RESEARCH PAPER

SPATIAL FEATURES OF COVID-2019 DIFFUSION IN RUSSIAN REGIONS: THE VIEW OF THE TRANSPORT GEOGRAPHER

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ABSTRACT. The purpose of the article was to analyze the spatial spread of COVID-2019 in the regions of Russia in comparison with European countries in 2020–21 from a transport-geographical point of view. The article reveals interregional differences in the number of cases and the incidence (sickness) rate as of August 1, 2021 for individual regions of Russia. The coronavirus entered two Russian regions directly from Wuhan (China) and eight regions from Northern Italy. The first virus carriers arrived by air transport, which was the main means of spreading the epidemic. Spatial diffusion of COVID-2019 in Russia was extremely uneven with epicenters in the large cities. In the early stages the coronavirus spread in an exclusively hierarchical way through the established extensive air communication system. The later stages of its spread were characterized by mixed diffusion with the dominance of the hierarchical form. COVID-2019 has six gradations of the incidence (sickness) rate expressed in the number of cases per 1 million inhabitants: very high (more than 140), high (90–140), moderate (70–90), medium (45–70), low (20–45), very low (6–20). For the Russian regions the most typical were low (51 regions) and medium (20 regions) incidence rates – 60% and 23.5% (84% in total), respectively. The incidence rate, according to official data from Rospotrebnadzor (Russian Agency of Consumer Supervision), is 38% lower than in European countries. The average number of Russian cases in the first seven months of 2021 was 1.8 times more than for the entire 2020.

KEYWORDS: COVID-2019, hierarchical diffusion, Russia, incidence rate

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INTRODUCTION

The COVID-2019 pandemic has completely changed the world and our understanding of its sustainability, having a strong impact on society and the economy, including the spatial allocation of the tertiary sector of the economy (especially tourism and transport). Its impact turned out to be far-reaching in terms of geography. Therefore, it is relevant to study social and the economic effects of the pandemic. It is important for geographers to understand the spatial differentiation of this impact, which largely depends on the spatial distribution of COVID-2019. The geographical features of the impact of the COVID-2019 pandemic on the structures of the economy and society in the most general terms are analyzed in a series of short articles in a special section of the Russian journal "Vestnik ARGO" (Bulletin of the Association of Russian Human Geographers) No. 9 for 2020 (Druzhinin 2020; Gerasimenko and Gerasimenko 2020; Kagansky 2020; Kolosov 2020; Kuznetsova 2020; Rodoman 2020; Shuper 2020; Zyryanov 2020, and others).

The publication (Zemtsov and Baburin 2020a) indicates that the spread of the epidemic in the regions of Russia obeys the patterns of diffusion of innovations and depends on the structure and interaction within regional communities. The first to become infected are innovators (tourists from the foci of the disease) and early adopters (social leaders) who spread the disease throughout the community. At the first stage of diffusion, more than 80% of all infected were concentrated in Moscow, the Moscow region, and the largest urban agglomerations. At an exponential stage, the number and proportion of cases outside Moscow grew steadily. The number of confirmed cases of the disease is higher in wealthy large urban regions, where the share of the more socially active part of the population is higher, its density and intensity of interaction are higher. In regions near large agglomerations, the number of cases is also significant due to the rapid spread of the disease from Moscow to neighboring regions. These authors rightly point out that in conditions of administrative pressure, imperfect statistics of the disease, many cases of illness and death associated with the epidemic will not be included in the coronavirus statistics.

The work (Kaganskiy 2020) shows that global crises such as the COVID-2019 pandemic lead to spatial inversions – loosely connected and backward regions and areas of

the world have advantages in their preservation, while the most developed and globally connected areas (regions, countries) turn out to be the most vulnerable and suffer the most from the consequences of such crises.

A number of other Russian publications that appeared a little later analyzed the diffusion of the pandemic, the factors of its spread, and considered the impact of the pandemic on the Russian economy in the regional context (Zemtsov and Baburin 2020b; Zubarevich and Safronov 2020; Pelyasov et al. 2021).

The article (Makhrova and Nefedova 2021) examines the possibilities of transition from seasonal countryside mobility to real suburbanization and deurbanization in areas of varying degrees of remoteness from Moscow under the new conditions of quarantine restrictions.

Panin et al. (2021) presented a cartographic analysis of the spatial patterns of the spread of the COVID-19 pandemic in Russia. They state that the three initial centers of its diffusion were the Moscow region, the oil and gas producing regions in the Western Siberia and the North Caucasus. The main factors of the rapid spread of COVID-19, from the point of view of the authors, were not only transport and logistics parameters, but also a high proportion of the creative class in the Moscow region, rotational flows and overcrowding of shift camps in the Yamal-Nenets autonomous area, increased contact and a weak healthcare system in regions of the North Caucasus.

The problems of the geographical study of the epidemics are also highlighted in the Russian monographs on medical geography. Thus, a monograph (Malkhazova 2001) is devoted to the methods of medical-geographical mapping, and a book (Semenova and Chistobaev 2015) considers the general problems of medical geography. An article by Pogorelov (2020) with an extensive bibliography (39 sources) presents a general overview of the current state of medical geography in Russia. Among foreign monographs on medical geography, especially famous are (Haggett 2000; Cliff et al. 2004; Lawson 2006; Souris 2019).

The article (Chen et al. 2021) is devoted to the study of the spatial diffusion of the COVID-19 disease, which spread from Wuhan (China) to cities in Hubei province by the gravity model. The simulation results showed that the total number of confirmed cases of the disease depended on the size of provincial cities and the distance from them to Wuhan (the epicenter of the pandemic). Its spread was hierarchical, while the immediate neighborhood of cities with each other did not matter much.

An increasing number of European articles analyze the geographical factors in the spread of COVID-19. The special issue of the Dutch magazine Tijdschrift voor economische en socale geografie (Journal of Economic and Social Geography) # 3 for 2020 contained a series of articles on the topic "Geography of the COVID-19 Pandemic, 2020" (Geography of the COVID-19 Pandemic 2020).

In the publication (Sigler et al. 2021), the authors, using regression analysis, come to the following conclusions: the spread of COVID-19 in countries with a large number of reported cases (per 1 million residents) could be predicted by the values of human development and the total population ; the larger the households, the older the population and the more intense globalization, which involves closer interaction between people, the better the spread of COVID-19 can be predicted in countries with a low incidence rate (cases per million inhabitants). Population density and other characteristics such as total population, proportion of elderly people, and household size are reliable indicators in the early weeks of the epidemic, but have little impact on the spread of COVID-19 over time. In contrast, the impact of interpersonal globalization and out-of-shop trade has increased over time, indicating that higher human mobility may best explain the persistent spread of the disease.

In (Kuebart and Stabler 2020), a spatial diffusion model is used to study the spread of COVID-19 within Germany. Some recent geographical publications are devoted to the spread of coronavirus in Italy (Ascani et al. 2020), Sweden (Florida and Mellander 2020), Iran (Ramírez-Aldana et al. 2020); new e-book (Shaw and Sui 2021) is devoted to the COVID-19 mapping.

The analysis of the literature showed that many economic-geographical aspects of the spread of the coronavirus infection have already been considered or studied to one degree or another. However, the spatial features of this process from a transport-geographic point of view are still poorly studied. The purpose of the article is to analyze the spatial characteristics of the spread of the COVID-19 pandemic over the territory of Russian regions from this point of view.

MATERIALS AND METHODS

In the economic-geographical analysis of the spread of coronavirus infection, the main parameters are the number of cases (registered cases) and the incidence (morbidity) rate (the number of cases per 1 million inhabitants). The latter indicator is more effective because it reflects relative incidence rates, rather than absolute values (which, sometimes, can be misleading in their size or distract from an appropriate comparison); in addition, it clearly shows the level of falsification of the initial statistics of the registered cases due to different diagnoses and underestimation of the incidence .

In addition, there are two more important indicators that describe the spatial diffusion of the disease – the geographical lag of its spread and the number of areas (countries, regions, loci) involved in this process. The first means the number of days of registration of the first cases of the disease in *all geographic areas* (countries, regions, localities) from the first to the last day, that is, the number of days from the record of the first case in the first area to its fixation in the last area of the analyzed territory. The second indicator reflects the cumulative increase in the number of geographical areas covered by the epidemic (pandemic). It increases slowly and then very quickly (exponentially) decreases along an S-shaped curve (see theoretical works on the diffusion of innovations by Torsten Hägerstrand and his followers; Hägerstrand 1967), covering at the end all the areas (countries, regions, loci).

