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Current State of Animal Anthrax Problems in the Republic of Kazakhstan and Ways to Solve it

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ABSTRACT

Anthrax cases in animals and humans are registered annually in Kazakhstan, causing significant economic and human losses. Therefore, the study aims to monitor the disease outbreaks in all regions of the Republic of Kazakhstan during 2019-2023, as well as to study the immunogenic characteristics of Kazakhstani biological preparations for the prevention of anthrax in farm animals. The study used analytical, monitoring, and statistical methods, as well as serological studies in determining the titers of specific post-vaccine antibodies. As a result of monitoring studies for the period from 2019 to 2023, two "active" anthrax foci were detected in Kazakhstan – the southern region (Zhambyl and Turkestan regions) and the northern region (Kostanay, North-Kazakhstan, East-Kazakhstan, and Akmola regions). At the same time, a tendency of increasing morbidity among the population in recent years has been revealed. The greatest correlation of anthrax morbidity was found with the growth of the cattle population in the region. The correlation coefficient was 0.87 at $P<0.001$. All Kazakhstani biopreparations for disease prevention caused the level of postvaccine antibodies sufficient for the protection of animals. At the same time antibodies in immunised animals after application of preparations of different manufacturers were detected at the same level. The study results enable us to forecast the development and spread of anthrax epizootic foci in the country and to develop effective methods of vaccine prophylaxis.

Key words: Monitoring, Correlation analysis, Enzyme immunoassay, Vaccine, Antibody titre.

INTRODUCTION

Anthrax is a dangerous anthropozoonotic disease, the causative agent, i.e., *Bacillus anthracis* (of which causes an infectious process with a high mortality rate (Ashiq et al. 2023; Rahim et al. 2023; Zaviriukha et al. 2024). At the same time, the Republic of Kazakhstan is one of the leaders in the region in terms of anthrax incidence not only among animals but also among humans. Such spread of the disease is connected with many factors, one of them being a long, more than 100 years, the ability of the pathogen to preserve its vitality and virulence in the external environment, as well as weak veterinary control of anti-epizootic measures for this disease. The growth of anthrax morbidity among the population of Kazakhstan is an urgent epidemiological problem for the country and there needs to be preventive approaches to reduce the spread of the disease. Anthrax is a significant problem in Kazakhstan's neighboring countries, including Kyrgyzstan (Kutmanova et al. 2022), Uzbekistan (Mengliev 2020), Russia (Ryazanova et al. 2023) and China (Zheng et al. 2024). These nations experience periodic outbreaks in animals and humans, influenced by similar environmental conditions and agricultural practices (Kutmanova et al. 2020; Kozytska et al. 2023; Khairullah et al. 2024). The porous borders and livestock movement exacerbate the spread (Bayir 2023; Sohail et al. 2023). In Russia, outbreaks often link to disturbed burial sites or improper handling of animal products (Haider et al. 2022; Ryazanova et al. 2023). China's western provinces also face outbreaks due to its vast livestock population (Zheng et al. 2024). These regional challenges highlight the need for coordinated efforts in monitoring, control, and prevention to mitigate anthrax's impact.

Chukayeva (2022) indicates that the main source of infection in the country is numerous anthrax centers – burial sites, which represent an internal threat of disease spread. According to Dzhusupova (2023), the presence of many unrecorded anthrax burials throughout the country. The researcher could lead to an increase in the number of

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people with the disease from 20 people in 2022 to 37 in 2023. As a rule, infection of farm animals occurs as a result of their grazing in unrecorded places of anthrax burials, and human diseases occur when cutting and eating meat from slaughtered diseased animals, as noted by Sushchikh et al. (2023) in a study a case of human disease in the village of Olginka, Akmola region.

According to Shamshit (2023), as of the end of 2023, the Veterinary Control Committee in Kazakhstan has information on 2571 anthrax burials. Following the Law of the Republic of Kazakhstan No. 339 "On veterinary medicine" (2002) the construction of fences, installation of warning signs, and their further maintenance are the responsibility of local executive bodies. All these places should be marked with identifying signs and have fences to prevent animals from entering and feeding on their territory. However, failure to fulfil these requirements causes the annual registration of anthrax diseases in animals, which is pointed out by veterinary inspectors. In addition, according to Shamshit (2023), some farm animals in Kazakhstan are not registered.

