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GEOINFORMATION TECHNOLOGIES FOR ASSESSING EPIZOOTOLOGIC AND EPIDEMIOLOGIC SITUATION WITH ANTHRAX

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The article dwells on opportunities granted by application of geoinformation technologies in surveillance over anthrax, an infection that still remains rather dangerous. It was shown that, in spite of a decrease in incidence with anthrax among animals and people, risks persist on the RF territory; these risks are caused by residual activity in soil foci. A geoinformation system was applied to determine that at present areas where anthrax can be detected are predominantly located in forest-steppe zones, steppe zones, dry steppe zones, and Caucasian-Crimean mountain regions. 82 % of all the outbreaks detected in the 21st century occurred in these geographic zones. Unfavorable situation with anthrax seems to be clearly bound to territories with prevailing leached black earth, common black earth, mountain black earth, and mountain cinnamonic soil. Over the last years most anthrax outbreaks have occurred on these territories. All these territories were shown to have warm climate, with predominant stockbreeding in agriculture, as well as great numbers of cattle in private households; these cattle grazed freely on territories of natural foci with anthrax, and a lot of household work was handled manually. Territories that took leading places among unfavorable ones usually had a lot of households with cattle that nowadays remains a basic source of epidemiologic risk. We chose Tatarstan as a model region to show opportunities offered by a geoinformation system for improving epidemiologic surveillance over anthrax in relation to risk assessment. This territory was chosen due to high epizootologic activity and sporadic incidence among population detected there. We revealed risk territories in the region, determined basic reasons for unfavorable situation with anthrax as well as factors that made this situation even more complicated.

Key words: *anthrax, soil focus, stationary unfavorable point, anthrax disposal, risk assessment, geoinformation system.*

Issues related to elimination of anthrax are rather complicated but nonetheless further decrease in population morbidity with the disease and even putting a stop to people getting infected due to sporadic morbidity among animals seems to be quite achievable in the Russian Federation [1–3]. It can be done due to long-term experience accumu-

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lated in managing epidemiologic processes with its key focus being on epizootologic and epidemiologic surveillance. Given that, experts have made a lot of efforts trying to improve organizational and, above all, conceptual and methodological components in surveillance over anthrax [4].

Spread of information technologies and development of geoinformation systems (GIS) provide new tools for analyzing and assessing epizootologic and epidemiologic risks. GIS technologies here are considered an instrument for pre-epidemic diagnostics and prediction of how a situation may develop in future [5, 6]. They allow accumulating significant data arrays on risk factors, performing conjugate multi-factor analysis with revealing indicators of unfavorable epizootologic and epidemiologic situations, and determining trends and forecasts of their future development [7]. Anthrax outbreak that occurred on Yamal Peninsula in 2016 proved it was necessary to monitor over natural and social risk factors that could cause the disease [8, 9]. Such monitoring should be oriented at anthrax soil foci, stationary unfavorable points (SUPs) that are located within them [10], and anthrax disposals where dead animals were buried [11] with their hazards being determined via GIS.

So, at present it is vital to develop and implement GIS technologies into surveillance over anthrax as it helps to provide sanitary-epidemiologic welfare of the population in the country.

Our research goal was to assess the existing epizootologic and epidemiologic situation as regards anthrax and risks related to its probable worsening on the RF territory applying GIS technologies.

Data and methods. We took official statistic data collected in 2001–2018 (The federal statistics reports, Form No. 2 "Data on infectious and parasitic diseases"; Forms No. 23-06 and 23-09 "Data on outbreaks of infectious diseases"; statistic data on morbidity with anthrax among animals in the Russian Federation given in forms No 1-VET and 1-VET A); information and analytical and archives materials; data taken from the Register of anthrax-related stationary unfavorable points (SUPs) in the Russian Federation [12] with the latest entries made in 2017 (3,5631 SUPs), the freshest data from the regional register of Tatarstan (1,205 SUPs), and also data on 806 anthrax disposals (ADs) existing in this region.

To assess existing risks, we took data provided by the Federal State Statistics Service on the structure and numbers of agricultural animals that were epidemiologically significant[1]; we also took data from other available sources that could help us describe social and economic development of the examined territories.

