3], as well as the yield of crops such as potatoes, sugar beets, vegetables, grains, and oilseeds, has a steady growth trend over the past 10 years in this area [4].

Given the history of the use of pesticides to increase crop yields and the multiplicity of existing names of drugs, and there are currently more than 100,000 of them [5, p.248], it becomes difficult to create a unified classification of them.

However, such widespread use of pesticides (annually more than 3 million tons of pesticides are used in the world [6]) inevitably leads to environmental pollution, contributing to the ingress of not only the active substances themselves, but also their metabolic products, both in the soil and in water, having a direct negative impact not only on target organisms [7]. Many of them have a whole range of negative effects on the body, including the ability to cause mutations [8], cancer [9]. The first publications on the study of the possible genotoxic effects of pesticides on animals and humans can be found in the 30s of the 20th centuries, when the mutagenic effects of chemicals were first discovered. And by the 70s, there have already been a lot of works studying the effects of a variety of chemicals that were widely used by humans in various fields of the national economy, including agriculture. Under the auspices of ICPEMC (International Commission for the Protection against Environmental Mutagens and Carcinogens) at the end of the 20th century, several works were published on the genotoxic effect of pesticides, for example, the effect of DDT on the appearance of chromosomal aberrations in bone marrow cells [10], mouse spermatocytes [11], the effects of dichlorvos on humans [12].

Most studies relate to the negative effects of chemicals on the human body, especially agricultural workers, farmers who are in direct contact with pesticides as a result of professional activities. For example, an increase in the frequency of chromosomal aberrations has been shown [13-17], which are often closely associated with an increased likelihood of malignant tumors.

In locations with a high level of chemical pollution, their effect on the human body is prevented by several factors (restrictions on the availability of contaminated territories, the use of imported products, countermeasures to reduce the pesticide content in agricultural products), but biota is negatively affected without restrictions. There are few studies devoted to the study of the genotoxicity of chemical plant protection products on mammals.

So, some scientists have demonstrated the ability of pesticides to cause damage to DNA molecules in the cells of mice and rats. In the study of animal cells using DNA comets, a significant excess of the DNA tail was obtained during cultivation under the conditions of treatment with pesticides such as chlorpyrifos [18, 19], penconazole [20], dimethoate, lambda-cygalotrin [21], mancozeb [22], pendimethalin [23]. The latter, in addition to introducing double breaks in DNA, showed the ability to induce the formation of micronuclei in rat lymphocytes. Similar effects were found in pesticides such as acetamipride [24], imidacloprid [25], tebuconazole [26], and in the metabolite of many organophosphorus compounds - diethyldithiophosphate [27]. Some of these substances have a clastogenic effect, contributing to the emergence of different types of chromosomal aberrations.

According to published data [24], acetamipride can be attributed to such pesticides, which caused chromatid and isochromatid ruptures at high doses and prolonged exposure to mice, promoted the appearance of ring chromosomes, centromere ruptures, and increased the number of chromosomes in cells. Other authors [20] showed that chlorpyrifos and penconazole are also able to exert a genotoxic effect on mouse cells, which is expressed in an increase in the frequency of occurrence of not only the above-mentioned abnormalities, but also such as deletion and paired fragments. Collective studies by scientists from Slovakia [28-30] indicate the occurrence of aberrations of both chromosome and chromatid type in the case of treatment of cattle cell culture with thiacloprid.

All the above-mentioned effects of pesticides on mammalian cells have two common features that fundamentally distinguish them from our studies. Firstly, all the works presented were carried out using pesticides authorized for use in Kazakhstan; and secondly, by adding a certain dose of pesticides to the cell culture.

Since even authorized pesticides harm a living organism of any level of development, there is a need for state control over their introduction into agriculture. In this connection, by the Decree of the Government of the Republic of Kazakhstan dated January 18, 2008 No. 29, to prevent environmental pollution and agricultural products, as well as the harmful effects of pesticides on human health and wildlife, it is forbidden to use highly toxic pesticides in the Republic of Kazakhstan that have pronounced cumulative, carcinogenic mutagenic, teratogenic, embryo- and gonadotoxic properties and the ability to accumulate in plants, soil and the aquatic environment.

