LOGICAL-LINGUISTIC MODEL OF ANTHRAX EPIZOOTIC MONITORING IN FAR NORTH

Kasim Laishev[1], Aleksandr Spesivtsev[2], Aleksandr Prokudin[3], Nelya Domshenko[4]
[1]North-West Centre of Interdisciplinary Researches of Problems of Food Maintenance, Russia;
[2]A.F.Mozhaisky Military Space Engineering Academy, Russia; [3]Scientific Research Institute of Agriculture and Ecology of the Arctic, Russia; [4]Saint Petersburg State University, Russia
layshev@mail.ru, sav2050@gmail.com

Abstract. According to veterinary statistics, the territory of the Taimyr region has 39 registered areas with an epizootic epidemic of anthrax fever. Anthrax is a potentially dangerous infect1ious disease for both animals and humans. The spores of the causative agent of anthrax retain their viability and pathogenicity for 50-70 years or more. Therefore, many old foci of anthrax infection ("epizooty sites") are potentially dangerous at the present time. In connection with the intensive industrial development of the Far North regions, leading to excavation in high-risk areas for anthrax, there is a need to predict the possibility of occurrence and prevention of infection in these areas. A logical-linguistic model for estimating the probability of occurrence of anthrax infection in the five-dimensional factor space has been constructed on the basis of expert knowledge, which makes it possible to carry out epizootic monitoring in a quantitative form. The results of the prognostic estimation have shown that the probability of anthrax occurrence on this territory under all favorable conditions for the development of an anthrax process without preventive measures is likely to be high and accounts for 0.484, however, under the same conditions with preventive measures it amounts to 0.287. The implementation of preventive measures reduces the risk of anthrax occurrence twice. A computerized automated system for assessing the territory of the Taimyr Municipal District has been developed in terms of the risk of anthrax outbreaks on the basis of the constructed logical-linguistic model in the five-dimensional space of fuzzy variables. This makes it possible to optimize the system of epizootic surveillance for this disease

Key words: anthrax, monitoring, logical-linguistic model.

Introduction

The research conducted by veterinary specialists shows that anthrax infection takes a special place among potentially dangerous infectious diseases of both animals and people [1; 2].

According to the veterinary statistics of the Far North Agriculture Research Institute the territory of the Taimyr region has 39 registered areas with anthrax pesthole epizooty.

Anthrax is a potentially dangerous infectious disease. This disease affects both domestic animals of different species and people The incidence of the disease poses a serious danger to herds of migrating animals, especially for reindeer [3; 4].

Experts who study anthrax are in a difficult situation, when it is necessary to make a prediction of the likelihood of its occurrence, especially in the period of intensive development of the depths of the Far North. The absence of mathematical models of epizootic anthrax leads to the need to use expert knowledge to solve similar problems. At present, a method of constructing logical-linguistic models [5; 6], including veterinary medicine [7], has been developed and is being applied in various fields. An example of the application of logical-linguistic modeling in agriculture is given in the study [8].

Most epizootic monitoring problems must be addressed at uncertainty of the initial information, including the structure of prognostic models for a particular anthrax pesthole. Probabilistic information is widely used in epizootic studies since many prognostic problems are solved using statistical methods. For example, the efficacy of vaccine agents is determined by a set of statistics in different regions. The least "accurate" information is considered oral (incorrect, qualitative), but in most cases it is the only existing epizootic monitoring in practice, especially in predicting the evolution of a new agent of the disease.

The knowledge of information to solve specific problems can be determined by three factors:

- complexity of the evolutionary structure of the epizootic process as a target of research;
- incompetence of cognition of the state of an epizootic process on a separate site and in general, which is due to the lack of certainty of our knowledge;

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- uncertainty of the situation, which is due to the lack of accurate data on the boundaries of the epizootic areas, the probability of grazing deer and their abundance and characteristic of most of the verbal concepts of our language [5; 6].

Along with difficulties in constructing predictive models, it is necessary to take into account their economic and, in particular, ecological significance: although complete disinfection of anthrax pesthole is technically and economically feasible, disinfection of the site involves the destruction of any biological species, which leads to an ecological catastrophe for this area.

Sick animals are a source of an anthrax infection agent, there are microbes in their secretions, which get into the environment and give rise to the incidence of the disease.

The main agents of the infection are the carcasses of dead animals. Numerous studies have shown that an anthrax substance, in the form of a spore in the soil is able to maintain viability and pathogenicity for more than 50 to 70 years. Consequently, many old centers of anthrax infection are potentially dangerous. Anthrax epizooty was recorded among domestic deer in the "Popigaysky" (1969) and "Oktyabrsky" (1977) settlements after grazing in the areas where the carcasses were buried [4; 7].

