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**UDC 619:616.9-036.22(574) (045)** **Research article**

# Impact of anthropogenic factors on the epidemiology of anthrax in Kazakhstan

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**Abstract**

Background and Aim. Despite significant success in the fight against anthrax, cases of animal and human disease are still registered in Kazakhstan. The presence of many permanently unfavorable points with numerous anthrax burial sites contributes to the maintenance of epidemiological unfavorability in the country. Moreover, active human activity in potentially dangerous zones often contributes to the activation of the epidemic process and the emergence of new infection outbreaks. The purpose of this research was to study the degree of influence of various anthropogenic factors on the epidemiology of anthrax in Kazakhstan.

Materials and Methods. The analysis object was information about anthrax outbreaks in Ka-zakhstan from 1933-2024. The study materials were data from the cadastre of stationary points unfavorable for anthrax, materials for statistical veterinary reporting, and our own records obtained during expedition trips. The data were analyzed using system modeling (Monte Carlo method) and spatial-geographical analysis via the Moran autocorrelation method.

Results. In total, 4,089 outbreaks of anthrax in Kazakhstan occurred during the study period. In chronological terms, 5 historical periods were distinguished, and the analysis of the available epidemiological data for 1933–2024 indicates that the main periods of increase and decrease in the annually registered anthrax outbreaks correspond to certain periods of economic and socioeconomic change in the country and the introduction of antiepizootic measures against this infection.

Conclusion. The analysis shows a pronounced uneven temporal and spatial distribution of anthrax foci and significant differences in the dynamics of the epizootic process in Kazakhstan. At the moment, new information is being formed on the factors influencing the ecology and epidemiology of the disease, which are associated with various forms of organization and management of the economy, urbanization of the population, changes in their social conditions and the influence of other anthropogenic factors.

**Keywords:** anthrax; anthrax burial sites; epizootic process; epizootic situation; Kazakhstan.

**Introduction**

Modern problems associated with the epizootic process of diseases in farm animals depend on the influence of several anthropogenic factors that aggravate the epizootic situation and contribute to the manifestation of an infectious disease in certain areas. Many authors (*S. Chowdhury* et al., 2021; *C. An* et al., 2023; *C.D. Reddell* et al., 2023; *I. Abirova* et al., 2023) point to the role of human activity in triggering the natural geographical and economic factors affecting the epizootic process of a disease [1, 2, 3, 4].

Moreover, outbreaks of such infections cause enormous economic losses for the country's agricultural sector and, more importantly, pose a serious threat to human health and life [4, 5, 6]. In this respect, studying potential sources and/or factors of pathogen transmission in a certain territory is critical. Such sources are often epidemiologically significant veterinary animals on which special sanitary and epidemiological requirements are imposed [7]. In this context, the role of veterinary epidemiology is also important, as this scientific field studies the epizootic process of especially dangerous infections and the potential impact of objects of epidemiological importance on the infection process [8].

Despite many years of success in combating anthrax, cases of animal and human disease are still registered in the Republic of Kazakhstan [9, 10]. Anthrax infection is a typical anthropurgic infection that is territorially confined and actively manifests itself, mainly in the warm season [11].

The existence of many permanent anthrax-unfavorable points (PAPs) with numerous burial sites for the corpses of animals that died from anthrax contributes to the maintenance of epizootologically and epidemiologically unfavorable conditions in the country. Research has shown that almost every fourth settlement in the Republic of Kazakhstan is permanently unfavorable for anthrax [12].

Currently, in almost all regions of the Republic of Kazakhstan, outbreaks of anthrax occur against the background of sporadic morbidity [9, 13]. The development of such a situation is facilitated by the changing socioeconomic living conditions of the population and the influence of numerous natural and anthropogenic factors that require further study [14, 15, 16, 17].

In this context, it is critical to establish the general territorial distribution patterns of anthrax in the Republic of Kazakhstan and the factors that preserve the activity of stationary unfavorable points for anthrax (SNP). Therefore, the present study aimed to determine the degree of influence of various anthropogenic factors on the epidemiology of anthrax in Kazakhstan.