According to the same regulatory document, “pesticides recognized as prohibited for use on the territory of the Republic of Kazakhstan or rendered unusable are subject to obligatory disposal or destruction. In this case, the burial of prohibited drugs or their destruction is carried out at the expense of their owner" [31].

However, to date, in Kazakhstan, there is a large number of unauthorized places of accumulation of pesticides that are not utilized and banned for use, which permanently have a polluting effect on the environment, and negatively affect the viability of organisms.

According to the data of the Ministry of Energy of the Republic of Kazakhstan, as of April 2014, the total number of obsolete pesticides stored at various facilities in Kazakhstan reached 1,617,637.75 kg and more than 169,660 containers under them. Compared to 2008 data, in 2014 the number of obsolete pesticides increased significantly, which may be due to the discovery of new sites with obsolete pesticides and containers from them [32].

There are data in the literature on the effects of pesticides such as fluopyram [26], ethion [33], fenpropilmorph [34], tolylfluanide [35-36], methyl parathion [37], fipronil [38-39]. All of them are not on the list of permitted for use on the territory of Kazakhstan, due to the fact that they significantly increase the amount of damage. They not only disrupt the structure and functioning of the cell, which is reflected in a decrease in the mitotic index and proliferation index, but also have a genotoxic effect, causing damage to the genetic material at different levels of its organization. The authors of such works showed the presence of double breaks in DNA, chromosomal aberrations, micronuclei in cells treated under cultured conditions with similar forbidden pesticides.

In the Almaty region, according to the inventory, there are unauthorized warehouses of pesticides, the use of which, at the moment, is legally prohibited in the republic. According to monitoring in 2010, near the village Belbulak more than 500 kg, and near the village Amangelds - more than 900 kg of a mixture of unused pesticides were found. Many of them are not labeled, and therefore their composition is unknown.

Another part of the chemicals stored in such places was identified as pesticides belonging to different groups [40]:

1. Organophosphorus - saifos (menazone), metaphos (methyl parathion)
2. Fluorine-containing - treflan (banned in 1996)
3. Derivatives of sym-triazine - atrazine, prot¬razine, propazine, ziazine (banned in the world since 1994)
4. Organochlorine - nitrophene (banned in the world since 1996), illoxan
5. Thiocar bamatnye - subject

Most pesticides from the list above are banned for use in Europe, the United States or the world since the mid-90s of the 20th century. That is, for about 20 years, these substances are not disposed of, and their metabolites continue to pollute the environment, spreading to nearby territories, exerting their detrimental effect on the biota that lives on such lands.

These warehouses are located in the areas adjacent to pasture lands, the total area of which in the Almaty region exceeds 5500 thousand hectares. Over the past 15 years, in this territory the number of sheep has increased to 3419.4 thousand animals, and the number of cattle has doubled. Contamination of pasture lands with forbidden and non-utilized pesticides and their decay products has a detrimental effect not only on the farm animal organisms, but also indirectly on the human body whose products they use.

In this regard, the study of the genotoxic effect of obsolete and non-utilized pesticides on the body of farm animals is very relevant. Moreover, to date there are publications on the study of the genotoxic effect of pesticides on living organisms, but they have been performed in vitro and using authorized and known pesticides. We worked with native blood of farm animals kept in close proximity to abandoned warehouses with prohibited and non-utilized pesticides.

ISSN(Print) 2616-7034 eISSN 2663-130X

Materials and research methods

Based on the chemical analysis of soil and water resources of the Almaty region, two experimental sites were identified - the Belbulak settlement and Amangeldy settlement in the most polluted Talgar region. The village Basshi in Kerbulak district was selected to be a control site. In each indicated location, blood was collected from sheep in sterile heparin tubes, with the participation of district veterinarians. Thus, biological material was obtained from 27 animals of both sexes and of different ages, in compliance with all requirements and without causing harm to animals.