To achieve the above goal, we used statistical data on the number of COVID-19 cases and the incidence rate taken from the sites https://stopcoronavirus.rf (https://стопкоронавирус.рф; Coronavirus COVID-2019: official information for the regions of Russia), https://github.com/CSSEGISandData / COVID-19 (COVID-2019 statistics by countries of the world by John Hopkins University).

These statistics were collected for three dates (August 2, 2020; January 16, 2021; and August 1, 2021), and then systematized by individual regions of Russia (regions (oblast'), territories (kray), republics, and autonomous regions; the latter were then aggregated by 11 macro-regions). This made it possible to conduct comparative geographical analysis and to identify the spatial characteristics of the spread of COVID-19, the differences in the number of cases and the incidence (sickness) rate in Russian individual regions.

The interregional differences in the number of cases and the incidence rates were analyzed as of August 1, 2021. The data for August 2, 2020 and January 16, 2021 were collected for understanding the course of the disease diffusion, but were not analyzed in detail (with a number of exceptions), since during the first seven months of 2021 the number of cases in the regions of Russia turned out to be almost two times higher than in the entire 2020.

RESULTS

Spatial distribution of the coronavirus in Russia: transport-geographical analysis

Table 1 presents the geographical origin of the first cases of the disease. It shows that on the first day (January 31), the carriers of the disease were Chinese citizens who came to Russia. These were isolated cases and the patients were quickly discharged. A month later, from February 27 to March 12, the main source of infection for Russia was Italy , from where arrived 32 infected people by air (including one Italian student who returned to classes at the St. Petersburg Medical University, and the rest were Russian travelers who had been vacationing in the ski resorts of the northern Italy and other regions). On March 13, the first sick Russian tourists arrived from France and Austria; on March 14–15 arrived infected tourists from Spain and Switzerland.

The last right column of the Table 1 proves that the main mode of transmission of the infection to Russia from abroad in the first phase of the epidemic was air transport.

Geographic patterns of the spread of COVID-2019 in Russia

To understand the spatial nature of the spread of the disease, we compiled Table 2, which chronologically ordered the first detection cases in each Russian region in the context of macro-regions (it is divided into two parts: the first, 2A, indicates the regions of European Russia; the second, 2B, indicates the regions of – Asian Russia). It shows that the spatial diffusion of COVID-2019 across the territory of Russia was extremely uneven, not only throughout the country, but even within the socio-economic macro-regions.

Since the old grid of Soviet economic regions has become somewhat obsolete due to the great changes in economic and settlement structure that have taken place over the past 30 years, we have proposed its modified version of large-scale territories for our study, which we call socio-economic macro-regions. They include entire units (regions) of the first administrative-territorial level[1]. In the course of empirical calculations and taking into account the proximity and transport connectivity of individual regions, we compiled the following grid of socio-economic macro-regions of Russia in contrast to traditional economic regions:

1) the European Center of Russia (the Big Center includes the former Central (excluding the Kostroma region) and Central Black Earth (Chernozyom) economic regions, as well as including the Penza and Nizhny Novgorod regions, Mordovia);

2) Kaliningrad (due to its exclave location and great remoteness from the rest of Russia, it is singled out as a special region, since it has strong territorial isolation, insignificant size, weak economic ties even with the North-West macro-region);

3) North-West (Pskov, Novgorod, Leningrad regions, but

Table 1. Geographical features of the spread of the SARS-CoV-2 coronavirus in Russian regions in the first days of the 2020 epidemic

Regions are ranged in the chronological order the first cases were registered

Date of record of the first case	Where it was brought from	Areas affected by the epidemic; number of people	Mode of transport, by which the infected people arrived
31.01.2020	China	Tyumen (1 Chinese citizen)	air transport
31.01.2020	China	Chita (Trans-Baikal Territory, 1 Chinese citizen)	air transport
27.02.2020	Northern Italy, ski resort	Moscow (1 Russian citizen)	air transport
2.03.2020	Italy	Moscow Region (1 Russian citizen)	air transport
5.03.2020	Italy	St. Petersburg (Italian student studying in St. Petersburg, arrived February 29, 2020)	air transport
6.03.2020	Italy	5 persons in Moscow + 1 person in Nizhny Novgorod (all Russian citizens)	air transport
8.03.2020	Italy	1 person in Kaliningrad, 1 person in Belgorod, 1 person in the Moscow region	air transport
12.03.2020	Italy	4 persons in Moscow, 1 person in Kaliningrad, 1 person in the Krasnodar Territory	air transport
13.03.2020	Italy	3 persons in Lipetsk, arrived in Moscow	air transport
13.03.2020	Italy, France, Austria	11 Russian citizens: 5 persons in Moscow, 1 person in the – Moscow region, 3 persons in the – St. Petersburg, 1 person in the – Leningrad region	air transport
14.03.2020	Italy, France	14 Russians: 9 persons in Moscow, 1 person in the – Moscow region, 1 person in – St. Petersburg, 2 persons in the – Kemerovo region, 1 person in the – Kaliningrad region	air transport
15.03.2020	Italy, France, Spain, Switzerland	4 Russians: 3 persons– in the Moscow region, 1 person – in the Tyumen region	air transport

Source: 304 references links to media reports and Rospotrebnadzor newsletters in https://en.wikipedia.org/wiki/Template:COVID-19_pandemic_data/Russia_medical_cases

[1]In legal language they are called subjects of the federation, that is, these are regions, territories, republics, autonomous districts and regions. Economic geographers often use not the legal term «subject of the federation» (or simply «subject», which, from the point of view of the literary language, does not quite adequately convey the meaning of the concept), but a more neutral (although also not very successful) term «region», which we will see below and used in the text.

without the Kaliningrad region);

4) European North (Karelia, Murmansk, Arkhangelsk, Vologda, Kostroma, Kirov regions, Komi Republic, and Nenets autonomous area);

5) Volga macro-region (Chuvash and Mari El Republics, the Republic of Tatarstan; Ulyanovsk, Samara, and Saratov regions);

6) European South (former North Caucasian economic region, as well as Volgograd and Astrakhan regions, Kalmyk Republic, Crimea including the city of Sevastopol);

7) Urals (the same);

8) Western Siberia (the same);

9) Eastern Siberia (Krasnoyarsk Territory, Khakas and Buryat Republics, as well as Republic of Tuva, Irkutsk region, and Trans-Baikal Territory);

10) North-East (Sakha-Yakut Republic, Magadan region, Chukotka autonomous area, Kamchatka Territory);

11) South of the Far East (Amur and Sakhalin regions, Primorsky and Khabarovsk Territories, Jewish autonomous region).

In European Russia (see Table 2A), the first foci of the disease were Moscow city, Moscow region, St. Petersburg, Nizhny Novgorod, Lipetsk and Kaliningrad regions. It outstripped Asian Russia in terms of the number of infected regions, in which the very first cases of COVID-2019 import from China were recorded. The largest macro-regions (the European Center and the European South) naturally comprised the largest number of European Russian regions – 20 and 15, respectively.

Although isolated cases of coronavirus on January 31 in Asian Russia were the first in the country (registered in Chinese citizens who arrived to Chita and Tyumen), the first wave of the *mass epidemic* came a little later than in the regions of European Russia – on March 14–19 (see Table 2B). Most recently the coronavirus was registered in the Asian regions of Russia: the Republic of Tuva (April 10), the Chukotka autonomous area (April 15) and the Altai Republic (April 17). In the European part the coronavirus was registered most recently in the Nenets autonomous area (April 15).