**Materials and Methods**

The objects of the study were data on the registration of cases of Anthrax throughout the Republic of Kazakhstan in the period from 1933 to 2024. Statistical data from the veterinary accounting and reporting of the Committee for Veterinary Control and Supervision of the Ministry of Agriculture of the Republic of Kazakhstan, data from the Cadastre of inpatient Anthrax-affected areas of the Republic of Kazakhstan (2002) [18], and our own records obtained during expedition-ary trips to livestock farms were also used as primary materials. In total, 4,089 anthrax outbreaks were registered in the territory of the Republic of Kazakhstan during the analyzed period.

For statistical processing of the data obtained, the basic principles of statistical analysis, with system modeling (Monte Carlo method) and spatial and geographical analysis, using the Moran automatic correlation technique [19], were used.

The Monte Carlo method is a group of numerical techniques that utilize random sampling to simulate various processes and solve mathematical problems. The essence of this method lies in the repeated execution of random experiments, the results of which are then analyzed to obtain a statistical estimate of the parameter of interest [20].

The spatial autocorrelation method (Global Moran’s I index) enables the analysis of spatial autocorrelation based on both the locations of objects (such as anthrax foci) and their attribute values. Using the provided set of objects and their associated attributes, the tool assesses whether the observed spatial pattern is clustered, evenly distributed, or random [21].

**Results and Discussion**

The long-term concept of combating anthrax in Kazakhstan (formerly the territory of the USSR) was based on the large number of registered and unregistered anthrax foci (burial sites) in the country, which

pose a constant potential threat of new outbreaks of the disease. The mainte-nance of epizootologically and epidemiologically unfavorable conditions in the country is facilitated by the presence of many SNPs with numerous burial sites for animals that died from anthrax. From 1933-2024, 1,767 SNPs were registered in Kazakhstan, in which >1,760 people and >25,000 animals became infected.

The long-term dynamics of the number of registered outbreaks of anthrax in Kazakhstan reveal a complex and ambiguous epidemiological situation (Figure 1).

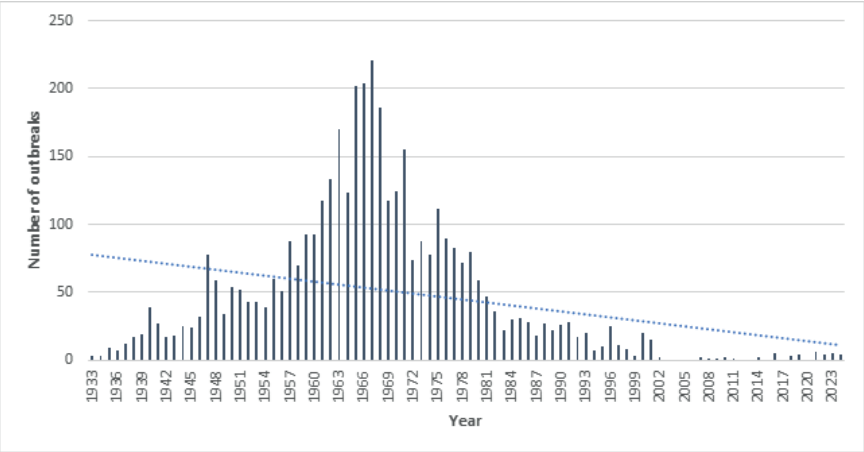


Figure 1 – Time dynamics of the registration of anthrax outbreak
s in Kazakhstan from 1933-2024

The figure demonstrates that, overall, there is a downward trend in the annual number of outbreaks across the country over the entire study period. However, it should be noted that the number of outbreaks varied significantly during different time intervals, ranging from isolated cas-es to several hundred outbreaks per year. Furthermore, no anthrax outbreaks among animals were offi-cially registered from 2003-2006.

Naturally, the dynamics of the epizootic process of anthrax over such a significant period are influenced by many factors, some of which are anthropogenic. Thus, the results of human economic activity, such as increasing the number of susceptible animals, expanding farms, organizing anthrax burial sites, conducting construction and excavation works, and implementing mass preventive measures, undoubtedly impacted the dynamics of the anthrax epizootic process. In this context, the analysis of the available epizootological data from 1933-2024 suggests that the main periods of increase and decrease in the annually registered anthrax outbreaks correspond to certain periods of socioeconomic and agricultural change in the country and the stages of the introduction of antiepi-zootic measures against this infection (Table 1).