The danger of infection spread is related to the fact that the largest number of northern wild reindeer called "Taimirsky" inhabits a vast territory of the Far North. A large number of animals and permanent migrations in the spring and summer, summer and autumn periods increase an incidence of anthrax. Meteorological, landscape and soil factors have a great influence on the occurrence and development of epizootics of anthrax. In most cases, outbreaks and rapid spread of the disease tend to occur in hot weather, localize the river, while the survival of the spore depends largely on the chemical composition of the soil. Intensive industrial development of the natural resources of the Far North leads to technogenic factors of infection with anthrax. Intensive work of excavation in potentially dangerous regions spreads the infection to another region. In addition, anthrax infection can penetrate into the susceptible body of animals [3]. That is why it is absolutely necessary to carry out epizootological and microbiological studies and predict the possibility of the occurrence and prevention of infection in regions with extensive earthwork [4; 7].

The main purpose of this article is to demonstrate the application of a logical-linguistic model built on the basis of expert knowledge to make an informed decision about the probability of anthrax and prognosis in conditions of changing the situation in a specific area of the area where the reindeer pastures are located.

Methods and materials

Modern decision theory has a number of methods that enable to formalize the decision-making process by several criteria interacting in a fuzzy environment [5; 6]. This method is based on the theory of fuzzy sets and experimental design.

Developing the theory of fuzzy sets, Zadeh [9] introduced a concept of a linguistic variable, which makes it possible to present an approximate verbal description of objects and phenomena provided that there is no definite description or it is absolutely impossible.

With regard to epizootic processes, the linguistic variable "presence of infectious agents" can be represented as: no agents, the average number, the maximum number of infectious agents [6].

A variable qualitative code can be encoded in the form of a linguistic variable Y – the probability of manifestation of anthrax is shown in Fig. 1.

The linguistic variabale makes it possible to translate verbal expert knowledge (the upper scale along the abscissa axis) into numerical (lower scale) for each particular variable, and the ordinate function is the membership function to the corresponding term sets, to which the range of oscillations of the variable is divided [5; 6].

Let us consider a specific example of the application of linguistic variable for decision making in a fuzzy environment. Suppose that there is expert knowledge about the evolution of the epizootic process, under equal conditions, there are agents that affect the evolution of the infectious disease. This knowledge can be represented in the form of a fuzzy production rule (PR): "If the quantity of infection agents is big, then the degree of evolution of the epizootic process is high". All that goes after `if is called a premise, a product, a condition, after `then` - a conclusion, an operation. If we design a polling matrix in a certain way as a set of production rules, we can obtain a polynomial analytical expression in accordance with the methods of the experimental design theory [5; 6].

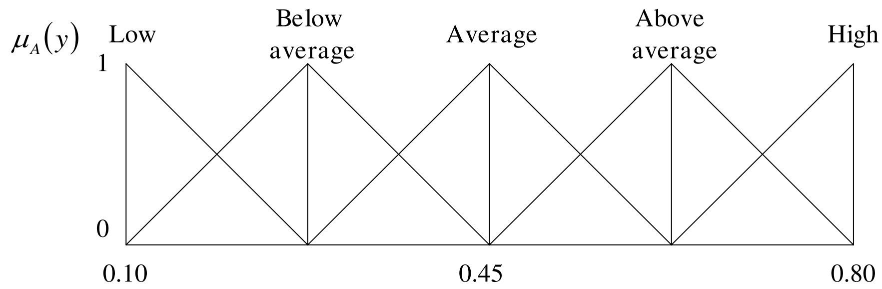

Fig.1. **Y as linguistic variable**

It is preferable to build fuzzy models in the form of polynomial expressions in order to describe the technical state of a complex object, which functions in a multidimensional space of fuzzy variables At the same time structuring the internal logic of a set of PR is achieved by using methods of the experimental design theory (EDT) [6]. EDT structures the set of production rules in the form of special polling tables.

The questionnaire matrix with its internal structure of implicative production rules in a system space determines the way of thinking making to think systemically thus ordering the expert knowledge.

Quotient space with the dependent variable has a clear physical meaning and can easily be interpreted in a natural language of a particular field of knowledge. The significant polynomial coefficients are obtained form an analytical expression for the calculation of quantitative estimations of the generalized indicator of the system for known values of the dependent variables.

As the number of input variables, which can be operated by the expert, is limited 7±2 [10], they if possible, should be “very intensive,” i.e. generalized. The concept of a generalized variable is rather subjective and depends, in our opinion, on the level of decision-making. For example, for the researcher and the decision maker of high-level, the degree of generalization of the same information about the course of the process is quite different [6].

Thus, a necessary condition for extraction of expert knowledge from the depths of his subconscious mind, where his experience and intuition are stored, is such technology of the expert survey, which does not require his additional knowledge or conditions. In other words, it is necessary to create a technology with “correctly specified” questions, so that the expert will reveal his intelligence. For example, asking an expert about the weight coefficients of significant variables, we deliberately restrict the scope of access to the implicit function of expert knowledge (experience, intuition by predetermining the linearized function of response, even if the phenomenon under investigation is certainly nonlinear).