Spatial and time dynamics of the situation with anthrax in the RF as well as any possibility it could get worse due to risk factors was assessed on the example of Tatarstan in GIS applications built on ArcGIS [www.esri.com] and QGIS [www.Qgis.org] platforms. To do that, we created digital maps that showed SUPs localization and activity as well as ADs locations. There were several stages in creating these subject maps; first, we created a cartographic database on registered anthrax outbreaks and SUPs becoming active; then we gave geocodes to SUPs and ADs and implemented cartographic layers into a developed GIS-project. These layers showed binding to settlements; administrative division; natural and agricultural zones existing on a territory; soil, landscape, and hydrographic conditions. Our task was to examine peculiarities related to territorial distribution of SUPs and ADs in Tatarstan; to do that, we built a digital map in a GIS-application and applied gradient coloring to show administrative districts depending on a number of anthrax outbreaks in each of them; we also created "a heat map" and applied gradient color-

[1] Basic results of agriculture in Russia in 2017: Bulletin. *The Federal State Statistics Service: official web-site*, 2018 Available at: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/publications/catalog/doc_1140096652250 (date of visit March 03, 2019).

ing to show the greatest density of spatial objects location on it.

Results and discussion. Intensity and geography of anthrax in the RF has changed considerably over almost a hundred-year observation period. Maximum number of registered anthrax outbreaks among animals occurred in the middle of the 20th century and reached 2,273 by 1950. Anthrax outbreaks among animals resulted in people being infected with the disease. Back then there were more than 500 registered anthrax cases among population in the Russian Soviet Federative Socialist Republic [13].

A set of activities was implemented; they were aimed at breaking an epizootologic chain (carcasses of dead animals were obligatorily burnt and there was large-scale regular vaccination of agricultural animals). It led to a steady decrease in intensity of anthrax epizooties. Number of outbreaks went down exponentially with approximately a three-time decrease occurring each ten years [14, 15].

Starting from 2001 on average 7 epizootic foci were registered annually in the RF; over the last decade an average annual number of anthrax outbreaks has been equal to 3.6. In 2001–2018 there were 2,926 anthrax cases registered among animals. Simultaneously with a decrease in morbidity among animals there was a drop in number of the RF regions where anthrax outbreaks were detected. Thus, in 50ties last century anthrax was detected in 79 regions in the country, but as for the last decades, it was detected in only 22 regions (Figures 1 and 2).

Most active SUPs were located in the Central Federal District (22.2%), Southern Federal District (20.7%), North-Caucasian Federal District (20.0%), and Privolzhskiy Federal District (19.2%).

In 2001–2018 there were 171 anthrax cases registered among people. We should note that recently ratio of morbidity among people to that among animals has changed. Thus, in the 20th century epizooties among animals didn't necessarily resulted in people getting infected; at present any registered epizooty leads to infection spread among population. Large epidemic foci that occurred during anthrax epizooties were detected in 2004 (Orenburg, 10 people), 2008 (Buryatia and Bashkortostan, 8 and 11 people respectively), 2010 (Omsk region and Dagestan, 6 people in each region), 2012 (Altai region, 6), 2016 (Yamal-Nenets Autonomous Area, 36 people). All the above-mentioned deteriorated situations were caused by recurrent activities in soil foci including those located close to old anthrax disposals (Altai region, Buryatia, and Bashkortostan) as well as close to places where a lot of animals had died prior to epidemics outbreaks (Yamal-Nenets Autonomous Area).

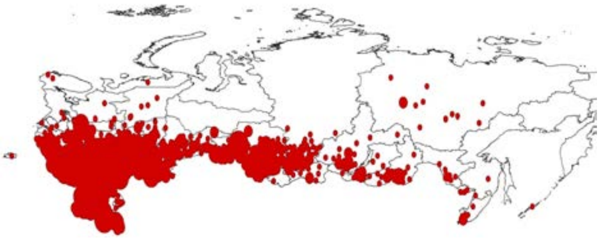


Figure 1. A map showing territorial distribution of epizootic anthrax foci in the Russian Federation in 1950–1959