This approach reduces the efficiency of veterinary accounting during prophylactic vaccination of animals in disease foci or adjacent areas, which also leads to an increase in the infection rate of biological objects. Weather factors such as high humidity and high groundwater levels in the territory of the cattle burial ground are also considered disposal factors. The main source of the disease, according to Lukhnova et al. (2019), are local strains of *B. anthracis*, although in the etiology of the disease in Kazakhstan, the same authors do not exclude the possibility of introduction of the pathogen from border regions with other countries where this disease is also observed – China, Kyrgyzstan, and other neighboring countries.

Anthrax is a common disease in the world. Following Nizkorodova et al. (2023), 2,433 epizootic and 2,249 soil anthrax outbreaks were officially registered in the country. However, following Vygovska et al. (2023), abandoned soil anthrax outbreaks are particularly dangerous in the epizootic process.

In total, in Kazakhstan, Shevtsov et al. (2021) identify six origins of *B. anthracis*, which are associated with Turkestan, Western Kazakhstan and the permafrost of Northern Siberia. The exception is strain KZ45, isolated in Eastern Kazakhstan from hides of unknown origin. Therefore, the possibility of cross-border transmission should not be dismissed. Kutmanova et al. (2020) presents cases of animal and human diseases in Kyrgyzstan. Analysis of 234 human cases shows that infection occurred during slaughter, cutting and sale of animal meat. Cases of infection occurred mainly in summer and autumn. Similar studies were conducted by Zorigt et al. (2021) Zorigt, 2022 in Mongolia, where two active outbreaks were found in the south and north of the Khubsgul region. The work also concluded that the main reason for the increase in the infectious process was the average annual summer air temperature in the area. Studies on the occurrence of anthrax by Kanankege et al. (2019) demonstrated that anthrax in other countries also exhibits seasonality with a peak in August.

From more distant regions, from where animals for breeding purposes were acquired to Kazakhstan were some European and Asian countries. In recent years, according to Railean et al. (2023), 8 cases of human anthrax were reported in Croatia by 2022 and 4 cases in Romania by 2023. Kozytska et al. (2023) note that from 2005 to 2022, 267 cases of anthrax in animals were reported in Europe, including 251 cases in domestic animals and 16 in wild animals in Albania, Russia, and Italy. In Ukraine, the highest number of confirmed cases was reported in 2018 in the Odesa region. Amiri et al. (2021) indicated that the high incidence of anthrax in Iran during 2010-2015 was observed in Kurdistan, North Khorasan and Bakhtiari provinces, respectively. An increase in the incidence rate was observed from 2010 to 2013, whereas the incidence rate decreased in 2014.

Preventive measures in most countries are limited to vaccination of animals in foci of infection. Viriyapong and Thammawong (2022) indicate that a more effective approach is simultaneous vaccination with soil sanitation. Soil disinfection of the infection centre is also suggested by Suchshikh et al. (2023), who conducted experimental studies with vaccine strains. Considering that more and more often industrial facilities are being built on the sites of anthrax foci, disinfection and elimination of soil foci is a particularly urgent problem. Even broader anti-epizootic approaches are proposed by Sarker et al. (2023). They also encompass laboratory-diagnostic operations to determine the pathogen and measures to prevent human infection during the elimination of anthrax infection foci.

The above studies indicate a significant spread of anthrax in Kazakhstan, both among the animal population and the population, which leads to significant economic and human losses. Therefore, the research relevance of prevention and elimination of the disease in the country is determined, and necessary. In this regard, the study aims to monitor the prevalence of infection in the Republic of Kazakhstan and to improve anti-anthrax measures to prevent morbidity among animals.

MATERIALS AND METHODS

The results of the monitoring study of morbidity of the population and farm animals in Kazakhstan for the period from 2019 to 2023, conducted within the framework of the scientific and technical research program of the Kazakh Research Veterinary Institute (Almaty) on the study of especially dangerous anthropozoonotic diseases in the Republic of Kazakhstan were used as the material for the study.