Table 2A. Geographic distribution of the first reported cases of COVID-2019 by regions of European Russia in February-April 2020 in the context of macro-regions

Regions are ranged in the chronological order the first cases were registered

Date of record of the first case	European Center	North-West and Kaliningrad	European North	Volga macro-region	European South	Urals
27.02.2020	Moscow					
2.03.2020	Moscow region					
5.03.2020		St. Petersburg				
6.03.2020	Nizhniy Novgorod region					
7.03.2020	Lipetsk region					
8.03.2020	Belgorod region	Kaliningrad region				
12.03.2020					Krasnodar Territory	
13.03.2020		Leningrad region				Perm Territory
16.03.2020			Komi republic, Kirov region	Samara region		
17.03.2020	Kaluga, Tambov, Tver', Yaroslavl, and Penza regions		Arkhangelsk region	Republic of Tatarstan		Sverdlovsk region
19.03.2020	Ivanovo, Ryazan, Tula, and Voronezh regions		Murmansk region	Chuvash Republic, Saratov region		Orenburg region
20.03.2020				Ulyanovsk region		
21.03.2020					Crimea, Kabardino-Balkar Republic, Stavropol Territory	Chelyabinsk and Kurgan regions
22.03.2020	Bryansk region	Novgorod region				Udmurt Republic
24.03.2020	Orel region				Volgograd region, Chechenia	Republic of Bashkortostan
25.03.2020		Pskov region			Rostov region	
27.03.2020	Republic of Mordovia				Sevastopol, Republic of Dagestan	

28.03.2020	Smolensk region		Kostroma region		Republic of Adygea	
30.03.2020	Vladimir region		Vologda region	Republic of Mari El	Kalmyk Republic	
31.03.2020					Astrakhan region	
1.04.2020	Kursk region				Republic of North Ossetia	
3.04.2020					Ingushetia	
6.04.2020			Republic of Karelia			
7.04.2020					Karachay-Cherkess Republic	
15.04.2020			Nenets autonomous area			

Source: References 1-304 in https://en.wikipedia.org/wiki/Template:COVID-19_pandemic_data/Russia_medical_cases

Table 2B. Geographic distribution of the first registered cases of COVID-2019 in the regions of Asian Russia in January-April 2020 in the context of macro-regions

Regions are ranged in the chronological order the first cases were registered

Date of fixation of the first case	West Siberia	East Siberia	North-East	South of the Far East
31.01.2020	Tyumen region	Zabaikalsky (Trans-Baikal) Territory		
14.03.2020	Kemerovo region			
17.03.2020		Krasnoyarsk Territory, Khakass Republic		
18.03.2020	Novosibirsk and Tomsk regions			
19.03.2020	Khanty-Mansi autonomous area		Sakha-Yakut Republic	Khabarovsk Territory
24.03.2020				Primorsky Territory
26.03.2020		Buryat Republic		
28.03.2020				Sakhalin region
29.03.2020	Omsk region	Irkutsk region		Amur region
30.03.2020	Altai Territory			
31.03.2020			Magadan region	
2.04.2020	Yamalo-Nenets autonomous area			
3.04.2020				Jewish autonomous region
5.04.2020			Kamchatka Territory	
10.04.2020		Republic of Tuva		
15.04.2020			Chukotka autonomous area	
17.04.2020	Altai republic			

Source: References 1-304 in https://en.wikipedia.org/wiki/Template:COVID-19_pandemic_data/Russia_medical_cases

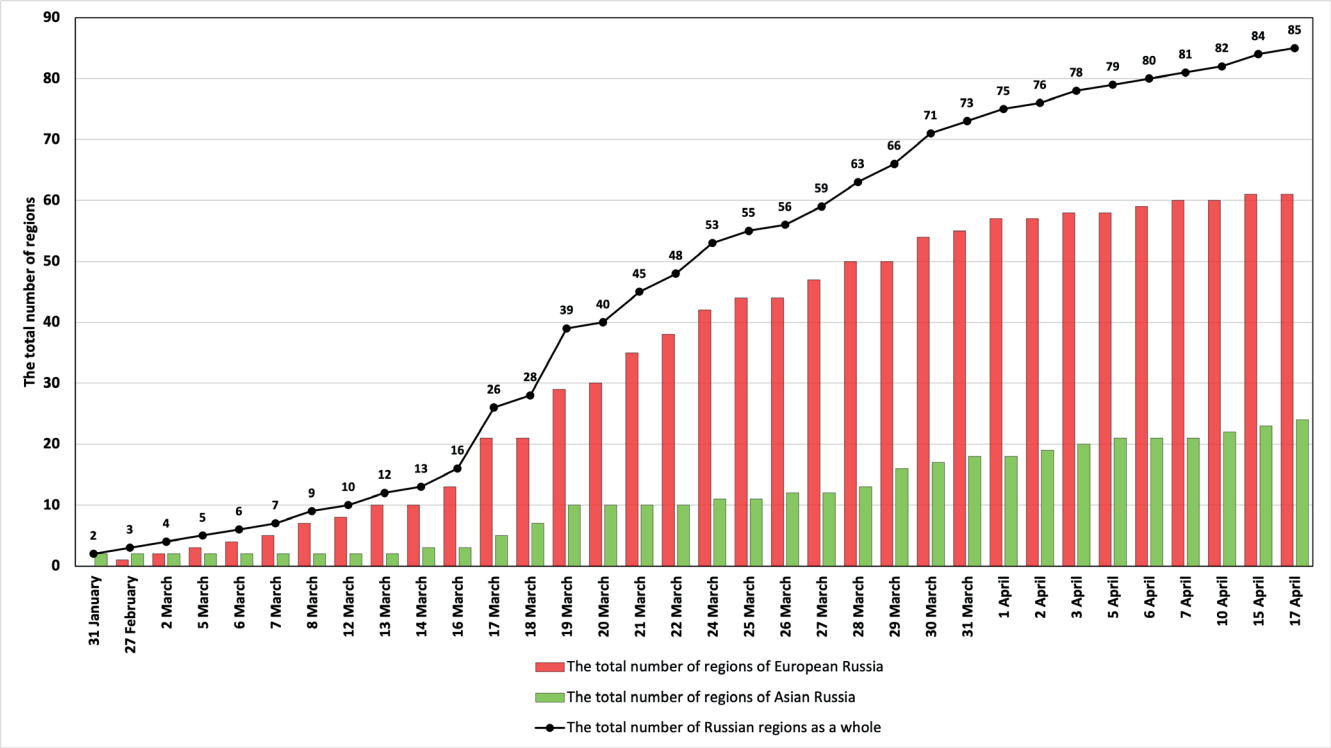


Fig. 1. Cumulative increase in the number of Russian regions with the first coronavirus cases in March-April 2020 in chronological order

Further, the epidemic began to expand rapidly in all geographic directions. The first and second peaks were concentrated in European Russia, the subsequent waves covered all the country.

By March 10, 2020, cases were registered in nine regions of the country (including in seven European and two in Asian regions); by March 20 – cases were registered in 40 regions (including in 30 European and 10 Asian regions), by March 25 – cases were registered in 55 regions (including in 44 European and 11 Asian regions), by March 30 – cases were registered in 71 regions (including in 54 European and 17 Asian regions), by April 5 cases were registered in – 79 regions (including in 58 European and 21 Asian regions), by April 17 – cases were registered in 85 regions (including in 61 European and 24 Asian regions). Due to its transport-geographical remoteness and complete or partial overland isolation, the last regions where the disease came to were Tuva and Altai republics as well as Nenets and Chukotka autonomous areas. This happened on April 10–17, 2020.

Thus, the geographical lag of the epidemic throughout Russia was 51 days (February 27 – April 17) apart from the first two cases on January 31.

The first regions involved in the epidemic were the European Center (February 27 – March 6), North-West (March 5), and Kaliningrad (March 8); a little later the coronavirus came to other regions of European Russia (March 12–17) and then to Asian Russia (from March 14–17) and some of the most remote regions of European Russia (first half of April) with unfavorable transport-geographical position (the Republics of Karelia and Karachay-Cherkessia and Nenets autonomous area).

The diffusion lag of the epidemic differed greatly from macro-region to macro-region – the rapid spread of infection was typical for the Urals (10 days), the Volga region (15 days), and the South of the Far East (15 days); in the North-West, East Siberia, European South and North-East it spread slower (20–27 days); protracted spread was registered in the European North (31 days) and the most protracted spread was registered in the West of Siberia (34 days) and the European Center of Russia (35 days). In European Russia, the duration of this lag was 49 days, in Asian Russia it lasted 34 days; the country's average was 51 days.