Cell cultivation was carried out in the laboratory of the Institute of General Genetics and Cytology in Almaty by a standard method. Blood of test animals in a volume of 0.5 ml. was placed in a nutrient medium (4 ml.), prepared based on medium 199 (OO NPP PanEco) with the addition of 1 ml. calf serum (OO NPP "PanEco") and 0.2 ml. PHA (OO NPP "PanEco") and cultivated for 72 hours at a temperature of 37°C. At the 70th hour of incubation, to block cell division at the metaphase stage, 0.4 ml of colchicine solution was added. (OO NPP "PanEco").

After this time, the cells were centrifuged and hypotenized with a solution of 0.56% KCL for 20 minutes, and then fixed with Carnoy's solution (ethyl alcohol / glacial acetic acid 3: 1). Preparation of metaphase chromosome slides was carried out according to the generally accepted cytogenetic technique. The slides were encoded and stained according to Romanovsky-Giemsa (OO NPP PanEko). In total, 407 sheep chromosome slides were made (121 - Amangeldy, 146 - Belbulak, 140 - Basshi).

The results obtained were processed by traditional methods of variation statistics. Differences were regarded as significant at $p < 0.05$. Significance level (P) was determined using Student's t-test.

Results

The karyotype of sheep is represented by 54 chromosomes, 3 pairs of which are metacentric, the rest are acrocentric. Cytogenetic analysis of the obtained slides was carried out by counting the frequency of occurrence of chromosomal aberrations and genomic mutations (hypodiploidy, hyperploidy, polyploidy). In the course of the study, we found that the cells of sheep blood samples from the control site (Basshi) have a similar level of genetic disorders from the experimental sites (Amangeldy, Belbulak). In addition, the study of samples of soil, water, plants, showed a high level of contamination with prohibited and unused pesticides and heavy metals. According to the results of the chemical analysis of water, it was found that the samples of drinking and natural water from Amangeldy settlement contain 4.4 DDD (DDT metabolite) in concentrations of 0.0002-0.0003 μg / dm3.

Chemical analysis of soils from monitoring points showed that in Amangeldy settlement there is an excess of MPC for the content of such pesticides as aldrin - 4.9 times; chlorobenzylate - 13.9 times; DDT - 12.4 times; DDE - 7.8 times; 4.4-DDD - 6.5 times; deldrin - 84.6 times; endrin - 859.5 times; heptachlorepoxide - 2.5 times, for Cd - 1.7 times and for Cu - 1.6 times; in Belbulak settlement: exceeding the MPC for DDT - by 1.75 times; 4.4-DDD - 5.2 times; for deldrin - 18.8 times, for Cd - 2 times, and for Ni - 1.05 times [40].

In this regard, we decided to use as control data obtained in 2017 from animals living near the city of Usharal (Almaty region).

The cytogenetic analysis of 2683 metaphases (Fig. 1) showed that the frequency of cells with identified genomic mutations in the experimental sites reliably exceeds those from the control site on average 1.98 times (Belbulak settlement - 1.8, Amangeldy settlement - 2,16, and Basshi - 2). The frequency of occurrence of cells with hypodiploidy in a diploid set ranges from 68 to 70% at all experimental points. Hyperdiploidy occurs in 4.27% of the cells of experimental animals. Cells with a polyploid set of chromosomes were found in the range from 25.2% to 27.9% of the studied cells.

The frequency of chromosomal aberrations in the blood samples of experimental animals exceeds the corresponding indicator at the control point by 4.1 times on average (Belbulak settlement - 3.32, Amangeldy settlement - 4.75, and Basshi settlement - 4.23). Among cells with chromosomal aberrations, cells with terminal deletions of chromatids, gaps in the centromere region of chromosomes, various types of gaps in chromatids, pulverization of individual chromosomes in the metaphase plate were identified.