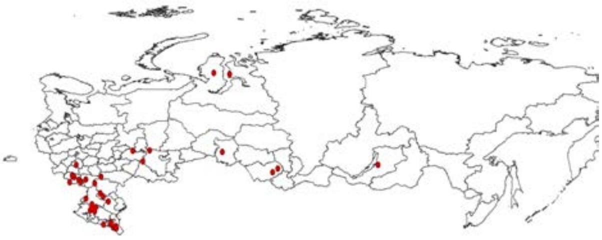


Figure 2. A map showing territorial distribution of epizootic anthrax foci in the Russian Federation in 2008–2017

Conjugated analysis of morbidity among people and animals revealed that sometimes anthrax cases among animals were detected only after anthrax had been diagnosed in people. Thus, our analysis revealed that only 46 out of total 55 epidemic foci were related to morbidity among animals. Any relation with morbidity among animals wasn't detected for 9 epidemic foci but still there were some indications that infected people had contacted either animals or animal raw materials. On one hand, it can be due to negligent surveillance over morbidity among animals; on the other hand, it can be caused by social and economic risks that led to changes in ways and factors of contagion.

To sum up, a contemporary situation with anthrax in Russia, as well as all over the world, can still deteriorate as there are risks that can cause it; such risks may result not only in epizooties but also in morbidity among population exposed to existing risk factors [16, 17]. An anthrax outbreak that occurred in 2016 on Yamal Peninsula is a good example; such outbreaks prove it is necessary to perform constant complex risk assessment. Recently GIS technologies have been widely and successfully used to solve this complicated scientific and practical task as they allow determining existing trends related to epizootic activity and tracking dynamics of changes in risk factors; consequently, such technologies enable predicting possible epizootic and epidemic complications [18].

GIS technologies allow determining territories where epizootologic and epidemiologic risks occur with geographic zones being ranked as per level of risks existing there and with identifying most significant risk factors. We performed spatial analysis of epizootic outbreaks localization and revealed that over the last 15 years unfavorable situations with anthrax have been clearly bound to zones with prevailing black soils. 58.1% anthrax outbreaks were registered exactly on such territories (Figure 3).

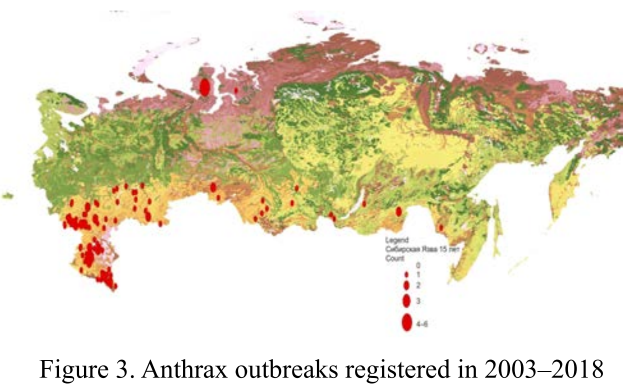


Figure 3. Anthrax outbreaks registered in 2003–2018 given on the map of Russia that shows types of soils

We analyzed how anthrax outbreaks were distributed over natural and agricultural zones and revealed that a contemporary anthrax area was predominantly located in forest-steppe, steppe, dry-steppe, and Caucasian-Crimean mountain zones. In 21st century 82% of all the registered anthrax outbreaks occurred in these four natural zones. All these territories have warm climate, animal breeding is well-developed there, and there are great numbers of cattle in private households. As is known, specific epidemiologic significance now belongs to cattle and small cattle bred in private and farmer households located on territories where the situation with anthrax is unfavorable.

As per data provided by Rosstat, in 2017 sheep accounted for the greatest specific share among agricultural animals in Russia (36.9%); pigs and cattle had the second and the third place with 34.9% and 28.2% respectively. Cattle were mostly bred by agricultural organizations (44.2%) and private households (42.4%); pigs were predominantly bred by agricultural organizations (85.6%); sheep were bred by private households (46.5%) and farmers (37.0%).