Thus, the coronavirus was the last to arrive in remote, mostly socio-economically backward regions with a deep-peripheral transport-geographic location.

Territorial differentiation by the number of cases. The first five regions in terms of the number of cases in August 2021 included Moscow city, St. Petersburg, Moscow, Nizhny Novgorod and Rostov regions. On August 2, 2020, 28.7% of the total number in Russia was registered in Moscow city; on January 16, 2021 this value was 25.0%; on August 1, 2021 this value was 24.0 %. As of August 2021, the shares of other regions in the total number of cases in the country was the following: St. Petersburg – 8.4%, Moscow region – 6.2%, Nizhny Novgorod region – 2.2%, Sverdlovsk region – 1.7%, Rostov region – 1.8%. In August 2021 the first five regions of Russia (combined) in terms of the number of coronavirus infected accounted for 42.6% of all cases.

The first 10 regions of the country (by their absolute number) accounted for 50.0% of cases in August 2021 i.e., half of all cases. In August 2021, the number of cases by regions decreased in the following order: Moscow city, St. Petersburg, Moscow, Nizhny Novgorod, Rostov, Sverdlovsk and Voronezh regions, Krasnoyarsk Territory, Irkutsk and Samara regions. As can be seen from this list, it mainly includes densely populated regions.

In August 2021, the first ten regions accounted for 49.99%, the second ten regions accounted for 11.00%, the third ten regions accounted for 9.23%, the fourth ten regions accounted for 8.27%, and in total, the first 40 regions accounted for 78.49% of cases (more than three quarters). The remaining 45 regions accounted for 22.5%. The last five regions with the minimum number of cases in August 2021 included the Chechen Republic (16.1 thousand people), Magadan region (9.5 thousand), Jewish autonomous region (5.8 thousand), Nenets (1.6 thousand) and Chukotka (1.2 thousand people) autonomous areas.

Thus, a high concentration of the number of cases was registered in the main urbanized areas of the country (50% in the first ten regions and 78% in the first forty regions), and the ratio of cases to the population in them is approximately 2:1.

Table 3. The number of cases and the incidence rate of COVID-2019 by regions of Russia from August 2, 2020 to August 1, 2021

Regions are sorted by incidence in descending order as of August 1, 2021

Region (oblast'), territory (krai), republic, autonomous area, federal city	The number of cases of infection (cumulative) as			Number of cases per 1 million people (incidence (sickness) rate)		Increase in the number of cases from January 16, 2021 to August 1, 2021,
	2.08.2020	16.01.2021	1.08.2021	16.01.2021	1.08.2021	
Russia	845,443	3,544,623	6,288,677	24,250	42,854	1.77
First 5 regions	383,333	1,499,885	2,677,290	45,157	80,606	1.78
First 10 regions	451,758	1,657,883	3,143,800	37,990	72,039	1.90
Moscow city	242,713	887,636	1,508,610	70,014	118,859	1.70
St. Petersburg	31,785	294,161	530,637	54,633	98,394	1.80
Republic of Kalmykia	2,659	16,245	24,932	60,170	91,988	1.53
Republic of Karelia	2,357	31,983	55,988	52,511	91,092	1.75
Altai republic	1,606	14,660	19,489	66,349	88,530	1.33
Murmansk region	10,507	39,989	62,122	54,565	83,778	1.55
Yamalo-Nenets autonomous area	11,235	34,290	43,757	62,686	80,434	1.28
Pskov region	3,797	26,941	43,758	43,436	69,896	1.62
Magadan region	1,357	7,489	9,525	53,865	67,939	1.27
Arkhangelsk region	8,842	47,446	74,156	43,823	67,891	1.56
Republic of Komi	5,396	33,969	55,454	41,752	67,613	1.63
Republic of Tuva	6,159	15,109	21,501	45,734	65,674	1.42
Novgorod	3,791	21,462	36,635	36,228	61,450	1.71
Khakass Republic	2,876	19,160	30,470	36,013	57,040	1.59
Sakhalin region	2,685	17,953	27,536	36,969	56,374	1.53
Orel region	5,707	24,165	40,254	33,345	54,866	1.67
Kamchatka territory	3,401	11,286	16,834	36,212	53,879	1.49
Ulyanovsk region	9,307	40,351	65,894	33,120	53,586	1.63
Trans-Baikal territory	4,106	30,970	56,590	29,398	53,404	1.83
Buryat Republic	4,159	28,162	52,572	28,578	53,313	1.87
Moscow region	63,755	176,026	386,895	22,835	50,327	2.20
Khabarovsk territory	7,759	40,096	65,773	30,816	50,006	1.69
Karachay-Cherkess republic	4,465	16,457	22,445	35,364	48,199	1.36
Vologda region	2,461	28,376	54,981	24,652	47,368	1.94
Sevastopol	352	8,224	20,960	16,126	46,699	2.55
Sakha-Yakut Republic	5,899	28,557	44,721	29,081	46,099	1.57
Bryansk region	7,430	26,264	54,362	22,207	45,584	2.07
Voronezh region	11,330	52,453	104,503	22,750	44,974	1.99
Smolensk region	5,705	19,611	41,666	21,290	44,575	2.12

Nizhny Novgorod region	24,097	77,255	141,093	24,320	44,039	1.83
Astrakhan region	4,657	21,770	43,676	21,818	43,417	2.01
Penza region	6,594	29,314	56,438	22,708	43,253	1.93
Kostroma region	2,261	16,180	27,318	25,747	43,130	1.69
Tver' region	4,655	25,910	53,898	20,801	42,764	2.08
Kaliningrad region	2,917	21,080	43,265	20,695	42,741	2.05
Kursk region	6,270	23,587	46,641	21,511	42,283	1.98
Ivanovo region	6,479	24,156	41,508	24,473	41,625	1.72
Kaluga region	7,260	23,638	41,287	23,615	41,284	1.75
Kirov region	4,888	29,329	50,426	23,460	39,940	1.72
Yaroslavl' region	6,112	25,320	49,935	20,396	39,846	1.97
Khanty-Mansi autonomous area	16,671	44,580	65,543	26,415	39,152	1.47
Tambov region	6,047	20,203	37,778	20,316	37,517	1.87
Jewish autonomous region	538	3,969	5,774	25,361	36,456	1.45
Nenets autonomous area	275	837	1,590	18,856	36,046	1.90
Irkutsk region	13,711	44,745	85,831	18,840	35,900	1.92
Republic of Adygea	2,803	12,211	16,351	26,364	35,281	1.34
Amur region	2,801	17,852	27,843	22,833	35,214	1.56
Lipetsk region	4,578	18,648	39,971	16,529	35,078	2.14
Republic of Ingushetia	3,729	13,247	17,692	25,694	34,917	1.34
Tomsk region	4,261	26,617	37,301	24,868	34,568	1.40
Tula region	8,379	26,104	47,546	18,014	32,432	1.82
Omsk region	6,990	34,110	61,623	17,918	31,986	1.81
Vladimir region	5,635	21,192	43,435	15,790	31,972	2.05
Krasnoyarsk territory	13,422	51,631	91,462	18,079	31,892	1.77
Ryazan region	6,352	20,221	35,292	18,412	31,825	1.75
Republic of Crimea	1,241	29,198	60,204	15,355	31,487	2.06
Kurgan region	2,303	13,708	25,899	16,746	31,319	1.89
Kabardino-Balkar Republic	6,008	17,398	27,092	20,016	31,206	1.56
Tyumen region	6,019	25,903	46,842	16,783	30,463	1.81
Saratov region	9,597	39,449	73,330	16,471	30,279	1.86
Republic of Mordovia	4,553	14,847	23,934	19,060	30,264	1.61
Leningrad region	5,955	27,356	56,327	14,453	30,019	2.06
Orenburg region	7,131	31,523	56,617	16,225	28,942	1.80
Primorsky territory	7,019	33,014	54,821	17,581	28,925	1.66
Belgorod region	6,042	24,769	44,732	16,071	28,905	1.81
Volgograd region	9,328	39,607	71,565	16,006	28,721	1.81