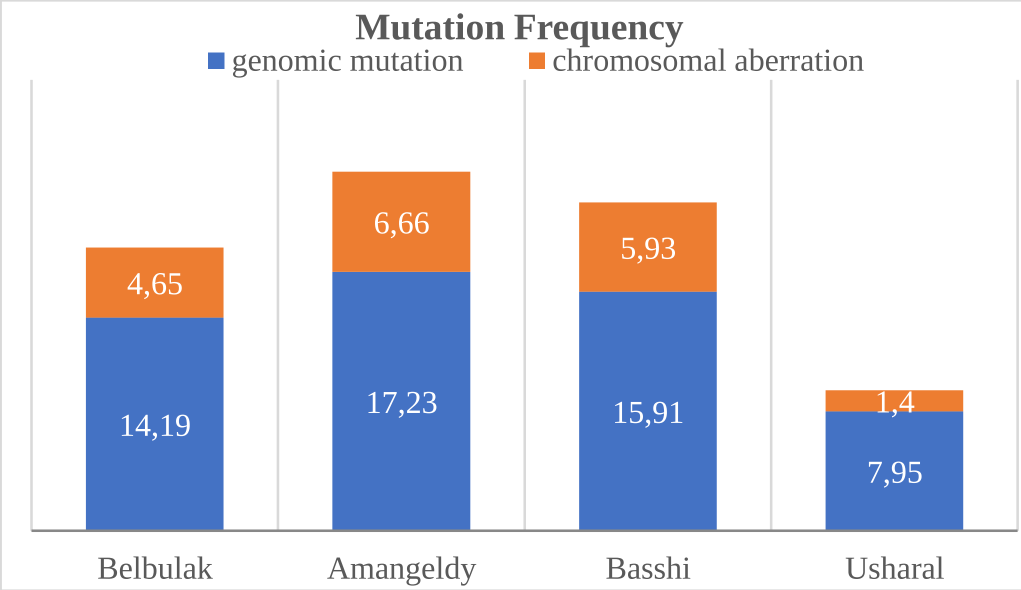

Figure 1. The frequency of occurrence in sheep of cells with genomic and chromosomal mutations at the experimental and control points of the Almaty region

An individual analysis of the cytogenetic parameters of experimental animals showed that cells with hypodiploidy are found in all sheep from three monitoring points with a frequency, with a variation from 6.6 to 15%. Cells with hyperdiploidy are found only in individual animals (for example, in 3 out of 7 sheep from Belbulak).

All three experimental sites have differences in the frequency of detection of cells with a polyploid set of chromosomes. So, polyploid cells were found in each animal from the site of Belbulak settlement, where the total frequency of such disorders is in the range from 2.5 to 6.79%. In the Amangeldy settlement, 50% of the animals had a similar deviation in more than 5% of the studied cells (the largest number was 8.82% in a three-year-old ewe). From the third monitoring site (Basshi), only 30% of the sheep showed the presence of a genetic disorder in the form of polyploidy, although its level was also high (more than 5%).

Chromosomal aberrations (Fig. 2) were identified in all studied animals kept in the studied territories, but their detection frequencies have individual variations. For example, in a sheep from Amangeldy (No. 7), the level of deviations exceeds the control animal by 7 times.

Thus, it is possible to calculate the total level of cytogenetic instability (A) of blood cells for each study area. This indicator includes the sum of the frequencies of cells with genomic mutations and chromosomal aberrations (Table 1).

As can be seen from table 1 and figure 1, the highest level of genetic instability was shown by sheep kept near Amangeldy. For a more complete analysis of the available data, we decided to split a single indicator A into two subgroups B and C.

Indicator B is a subtraction from indicator A of the number of cells with hypodiploidy. This is explained by the fact that the loss of one chromosome during the preparation of cytogenetic preparations is possible as a result of processing the cells with a hypotonic solution and fixative, therefore its exclusion contributes to a more accurate determination of the genotoxic effect of the chemical constituents of pesticides.