Table 1 – Summary of anthrax outbreaks in Kazakhstan across various historical periods from 1933-2024

| Period, years | Total number of outbreaks during the period | Number of outbreaks by animal species | | | | Minimum number of outbreaks per year | Maximum number of outbreaks per year |
|---|---|---|---|---|---|---|---|
| | | Cattle | Horses | Pigs | Small ruminants | | |
| 1933-1953 | 615 | 415 | 34 | 22 | 144 | 3 | 78 |
| 1954-1968 | 1850 | 1051 | 90 | 95 | 614 | 39 | 221 |
| 1969-1983 | 1236 | 747 | 73 | 30 | 386 | 22 | 155 |
| 1984-2001 | 346 | 218 | 34 | 5 | 89 | 3 | 31 |
| 2002-2024 | 42 | 30 | 7 | 2 | 3 | 0 | 6 |

In total, 4,092 anthrax outbreaks occurred in Kazakhstan during the study period. In chronological terms, 5 historical periods (1933-1953, 1954-1968, 1969-1983, 1984-2001, and 2002-2024) corresponded to the stages of increase and decrease in annual morbidity and were associated with the peculiarities of various political decisions, economic activities, and veterinary supervision processes in the republic.

During the first period (1933-1953), there was a significant increase in annual morbidity (615 outbreaks officially registered), most likely due to the development of the national economy and the increase in the number of farm animals. Moreover, the organization of measures for disinfecting and disposing of dead animals was weak. For example, according to data from the National Statistics Committee, there were 1.8 mln heads of cattle and 2.2 mln heads of small cattle in Kazakhstan in 1933; by 1953, their numbers had reached 4.1 and 18.2 mln heads, respectively [22].

In 1951, with the adoption of new veterinary and sanitary rules regulating the mandatory burning of anthrax corpses without prior dismemberment to stop further contamination of the soil with anthrax bacilli, a slight decrease in the incidence rate was noticeable from 1951-1954 (Figure 1).

However, starting in 1955, there was a significant increase in the registration of disease outbreaks. The second period (1954-1968) demonstrated the highest incidence of anthrax in animals in Kazakhstan. In total, 1.850 outbreaks were registered during this historical period; the average number of outbreaks per year was 123, and the maximum number (221) for the entire observation period was registered in 1967. One of the most likely reasons for this high outbreak prevalence is the state campaign to develop virgin lands that began in 1954 and significantly affected Kazakhstan. A massive influx of people (>2 mln) began, with individuals moving to Kazakhstan from all over the USSR to develop virgin lands. Accordingly, the growth of the rural population contributed to the growth of the livestock population (the number of small cattle and pigs increased 4-fold from 1941–1961). In addition, the mass plowing of virgin lands led to the removal of anthrax spores from the soil surface in the territories of old and/or unaccounted anthrax burial sites. Subsequently, the erosion of soils by wind contributed to the spread of anthrax spores across significant distances. All these factors significantly increased the likelihood of animal contact with anthrax spores, which was confirmed by studies by Soviet scientists [23].

The republic has immunized susceptible animals against anthrax since the beginning of the 1950s; however, mass vaccination of the entire susceptible population of farm animals has been applied only since 1961. Thus, although a downward trend in the annual incidence of anthrax has been observed since 1969, the situation remained tense until the early 1980s. In total, 1.236 outbreaks of anthrax were registered in Kazakhstan from 1969-1983, with an average of >80 outbreaks annually.

Since 1983, the incidence rate has been stabilized at an average of 20 outbreaks per year (a total of 346 outbreaks were registered between 1984 and 2001), facilitated by the establishment of control over compliance with veterinary legislation, alignment and compliance with veterinary and sanitary rules at facilities of epidemiological significance, and wider susceptible livestock vac-cination coverage [24].

The collapse of the USSR led to a profound crisis in the agro-industrial complex of all post-Soviet republics, including the Republic of Kazakhstan. The established economic system was disrupted, and former state and collective farms began to disband due to bankruptcy, which was accompanied by a significant migration of the rural population to cities, leading to a sharp reduction in the number of all farm animal types. For example, from 1991-1998, the number of cattle in the Re-public of Kazakhstan decreased from 9.592 thousand heads to 3.958 thousand heads, that is, an almost 2.3-fold decrease; the same trend was observed for other farm animal types [25, 26]. That is, the decrease in the number of animals susceptible to anthrax in the country has to some ex-tent influenced the dynamics of the epizootic process and contributed to reducing the tension of the epidemic situation.