Cattle are mostly bred in Privolzhskiy Federal District (27.6%), Siberian Federal District (21.9%), Central Federal District (15.6%), Southern Federal District (12.5%), and North Caucasian Federal District (11.8%). The greatest cattle numbers are bred in Bashkortostan, Tatarstan, Dagestan, Altai region, Krasnodar region, Rostov region, and Orenburg region; all these territories are stationary unfavorable as per anthrax. Also significant numbers of cattle are bred In Novosibirsk region, Voronezh region, Bryansk region, Saratov region, Zabaikalye region, Krasnoyarsk region, and Kalmykia; there are SUPs in all these regions.

The greatest numbers of small cattle are bred in North Caucasian Federal District (40.0%), Southern Federal District (26.4%), Siberian Federal District (16.1%), and Privolzhskiy Federal District (11.0%). Leading regions in this respect are Dagestan, Kalmykia, Tyva, Karachai-Cherkess, Stavropol region, Astrakhan region, Rostov region, and Volgograd region. More than 400 thousand small cattle are bred in Bashkortostan, Altai region, Transbaikalia, and Saratov region, that is, on territories with elevated anthrax risks.

Table 1

Active anthrax-related stationary unfavorable points depending on soil types, %

Soil types	Periods during which stationary unfavorable points became active, years			
	1929–1953	1954–1978	1979–2002	2003–2017
Sod-podzol	8.3	3.9	5.4	1.4
Gray forest	12.3	4.8	7	4.1
Leached-black	14.8	14.8	25.4*	24.3*
Typical black	1.1	3.1	9.2	8.1
Ordinary black	6.5	7.9	17.1*	24.3*
Southern black	2.6	3	9.2*	1.4
Chestnut	0.2	0.4	2	2.7
Chestnut-Solonetzic	0.9	1	3.3	5.4
Others	63.3	71.1	31.4	38.3

*$p<0.001$ against 1929–1953 and 1954–1978.

If we compare boundaries of nosoareas that existed in different time periods, we can see that starting from the end of the last century territories with leached-black and ordinary black soils have become much more significant from epizootologic point of view whereas territories with gray forest soils and sod-podzol soils have become considerably less significant (Table 1).

Simultaneously, a share of zones located in mountains has grown from 2% to 16.3%. Given complicated landscapes in mountains and prevailing combinations of several different soil types there, it was difficult to exactly determine a type of soil in a zone where a SUP occurred; most probably, animals caught the disease on pastures that were predominantly located in areas with mountain black soils and mountain cinnamonic soils (Dagestan and Chechnya).

We analyzed spatial distribution of SUPs and ADs in a specific region with a GIS application on larger-scaled maps and it allowed us to examine risks in greater detail.

We chose Tatarstan as a model region for demonstrating how GIS technologies could be applied to improve epidemiologic surveillance over anthrax and to assess related risks more precisely. This region is permanently considered unfavorable from epizootologic points of view. Over the last 100 years 2,035 anthrax outbreaks have been registered in Tatarstan in 1,205 SUPs located there (3.4% out of total anthrax-related SUPs in the Russian Federation, the 7^{th} rank place in the country). At present the situation is unfavorable in 37.5% settlements located in Tatarstan (the 27^{th} rank place in the RF), and SUPs density amounts to 17.7 per 1,000 square km (the 14^{th} rank place in the RF)

In 2001–2018 epizootic activity was high in Tatarstan and occurred in 8 SUPs located in 7 municipal districts; 3 people got infected with anthrax and fell ill (Table 2).

Table 2

Active anthrax-related stationary unfavorable points in Tatarstan

District	Settlement	Active SUP				Morbidity	
		Multiplicity, times	The 1st year	The last but one year	The last year	people	animals
Tukaevskiy	Terovo village	1			2001		+
Cheremshanskiy	Chyorniy Klyuch village	2	1967	1967	2001		+
Myslyumovskiy	Tegermyanlek village	1			2002		+
Sarmanovskiy	Martysh-Tamak village	1			2003		+
Zelenodol'skiy	Kugushevo village	2	1962	1962	2003	+	+
Bavlinskiy	Isergapovo village	3	1935	1953	2008		+
Kukmorsliy	Knyabash village	2	1937	1937	2014	+	+
	Lyuga village	6	1942	1951	2014	+	+