Perm Territory	6,018	35,404	73,526	13,726	28,287	2.08
Republic of North Ossetia	4,568	13,343	18,821	19,251	27,000	1.41
Altay Territory	9,326	36,150	62,365	15,742	26,916	1.73
Republic of Udmurtia	2,398	22,877	40,057	15,319	26,687	1.75
Rostov region	13,205	57,921	110,055	13,852	26,233	1.90
Sverdlovsk region	20,983	64,807	107,941	15,106	25,039	1.67
Samara region	6,930	36,011	76,773	11,417	24,150	2.13
Chuvash Republic	6,811	17,955	29,364	14,865	24,112	1.64
Republic of Mari El	3,800	9,980	16,142	14,778	23,770	1.62
Stavropol territory	8,449	38,949	64,912	13,946	23,158	1.67
Chukotka autonomous area	154	580	1,173	11,711	23,124	2.02
Chelyabinsk region	11,416	39,447	73,846	11,458	21,300	1.87
Novosibirsk region	9,548	30,181	52,919	10,834	18,911	1.75
Kemerovo region	3,702	27,704	46,069	10,520	17,334	1.66
Republic of Dagestan	9,350	25,996	41,917	8,297	13,472	1.61
Republic of Bashkortostan	6,815	21,735	48,509	5,415	12,014	2.23
Chechen Republic	2,082	10,110	16,092	6,749	10,897	1.59
Krasnodar territory	8,472	30,769	59,314	5,413	10,447	1.93
Republic of Tatarstan	5,664	14,735	23,982	3,784	6,145	1.63

Compiled by the author based on materials from sites:
https: //stopkoronavirus.rf – Coronavirus COVID-19: Official information. Some demographers argue that the data provided on this website underestimates the number of actual cases, since those infected are diagnosed with other diseases than coronavirus.

Table 3 shows that the number of cases of COVID-2019 and the incidence rate (number of cases per 1 million inhabitants) increased sharply during 2021 compared to 2020. In general, the number of cases in Russia during January-July 2021 turned out to be 1.8 times more than for the entire 2020, despite the fact that 2021 is not over yet. At the same time, in a significant number of regions it grew more than the national average (there are 38 of them, including more than 2 times in Sevastopol (2.6 times), Republic of Bashkortostan (2.2), Moscow region (2.2), Lipetsk, Smolensk, Samara regions, Perm territory, Bryansk region, Republic of Crimea, Leningrad and Vladimir regions, Chukotka autonomous area), and in most others (there are 41 of them), on the contrary, it is less than the national average, and in some of them it is very small (Magadan region and Yamalo-Nenets autonomous area) – less than 1.3 times. This growth is due to the continuation of the pandemic, which covers more and more cohorts of the population.

Territorial differentiation of the number of cases by socio-economic macro-regions. If we consider the distribution of the number of cases in August 2021 by large socio-economic macro-regions, then within each of them there are spatial disparities (see Fig. 2).

Thus, in the macro-region European Center, the number of cases reached 2.840 thousand, i.e. 45% of all in the country. The share of the Moscow area (Moscow city + Moscow region) was 66.7% of all cases in this macro-region.

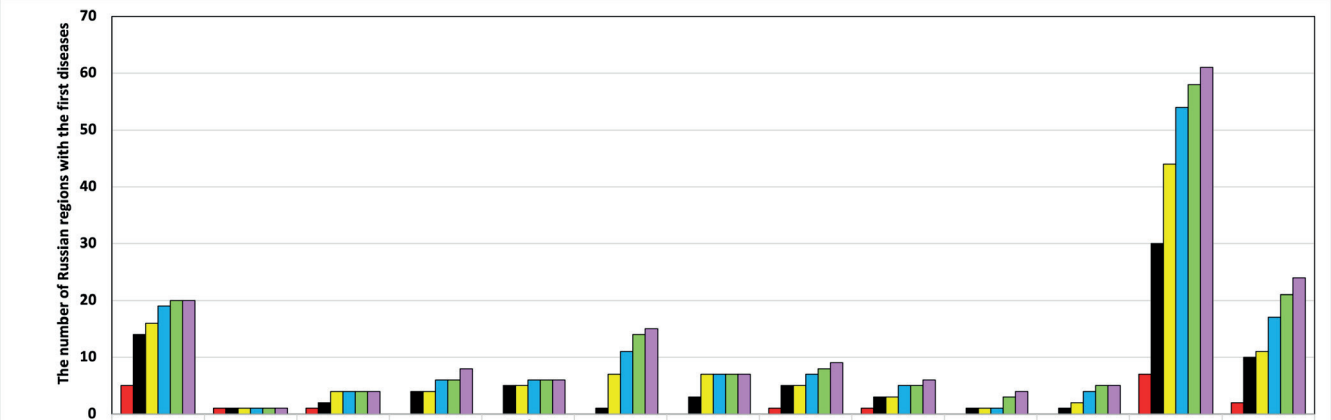
The *Kaliningrad* region was distinguished by a rapid increase in the number of cases – in January 2021 (22 thousand) it ranked 57th among the regions of Russia, but by August 2021 it had moved up to 50th place (43 thousand people).

In the *North-West* macro-region, the number of cases was 667 thousand, i.e. almost 11% of the total number in the country. The share of St. Petersburg was 79.5% of all cases in this macro-region (in August 2021 there were 531 thousand infected).

In the macro-region *European North*, the number of cases was 382 thousand, i.e. 6% of the total number in the country. The region was characterized by an even spread (due to shallow polycentricity), and the Arkhangelsk and Murmansk regions (74 and 62 thousand infected, respectively) accounted for 35.7% of all cases in this macro-region.

In the *Volga macro-region*, the number of cases was 285 thousand, i.e. 4.5% of the total number in the country. The region was characterized by an even spread due to polycentricity with the highest indicators in the centers. These include the Samara (77 thousand infected), Saratov (73 thousand), and Ulyanovsk (66 thousand) regions; these three regions together accounted for 75.7% of all cases in this macro-region.

In the macro-region *European South*, the number of cases on August 1, 2021 was 616 thousand, i.e. 10% of the total number in the country. Here, the highest incidence



	European Center	Kaliningrad	North-West	European North	Volga macro-region	European South	Urals	West Siberia	East Siberia	North-East	South of the Far East	European Russia	Asian Russia
10 March	5	1	1					1	1			7	2
20 March	14	1	2	4	5	1	3	5	3	1	1	30	10
25 March	16	1	4	4	5	7	7	5	3	1	2	44	11
30 March	19	1	4	6	6	11	7	7	5	1	4	54	17
5 April	20	1	4	6	6	14	7	8	5	3	5	58	21
17 April	20	1	4	8	6	15	7	9	6	4	5	61	24

Fig. 2. Cumulative increase in the number of regions with the first cases by macro-regions of Russia in March-April 2020

rate was registered in the Rostov region (110 thousand people). But this macro-region is polycentric, and there are secondary foci of concentration of the disease – the Volgograd region (72 thousand infected), Stavropol territory (65 thousand people) and Crimea (60 thousand people). These four foci accounted for 49.8% of all cases in this macro-region, i.e. the concentration is high, but not as high as in the European Center and North-West.

In the *Urals* macro-region, the number of cases was 426 thousand, i.e. 7% of the total number in the country. This region is traditionally characterized by tri-centricity, although Yekaterinburg and Sverdlovsk region in general (108 thousand cases) still dominates, but two other centers are also important – the Chelyabinsk region (74 thousand infected) and the Perm territory (74 thousand). These three regions accounted for 60% of all cases in this macro-region.

In the *Western Siberia* macro-region, the number of cases was 436 thousand, i.e. 7% of the total number in the country. Although nominally the center of the macro-region is Novosibirsk (its zone of influence includes the Tomsk and Kemerovo regions and Altai territory), it does not dominate so much in comparison, for example, with Tyumen and Omsk regions. The main foci of morbidity here are the Khanty-Mansi autonomous area (66 thousand cases), the Altai territory (62 thousand cases), and the Omsk region (62 thousand cases); altogether they accounted for 43% of all cases in this macro-region.

In the *East Siberia* macro-region, the number of cases was 338 thousand, i.e. 5% of the total number in the country. It is polycentric, and there is no single major center. The main foci of morbidity are the Krasnoyarsk territory (91 thousand cases) and the Irkutsk region (86 thousand cases); they accounted for 52% of all cases in this macro-region.

