COVID-19 pandemic: Lessons from physics

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Abstract
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Keywords: COVID-19, physical instruments, diffusion, gravitational model, percolation model, kinetic theory of gases, verification, social and economic context, Slovakia

Article

COVID-19 andemic: Lessons from physics

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Abstract
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Introduction

The COVID-19 pandemic offers an opportunity for the science to show its usefulness and irretrievability. Virologists and pharmacologists earned the highest marks; the contributions of mathematicians, economists, sociologists, historians and others deserve an equal appreciation. Social phenomena, including epidemic, are amenable to modeling also with the help of the laws of physics.

1. Widespread are applications of the **phenomenological theory of diffusion** – the first and second Fick's laws. They present a simple description of diffusion, without considering molecular mechanisms. Their basis on is the empirical observation that the diffusion in any system proceeds in the direction of the negative gradient of the concentration. The laws are used in a number of different fields: in physics and in technology of materials; in the examination of the spread of innovations [1]; in the sharing of the technology of the renewable sources of energy [2]; or in mapping the migration flows [3].

2. Useful is the **kinetic theory of gases** [4]. Researchers believe that the properties of the large assemblies of molecules and the behavior of large communities have a lot in common [5]. Unavoidable in this context is the introduction of a virtual "social" temperature. French philosopher M. Halowachs occupied himself with this question as early as 1830 and A. Lepkowski drew attention to the fact that I. Prigogine's nonlinear thermodynamis helped to grasp the social phenomena [6].

3. **Thermodynamics** itself and its principles find their use in the formulation of the patterns and models of the dynamics of epidemics (e. g. [7]).

4. Yet another tool is the **gravitational model** derived from the Newton's law of gravitation. Since the beginning of the 20th century it has been used to study the urbanization processes [8] and to characterize migration [3, 9].

5. We may find a certain analogy with the spreading of the corona-virus in the **recombination of the charge carriers in semiconductors** [10].

6. The **theory of percolation** as an effective tool for studying the transmission of COVID-19 pathogens [11] was operatively applied by A. Bonasera et al. [12, 13]. We will give an example of their results.

Models

Predicting and modeling of the evolution of an epidemic have been effective weapons in the past and it continues to be so in the current crisis. The inspirational work [7] leans upon thermodynamics. Epidemic is seen as a process that feeds on the free energy, and once it had used it up all, it stops. Despite the powerful initial tool even the sophisticated models are just approximate. Social processes are not deterministic. The causes and consequences pervade each other and interfere with the measures that influence the process. (The measures are as follows: physical – limitation of mobility, isolation, barriers; chemical – disinfection, filtration; biological – vaccination, mutations.) The authors [7] start with the equation

$$\mathrm{d}N_s/\mathrm{d}t = -\beta N_{s.}N_i \qquad (1)$$

where N_s is the community exposed (or susceptible) to the infection, N_i are the infected, β is the intensity of contact, and t is time. Equations of this type lead to the exponential solutions, as is always the case when the increment is proportional to the instantaneous value of the function. Hence,

$$\mathrm{d}x/\mathrm{d}t \sim x \qquad (2)$$

Integration results in an exponential function

$$x \sim \mathrm{e}^t \qquad (3)$$

Exponential models [14] have manifold applications. We note an exponential growth of population, an exponential reproduction of bacteria, an exponential radioactive decay. The empirically verified course of the spread of epidemic is expressed by the logistic curve – a sigmoid with an initial exponential growth and a transition through the inflexion point into saturation.

The fact that we are dealing with the exponential functions (characterized by the most rapid growth), testifies to the danger posed by the epidemics or pandemics. With the introduction of appropriate measures we may slow down or stop the growth; we then set factor f < 1 in the exponent of the function. (Here we mention the deliberations of Krempasky [15] on the dynamics in the system predator – victim. In particular, after the predators, e. g., mountain lions, have consumed all the available food – rabbits, they are dying of hunger. This parellel is too drastic for the present day. It might have held for the medieval pandemics.)