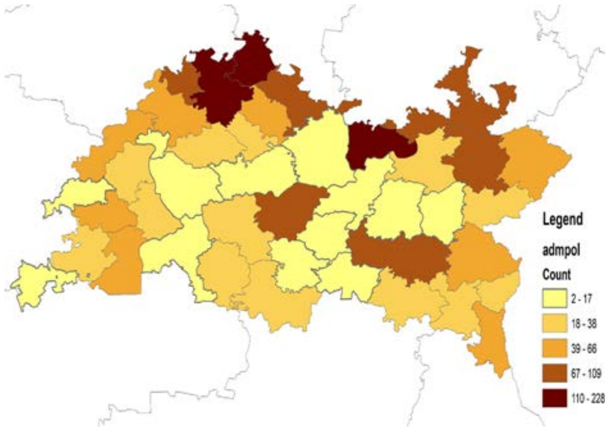


Figure 4. Territorial distribution of anthrax-related stationary unfavorable points registered in Tatarstan

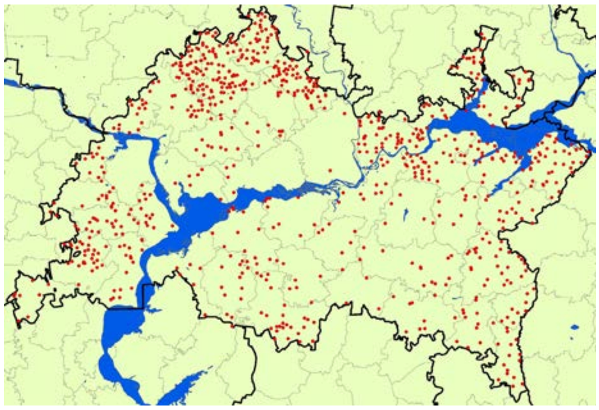


Figure 5. Anthrax disposals located in Tatarstan

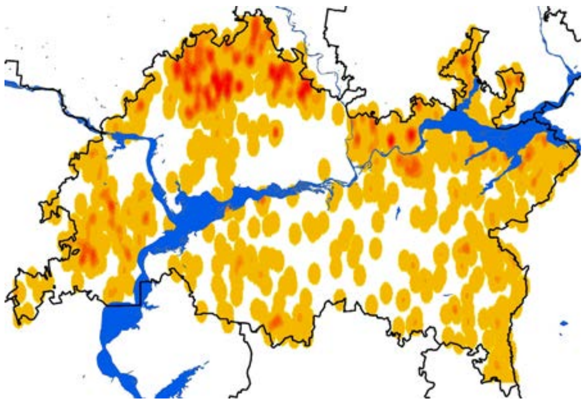


Figure 6. "Heat" map showing density of anthrax disposals in Tatarstan Zones with higher density are given in darker color; red color means the maximum density

Accomplished SUPs mapping revealed that in the 21st century the most epizootically unfavorable situation occurred in the northern and central parts of the region (Figure 4). Baltasinskiy, Elabuga, Mendeleevskiy, Al'metyevskiy, Chistopolskiy, Atninskiy, and Kukmorskiy districts as well as Naberezhnye Chelni are the most unfavorable as per SUPs density. Animal breeding is well-developed in all the above-mentioned regions, except from Baltasinksiy district and Naberezhnye Chelni. Agricultural organizations in the region, including farmers, are numerous (there can be more than 100 hundred of them in a district, for example, in Kukmorskiy district); they breed cattle and small cattle as well as pigs and horses; consequently, certain anthrax-related risks may well occur on these territories.

ADs mapping revealed that they occurred in most administrative districts in the republic (Figure 5).

However, spatial analysis didn't reveal their exact binding to SUPs that have become active over the last 20 years. All the anthrax disposals were located 1,000 meters or more away from SUPs. It can be explained via multiple anthrax soil foci that occurred in the past in places where animals died; such places were often located far from boundaries of areas where cattle were buried. At the same time, we can't neglect a possibility that there are spontaneous animal burial places that haven't been registered; such burials can contain carcasses of animals infected with anthrax as those animals died from the disease during mass epizooties that occurred in the 19th and early 20th century.