In the *North-East* macro-region, the number of cases was 72 thousand, i.e. 1% of their total number in the country. It is characterized by a system with a very weak and very diffuse polycentricity. The main focus of morbidity here is the Sakha-Yakut Republic (45 thousand cases; average level), i.e. it accounts for 62% of all cases in this macro-region.

In the macro-region *South of the Far East*, the number of cases was 182 thousand, i.e. 3% of the total number in the country. It is characterized by bi-centricity. The main foci of morbidity here are the Khabarovsk (66 thousand infected) and Primorsky (55 thousand) territories; they accounted for 66% of all cases in the macro-region.

In macro-regions with a pronounced strong monocentricity (European Center, North-West, Kaliningrad), the share of the main central area of the region is high; in macro-regions with strong polycentricity (European South, Volga region, Urals, and Western Siberia), the shares of large numerous centers are moderate; in macro-regions with fractional polycentricity (Eastern Siberia and the South of the Far East), the number of cases is concentrated in two main foci; in macro-regions with a very weak, diffuse polycentricity (European North and North-East), the shares of the main foci of morbidity are insignificant.

Territorial differentiation by the incidence (morbidity) rate

The average incidence rate (number of cases per 1 million inhabitants) in Russia in August 2020 was 6 thousand; in January 2021 – it was 24 thousand; in August 2021 – it was 43 thousand people per 1 million inhabitants. That is, due to the expansion of the pandemic, it increased by 7.4 times (the number of cases also increased by 7.4 times). For comparison, in European countries, on August 1, 2021, it averaged 69 thousand per 1 million inhabitants. This means that in Russia the incidence rate, according to official data from Rospotrebnadzor, is 38% lower than in European countries.

A high incidence rate (number of cases per 1 million inhabitants; see Table 4) in August 2021 was in Moscow and St. Petersburg, regions of the European North (republics of Karelia and Komi, Murmansk and Arkhangelsk regions), North-West (especially the Pskov region), the north of Western Siberia (Yamalo-Nenets autonomous area), the North-East and some republics of the south of Siberia (that is, where the share of the urban population is greater, and it is concentrated in several urban settlements; or the share of ethnic rural population), in the Republic of Kalmykia (92 thousand). A moderate incidence rate (thousand cases per 1 million inhabitants in August 2021) was characteristic of the most economically backward Republic of Altai (89 thousand); –a medium incidence rate was registered in the Republic of Tuva (66 thousand) and the Magadan region (68 thousand).

A low incidence rate in August 2021 was observed in the south of the Far East, East Siberia, Kaliningrad region, West of Siberia, the Urals, the European South (where the share of the rural population is relatively high, but there are exceptions, for example, the republics of Karachay-Cherkessia, Adygea, and Ingushetia), and in the Volga macro-region.

The minimum incidence per 1 million inhabitants on August 1, 2021 (a very low incidence rate) was registered in the republics of Dagestan (13 thousand people), Bashkortostan (12), Chechen Republic (11), Krasnodar territory (10), and the Republic of Tatarstan (6 thousand). Such extremely low values, for example, in the Krasnodar territory, republics of Bashkortostan and Tatarstan, where the share of the rural population is relatively high, suggest that the initial data are somewhat unreliable, since there are many large cities. The same doubts arise about the Kemerovo, Chelyabinsk and a number of other regions with very low incidence rates. Therefore the incidence rate here, apparently, is underestimated when compared with the values in the neighboring regions. For example, in the Republic of Ingushetia there are 35 thousand cases per 1 million inhabitants, and in the neighboring Chechen Republic was registered 11 thousand cases; in Adygea was registered 35 thousand cases, but in the surrounding Krasnodar territory – 10 thousand cases; in the Ulyanovsk region – was registered 54 thousand cases, but in neighboring Tatarstan – 6 thousand cases.

When compared with European countries, the overall incidence rate in Russian regions is much lower (see Fig. 5 and 6): in 51 out of 85 regions incidence rate is low (20–45 cases per 1 million inhabitants) and in 20 regions incidence rate is medium (45–70 cases).

Territorial differentiation of the incidence rate by socio-economic macro-regions (see Figures 3 and 4). In the macro-region *European Center*, Moscow city was registered a high incidence rate (119 thousand people per 1 million inhabitants); –four regions were registered a low medium incidence rate (20–45 thousand), and low rate – 15 regions (most).

The *Kaliningrad* region is characterized by medium incidence rate (43 thousand cases per 1 million inhabitants).

In the *North-West* macro-region, only St. Petersburg (98 thousand cases) had a high incidence rate, the medium rate was registered in Pskov (70 thousand cases) and Novgorod (62 thousand cases) regions and the lowest rate was registered in the Leningrad region (30 thousand cases). This macro-region stands out among the rest with an increased incidence rate.

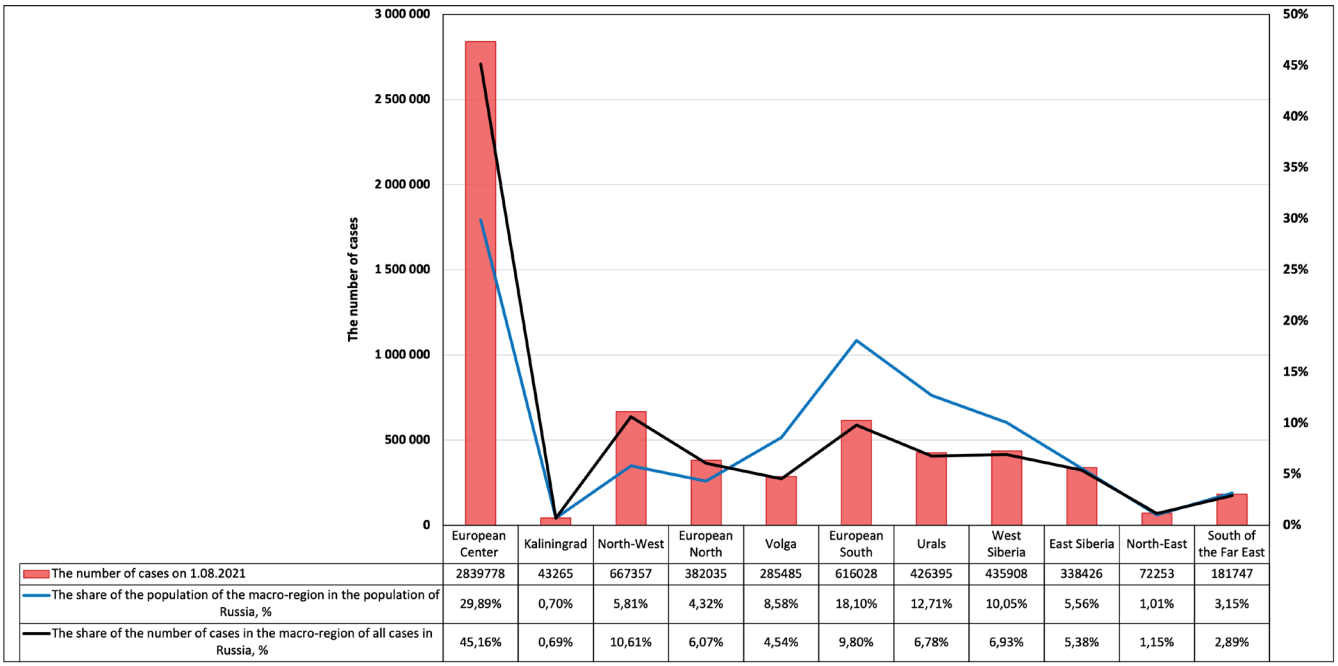
The same is true for the *European North* macro-region. Only the Republic of Karelia was registered a high incidence rate (91 thousand cases per 1 million inhabitants); moderate incidence rate was registered only in the Murmansk region (84 thousand cases); the medium incidence rate was registered in the Arkhangelsk region (68 thousand cases), the Komi Republic (68 thousand cases) and the Vologda region (47 thousand cases); the low incidence rate was registered in the remaining three regions.