The main source of materials for the analytical study were reports submitted by the Ministry of Agriculture of the Republic of Kazakhstan (Report of the Chairman of the Committee…, 2020), the Sanitary and Epidemiological Control Committee of the Ministry of Health (Watch out for anthrax, 2023), and materials from the work of interdepartmental commissions to investigate anthrax cases, as well as documents of other local government bodies responsible for anti-epizootic measures per Order of the Minister of Agriculture of the Republic of Kazakhstan No. 7-1/587 "On approval of Veterinary (veterinary and sanitary) rules" (2015). At the same time, the main focus was on cases of morbidity that occurred in 2019-2023. The monitoring studies also included the results of work carried out by the staff of the Kazakh Research Veterinary Institute during scheduled

and emergency visits to anthrax hotspots and foci of human and animal diseases. Ethical approval for this study was granted by the Ethics Committee of Kazakh Research Veterinary Institute, approval number A-105.

The next study stage was to investigate the immunological properties of biological preparations used in the Republic of Kazakhstan for anthrax prophylaxis. For this purpose, blood samples were collected from three groups of 50 animals each, which had been previously vaccinated with biological preparations from various Kazakhstani manufacturers included in the register authorised for use in the Republic of Kazakhstan. The period from vaccination to blood sampling for the immunological study did not exceed the interval from 3 to 4 months when antibody titres have maximum values. Blood was collected in sterile vacuum tubes with subsequent sedimentation to obtain serum. Immunological studies were carried out in the laboratory of bacteriology of the Kazakh Research Veterinary Institute.

Blood/sera of animals were examined for the presence of anti-anthrax antibodies by a serological method using an indirect hemagglutination test (IHA). Dry erythrocytic anthrax antigenic diagnostic (registration No. RK-IMN-5 No. 008938), produced by Republican State Enterprise M. Aikimbayev National Scientific Centre for Quarantine, Republic of Kazakhstan, was used for the experiment. The serological reaction was performed with the whole blood serum of vaccinated animals using the macro method according to the approved instructions of the diagnostic manufacturer.

The results of monitoring and immunological studies were further entered into a database in spreadsheet format for further statistical processing. The obtained results were mathematically processed using TIBCO Statistica v14.0.0.15 (USA) software. Graphical materials for visualisation of the obtained data were also created with the help of this program. Conclusions and recommendations for further research were formed based on the study results.

RESULTS

Monitoring studies of the development of the infectious process of animal and human anthrax morbidity in the Republic of Kazakhstan are associated with several problems. The Committee of Veterinary Control and Supervision of the Ministry of Agriculture supervises animal morbidity and preventive measures in the disease foci, human cases are controlled by the Committee of Sanitary and Epidemiological Control of the Ministry of Health, and local authorities are responsible for controlling the condition and measures at the burial sites of dead animals. Such distribution of responsibilities for anthrax elimination and prevention in Kazakhstan between different structures not only complicates monitoring studies but also reduces the effectiveness of anti-epizootic and anti-epidemiological efforts.

Analyses of anthrax incidence in Kazakhstan have been conducted for a long period, as the pathogen has persisted in the environment for more than a hundred years. However, the most important studies on the development of the infectious process in the territory of the country over the last few years, as they demonstrate the status and trends of morbidity among susceptible biological objects. The results of analyses of the occurrence of new anthrax cases in Kazakhstan over the last 5 years are presented in Table 1.

Table 1: Results of monitoring studies of the occurrence of anthrax outbreaks in Kazakhstan over the last 5 years

No.	Region	Number of inpatient unfavorable locations	
		Total	Increase over last 5 years
1	Akmola	227	+2
2	Aktobe	101	+2
3	Almaty	184	0
4	Atyrau	25	0
5	East Kazakhstan	199	+1
6	Jambyl	92	+7
7	West Kazakhstan	157	0
8	Karaganda	115	+1
9	Kostanay	158	+3
10	Kyzylorda	52	0
11	Mangistau	6	0
12	Pavlodar	115	0
13	North Kazakhstan	153	+1
14	Turkestan	226	+3

Source: Compiled by the authors based on Report of the Chairman of the Committee of State Inspection in AIC of the Ministry of Agriculture of the Republic of Kazakhstan MARS A.M. “On the results of work and plans in the field of veterinary and phytosanitary security” (2020).