We analyzed density of risk objects location and revealed that anthrax disposals were predominantly located in districts that were close to boundaries of the region and the maximum density was observed in the northern parts (Figure 6). The results we obtained are naturally in line with SUPs distribution in the republic and correspond to places where anthrax epizooties were registered in the 20th century. Over the last 100 years animal-breeding areas located in the northern parts of the republic suffered most from anthrax epizooties (Figure 7), and it should result in them being the most contaminated with *B.anthracis* spores.

Hiowever, northern areas mostly have gray forest soils with average humus contents, whereas black soils with high humus contents

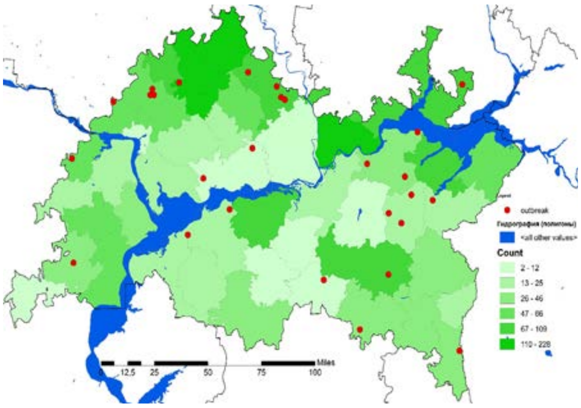
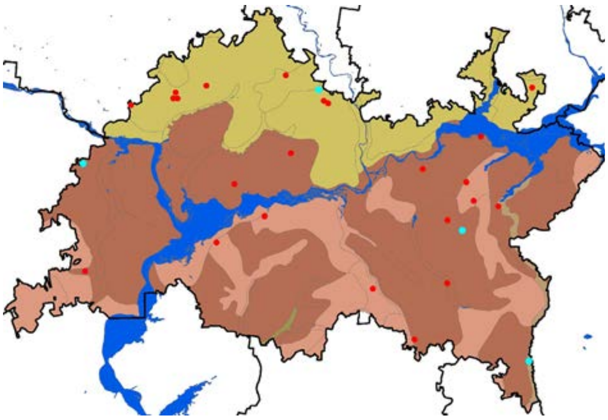


Figure 7. A map showing density of anthrax outbreaks in Tatarstan



Anthrax outbreaks from 1988 to 2002
Anthrax outbreaks after 2003

Figure 8. Territorial distribution of anthrax outbreaks in Tatarstan from 1988 to 2018 (combined with soils map)

can be found in central and southern parts of the republic (Figure 8).

Should we stick to a concept that describes formaiton of "incubation" soil zones [19, 20], than in Tatarstan we face a situation when initially maximum soil foci occurred in the north of the republic whereas the most stable soil foci should have occurred in the center and in the south of it. The existing epizootic situation is well in line with this hypothesis. Over the last 30 years anthrax outbreaks were divided in approximately even proportions between areas with bleached black soils and gray forest soils, 35% and 31% respectively.

Since 2003 there have been 4 anthrax outbreaks registered in 4 administrative districts in Tatarstan located in the north (Kukmorskiy district), west (Zelenodol'skiy district), east (Sarmanovskiy district), and southeast (Bavlinskiy district) of the republic. Unfavorable situations with anthrax were mostly (in three cases) due to recurrent activities in SUPs located in areas with back soils.

An only exception here is an outbreak that occurred in 2014 in Kukmorskiy district, a territory with high SUPs density and prevailing gray forest soils; there were several settlements involved and 2 people got infected. Epizootology might occur due to recurrent activities in soil foci that resulted in stored forages being contaminated with the infectious agent; it might also occur due to infected cattle being brought to the district from other unfavorable territories.

Conclusions. In the next decades epizootic situation as regards anthrax is going to remain the same as it is now, given the existing procedures for veterinary-sanitary surveillance activities and trends in animal breeding development in the RF. Risks that it may deteriorate are persistent due to recurrent activities in soil foci that have been inactive for a long period of time; expectation period here may amount to 40 and even more years.