In the *Volga macro-region*, the medium incidence rate was only in the Ulyanovsk region (54 thousand cases per 1 million inhabitants). Most of its regions (four) had low and very low incidence rates. Minimal rate among all Russian regions was registered in the Republic of– Tatarstan (6 thousand cases).

In the *European South* macro-region, only one region – the Republic of Kalmykia – was registered a high incidence rate (92 thousand cases per 1 million inhabitants). There were no regions with a moderate level at all. The medium level was noted in two regions; low level was noted – in eight regions; very low level was noted – in the Republic of Dagestan (14 thousand cases) and in the Chechen Republic (11 thousand cases) as well as in the Krasnodar territory (10 thousand cases).

In the *Urals*, there were no regions with high, moderate, and medium incidence rates. Six regions had a low level (20–45 thousand) and only the Republic of Bashkortostan had a very low level (12 thousand cases per 1 million inhabitants).

In the macro-region of *West Siberia*, a moderate incidence rate was in the Altai Republic (89 thousand people per 1 million inhabitants) and the Yamalo-Nenets autonomous area (80 thousand). There were no regions with a medium level. Five regions had a low incidence rate; two regions had a very low incidence rate.



	European Center	Kaliningrad	North-West	European North	Volga	European South	Urals	West Siberia	East Siberia	North-East	South of the Far East
The number of cases on 1.08.2021	2839778	43265	667357	382035	285485	616028	426395	435908	338426	72253	181747
The share of the population of the macro-region in the population of Russia, %	29,89%	0,70%	5,81%	4,32%	8,58%	18,10%	12,71%	10,05%	5,56%	1,01%	3,15%
The share of the number of cases in the macro-region of all cases in Russia, %	45,16%	0,69%	10,61%	6,07%	4,54%	9,80%	6,78%	6,93%	5,38%	1,15%	2,89%

Fig. 3. Distribution of the number of SARS-CoV-2 coronavirus cases and its shares by Russian macro-regions (%) as of August 1, 2021

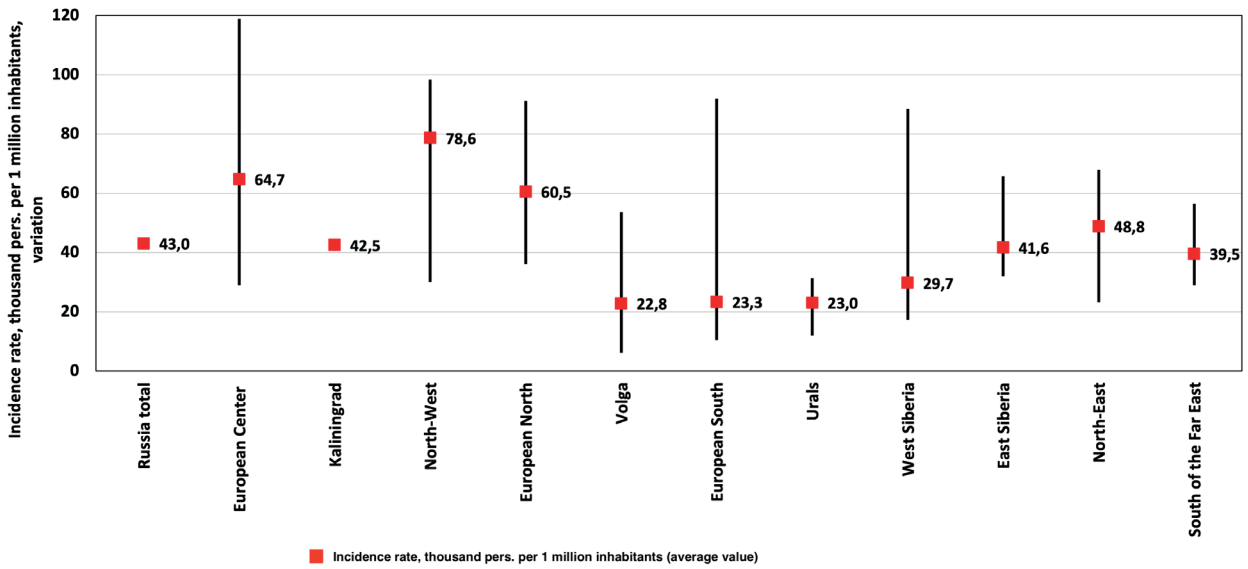


Fig. 4. Distribution of the morbidity rate of SARS-CoV-2 coronavirus by socio-economic macro-regions of Russia as of August 1, 2021

Tuva (66 thousand) and Khakass (57 thousand cases) republics, Trans-Baikal territory (53 thousand) and Buryat Republic (53 thousand cases) had a medium incidence rate (45–70 thousand cases per 1 million inhabitants) in the *East Siberia* macro-region; low incidence rate was registered in the Irkutsk region (36 thousand cases) and the Krasnoyarsk territory (32 thousand cases).

The *North-East* macro-region included three regions with a medium incidence rate and one (Chukotka autonomous area) with a low (23 thousand cases) incidence rate.

In the *South of the Far East*, the medium incidence rate was typical for the Sakhalin region (56 thousand) and Khabarovsk territory (50 thousand); in the other regions the incidence rate was low.

In the south of Siberia and the Far East, a low incidence rate is characteristic of the Krasnoyarsk and Primorsky territories, which are leading here in the absolute number of cases. This is due to the large population in these regions compared to other regions of these macro-regions.

Thus, there are very large geographical differences between Russian regions, both in the number of cases and in the incidence rate. They are characterized by a high concentration of cases in the largest urbanized areas.

DISCUSSION

With the application of theory of spatial diffusion (see Hägerstrand 1967; Smirnyagin and Tarkhov 2013), geographers in the 2000s studied the spatial distribution of influenza and epizootic epidemics (Haggett 2000; Cliff et al. 2004; Lawson 2006; Souris 2019).

With the spread of diseases, the features of three special forms (contact, hierarchical, mixed) are as follows. Contact (wave) diffusion of infection is characterized by an outbreak in one region (area) and then spread to neighboring regions and districts, so that the disease has the highest intensity at the place of origin and spreads with less intensity to neighboring territories. On the contrary, hierarchical spread is characterized by the onset of the disease in a certain place and its transfer to more distant areas and points associated with the initial place of its origin by hierarchical connections. The process of diffusion of the disease can also be mixed, when its wave and hierarchical spread are observed simultaneously.

If in the pre-aviation era epidemics spread linearly and hierarchically through land and water transport, then in the modern era, when air transport dominates, they spread hierarchically pointwise through airports.

From the point of view of the theory of spatial diffusion of innovations, the ***coronavirus spread at the first stages*** in an exclusively ***hierarchical way through*** the existing extensive ***air communication system*** – the largest and big cities, large urban agglomerations, to which direct flights from Italian air hubs were made, were the first to suffer. Of these, the coronavirus at later stages began to penetrate with the passengers through land transport to medium and small cities located in the zone of influence of the largest and large cities; last but not least, it penetrated into the countryside. At the ***later stages*** of its spread, it was characterized by a ***mixed form of diffusion*** dominated by a hierarchical form.

Carriers of coronavirus in the late stages of diffusion moved not so much by air as by land transport, except for remote and inaccessible regions, which were reached exclusively by air. The first cases were registered in people who arrived by air transport, which became the main means of spreading COVID-2019.

As a result of such a hierarchical spread of the epidemic, the regions affected first of all were the most economically advanced cities with the largest airports, then the virus spread to the regions with middle level of economic development, and to a lesser extent – the virus spread to the peripheral regions with a more disadvantageous transport-geographical position and the dominance of air transport against the background of weak development of the other modes of transport.

Empirically, our study[2] established the following gradations of the incidence rate (number of cases in thousand per 1 million inhabitants) as of August 1, 2021: very high values are considered from 140 to 200, high values are considered – from 90 to 140, moderate values are considered – from 70 to 90, medium values are considered – from 45 to 70, low values are considered – from 20 to 45, very low values are considered – less than 20. Comparison of the distribution of the number of Russian regions and European countries by the incidence rate is shown in Figures 5 and 6.