Based on the results of the monitoring analysis, the territory of the Republic of Kazakhstan can be grouped into regions with significant spread of the disease – Zhambyl, Turkestan, Akmola, Almaty, and East Kazakhstan. Regions with moderate spread of the disease – West Kazakhstan, Karaganda, Kostanay, Aktobe, North Kazakhstan and Pavlodar regions, relatively low spread – Atyrau, Kyzylorda and Mangystau regions. Monitoring studies indicate that in virtually all areas with significant disease spread, new infections of susceptible animals and humans occur annually. Retrospective analyses of disease incidence from 1935 to 2023 show a high risk of anthrax infection of susceptible animals and humans in the high-altitude zone of mountains, in the southern and eastern regions of Turkestan, Zhambyl, East Kazakhstan and Almaty regions, and the steppe zone of West Kazakhstan and Kostanay. Moderate risk of infection is noted in Aktobe, Akmola, Karaganda, North-Kazakhstan, and Pavlodar regions. Relatively favorable regions include Mangistau, Atyrau and Kyzylorda regions. At the same time, it is worth considering that each region with a high incidence of the disease and territories where the disease has never been registered.

Thus, according to the Ministry of Health, in 2021 in the Zhambyl region, only 1 case out of 27 occurred in the country, and 2022 already 13 out of 20. A similar situation with an increase in the number of cases among the population was also observed in Kostanay and Akmola regions. This increase was observed during 2020-2023, which may be due to global warming and the recent increase in average monthly temperatures during the summer months. It is therefore planned to carry out monitoring surveys in the regions bordering Kazakhstan to determine possible pathways of anthrax spread over the period under review. For clarity, all cases are plotted on a map (Fig. 1).

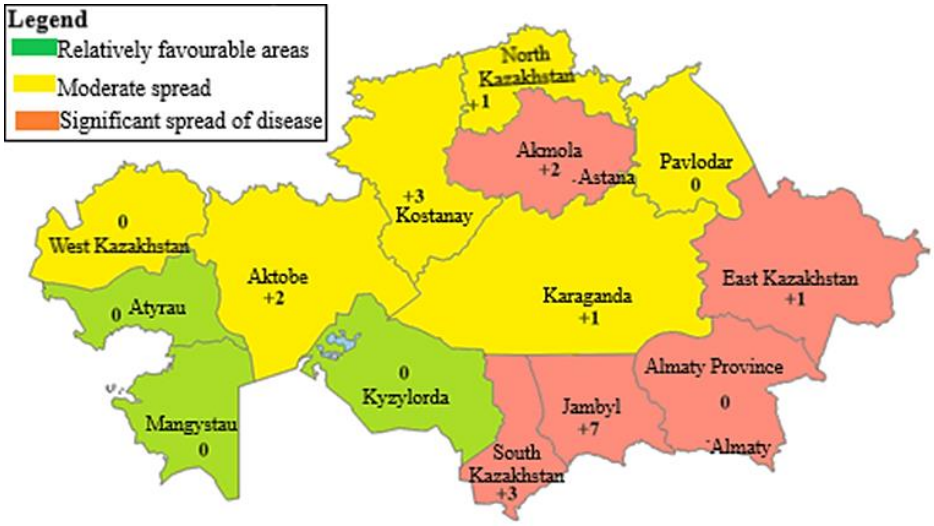

Fig. 1: Graphical distribution of the number of anthrax hotspots in the Republic of Kazakhstan over the last 5 years. Source: compiled by the authors based on Report of the Chairman of the Committee of State Inspection in AIC of the Ministry of Agriculture of the Republic of Kazakhstan MARS A.M. "On the results of work and plans in the field of veterinary and phytosanitary security" (2020).

The graphical format of the information provided indicates that the bulk of the incidence of disease in the population and animals is in the southern and south-eastern regions of the country, which border the People's Republic of China and Kyrgyzstan, which is also unfavorable for anthrax. There is also a tendency to increase the number of anthrax outbreaks in the northern regions of the country, which also provides for clarification of the epizootological reasons for this circumstance.

Correlation analyses were conducted between population density and animal numbers in the region, as well as the number of unaffected sites and cases. For this statistical analysis, information on population and animal numbers was taken from the website of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan. Only susceptible cattle, sheep and goats were considered. Since these animals were the main source of morbidity in the population during epizootological and epidemiological investigations. The most significant and statistically reliable correlation coefficient was found between the number of anthrax cases and the number of cattle on the territory of the region (Fig. 2).