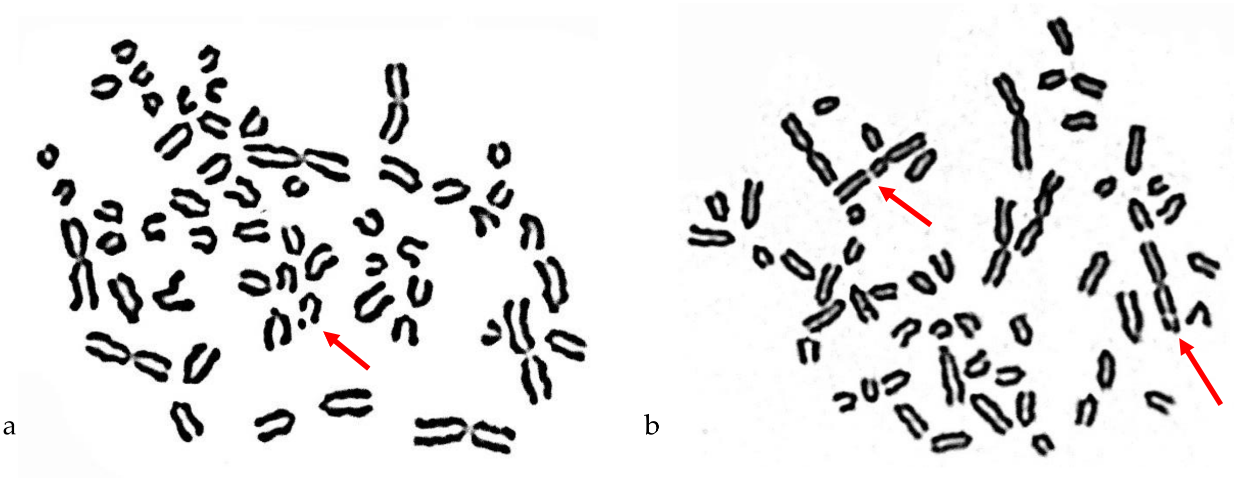

Figure 2. Metaphase cells of ewes from the point of Amangeldy (a - deletion in the acrocentric chromosome in animal No. 1; b - deletion in two chromatids of the metacentric chromosome (fragments are nearby) in animal No. 10)

Table 1

The level of cytogenetic instability of sheep blood cells from experimental and control points of the Almaty region

Monitoring points	Number of animals	Metaphases studied	General level of cytogenetic instability,%		
			A	B	C
Belbulak	7	626	18,85±1,47	8,88±1,03	5,07±0,62
Amangeldy	10	1017	23,90±1,94	12,16±1,18	7,25±0,74
Basshi	10	1040	21,85±0,83	10,58±0,91	6,57±0,65
Control (Usharal)	10	856	9,35±0,41	3,16±0,25	1,52±1,7

Notes

1- A - the general level of cytogenetic instability, taking into account cells with a hypodiploid, hyperdiploid and polyploid sets of chromosomes, as well as cells with chromosomal aberrations;

2- B - the level of cytogenetic instability, taking into account cells only with hyperdiploid and polyploid sets of chromosomes, as well as cells with chromosomal aberrations.

3- B - the level of cytogenetic instability, taking into account cells with only a hyperdiploid set of chromosomes and cells with chromosomal aberrations.

Hyperdiploidy cannot be explained by artifacts that occur during the preparation of slides, since the chromosomes of each metaphase plate have individual characteristics of spiralization and color, so the probability of erroneous accounting for an extra chromosome is impossible. Therefore, it becomes necessary to form, from the indicator of general cytogenetic instability, A, another indicator, C, which is the sum of the frequencies of cells with only a hyperdiploid set and cells with chromosomal aberrations.

Such a detailing of the indicator of total genomic stability allows us to trace, due to which chromosomal abnormalities, an increase in the genotoxic effect on the organism of sheep, which are contained in grazing areas, which are located near old, abandoned pesticide warehouses, occurs.

The study analyzed the frequency of occurrence of genetic disorders in animals of different ages and sex. According to the results obtained, a high level of genomic mutations and chromosomal aberrations were registered in sheep of different ages. So, for example, the highest level of cells with a polyploid set of chromosomes was found both in the one-year-old bright (animal No. 4, Belbulak village - 6.79%) and three-year-old ewes (animal No. 7, Amangeldy village - 8.82%). The same cytogenetic picture is observed in the analysis of cells with chromosomal aberrations. In a one-year-old bright (animal No. 6, Belbulak settlement) of the analyzed cells, 7.0% were with chromosome aberrations, and in a three-year-old ewe (animal No. 7, Amangeldy settlement) - 9.8%. The lowest level of cells with chromosomal aberrations was recorded in a three-year-old ewe (animal No. 10 - 2.80%) from the area of Belbulak, and the highest in a three-year-old ewe (animal No. 3 - 9.8%) from the area of Amangeldy.