The measures adopted in Slovakia during the first COVID-19 wave were not as strict as those in Italy when the epidemic had already been in full swing. To our advantage, we had before our eyes the catastrophic developments in Italy and Spain and later in Brazil and the USA. (An uncontrolled exponential growth tends toward an explosion. Already Kapica [16] made that point in connection with the 200-years lasting growth in the number of scientific periodicals. Since this growth continues, it serves as a piquant warning to us, scientists. Comparison with the splitting of the isotope ^{235}U gives a more ominous picture. Capture of a neutron by the nucleus causes the nucleus to split and release two – three neutrons. Instantly, they split the neighbouring nuclei. This is the ^{235}U chain reaction, the principle of the atomic bomb. The coefficient R0 which multiplies the SARS-CoV-2 falls usually in the interval 1 – 2 and the task is to suppress it to the deepest below 1, although many claim that it has only an orientation meaning. Anyway, a value of 2 is already very threatening.

Short history of COVID-spread in Slovakia and its neighbourhood

First wave

Infections spread fast, usually triggered by a singular invasive action (a group of people attending a funeral in Guinea are believed to have brought EVD – ebola – into Sierra Leone [7]). The first case of infection by the SARS-CoV-2 virus had been recorded in China on December 2019; the first case in the Czech Republic on 1 March 2020; the first case in the Slovakia on 5 March 2020. (The source of the first case in Slovakia was a citizens returning from Italy.) Exceptional stituation was declared in Slovakia on 11 March; the state of emergency on 15 March. Measures regulating the cross-border movement and associated with it quarantines were introduced in Central Europe in mid-March 2020. The initial conditions for the spreading of the virus and for the modeling of it were substantially altered in the second half of March. After about two months, i.e. at the beginning of May, the situation temporarily stabilized and in Slovakia we had only single-digit daily increases of infected. At the beginning of July 2020, the long-term chart showed a renewed increase, which could initially be understood as a fluctuation.

In further calculations we will use the initial spread situation within the cluster next to Bratislava which extends 25 – 50 km to the east up to the city Trnava, which emerged in 13 days, from 5 March to 18 March. The total number of infected was 56. Individually: Bratislava 37, Malacky 4, Pezinok 4, Dunajská Streda, 4, Senec 3, etc. The number of all infected persons in Slovakia was then 105 [17]. Later the picture changed as it is shown in Fig. 1.

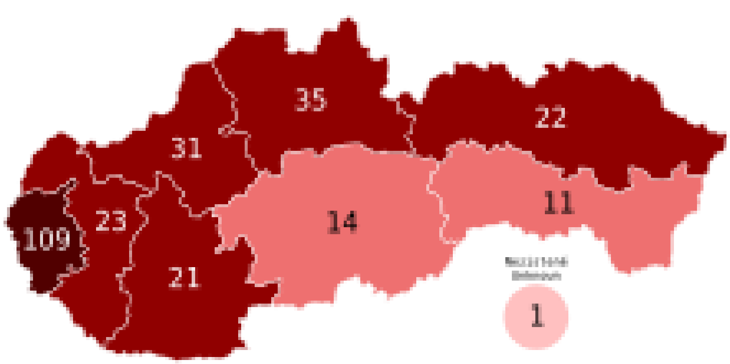

Fig. 1. Distribution of the identified infected persons in the administrative regions of Slovakia. Date: 27 March 2020, 1st wave. The north-west belt moved through the country from Györ (Hungary) along the river Váh up to Eastern Slovakia. Infection seems to be imported from Austria towards Bratislava and from the Czech Republic where neighbouring Morava has suffered a particularly hard hit. The belt spreads along the north-eastern corridor along the railway line and the highway (*https://www.dnes24.sk/*)

Second wave

During August 2020, the 2nd wave of COVID-19 began to be discussed. In the period of three weeks from 20 August to 10 September 2020, the situation in Slovakia has worsened. We got used to daily increments of around 100 with the maximum of 226. Bratislava and its 50 km surroundings had a share of 47% in these increments. The capital entered the red zone. Large increases were also reported by other countries, e.g. Croatia, which has become one of the main sources of our 2nd wave growth as a result of the summer holidays. The second wave of pandemic tends to be more intense than the first one, with population fatigue also playing a role.

From about 15 September to 15 November, the situation in Slovakia dramatically deteriorated. On 25 October we have exceeded the daily influx of infected 3 000. Critical were the districts of north-western Slovakia where the economy depends on the employment in the neighbouring industrial zones of the Czech Republic and Poland. From there, the disease could spread to Slovakia. Nevertheless, we observed an inversion, the best situation appeared in the capital Bratislava, where, probably, the experience from the previous months could be capitalized. Anyway, satisfaction with the course of the first wave in Slovakia was avenged in the second wave.