While other indicators such as the number of small ruminants in the region (r=0.41) or the population in the region (r=0.47) had no significant influence on the number of cases. The correlation coefficients were several times lower than the degree of influence of the number of cattle on anthrax incidence. Of the total number of recorded cases of anthrax in farm animals, 93.4% occurred in large animal species such as cows and horses, while only 6.6% occurred in sheep and goats. It should be noted that records of animal morbidity are not always kept, especially among small animals, so it is best to be guided by cases of anthrax in humans. According to official statistics, for the last 5 years, from 2019 to 2023, 100 people contracted the disease, of which 2 cases were fatal (the first case in Zhambyl region in 2022, the second case in Karaganda region in 2023). Moreover, the forced slaughter of only 53 cattle and 17 horses became known (Why is anthrax rampant in Kazakhstan, 2023).

Therefore, when monitoring infectious diseases, it is better to focus on cases that are subject to mandatory documentation. Currently, isolated cases of human and animal diseases are registered almost annually in Kazakhstan. The number of cases of diseases among the population in the Republic of Kazakhstan for this period is presented in Fig. 3.

The incidence of human cases in Kazakhstan is characterised by considerable variability, ranging from 4 people in 2020 to 37 people in 2023 (Why is anthrax rampant in Kazakhstan, 2023). However, the trend of increasing numbers of cases in recent years may indicate a weak level of preventive measures in areas where an increase in cases has been observed. If the prevention of anthrax in animals is not given due attention, the number of sick people will only increase from year to year, leading to a more rapid spread of the infectious process in Kazakhstan. Therefore, it is necessary to address the issues of vaccine prophylaxis, which is carried out annually in all regions of the country. In general, systematic veterinary service and regular control over anti-epizootic measures will reduce the number of epizootic and epidemiological foci of the disease in the republic.

The next study stage addressed antigenic properties and intensity of immune response in animals to the administration of anthrax vaccines. For this purpose, only vaccines registered and authorized for use in Kazakhstan and included in the state register of veterinary drugs and feed additives were used (MoARK, 2023). The results of determining the postvaccine antibody titer in cows 3-4 months after vaccination are presented in Table 2.

The obtained results indicate that all vaccines registered in the Republic of Kazakhstan are capable of inducing high post-vaccine antibody levels sufficient to protect animals from the disease. Control check of immunity intensity in vaccinated animals, conducted at 3-4 months, revealed that biological preparations produced by JSC "National Holding QazBioPharm", SPC "Antigen" LLP and "BiotronGroup" LLP maintained the level of specific antibodies practically at the same level. Titers were within 125.1±5.8; 121.3±2.66 and 128.1±1.87, respectively.

Table 2: Level of specific antibodies in the blood of animals at 3-4 months after administration of anthrax vaccines

Vaccine	Number of animals	Average antibody titer
Vaccine against anthrax in animals from strain 55 – VNIIVVVIM liquid, Biotron Group LLP, Kazakhstan, registration RK-VP-1-3274-17 of 13.03.2017	50	128.1±1.87
Vaccine against anthrax in animals from strain 55 – VNIIVVVIM live liquid, LLP Scientific and Production Enterprise "Antigen", Kazakhstan, registration RK-VP-1-3459-17 of 01.11.2017	50	121.3±2.66
Live liquid vaccine against anthrax in animals from strain 55 – VNIIVVVIM Kazakh Research Veterinary Institute, Kazakhstan, JSC "National Holding QazBioPharm", Kazakhstan, registration RK-VP-1-3950-19 of 14.05.2019	50	125.1±5.8

Source: compiled by the authors. Statistical analysis using TIBCO Statistica v14.0.0.15 revealed that the differences in the average antibody titers between the vaccines were not statistically significant (P>0.05), indicating similar immunogenicity across the different preparations.