Discussion

It is known that studying the frequency of cells with genomic mutations and chromosomal aberrations is a widely used method for determining the genotoxic effect of chemicals on a living organism. We studied blood samples of 27 sheep contained in the territory of three monitoring sites of the Almaty region, contaminated with the chemical components of banned and non-utilized pesticides, which were stored in abandoned warehouses. A comprehensive analysis of metaphase plates was carried out, the total number of which was 2683, in which such disorders as hypodiploidy, hyperdiploidy, polyploidy, chromosomal aberrations were identified. Three indicators were calculated that exhaustively characterize the contribution of each of the disturbances to the overall level of cytogenetic instability of animal cells.

In our studies, polyploid sets of chromosomes were found in the cells of all experimental animals. The appearance of such a deviation can be considered as a protective mechanism of the cell, developed during evolution and aimed at eliminating from the population of those cells in which unbalanced damage to the genome occurred. There is also evidence that such polyploid cells are actively involved in the processes of restoration of the structure of organs during radiation damage to the body. Therefore, the increased frequency of such cells in the population of mouse-like rodents living under conditions of high levels of radiation exposure is defined as a pre-pathological state, in connection with which, such territories are considered to be zones of high genotoxic hazard for animals and humans [41-42].

Analysis of the data showed that cells with chromosomal aberrations were detected in the blood system of all animals. This indicator varies from 2.8% (sheep No. 10 from the village of Belbulak) to 9.8% (sheep No. 3 from the village of Amangeldy).

Literature sources [43] indicate that the appearance of cytogenetic disorders is caused by the blocking of the mitotic apparatus in the cell, which can be caused by some types of pesticides that have a mitostatic effect and contribute to the specific arrangement of cell chromosomes on the periphery in the form of a circle or widespread of chromosomes over the entire cell area. We have identified the same phenomena in experimental animals. Pesticides inhibit the formation of the fission spindle and disrupt the cytokinesis process, which leads to the formation of cells with chromosomal abnormalities.

When studying the environment near old storages of the Almaty region, DDT metabolites in doses exceeding the permissible limits were identified in soil and water. In the soil, an excess of the MPC of copper was also found, and in water - cadmium by 2-3 times in different studied areas. Analysis of vegetables and fruits grown near the studied territories was carried out, which showed an excess in them of residues of pesticides such as endosulfan, DDT, aldrin, and deldrin.

As part of the study of the state of healthy living at these points, it was revealed that the population of Belbulak and Amangeldy, exposed to acute pesticide exposure, has an excess of low health indicators by 35.5%, this is expressed in more pronounced aging of the body, muscle deficiency. (25-30% less than normal), water deficiency in the body in the range from 10 to 15% and bone tissue (10% less than normal), a decrease in cognitive abilities (a significant decrease in working capacity, with a characteristic predominance of inhibitory reactions in the central nervous system, the development of fatigue and asthenization of the body).

The state of cytogenetic indicators of people living in these settlements was also studied. An increased level of the frequency of chromosomal aberrations is characteristic of 43% of the Belbulak cohort, 56% of the Amangeldy cohort, and 18% of the Basshi cohort. The highest level of chromosomal aberrations was demonstrated by the surveyed residents of Belbulak settlement, the proportion of people with a high level of aberrations was 38% [40].

