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# Multi-purpose transport monitoring of passenger-cargo traffic in Ukraine

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## ABSTRACT

***Background:*** *The epidemiological and environmental security of states is the most important component for the functioning of the International Transport Corridors (ITC). The growing capacity of passenger and cargo flows increases the risk of the spread of dangerous infectious diseases in the territories of the countries on the route of the ITC. Preventing the introduction of dangerous infections by various vehicles and the activation of local natural foci are the priority in the anti-epidemic provision of the population of Ukraine.*

***Materials and methods:*** *The study of the features of the functioning of border checkpoints (BCPs) for various types of transport in different regions of Ukraine made it possible to create their classification, taking into account the nature of the goods and the intensity of passenger traffic.*

***Results:*** *The functioning of 204 checkpoints in 20 different localities, employing more than 29,000 specialists, was studied. When conducting a retrospective epidemiological analysis of documentation for maritime, aviation, road and rail transport for 2000–2013, non-compliance with sanitary-hygienic and anti-epidemic requirements to prevent the introduction and spread of dangerous infections and their carriers were revealed. The authors scientifically substantiated recommendations on sanitary-hygienic and anti-epidemic support of the BCP. Based on the results of a survey of 112 BCPs (54.9 ± 1.2%), taking into account the degree of epidemiological danger in the areas of their operation, indicators of the presence of rodents, blood-sucking insects and the nature of the goods transported, five epidemic zones were identified.*

***Conclusions:*** *Inadequate operation of the BCP was expressed in non-compliance with sanitary and anti-epidemic requirements. Control of the personal property of passengers and luggage was less than 30%. The analysis of the functioning of the BCPs made it possible to unify their work and identify priority areas for improvement.*

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**Key words: biological safety, border checkpoints, epidemiological safety, international transport corridors, state border**

## INTRODUCTION

The Rules for the Sanitary Protection of the Territory of Ukraine No. 893 dated 22.08.2011 regulate the list of infectious (parasitic) diseases (as amended by the Decree of the Cabinet of Ministers of Ukraine No. 272 of 04/08/2020), requiring special measures for the sanitary protection of the territory.

The deepening globalisation plays a leading role in maintaining interstate economic, logistical, cultural, and tourism ties.

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To improve the efficiency of foreign trade and transit relations, the interested European-Asian states formed the system of International Transport Corridors (ITC) [1–5].

The favourable geographical location of Ukraine in the centre of the Eurasian transport systems predetermines its role as a powerful transit state [6–8].

This is confirmed by the existing system of Pan-European transport corridors covering the territory of Ukraine, including the Western, Transnistrian, and Black Sea regions with their environmental and man-made changes in the environment that have been developed in recent years [9, 10].

According to World Health Organization (WHO), about 1 billion people globally are affected by parasitic diseases.

Two hundred forty-one million cases of malaria were reported worldwide in 2020 (227 million cases in 2019). The number of deaths from malaria in 2020 is estimated at 627,000 people.

The list of malaria endemic countries includes Bangladesh, Bhutan, Brunei, Vietnam, India, Indonesia, Yemen, Cambodia, Laos, Nepal, Oman, Pakistan, Timor-Leste, Philippines.

According to the Centre for Public Health of the Ministry of Health of Ukraine, malaria transmission occurs in 87 countries around the world. A significant proportion of the global incidence of malaria, according to WHO, occurs in the African Region. In 2020, the Region accounted for 95% of all malaria cases and 96% of fatal malaria cases worldwide. At the same time, children under the age of 5 years accounted for 80% of all deaths from malaria.

The number of imported cases of malaria in Ukraine in recent years has fluctuated widely from 168 cases in 2003, 34 cases in 2009, 14 cases in 2020, to 26 cases in 2021 which indicates an unpredictable and uncontrollable trend in this nosology.

Malaria infections in Ukrainian citizens reported in 2000–2014 mainly (90.0%) occurred in visitors to South-West Africa: Guinea, Liberia, Cameroon, Nigeria, and Benin.

An essential component of malaria control and elimination strategy is vector control. Unfortunately, this is significantly hindered by the growing resistance of Anopheles mosquitoes to modern insecticides. Mixed malaria infections, i.e. cases when 2–3 pathogens are simultaneously introduced into the human body are increasingly more common [11, 12].

Natural focal infections also pose a certain threat in places where a large number of vehicles and people are congested at the border. The main source of these infections is wild, agricultural, domestic animals and mouse-like rodents living in the open air or in residential buildings or outbuildings.

