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METHODOLOGICAL APPROACHES TO ASSESSING ECONOMIC EFFECTS OF ACTIVITIES AIMED AT MINIMIZING HEALTH RISKS RELATED TO EXTREMELY DANGEROUS INFECTIONS

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As we assess health risks caused by extremely dangerous infections, we can apply mathematical modeling to estimate a disease or a death case probability. This mathematical modeling describes epidemiological processes and allows to imitate their development without performing any anti-epidemic activities. Parameters which quantitatively assess morbidity and mortality cases obtained via this modeling together with actual data on losses which were not prevented even if anti-epidemic activities were in place, can be used as grounds for economic effects assessment. An economic effect of anti-epidemic activities was calculated in terms of indirect prevented losses which became possible due to decrease in mortality and morbidity; the effect was calculated in money units which were applied in the GDP calculation.

The calculation is performed in full conformity with 'The Methodology for calculating economic losses caused by population mortality, morbidity, and disability" (Moscow, 2012) and envisages assessment of losses in the current year and over a period of survival (for death cases).

The methodology was tested on the example of Ebola fever outbreak in Guinea in 2014-2016. The testing results revealed that if not for anti-epidemic activities which included substantial assistance rendered by other countries (the RF among them), a number of morbidity cases caused by Ebola virus would have reached 521,289, and a number of death cases, 56,345.

The RF Rospotrebnadzor made a significant contribution into Ebola fever outbreak elimination in Guinea; it sent a special anti-epidemic team there in August 2014. The team participated in diagnostic procedures, staff training, and anti-epidemic activities organization. Risk prevented due to assistance rendered by other countries, including the RF, amounted to 517,485 morbidity cases, and 53,809 death cases. Economic effects for Guinea achieved due to anti-epidemic activities aimed at risk minimization with the help of other countries is estimated to be equal to 229.51 million USD; it amounts to approximately 3.5% of Guinea GDP.

Key words: *risk assessment, economic effect, modeling, risk minimization, extremely dangerous infections, anti-epidemic activities, Ebola virus.*

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The global practice conventionally refers diseases which can cause an emergency sanitary and epidemiological situation of international concern, according to WHO International Health Regulations (IHR-2005)[1] to extremely dangerous infections (EDI). These infections are characterized by high contagiousness, have rapid epidemic spreading to large populations and /or can cause severe or persistent individual health disorders with a high probability of death in a short period since having been infected, or a long-term loss of ability to work, and disability of those who have recovered.

To reduce threats due to EDI, it is necessary to take preventive and anti-epidemic measures with an assessment of their outcome and effectiveness. Ap-proaches are known when, in assessing the effect of vaccine prophylaxis, the difference in incidence rates in vaccinated and unvaccinated groups was used as estimating parameters [3, 6].

In planning such measures, an assessment of their economic effect is getting ever higher relevance. At the same time, it is advisable to consider the prevented risk to public health as an effect of anti-epidemic activities [1, 5]. However, the approaches to assess this effect using risk criteria that allows for quantification of the avoided losses caused by EDI, and their economic evaluation have been poorly developed by now, both in the world and in Russia, since no 'risk' application found in EDI analysis.

When analyzing health risk caused by EDI, mathematical modeling of epidemiological process can be used to assess disease and death probability, allowing to simulate its development at no anti-epidemic activities in place, with quantification of morbidity and mortality cases [4, 10, 14, 17, 20]. Such information, together with the actual data on non-prevented losses, even in the context of measures to stop epidemy, can be used as a basis for assessing the economic effect of anti-epidemic activities and, accordingly, to improve planning of future measures to counter EDI and their trans-border spreading.

It was considered relevant to test these approaches using the example of a disease caused by Ebola virus (EVD). The largest outbreak in the history of this infection was registered in 2014-2016 in three countries of West Africa (the Republic of Guinea, Liberia and Sierra Leone). The disease not only caused significant economic damage, but also became a serious threat to biological safety throughout the world.

The target of the work is to develop methodological approaches to assessing economic effects of activities to minimize health risks associated with especially dangerous infections, and test these methods using the example of EVD epidemic abortion in the Republic of Guinea.