As our research has revealed, there is a hazard that new anthrax outbreaks may occur in any SUP should there be any relevant risks; such risks are suitable soils as well as susceptible animals that contact potentially hazardous soils. Given that, at present the greatest epizootologic and epidemiologic risks are related to private agricultural farms and households where cattle and small cattle graze freely and most tasks are man-handled.

Data accumulated in cartographic databases allow accomplishing comprehensive spatial-time analysis of anthrax prevalence on the RF territory. Its results indicate that maximum epizootic and epidemiologic risks still tend to occur on areas with black soils. But still, other soil types, especially gray forest soils and chestnut soils, are still significant form epizootologic point of view in some regions, including Tatarstan.

At present application of GIS technologies in surveillance over anthrax is an integral component in epidemic diagnostics as it allows establishing dynamics in soil foci activity, putting forward hypotheses on causes and conditions of epizootic and epidemiologic processes as well as ranking regions in the country as per potential epizootic and epidemiologic risks.

It is necessary to integrate data on stationary unfavorable points and anthrax disposals with cartographic grounds for administrative-territorial division and natural and agricultural zoning basing on GIS applications; it is a significant step in improving risks prediction and providing information support for decision making in the sphere of surveillance and control over anthrax in the Russian Federation.

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Conflict of interests. The authors declare there is no any conflict of interests..

References

1. Cherkasskii B.L. Epidemiologiya i profilaktika sibirskoi yazvy [Anthrax: epidemiology and prevention]. Moscow, Intersen Publ., 2002, 384 p. (in Russian).

2. Onishchenko G.G., Darmov I.V., Vasil'ev N.T., Kirillov I.A., Kikot' S.G., Borisevich S.V., Tumanov A.S., Bakulin M.K. [et al.] Sibirskaya yazva: aktual'nye problem razrabotki i vnedreniya meditsinskikh sredstv zashchity [Anthrax: vital issues related to development and implementation of medical protection]. In: G.G. Onishchenko, I.V. Darmov, S.V. Borisevich eds. 2-nd edition. Sergiev Posad, 2018, 591 p. (in Russian).

3. Makarov V.V. Anthrax in the early 21st century. *Veterinariya*, 2017, no. 1, pp. 3–8 (in Russian).

4. Popova A.Yu., Ezhlova E.B., Demina Yu.V., Kulichenko A.N., Ryazanova A.G., Buravtseva N.P., Eremenko E.I., Dyatlov I.A. [et al.]. Ways to improve the epidemiological surveillance and control of anthrax in the Russian Federation. *Problemy osobo opasnykh infektsii*, 2017, no. 1, pp. 84–88 (in Russian).

5. Clarke K.C., McLafferty S.L., Tempalski B.J. On epidemiology and geographic information systems: a review and discussion of future directions. *Emerg. Infect. Dis.*, 1996, no. 2, pp. 85–92. DOI: 10.3201/eid0202.960202

6. Curtis A.C., Blackburn J.K., Sansyzbayev Y. Using a geographic information system to spatially investigate infectious disease. In: M. Tibayrenc ed. *Encyclopedia of infectious diseases: modern methodologies*, London, John Wiley & Sons, Inc. Publ., Hoboken, New Jersey, 2007, 800 p.

7. Blackburn J.K. Integrating Geographic Information Systems and Ecological Niche Modeling into Disease Ecology: A Case Study of Bacillus anthracis in the United States and Mexico. *Emerging and Endemic Pathogens: Conference proceedings. Part of the NATO Science for Peace and Security Series A: Chemistry and Biology*. Dordrecht, Springer, 2010, pp. 59–88. DOI: 10.1007/978-90-481-9637-1_7

8. Simonova E.G., Kartavaya S.A., Titkov A.V., Loktionova M.N., Raichich S.R., Tolpin V.A., Lupyan E.A., Platonov A.E. Anthrax in the territory of Yamal: assessment of epizootiological and epidemiological risks. *Problemy osobo opasnykh infektsii,* 2017, no. 1, pp. 89–93 (in Russian). DOI: 10.21055/0370-1069-2017-1-89-93

9. Selyaninov Yu.O., Egorova I.Yu., Kolbasov D.V., Listishenko A.A. Anthrax in Yamal: reemergence causes and diagnostic issues. *Veterinariya*, 2016, no. 10, pp. 3–7(in Russian).