Infection occurs through contact with sick animals, environmental objects, drinking water or eating food contaminated with rodent secretions, as well as through animal bites and bites of blood-sucking insects.

Recently, a number of authors have pointed to the need to organize urgent measures to prevent the introduction and spread of viral haemorrhagic fevers and other dangerous infections in Ukraine. To this end, it is proposed to create specialized diagnostic laboratories for the early detection of natural focal, tropical and exotic diseases directly at border checkpoints (BCPs) [13–23].

Another epidemiological problem associated with the functioning of the "Western Europe–Western China" ITC is the high risk of bringing a particularly dangerous infection — plague — into Ukraine.

According to WHO, only from 1989 to 2004, about 40,000 cases of plague were recorded in 24 countries, with a mortality rate reaching 7%. In a number of countries in Asia (Kazakhstan, China, Mongolia, Vietnam), Africa (Congo, Madagascar), and the Western Hemisphere (USA, Peru), human cases of plaque are recorded almost every year.

About 2,500 cases of plague are registered annually in the world. At the same time, most cases (about 1000 cases per year) are recorded in the small Congolese province of Ituri.

In Russia, a natural focus of plague exists within an area of more than 253,000 km$^2$. This means that more than 20,000 people living in the area are at risk of infection.

The situation is further complicated by the fact that every year new cases of the disease are detected in the states bordering Russia (Kazakhstan, Mongolia, China). There is a significant risk of importation of the plague vector *Xenopsylla cheopis* from Southeast Asia (traffic flows). From 2001 to 2006, 752 strains of the plague pathogen were identified in Russia.

From 2001 to 2003, 7 cases of plague were registered in the Republic of Kazakhstan (including 1 death), in Mongolia — 23 (including 3 deaths). In China in the period 2001–2002 109 people were infected (including 9 deaths). The forecast of the epizootic and epidemic situation in the natural foci of the Republic of Kazakhstan, bordering the Russian Federation, remains unfavourable today (where natural plague foci are present on 39% of the territory). A similar situation remains on the border with China and Mongolia.

There is a continuing risk of introducing plague from Mongolia and China by air transport.

The risk of plague importation from areas with high epizootic activity (taking into account the new ITC routes) makes the development of medical and environmental forecasts a priority task for the sanitary and epidemiological service of Ukraine [24].

Medico-biological and anti-epidemic protection of vehicles and territories adjacent to the ports of the Black Sea region of Ukraine, within the framework of the national doctrine of protection against dangerous infections and alien aquatic organisms, require further development of

preventive measures for the sanitary protection of maritime borders [25].

Thus, in the territories where various types of vehicles cross the state border of Ukraine, due to the increase in passenger and freight traffic, along with environmental pollution, taking into account the climatic, zoogeographical and faunistic features of the region, the risk of transboundary penetration and spread of viral, bacterial and parasitic infections remains high. This is evidenced by literature data on diseases associated with the transfer of pathogens over long distances by various vehicles [26, 27].

Therefore, the primary task of the sanitary and epidemiological service of Ukraine is the constant monitoring and forecasting of possible ways of importing dangerous infections from neighbouring countries by sea, air and land.

The authors studied the incidence and prevalence of the most significant natural focal infectious and parasitic human diseases (including malaria). Currently, the epidemiological and prognostic situation in Ukraine remains tense [28–32].

The incidence of certain diseases among the population of Ukraine and intensive indicators of nosology forms were studied in dynamics for the period 1986–2000. The dominant ones were: leptospirosis — 88.25% (Vinnytsia, Zaporizhzhia, Kirovograd, Lviv, Mykolaiv, Odesa regions), tularaemia — 8.12% (Mykolaiv, Odesa, Donetsk, Cherkasy regions), anthrax — 3.05% (Donetsk, Kherson, Cherkasy regions, Autonomous Republic of Crimea) a growing trend has been observed. In recent years, sporadic cases of rabies, ornithosis and Q fever have been noted: 1.53%, 1.19%, 2.29%, respectively. The incidence of imported malaria (87.93%) is increasing in Ukraine.

Since the beginning of 2020, 680 cases of rabies in animals have been registered in Ukraine, including 221 cases in wild animals, and 459 cases in domestic and farm animals. In general, the largest number of cases of rabies was registered in the Vinnytsia region — 147, Kyiv region — more than 90 cases (mainly among domestic animals) and Donetsk region — 61 cases.