Materials and methods. To develop methodological approaches, we studied 143 references to especially dangerous infections. We used search platforms (Pubmed, elibrary.ru). The average actual data on morbidity, mortality, population was obtained from open sources, such as the WHO website (http://www.who.int/en/), Pubmed (https://www.ncbi.nlm.nih.gov

[1] International Health Regulations (2005). 3rd ed. World Health Organization, 2016, 92 p. Available at: http://www.who.int/ihr/publications/9789241580496/ru/ (12.06.2017).

/pubmed/). Economic data were obtained from official sources, such as the World Bank website (http://www.worldbank.org/), the UN database (http://data.un.org), the WHO website (http://www.who.int).

To simulate epidemic development without healthcare delivery, mathematical SEIHFR model was used, which describes quite fully the course of the disease [9].

The economic effect of anti-epidemic activities was calculated in terms of indirect prevented losses from reducing mortality and morbidity cases in monetary units of GDP. The calculation was carried out in accordance with 'The Methodology for calculating economic losses caused by population mortality, morbidity, and disability" (Moscow, 2012) approved by the Order of the Ministry of Economic Development, Ministry of Healthcare and Social Development, Ministry of Finance and Rosstat of April 10, 2012 No. 192/323n / 45n / 113[2], taking into account the assessment of losses in the current year and survival period (for deaths cases). Evaluation of the effect in monetary terms makes it possible to calculate the economic effectiveness of such activities to reduce risks to population life and health from EDI.

When developing methodological approaches to assess economic effect of activities to minimize health risks associated with especially dangerous infections, the following provisions were taken into account:

1) assessment of morbidity and mortality risks associated with especially dangerous infections, without actions aimed at reducing it, is based on the results of mathematical modeling of the epidemic process;

2) assessment of morbidity and mortality risks associated with especially dangerous infections, when taking actions to reduce it, is based on evidence;

3) difference between the forecasted risk without actions and actual evidence data is considered as risk prevented in result of anti-epidemic activities.

The suggested methodical approaches include:

1) assessment of potential risks of morbidity and mortality due to EDI in case of epidemic natural spread using mathematical modeling;

2) analysis of actual evidence data on morbidity and mortality due to EDI;

3) assessment of prevented risks as a difference between potential risk and actual data;

4) economic assessment of prevented risk as an effect of anti-epidemic activities.

To calculate quantitative indicators of potential risks of morbidity and mortality due to especially dangerous infection, we suggest using mathematical models such as SEIR, SEIHFR for Ebola, SIR for HIV infection, etc. [14–16].

For such models, the key classes are:

- the number of susceptible individuals at risk at a time t;

- the number of infected individuals able to spread the disease at a time t;

- the number of individuals who left the previous class as a result of recovery or death, at a time t.

The given models can be implemented

[2] Methodology for calculating economic losses from mortality, morbidity and disability of the population / approved Order of the Ministry of Economic Development, the Ministry of Health and Social Development, the Ministry of Finance and Rosstat № 192/323н/45н/113 from 10 April 2012, 12 p. Available at: https://rg.ru/pril/73/43/77/23983_metodologiia.pdf (12.06.2017).

using MATLAB application package.

The analysis of actual data on morbidity and mortality due to EDI is made using information from open sources, for example, the World Health Organization website, the PubMed library, the databases of the Centers for Disease Control, and others.

When assessing the preventable risk as the difference between potential risk and actual data on morbidity and mortality, it should be borne in mind that in some cases the incidence in the presence of effective anti-epidemic activities may be higher due to greater detectability of an infection. At the same time, mortality as a result of anti-epidemic activities is usually reduced, due to early detection of a disease and timely assistance.

For economic evaluation of activities effect (or participation in similar activities) aimed at reducing health risk to the country's population, a scenario approach is envisaged. Scenarios of epidemic process natural development without anti-epidemic activities ("inaction model"), providing for the full realization of EDI morbidity and mortality due to this infection, and a scenario in which such a risk not being fully realized, owing to anti-epidemic activities ("actual").