[2] including European countries

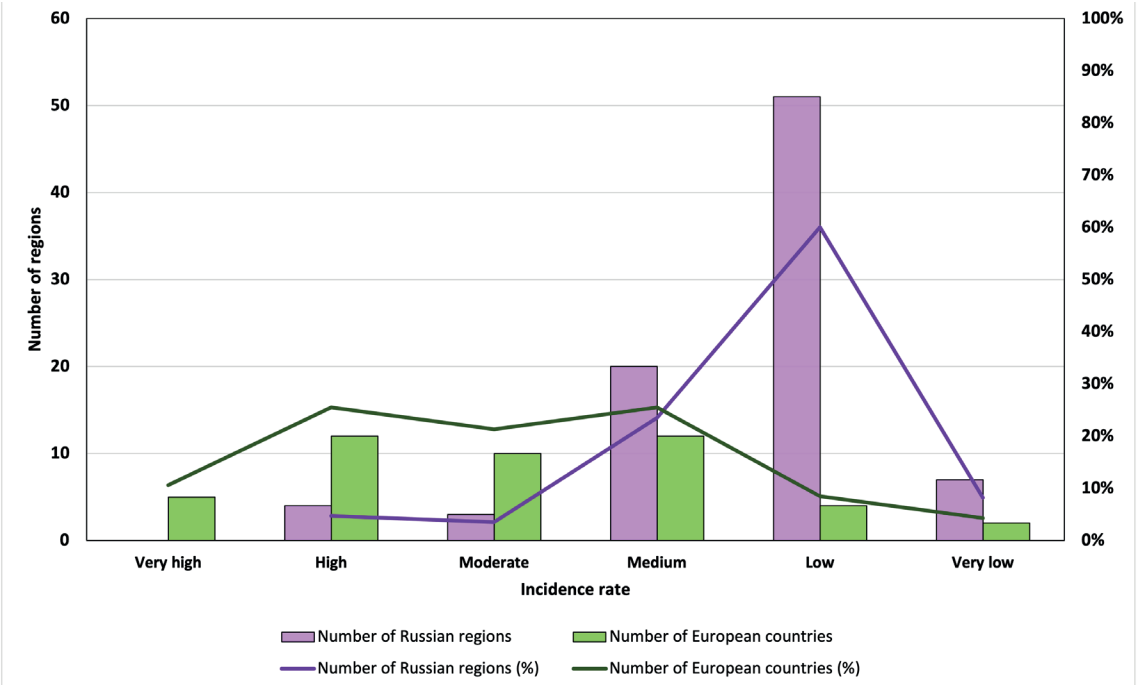


Fig. 5. Distribution of the number of Russian regions and European countries (and its shares in %) by the incidence rate of COVID-2019 as of August 1, 2021

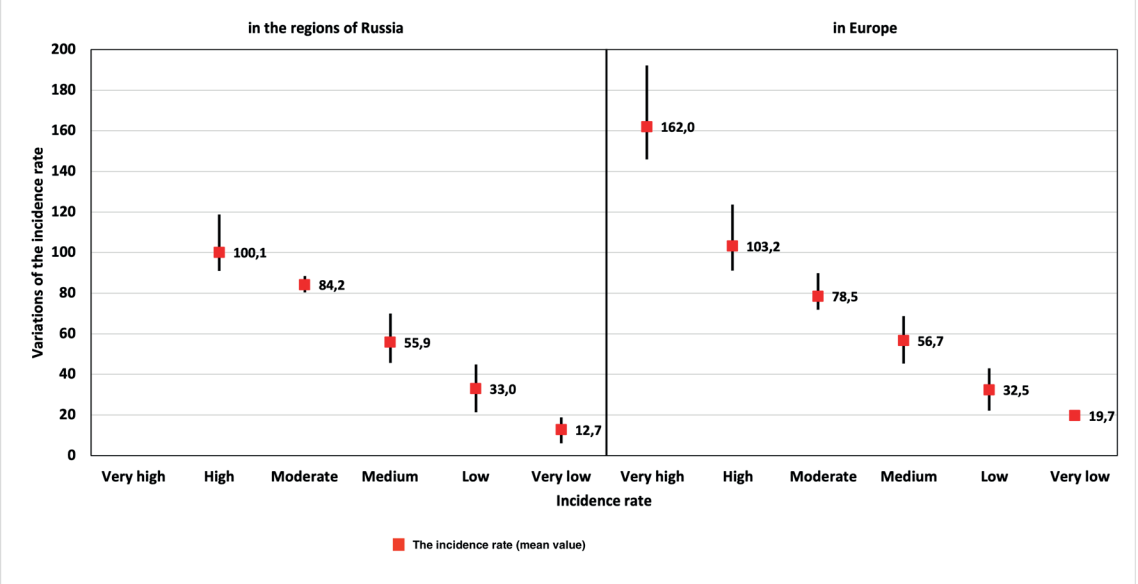


Fig. 6. The variation of the mean incidence rate in the regions of Russia and European countries as of August 1, 2021

The analysis of these Figures showed that most Russian regions have a low (60%) and medium (24%) incidence rate (71 regions out of 85; 74% overall), while in European countries the incidence rate is generally higher and more dispersed – in 26% of countries it is high; in 21% of countries it is moderate; in 26% of countries it is medium (73% overall). This distribution of shares across European countries and Russian regions (skewed distribution towards higher values in European countries and towards lower values in Russian regions) indicates both obvious geographical differences and partial unreliability of the initial data on the number of registered cases.

Attention is drawn to the average values of the incidence rate in Russian regions in comparison with European countries (6.1 thousand cases and 19.7 thousand cases per 1 million inhabitants). Therefore, such a comparison of the incidence rate makes it possible to judge the quality of the primary registration statistics, to determine the geographically obvious discrepancies in real terms. Given this circumstance, the initial statistics on the absolute number of diseases should be used very carefully, since for a number of regions and countries it may be underestimated.

CONCLUSIONS

The COVID-2019 pandemic spread in space extremely unevenly, covering first the most economically developed regions, and later semi-peripheral and peripheral regions. The spatial diffusion model of innovations is most suitable for explaining the spread of this disease. For this pandemic, the disease spread mostly hierarchically, that is, from the main focus (center), it penetrated into the centers of the 2nd and then the 3rd level, from where it already spread within the zones of their influence.

Air transport became the main source of the spread of the disease. Cities and agglomerations, where airports with a large share of international air passengers were located, that is, the largest cities, were the first to suffer.

The first infected arrived to Russia by air from China and Italy. In March, the virus was brought to Russia mainly by tourists returning from cities and ski centers in Northern

Italy. Further, from Moscow and St. Petersburg, where they originally arrived, they moved by air and by train to their places of residence, spreading the disease, first of all, to all the largest cities of the country. At the same time, the disease was transmitted by ground transport passengers in the zones of influence of these major cities. Those ill at the later stages of diffusion moved not so much by air as by land transport, but to remote and inaccessible regions they travelled exclusively by air. Thus, at the first stage of the infection spread, the main role was played by air traffic and flights from Moscow and St. Petersburg to the largest regional centers of the country; in the later ones, it was combined (air, rail and road transport).

The spread of coronavirus infection in Russian regions had a small peak during the first six days (early March), when the pandemic covered nine regions. The second, largest peak occurred on March 16–19, when 26 more regions were covered, and the third peak occurred on March 21–25, when another 17 regions were added to the list. Later, the number of new regions involved in the pandemic did not increase so quickly: on March 30 there were 71 regions, on April 5 there were 79 regions. The S-curve reached its saturation by April 17, when the first cases were registered in all 85 regions. Thus, the geographical lag of the spread of the epidemic in the Russian regions was 51 days (February 27 – April 17).

The coronavirus came to remote, mostly socio-economically more backward regions with a deep peripheral transport-geographical location the latest, and first of all to the regions with a favorable transport-geographical location and a high level of socio-economic development (especially in the largest urban areas and agglomeration). The main urbanized areas account for the most of the cases.

Most Russian regions have low and medium incidence rates – 60% and 23.5%, respectively – with some exceptions with a very low level. A very high incidence rate was not registered in any Russian region.

In the regions with a pronounced monocentricity, the share of the main central area is high; in regions with strong polycentricity, the share of large numerous centers is moderate; in regions with fractional polycentricity, the number of cases is concentrated in two main foci; in regions with very weak, diffuse polycentricity, the shares of the main foci of the disease are insignificant.

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