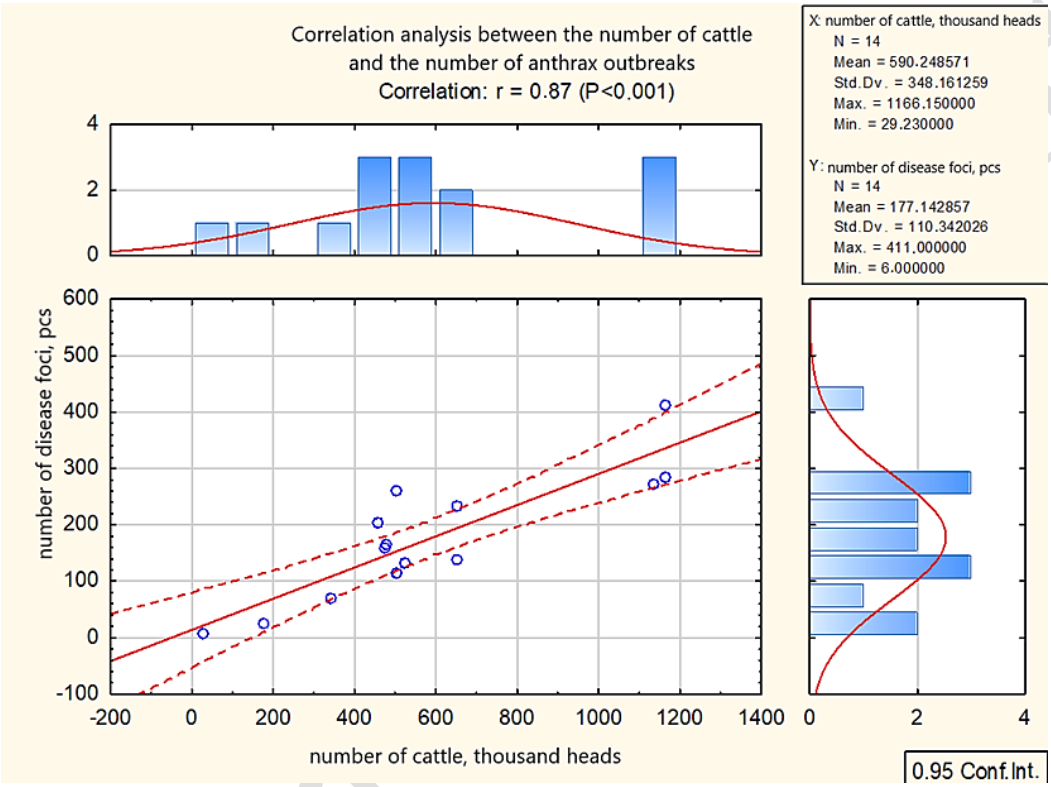

Fig. 2: Results of correlation analysis between the number of disease foci and the number of cattle in Kazakhstan regions. Source: compiled by the authors.

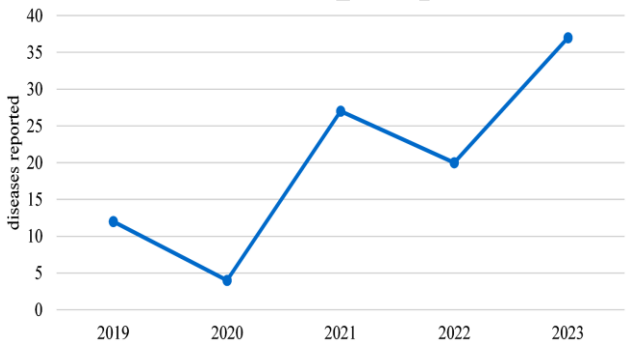

Fig. 3: Human anthrax incidence over the last 5 years. Source: Compiled by the authors.

At the same time, a single vaccination of animals, especially in regions with maximum and high risk of anthrax infection, does not guarantee complete protection of animals from the disease. Therefore, more detailed studies on the dynamics of antibody level reduction in the blood of vaccinated animals during the whole period between vaccinations are needed. This will reduce the incidence of anthrax among the animal population in Kazakhstan and thus improve the epidemiological situation in the country.

DISCUSSION

Currently, sporadic cases of anthrax in humans and animals are registered in Kazakhstan every year, indicating the functioning of several active foci of the disease. But recently the number of such cases has increased. In the last 5 years alone, the incidence among the population of Kazakhstan has increased from 4 cases in 2020 to 37 in the past year. Monitoring studies show that 5-7 years ago the main part of the disease was registered mainly in the southern regions, in the last 2-3 years this trend has increased and spread also to the northern regions of Kazakhstan – Kostanay, Akmola and North-Kazakhstan regions. Such a change in the geography of anthrax incidence in the Republic of Kazakhstan is probably related to global changes in climatic conditions, including in Central Asia.