Prevented losses in monetary terms (the prevented losses of the country's GDP) due to mortality and morbidity reduction are estimated as the difference between losses in monetary terms under "inaction model" and actual losses in monetary terms:

$$PEL = EL_{"IM"} - EL_{actual},$$

where PEL – prevented economic losses (effect of anti-epidemic activities);

EL"IM": economic losses under "inaction model" (losses due to EDI morbidity and mortality in population, without activities and expenditures for anti-epidemic activities);

ELactual: actual economic losses (losses due to population mortality and morbidity due to EDI).

Economic losses (for any scenario) are made up of economic losses from mortality and morbidity:

$$EL_j = ELM_j + ELL_j,$$

where EL_j – economic losses due to EDI related to mortality and morbidity of the population under scenario j (actual, "inaction model");ЭПЗ$_j$ – экономические потери от заболеваемости населения по сценарию *j* (факт, «модель бездействия»);

ELM_j – economic losses due to the population morbidity under scenario j (actual, "inaction model");

ELL_j: economic losses due to the population lethality under scenario j (actual, "inaction model").

Economic losses due to morbidity of the population as an effect of EDI for the year are calculated by the formula:

$$ELMj = ADMEj \cdot NMEj \cdot \frac{GDP}{365 \cdot NE}$$

where $ADME_j$ – the average duration of a morbid event among the working-age population according to scenario j (actual, "inaction model");

NME_j – the number of morbid events among the working-age population according to scenario j (actual, "inaction model");

GDP – the country's gross domestic product in the reporting year;

NE – number of employed in the country in the reporting year.

Economic losses as a result of mortality of the working-age population of the country where EDI has occurred for the year are calculated by the formula:

$$ELM_j = NDC_j \cdot \frac{GDP}{NE} \cdot \left(0{,}5 + \sum_{i}^{70} LE_i \cdot p_i \right),$$

where NDC_j – the number of death cases among the population according to scenario j (actual, "inaction model");

LE_i – the level of employment in the country in the reporting year;

p_i – probability of survival from age x-1 to age x in the country under study.

0,5 – coefficient that takes into account the time of deaths distribution during a year (used only for the working-age population).

The proposed methodological approaches were tried out on the example of assessing the effectiveness of measures to stop the outbreak caused by Ebola virus (EVD) in the Republic of Guinea in 2013–2016.

In calculating quantitative indicators of the potential morbidity and mortality risks due to EVD in the Republic of Guinea, SEIHFR model was used, which includes the following variables:

- S(t) is the number of susceptible individuals at risk at a time t;
- E(t) is the number of individuals with the disease in incubation period, at a time t;
- I(t) is the number of infected individuals able to spread the disease at a time t;
- H(t) is the number of individuals who were hospitalized, at the moment of a time t;
- F(t) is the number of individuals who died at a time t;
- R(t) is the number of individuals who dropped out of the previous class as a result of recovery or death at a time t

Study results and discussion. Using the parameters obtained by reviewing the sources data [6,7,13,15] (Table 1) has

Table 1

Parameters applicable to mathematical SEIHFR model for EVD in the Republic of Guinea, for 2013–2016

Parameters	Parameter value
Social contact speed, people in contact with 1 in-fected	1,4
Contact speed in hospital, people in contact with 1 in-fected	0,4
Contact speed at funeral, people in contact with 1 in-fected	0,5
Incubation period, days	12,7
Time prior hospitalization, days	3,24
Time from hospitalization to death, days	5,0
Duration of traditional funeral, days	4,5
Duration of infection, days	15,00
Time from infection to death, days	13,31
Time from hospitalization to recovery, days	15,88
Probability of hospitalization	0,197
Mortality rate, not hospitalized	0,6
Average duration of Ebola fever morbid case, days	21
Patient mortality rate, hospitalized	0,4

shown that, based on the simulation results for the entire period of the epidemic in the Republic of Guinea in 2013-2016, 521,289 people could have been infected, 56,545 would have died. At the same time, as noted in the scientific literature, it should be taken into account that modeling due to inevitable simplification of the process under study, impossibility to consider its real characteristics under specific conditions, etc., cannot assure that the results obtained in this way reflect absolutely accurately the development patterns of a real epidemic process, which is probably reflected in the modeling of lethality [2,7]. When reviewing actual data on morbidity and mortality due to EVD, we established that the incidence rate of the diseases (NME) with Ebola fever for the entire period was 3,804 cases, and the frequency of deaths from Ebola fever for the whole period was 2,536 people[3].