10. Simonova E.G., Raichich S.R., Kartavaya S.A., Loktionova M.N., Shabeikin A.A. Manifestation of Activity of Potentially Hazardous as regards Anthrax Areas across the Russian Federation under Current Conditions. *Problemy osobo opasnykh infektsii,* 2018, no. 2, pp. 90–94 (in Russian).

11. Marinin L.I., Dyatlov I.A., Shishkova N.A., Gerasimov V.N. Sibireyazvennye skotomogil'niki: problem i resheniya [Burial grounds of cattle that contain anthrax: problems and solution to them]. Moscow, Dinastiya Publ., 2017, 216 p. (in Russian).

12. Kadastr statsionarno neblagopoluchnykh po sibirskoiy azve punktov Rossiiskoi Federatsii [The cadastre of territories in the RF that are stationary unfavorable in terms of anthrax]. In: B.L. Cherkasskii ed. Moscow, 2005, 829 p. (in Russian).

13. Pokrovskii V.I., Onishchenko G.G., Cherkasskii B.L. Evolyutsiya infektsionnykh boleznei v Rossii v XX veke [Evolution of infectious diseases in Russia in the 20th century]. Moscow, Meditsina Publ., 2003, 589 p. (inRussian).

14. Eremenko E.I., Ryazanova A.G., Buravtseva N.P., Tsygankova O.I., Aksenova L.Yu. [et al.]. Evaluation of Anthrax Morbidity Rate in 2012, Prognosis for 2013. *Problemy osobo opasnykh infektsii*, 2013, no. 1, pp. 18–21 (in Russian).

15. Ryazanova A.G., Ezhlova E.B., Pakskina N.D., Semenova O.V., Aksenova L.Y., Eremenko E.I., Buravtseva N.P., Golovinskaya T.M. [et al.]. Epidemiological Situation on Anthrax in 2018, the Forecast for 2019. *Problemy osobo opasnykh infektsii*, 2019, no. 1, pp. 98–102 (in Russian). DOI: 10.21055/0370-1069-2019-1-98-102

16. Schmid G., Kaufmann A. Anthrax in Europe: its epidemiology, clinical characteristics, and role in bioterrorism. *Clin. Microbiol. Infect*, 2002, no. 8, pp. 479–488. DOI: 10.1046/j.1469-0691.2002.00500.x

17. Anthrax in humans and animals. Fourth edition. P. Turnbull ed. Geneva, World Health Organization, 2008, pp. 89–100. Available at: https://www.who.int/csr/resources/publications/anthrax_webs.pdf (03.03.2019).

18. Blackburn J.K., McNyset K.M., Hugh-Jones M.E., Curtis A. Modeling the geographic distribution of Bacillus anthracis, the causative agent of anthrax disease, for the contiguous United States using predictive ecological niche modeling.*Am. J. Trop. Med. Hyg.*, 2007, vol. 77, pp. 1103–1110. DOI: 10.4269/ajtmh.16-0758

19. Van Ness G.B. Ecology of anthrax. *Science*, 1971, vol. 172, no. 3990, pp. 1303–1307. DOI: 10.1126/science.172.3990.1303

20. Helgason E., Okstad O.A., Caugant D.A., Johansen H.A., Fouet A., Mock M., Hegna I., Kolsto A.B. Bacillus anthracis, Bacillus cereus, and Bacillus thuringiensis – one species on the basis of genetic evidence. *Applied and Environmental Microbiology*, 2000, vol. 66, pp. 2627–2630. DOI: 10.1128/aem.66.6.2627-2630.2000

Simonova E.G., Shabeikin A.A., Raichich S.R., Loktionova M.N., Saburova S.A., Patyashina M.A., Ladnyi V.I., Gulyukin A.M. Geoinformation technologies for assessing epizootologic and epidemiologic situation with anthrax. Health Risk Analysis, 2019, no. 3, pp. 74–82. DOI: 10.21668/health.risk/2019.3.09.eng

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