The use of the above-mentioned methods of solving the problem of extraction and formalization of expert knowledge makes it possible for the expert to effectively fulfill himself as “intelligent measurement and diagnostic system,” bearing the responsibility for realizing the obtained model because he and only he is the author of the intellectual product.

Let us consider the application of the given methods for modelling probability of an epizootic situation with anthrax in the zone of gas extractive deposits.

One of the paramount tasks in the expert`s work is determination of the factor`s space, in which this model is going to be constructed [5; 6]. For forecasting the epizootic situation with the anthrax center the expert chose five factors in the form of input linguistic variables. The variables are coded as follows: X_1 – soil quality; X_2 – technogenic impact; X_3 – preventive measures; X_4 – temperature of the summer period; X_5 – the availability of additional carriers.

It should be noted that the model has been constructed in consideration of the anthrax pesthole on the given territory.

The fragment of the polling matrix with expert estimates is shown in Table 1.

For example, row 18 of the matrix is presented in the following way: if the quality of the soil (X_1) is *good* and both technogenic influence (X_2) and preventive measures (X_3) are *low*, the temperature of the summer period is *low* (X_4) and the availability of additional carriers is *high*, the probability of evolution of an epizootic situation between variables is *low-below average*.

Table 1

Fragment of the polling matrix with expert estimates

Number p/n	Quality of soil	Technogenic influence	Preventive measures	Temperature of the summer period	Availability of additional carriers	Probability of manifestation of anthrax
	X_1	X_2	$X3$	X_4	X_5	Y
…	…	…	…	…	…	…
15	Low	High	High	High	Low	Below average to average
16	High	High	High	High	Low	Average
17	Low	Low	Low	Low	High	Below average
18	High	Low	Low	Low	High	Low to below average
…	…	…	…	…	…	…

The construction of the polling matrix, the processing of the results of the expert's survey and the corresponding assessment were carried out in accordance with the developed methodology [5].

The resulting analytical expression takes the form:

$$Y = 0.2906 + 0.0219\, x_1 + 0.0438\, x_2 + 0.0937\, x_3 + 0.0160\, x_4 + 0.0187\, x_5 +$$
$$+ 0.0094\, x_2 x_3 - 0.0063\, x_2 x_4 - 0.0156\, x_2 x_5 + 0.0063\, x_3 x_4 + 0.0063\, x_4 x_5$$

Only important coefficients are presented in the analytical expression.

Results and discussion

It should be noted that according to the model obtained the coefficients reflect the experience and knowledge of the expert and fundamentally differ from the coefficients of the conventional regression model that describes the initial data sample [5; 6].

The presented method makes it possible to compare the degree of influence of various factors on the evolution of the anthrax epizootic process by the value of dimensionless coefficients at unknown variables both by the value and the direction of their influence on the phenomenon studied.

It has been found that the availability of preventive measures (X_3) and additional carriers (X_5), and technogenic influence (X_2) has the most considerable influence (negative or positive) on the epizootic situation with the registered anthrax on a particular territory.

The quality of the soil and the temperature refer to the second category. Cumulative action of several factors is commensurable to a degree of influence with linear factors.

Considering possible evolution of an infectious process we quote the following variants (Table 2).

Table 2

Variants of possible evolution of an infectious process

Epizooty conditions	X_1	X_2	X_3	X_4	X_5	Y
	Quality of soil	Technogenic influence	Preventive measures	Temperature of a summer period	Availability of additional carriers	Degree of evolution of the epizootic process
Favourable	good	earth work is carried out	are not taken	24 ºC	a lot	0.484.
Unfavourable	poor	no earth work	are taken	0 ºC	a few	0.096
Favourable with preventive measures	good	earth work is performed	are taken	24 ºC	a lot	0.287

Thus, the results of the prognostic estimation have shown that the probability of anthrax occurrence on this territory under all favorable conditions for the development of an anthrax process without preventive measures is likely to be high and accounts for 0.484, however, under the same conditions with preventive measures it amounts to 0.287. The implementation of preventive measures reduces the risk of anthrax occurrence twofold.

Conclusions

1. A logical-linguistic model for estimating the likelihood of an epizootic situation in a certain area of intensive industrial development in the Far North regions with a registered anthrax was constructed on the basis of expert knowledge, which made it possible to quantify and evaluate the effectiveness of the use of preventive measures by reducing the occurrence of anthrax by more than 1.5 times.
2. A computerized automated system for assessing the territory of the Taimyr Municipal District has been developed in terms of the risk of anthrax outbreaks on the basis of the constructed logical-linguistic model in the five-dimensional space of fuzzy variables. This makes it possible to optimize the system of epizootic surveillance for this disease.
3. The method of constructing logical-linguistic models is universal and allows one to obtain analytical expressions for weakly structured systems under conditions of significant uncertainty, which include almost all agricultural technologies and objects.

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