Considering that the absence of anthrax manifestation in susceptible animals for even a fairly long period does not mean that the risk of its occurrence in this territory in the future has completely disappeared. Since *B. anthracis* can remain viable and virulent in soil for tens of years, an increase in temperature during the summer period, when the disease is manifested, may be associated with the destruction of surface soil layers, and thus increase the probability of spore contact with susceptible organisms. A high correlation between the melting of permafrost ice cover triggered by global temperature increases and animal disease incidence in the north, as reported by Stella et al. (2020), Sushma et al. (2021) and Yanenko et al. (2022). Zorigt (2022) also associates this phenomenon with an increase in the incidence of anthrax in cattle in Mongolia. However, Kazakhstan is far away from permafrost areas to assume that this is the reason for the increased incidence in the northern regions of the country. There must be another explanation for this phenomenon.

Otieno et al. (2021) and Brownlie et al. (2020) indicate an increase in the incidence of anthrax in years with drier summer conditions and countries with hotter climates – Kenya and Australia. However, these papers have not yet provided a logical explanation for the reasons for the increased incidence among susceptible animals in hot years. The only logical explanation could be dust erosion of certain types of soil during hot periods. This assumption was partially confirmed in the study of Abdrakhmanov et al. (2019), who indicated that the maximum number of anthrax cases occurred on chernozem and chestnut runes and loamy soil, and the least on swampy soil. Of the other assumptions, it may still be the acidity of the soils or other characteristics, which will be the subject of more detailed studies in future work. This is confirmed by the persistent, "hot" anthrax hotspot in the southern regions of Kazakhstan, where the average monthly summer temperature is about 30°C.

The only point of agreement among all researchers is the high correlation between the number of anthrax cases and the number of cattle in the area. In a study conducted in Kazakhstan, the correlation between the number of anthrax outbreaks and the number of cattle was 0.87 with a high degree of confidence $P<0.001$. Other factors such as population density in the study areas or the number of other susceptible animals were not significant or reliable. Similar results were obtained by Sushma et al. (2021) and Kinkpe et al. (2022), who also confirmed that the risk of anthrax increased with increasing numbers of cattle.

The low correlation of the other factors used in the study could be due to the lack of full control of all animal morbidity cases, especially among goats and sheep that are grazing, where there is no veterinary care, and the causes of mortality are not adequately addressed. This is also fuelled by the lack of meaningful identification of animals in the country. Therefore, not all cases of animal morbidity may be included in the monitoring studies. The same cannot be said about the manifestation of the disease among the population of the country. Medical records in Kazakhstan are more objective than veterinary records, so the monitoring was focused on human cases of anthrax. The trend obtained as a result of monitoring studies indicates an increase in the incidence of the disease among the population in Kazakhstan recently, and since the main route of human infection is through contact with sick animals or their products, this may also indicate an increase in the incidence of the disease among farm animals. Similar conclusions were made by Kyrgyz researchers Kutmanova et al. (2020) in the study of the causes of population morbidity in Kyrgyzstan.

Anthrax remains a significant problem also in the surrounding countries of Kazakhstan, including Kyrgyzstan (Kutmanova et al. 2022), Uzbekistan (Mengliev 2020), Russia (Ryazanova et al. 2023), and China (Zheng et al. 2024). Each of these countries faces periodic outbreaks of the disease in both animals and humans, contributing to regional epidemiological concerns. In Kyrgyzstan (Kutmanova et al. 2022) and Uzbekistan (Mengliev 2020), the prevalence of anthrax is influenced by similar environmental conditions and agricultural practices as in Kazakhstan. The porous borders and movement of livestock between these countries exacerbate the spread of the disease. In Russia, particularly in the Siberian and Far Eastern regions, anthrax cases have been reported sporadically, often linked to the disturbance of old burial sites of infected animals or the improper handling of animal products. The extensive geographical area and diverse climatic conditions contribute to the persistence of anthrax spores in the environment (Bilal et al. 2023; García-Rubio et al. 2023). China (Zheng et al. 2024), sharing a lengthy border with Kazakhstan, also experiences anthrax outbreaks, primarily in its western provinces. The country's vast livestock population and varied veterinary control measures create a complex landscape for managing and preventing the disease. Collectively, these countries' experiences with anthrax highlight the need for a coordinated regional approach to monitoring, controlling, and preventing outbreaks (Chukayeva 2022).