The gradual improvement of the economic situation in Kazakhstan since the late 1990s, the attraction of large investments in livestock farming, and the improvement of veterinary services have also contributed to the improvement of the epizootic situation, reflected in the registration of anthrax cases since 2002. A total of 42 outbreaks of anthrax were registered from 2002-2024.

Due to the systematic implementation of complex preventive and antiepidemic measures, the areas of anthrax registrations in Kazakhstan have gradually changed. Unlike the situation in the 1950s to the 1970s, outbreaks of the disease have virtually ceased in vast territories, including the Atyrau, Kostanay, and Mangistau regions, where no cases of the disease have been observed in humans or animals for

the past 20-30 years (Mangistau – 50 years). Nevertheless, outbreaks have been registered in areas that previously experienced intense morbidity, potentially indicating a continuing threat of the anthrax pathogen being carried out from old and/or unaccounted burial sites due to agricultural activities, construction, and other human activities. Various natural factors, such as floods and earthquakes, represent an additional source of infection.

Epidemiologically significant veterinary objects significantly influence the epizootic process of a particular nosological unit in many socially significant zoonoses. The territory of Kazakhstan has historically been considered unfavorable for many diseases of contagious etiology common to humans and animals. Some nosological forms have a natural focal character; other diseases are anthropurgic, meaning that the development of the epizootic process of such diseases depends directly on human activity [6, 14, 15].

For example, the development of virgin fallow lands in Kazakhstan aimed to strengthen national food security and improve the economic indicators of virgin regions. However, this campaign had many negative effects, including negatively impacting the dynamics of the epizootic process of socially significant infections, such as anthrax.

During the intensification of the agro-industrial complex, livestock complexes were organized on state farms, the number of livestock increased, enterprises for the production and processing of meat and dairy products were built, and wool, leather, and fur procurement points were created. There are several challenges affecting animal health and safety. Poor infrastructure, lack of reliable medicines for prevention, insufficient trained veterinary staff, and ineffective disease control make it difficult to protect people from infections spread by animals [22, 25].

In this context, without proper epidemiological control over objects of potential epidemiological significance, the development of virgin lands has worsened the epidemiological situation. As a result, due to an increase in the number of susceptible animals, an increase in the number of objects of epidemiological significance (e.g., livestock complexes, cattle burial grounds, anthrax burial sites, and slaughterhouses), the development of transport logistics, both between farms and among the abovementioned objects, has worsened the epizootic situation regarding anthrax in Kazakhstan [23, 27].

Undoubtedly, the vaccination of susceptible farm animals has significantly affected the dynamics of the anthrax epizootic process in Kazakhstan. In Kazakhstan, specific animal immunization against anthrax began in the 1950s, and since 1961, mass animal vaccinations have been organized in many regions. Even so, in those years, the level of vaccination could not ensure coverage of susceptible livestock, which is explained by the intensive increase in the number of animals, the insufficient vaccine supply at the local level, a lack of personnel, and poor accounting and planning of veterinary measures. Thus, although there has been a tendency toward a decline in the annual incidence of anthrax since 1969, the situation remained tense, and >50 outbreaks were registered in the republic per year until the 1980s [24].

Overall, from 1961-2010, the use of vaccine prophylaxis as part of antiepidemic measures reduced the number of infection foci by 107 times and reduced the incidence of anthrax in animals to isolated cases [27].

Full vaccination coverage of all susceptible livestock, strict control over the implementation of the entire range of preventive measures, and constant epizootological monitoring of the epizootic situation with anthrax in each region of the republic currently allow the country to maintain a stable situation.

**Conclusion**

Thus, the analysis shows a pronounced uneven temporal and spatial distribution of anthrax foci and significant differences in the dynamics of the development of the epizootic process in the territory of Kazakhstan. At the moment, new information is being formed on the factors influencing the ecology and epidemiology of the disease, which are associated with various forms of organization and management, urbanization of the population, changes in their social conditions and the influence of other anthropogenic factors.

**Authors' Contributions**

YM and SA: Developed the concept and design of the study. BK and TK conducted a comprehensive literature search, analyzed the collected data, and drafted the manuscript. AM and MB: performed final revision and proofreading of the manuscript. All authors have read, reviewed, and approved the final manuscript.

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