Using the data obtained from modeling (forecasted risk) and the actual data (realized risk) on morbidity and mortality, we assessed the prevented risk. It was established that, provided the third countries assistance (including Russian Federation), 517,485 cases of infection with Ebola, and 53,809 lethal cases were prevented in the Republic of Guinea [2.7]. The data obtained were used to calculate the economic effect of activities to minimize health risks.

For the purpose of economic assessment for prevented risks as an effect of anti-epidemic activities, in addition to the values shown in Table 1, we also used the medical-demographic and economic parameters shown in Table 2.

Table 2

Medical-demographic and economic parameters to assess economic effects of anti-epidemic activities to stop Ebola outbreak in Guinea, in 2014–2016

Parameters	Parameter value
Population, people	13 247 808
NE, million people	6,138[4]
GDP, billion dollars	6,579[3]
NME of Ebola fever for the entire period (actual), morbid cases	3 804
NME of Ebola fever for the entire period (under "inaction model"), morbid cases	521 289
Average duration of Ebola fever morbid event (actual), days	15
Proportion of children / adults among the infected, %	20/80
NDC due to Ebola fever for the entire period (actual), people	2 536
NDC due to Ebola fever for the entire period (under "inaction model"), people	56 345

Different research groups studied the economic aspects of Ebola fever spreading in African countries:

♦ The World Bank Group reports (2014, 2015) contain data on the short-term GDP losses in West Africa from 2.2 to 7.4 billion dollars (2014); medium-

[3] UNData: A World of information. Available at: http://data.un.org (13.06.2017).
[4] Central Intelligence Agency. Available at: www.cia.gov (13.06.2017).

term losses are estimated at 1.6 to 25.2 billion dollars (depending on epidemic scenario) [12,20];

♦ The studies by The United Nations Development Group in West and Central Africa contain information on the average forecasted losses in GDP, in 2014-2017, in Guinea at 184.4 million dollars annually, 187.7 million dollars in Liberia, from 219 million to 286 million dollars in Sierra Leone (depending on the scenario) [8,18,19];

♦ According to the US Centers for Disease Control and Prevention, "2.2 billion dollars was the loss of GDP in Guinea, Liberia and Sierra Leone in 2015, posing a threat not only to macroeconomic stability, but also to the food security, human capital development and growth in the private sector"[11].

These studies considered both the direct and indirect losses from reduction of the country's labor resources. In all cases, a prerequisite for economic evaluation is the scenario analysis of events progress.

The prevented economic losses of Guinea's GDP due to morbidity, and effectiveness of anti-epidemic activities amounted to 25.5 million dollars and the prevented economic losses of Guinea's GDP from mortality: 204.01 million dollars. Thus, the effect of anti-epidemic activities amounted to 229.51 million dollars.

The effect reflects the prevented economic losses of the Republic of Guinea only from the reduction in the period of economic activity of the country's population as a result of mortality (in the reporting period, and for the period of survival to 70 years old) and morbidity (taking into account labor productivity in the country) from Ebola fever. Even in this case, the losses estimates are comparable with the results obtained earlier.

Conclusions:

1. Methodological approaches to assessing the effect of activities to reduce health risks caused by extremely dangerous infections (in this case, anti-epidemic activities) should include mathematical modeling of morbidity and mortality risks as a result of epidemic process, analysis of actual morbidity and mortality rates with an assessment of economic losses, caused by epidemic.

2. Approbation of the approaches proposed, as a result of epidemic process mathematical modeling using the example of Ebola outbreak in the Republic of Guinea, in 2014-2016, showed that without anti-epidemic measures taken, including assistance from third countries, and Russian Federation in particular, the number of Ebola fever diseases could be 521,289 cases, and the number of deaths for this reason: 56,345.

3. The prevented risks owing to anti-epidemic activities, including assistance from third countries, and Russian Federation in particular, made 517,485 cases and 53,809 deaths.

4. The economic effect of anti-epidemic activities to minimize risks with the help of third countries, and Russian Federation, is estimated at 229.51 million dollars of Guinea GDP.

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