The surrounding environment significantly impacts anthrax control in Kazakhstan. The country's diverse climate, ranging from arid deserts to mountainous regions, creates varied conditions for the survival and spread of anthrax spores. Hot, dry conditions in the southern regions facilitate the persistence of spores in soil, while flooding in northern areas can disperse spores over wider areas, increasing the risk of outbreaks. The extensive agricultural activities, particularly cattle farming, also play a crucial role. Livestock movement between pastures and regions, often across porous borders with neighboring countries, facilitates the spread of anthrax. The presence of old burial sites of infected animals poses a constant threat, as spores can remain viable for decades, becoming a source of new infections if disturbed. Additionally, wildlife reservoirs, including rodents and wild herbivores, contribute to the disease's persistence and spread. Weak veterinary control and inconsistent implementation of anti-epizootic measures further exacerbate the problem, making it challenging to maintain effective surveillance and rapid response to outbreaks.

The only realistic method of anthrax prevention is to prevent new cases of disease in susceptible animals and, consequently, to reduce the number of *B. anthracis* spores in the soil. For this purpose, it is advisable to use vaccine preparations, which are highly likely to protect susceptible animals and thus reduce the manifestation of the infectious

process. In Kazakhstan, only vaccines of domestic production are registered and allowed for use, and these include 3 variants based on vaccine strain 55-VNIIVVIM of *B. anthracis* – "BiotronGroup" LLP, Scientific and Production Enterprise "Antigen" LLP and Kazakh Research Veterinary Institute. All biological products showed high immunogenic activity and protective protection of animals when used. After 3-4 months of vaccination, the level of specific antibodies in the blood of vaccinated animals of the experimental groups did not differ significantly. The analysis was justified only based on a single study, conducted, as it was supposed, in the period of peak antibody production. However, this result offers no conclusions on the prophylactic effect of each of the preparations through a relatively small sample of control animals.

Therefore, there was nothing to compare the results of different vaccines when used simultaneously under the same conditions, which needs further research. Cases of immune breakthroughs in vaccinated animals have been observed, resulting in lethal outcomes. Therefore, in the future, it is planned to conduct a more detailed study on the dynamics of the increase and decrease of antibody titre in the blood of cattle and small ruminants vaccinated with biological preparations of Kazakhstani production with the involvement of a large number of controlled animals.

Conclusion

The results of the monitoring study of anthrax spread in the territory of the Republic of Kazakhstan in recent years, as well as the immunological effect of Kazakhstan-made medicines for the prevention of this disease among farm animals conclude the following conclusions and develop several directions for future studies.

An increasing trend in the anthrax incidence among the population and farm animals in the Republic of Kazakhstan has been observed in recent years. The maximum incidence is observed in the southern region of the country – Zhambyl and Turkestan regions. Also, there is a tendency for an increase in the number of diseases in the northern regions – Akmola, Kostanay and North-Kazakhstan regions. A high correlation between anthrax morbidity and the number of cattle in the region was found. The correlation coefficient was 0.87 with a high level of reliability $P<0.001$, while the influence of such indicators as population density ($r=0.48$) and the number of small ruminants ($r=0.41$) was not reliable. In carrying out immunological research on the influence of preparations of Kazakhstan manufacture and their protective properties the received results specify that all three preparations provide the production of specific antibodies in the blood of cattle at vaccination in titres from 121.3±2.66 to 128.1±1.87.

Due to the small number of animals involved in the study of immunological properties of biopreparations, a detailed study of the dynamics of changes in antibody titre in blood from vaccination to the end of the guaranteed period of protection on a sufficient number of susceptible animal species is planned. Furthermore, in the plans of future research, the study of the causes of the growth of animal morbidity in the northern regions of the Republic of Kazakhstan.

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Author's contribution: All authors contributed equally.

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