Conclusion

Thus, the high level of abnormalities in the number and structure of chromosomes in the blood cells of experimental animals that we have revealed indicates that unused and banned pesticides have a genotoxic effect on the body of sheep contained in these three monitoring sites. Thus, in meat and milk produced in the studied territories, multiple excesses of the MPC of pesticides, such as α-HCH, β HCH, γ-HCH, δ-HCH, endosulfan 1, DDT, DDE, DDD, 2,4-DDD, deldrin, chlordane, chlorobenzylate, endrin, endosulfan 2, endosulfan sulfate, methoxychlor, hexabromobenzene was found. Exceeding the MPC for heavy metals can also contribute to the formation of genetic disorders, in addition to the effect of pesticides. It is difficult to separate the influence of these two factors [40]. Therefore, accumulating in the tissues of farm animals, these substances, through products of animal origin, along the food chain, enter the human body. People living in these settlements of the Almaty region are even more affected by unused and banned pesticides.

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Алматы облысының жойылмаған және тыйым салынған пестицидтермен ластанған аумағында ұсталатын қойлардың цитогенетикалық бұзылулары

Аңдатпа: Мақалада Алматы облысының аумағындағы елді мекендерде орналасқан тыйым салынған және жойылмаған пестицидтердің қоймалары бар жерлерде өсірілетін ауыл шаруашылық малдарына осы пестицидтердің генотоксикалық әсерлері зерттелді. Үш мониторингтік нүктелерден 27 қойдың қан үлгілеріндегі жеке жасушаларда геномдық мутациялар мен хромосомдық аберрациялардың болуына талдау жүргізілді. Жасушаларды өсіру және препараттарды дайындау стандартты цитогенетикалық әдістермен жүргізілді.

Жануарлардың эксперименталды топтарының қан жүйесінде геномдық мутациялардың туындау жиілігін бақылау тобында орташа есеппен 1,98 есе, ал хромосомдық аберрациялар - 4,1 есе артты. Гиподиплоидты жасушалардың үлесі геномдық мутациялардың жалпы санының 70% құрады. Полиплоидия - 27,9% дейін, ал гипердиплоидия жеке жасушаларда кездесті. Жалпы цитогенетикалық тұрақсыздық көрсеткіштерін есептеу гипердиплоидия мен хромосомдық аберрация осы көрсеткіштің негізгі компоненттері болып табылатынын көрсетті, ол орташа есеппен үш мониторингтік учаскелер бойынша бақылау деректерінен 4,14 есе асып түсті. Деректерді статистикалық өңдеу қой ағзасына тыйым салынған және жойылмаған пестицидтердің кластогенді, анеогенді және мутагенді жағынан әсер ететінін көрсетті.

Түйін сөздер: қойлар, пестицидтер, перифериялық қанның лимфоциттері, хромосомдық аберрациялар, геномдық мутациялар, цитогенетика.

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Цитогенетические нарушения у овец, содержащихся на территории Алматинской области, загрязненной неутилизированными и запрещенными пестицидами

Аннотация. На территории Алматинской области имеются склады с запрещенными и неутилизированными пестицидами, активные вещества и метаболиты которых загрязняют пастбища сельскохозяйственных животных, располагающихся рядом. Был проведен анализ образцов крови 27 овец с трех мониторинговых точек Алматинской области на предмет наличия геномных мутаций и хромосомных аберраций. Культивирование клеток и приготовление препаратов производилось стандартными цитогенетическими методиками.

Частота возникновения геномных мутаций в системе крови экспериментальных групп животных превысила аналогичный показатель в контрольной группе в среднем в 1,98 раз, а хромосомных аберраций - в 4,1 раза. Доля гиподиплоидных клеток составила 70% от общего количества геномных мутаций. На полиплоидию пришлось до 27,9%, а гипердиплоидия встречалась в единичных клетках. Расчет показателей общей цитогенетической нестабильности показал, что гипердиплоидия и хромосомные аберрации являются основными компонентами данного показателя, который, в среднем по трем мониторинговым участкам, превысил контрольные данные в 4,14 раз. Статистическая обработка данных позволяет сделать вывод о генотоксическом действии запрещенных и неутилизированных пестицидов на организм овец, которые оказывают кластогенный, анеугенный и мутагенный эффект.

Ключевые слова: овцы, пестициды, лимфоциты периферической крови, хромосомные аберрации, геномные мутации, цитогенетика.

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ISSN(Print) 2616-7034 eISSN 2663-130X