It should be taken into account that various vehicles transporting dangerous goods from Asia, Africa and South America can also be a potential source of importation of pathogens and their ectoparasites.

Particular attention should be paid to the study of border areas on the routes of migratory flights of birds. There is a real threat of the introduction of viruses and their carriers from various wintering areas, where strains of West Nile fever from Culex mosquitoes were previously isolated on the territory of Ukraine. As of August 27, 2020, the European Centre for Disease Prevention and Control (ECDC) reports of 122 cases of West Nile fever including 10 fatalities. The cases have been reported in Greece (54 cases, including 8 deaths), Spain (44 cases, including 2 deaths), Italy (22) and Romania (2) [33].

According to the Centre for Public Health in Ukraine, there are also enzootic territories for West Nile fever. Compared to 2020 (1 registered case of the disease), in 2021, 6 cases of West Nile fever were registered in Ukraine.

The formation of such enzootic natural foci of infection is facilitated by the climatic and environmental features of the Ukrainian Black Sea region.

The risk of contracting diseases such as Lassa fever, Ebola virus disease, as well as Q fever, viral mosquito fevers, and viral meningitis is increasing (14 cases in 2021 against 48 in 2020). These diseases were identified and described in Ukraine in the 1980s. Sporadic cases of Q fever have been registered in almost all regions of Ukraine and in the Autonomous Republic of Crimea. In a number of regions (Chernivtsi, Ivano-Frankivsk, Zakarpattia, Mykolaiv, Odesa) epidemic outbreaks were observed (transmission from farm animals).

Natural foci of Q fever were found in 10 regions of Ukraine, and in the Autonomous Republic of Crimea, Dnepropetrovsk and Lviv regions, where they have been active for more than 40 years [34–37].

When conducting a sample survey of various types of water, road, rail and air transport, non-compliance with sanitary-hygienic and anti-epidemic requirements regulating the prevention of the introduction and spread of dangerous infections and their carriers were revealed. Accordingly, the maximum number of violations in terms of passenger traffic was detected on the border with Moldova, and in terms of cargo — on the border with Poland. The lowest number of violations in terms of passenger traffic was seen on the border with Romania, and in terms of cargo traffic — on the border with Hungary.

From the nomenclature of goods (in terms of epidemic danger), animals and products of animal origin imported from Russia prevailed.

For air transport, perishable foodstuffs and medicines were the most dangerous.

Water transport was mainly used for hazardous chemicals (ammonia, liquefied gas, sulphur), ores, metal, paper, timber, coal, oil products, as well as food and agricultural products [38].

In the process of sanitary and epidemiological zoning of the BCPs according to the degree of zoological and entomological hazard and environmental risk factors, five climatic and faunal biocenoses, as well as border areas were ranked.

A set of measures has been developed to ensure the safety of international transport corridors in accordance with the current doctrine of the prevention of dangerous infectious and parasitic diseases in Ukraine [39, 40].

## MATERIALS AND METHODS

### MATERIALS

A comparative analysis of the materials of annual inspections of regional BCPs and a retrospective epidemiological

analysis of statistical data received from departments that ensure the operation of maritime, road, rail and air transport for the period 2000–2013 were carried out.

Two hundred and four BCPs were surveyed and classified at state border crossing points in 20 regions of Ukraine, taking into account their daily intensity of passenger and freight traffic, features of work, geographical location.

Currently, the state of health and morbidity (including infection) of seafarers working both on Ukrainian ships and on ships under a foreign flag is being constantly monitored.

## METHODS

The assessment of the functioning of individual BCPs was carried out by means of selective control and observation, epidemiological analysis directly at the checkpoint in cooperation with the relevant departmental specialists during on-site inspections in the regions.

Methods for monitoring disinfection, derating and pest control measures in epidemically difficult areas of passenger and freight traffic in various regions of Ukraine have been systematised and optimized, taking into account the nature of the transported goods and vehicles.

In the process of studying and grouping the results obtained, the methods of mathematical analysis and modelling adopted in healthcare were used.

## RESULTS

The functioning of 204 BCPs at 20 different locations, employing more than 29,000 specialists, was analysed.

The daily passenger flow at the inspected locations amounted to 187,847 people transported by 45,347 transport units along the entire perimeter of the state border. In the course of the analysis of the workload of freight and passenger traffic in terms of the number of employees, it turned out that the number of the latter does not correspond to the BCP category (Table 1, Figs. 1, 2).

The daily load of passenger/freight traffic on the Ukrainian borders for various modes of transport has been established. The maximum load in terms of the number of passengers and cargo was seen on the border with Russia, Poland, and Moldova, and the minimum — was on the border with Slovenia and Romania. On average, most of the cargo is transported via water transport.

In the Vinnytsia region, at 16 operating BCPs (international: 6 — motor vehicles, 1 — rail, local — 9), with daily passenger/freight traffic of 12,002 people and 4,165 units, respectively, the number of employees was 93 people. In the Autonomous Republic of Crimea at the 12 inspected BCPs (international: 11 water and 1 air) with daily passenger/cargo traffic of 4,270 people and 73 units, respectively, the number of employees was 231 people. Daily load at the BCP for passenger transportation of automobile and rail

**Table 1.** The daily intensity of passenger/freight traffic at the borders with neighbouring states of Ukraine

| Borders with countries | Per cent ratio | |
|---|---|---|
| | Passenger traffic | Freight traffic |
| Border with Russia | 19.1% | 30.3% |
| Border with Slovenia | 2.9% | 1.0% |
| Border with Hungary | 9.3% | 2.8% |
| Border with Moldova | 29.2% | 5.2% |
| Border with Romania | 1.2% | 1.3% |
| Border with Poland | 19.3% | 14.8% |
| Border with Belarus | 9.6% | 7.4% |
| Other destinations | 9.4% | 37.2% |

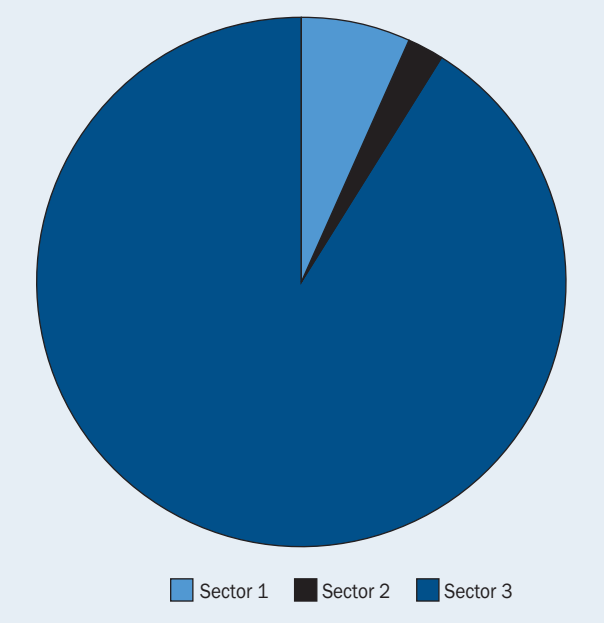


**Figure 1.** The ratio in per cent of passenger traffic through the border checkpoints of Ukraine: Sector 1 — aircraft — 6.7; Sector 2 — water (sea, river) vehicles — 2.4; Sector 3 — road, rail — 90.9

transport is from 90% to 20%, respectively, for other modes of transport — water and local — up to 10.0%.

Up to 92% of cargo is usually transported by water, while only 8% is transported by rail, road, air and local transport (Table 2).

The authors scientifically substantiated the criteria for assessing passenger and cargo flows, daily traffic intensity, as well as recommendations for anti-epidemic support of the BCPs across the state border of Ukraine.

Based on the analysis of the operation of 204 operating BCPs (80 ± 0.9%), studies and observations performed (over

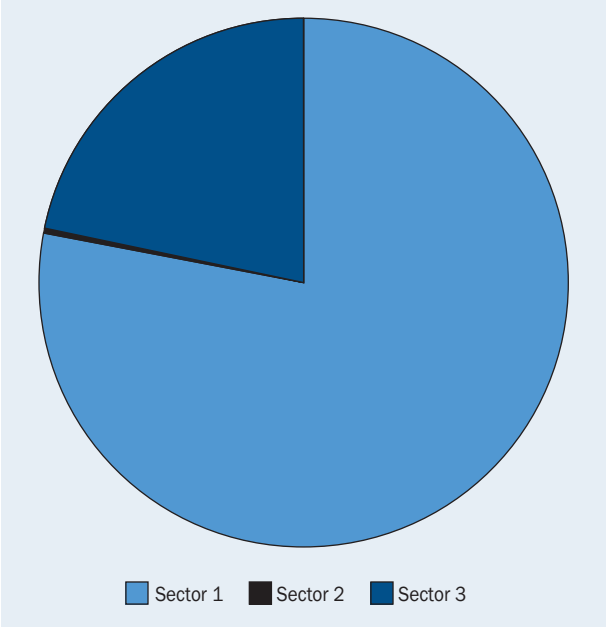


**Figure 2.** The ratio in per cent of cargo flows through the border checkpoints of Ukraine: Sector 1 — water (sea, river) vehicles — 78; Sector 2 — aviation — 0.3; Sector 3 — railway, road — 21.7

6000), the load on passenger transportation by road, rail and air was determined.

Potentially hazardous chemical cargoes (fuels and lubricants, fertilizers, detergents, etc.), as well as food products, are transported across the border of Ukraine mainly by rail and road. Conditionally dangerous goods (skins, down, animals and livestock products) are transported mainly from Russia and Poland. Perishable goods, medicines are mainly transported by air. Sea transport mainly transports hazardous chemicals (ammonia, sulphur, ore), as well as metal, paper, food and agricultural products.

Based on the results of the sanitary and epidemiological zoning of the border areas of Ukraine, the authors substantiated the concept of the functional structure of the outbreak and the circulation of potential sources and vectors of infections through direct and indirect links with natural factors.

According to the results of zoning of 112 BCPs (54.9 ± 1.2%), according to the degree of epidemiological danger, indicators of the presence or absence of mouse-like rodents, blood-sucking insects, taking into account the nature of the transported dangerous goods, five zones were identified: I — "entomogenic" zone (EZ), II — "zoogenic" zone (ZZ), III — "toxicogenic" zone (TZ), IV — "mixed" zone (MZ), V — "safe" zone (SZ). Of these, BCP operating on the territory of MZ — 99 BCP (88.4 ± 3.1%), TZ — 3 BCP (2.8 ± 0.1%), ZZ — 2 BCP (1.8 ± 0.05%), EZ — 2 BCP (1.8 ± 0.05%), SZ — 6 BCP (5.4 ± 0.7%) [41].

## DISCUSSION

In the process of sanitary and epidemiological examination of the BCPs geographically located in heterogeneous biocenotic areas, data on regional climatic, landscape and flora and fauna characteristics were used as prerequisites for diseases. The concept of the active functional structure of the focus and the circulation of a potential pathogen (conditionally) has been developed.

Complex biocenotic connections of the landscape, physical conditions of the environment, as well as the human factor have been established.

Priority sanitary-regulated technologies for the transportation of goods and effective measures to ensure the epidemiological safety of the ITC have been optimised. The main conceptual directions of medical and environmental forecasting have been determined, and the system of measures aimed at identifying, diagnosing, and preventing natural focal diseases, the range of which is located both in the equatorial latitudes and territorially connected with the ITC, has been improved.

At the same time, the epizootic activity of plague foci is shown in Central Asia, where strains with a high epidemic potential circulate, which creates a real threat of plague importation through the territories bordering Russia. There is also a constant possibility of bringing plague from Mongolia and China by air transport corridors, where cases of pneumonic plague are recorded almost every year.

## CONCLUSIONS

Taking into account the location and nature of transport communications (sea, river, air, road, rail), the characteris-

**Table 2.** Data on the number of ship calls and ships in the ports of Ukraine for the period from 2000 to 2007

| Ship calls/ships | Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
| Number of ship calls | 12836 | 12899 | 17785 | 19159 | 17684 | 17822 | 17995 | 19653 |
| Quantity ships with Ukrainian crew | 3644 | 3489 | 3786 | 3805 | 4316 | 4174 | 3889 | 4094 |
| Number of foreign vessels | 9192 | 9410 | 13999 | 15354 | 13358 | 13648 | 14048 | 15559 |

tics of the natural environment and the characteristics of international and local passenger traffic, the methodology for epidemiological certification of BCPs has been developed.

Sanitary-hygienic and anti-epidemic algorithms of actions aimed at preventing the importation and spread of dangerous infections to Ukraine through the relevant BCPs have been determined.

Recommendations on anti-epidemic support for leptospirosis, tularaemia, anthrax, rabies and other dangerous infections (including tropical and exotic ones) have been corrected.

A roadmap has been developed for conducting sanitary and epidemiological reconnaissance on an ongoing basis, together with local and regional medical institutions.

The system for monitoring the health of sailors, drivers of vehicles, crews of airliners, and tourists has been unified.

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