In this situation, the government proceeded to nationwide testing of the population with antigen tests, which have a low degree of reliability and have become the subject of political controversy. The number of those infected using these tests was about 3.97 % in the pilot testing of mostly infected districts and 1.06 % from nationwide testing one week later (31 October. – 1 November 2020). The number of infected by PCR – polymerase chain reaction assays concentrated on suspects, e.g. those who have been in suspicious contact, is maitained around 20 % in the third decade od November. This incidence should be at least halved to bring the disease under control. In spite of that the situation in Slovakia is not so bad (Tab. 1).

Tab. 1 COVID-19 situation update in Slovakia and in the neighbouring countries, as of 22 November 2020 [18].

Country	**Sum of cases**	**Number of deaths**
Austria	240 909	2 155
Czech Republic	490 750	7 095
Poland	843 475	13 288
Ukraine	612 665	10 813
Hungary	174 618	3 800
Slovakia	95 257	644

Diffusion in the study of the dynamics of epidemics

The two basic types of diffusion in solids, e.g., in semiconductors, are
a) diffusion from a temporally constant, i.e., unlimited source of admixtures on the surface,
b) diffusion from a finite and gradually depleting source of admixtures on the surface; dopants rearrange themselves in the volume of the semiconductor.

Our modeling is predicated upon the first type because the virus reproduces itself with the factor R0 often larger than 1. Then, from the Fick's 2nd law for a one-dimensional case (in the direction of *x*) we get the solution

$$N(x, t) = N_{\mathrm{p}} \operatorname{erfc} [x / 2(\mathrm{D}t)^{0.5}] \qquad (4)$$

where N is the concentration of the admixtures at the location x and at the time t, N_p is the concentration at the surface – in our case in the primary focal point or at the country's boundary, D is the diffusion coefficient, and erfc is the complementary error function. Examples of the diffusion profiles are presented in Fig. 2.

Modeling of the situation in Slovakia is hampered – fortunately – by low numbers of the infected. The basic isothermal diffusion in the gradient of concentration – stimulated by the so-called configuration driving force – assumes the gradient of concentration to be a continuous function. (We are familiar with other mechanisms of diffusion also. The thermal migration depends on the driving force derived from the temperature gradient. In the electromigration it is the high-density electric current or the electric field that carry the material.)

Despite of certain limitations, we will make at least an estimate of the diffusion around the cluster Bratislava and its vicinity (described in the frame above). The cluster extends 25 to 50 km including three district towns next to Bratislava and county town Trnava, respectively. The diffusion distance L is given by

$$L = 2\,(\mathrm{D}t)^{0,5} \qquad (5)$$

The values of the diffusion coefficients, 12 and 48 km^2/day, follow from (5). (We have introduced the unit km^2/day in [3], when dealing with the diffusion of migrants. The diffusion coefficient in semiconductors is expressed in the units of cm^2/s). For comparison, Tab. 2 shows the diffusion coefficients for various historical population transfers. Similarity between the coefficients of migration and the spread of the COVID-19 follows from the fact than in both cases the same transport mechanisms are employed and similar barriers need to be overcome. While the value 12 km^2/day appears to be reasonable, the value 48 km^2/day seems to be high for the 1st wave. Trnava probably should not belong into the Bratislava diffusion cluster in this case.

Slovakia adopted localization measures in the course of March 2020. Those measures markedly suppressed the diffusion within the 1st wave. (The most fitting case for applying the diffusion theory would be the spread of infection from the center of New York to the city's metropolitan area which has the population of over 20 million.)

The rapid growth in the number of those infected in north-western districts of Slovakia during six weeks after 15 September testifies to the resurrection of diffuse transport, If we take into account the average distance between the respective Slovak localities and Czech and Polish destinations, we calculate from Eq. (5) the diffusion coefficient of 27 km^2/day. The value corresponds to the previous calculation.

Tab. 2 Diffusion coefficients for the great movements of populations [19]

Process	**Diffusion coefficient [km^2/day]**
California gold rush	1 370
Settling of Siberia up to Lake Baikal	142
Migration to Europe in 2013 [3]	52
Transfer of Hungarians to the Carpathian basin	9

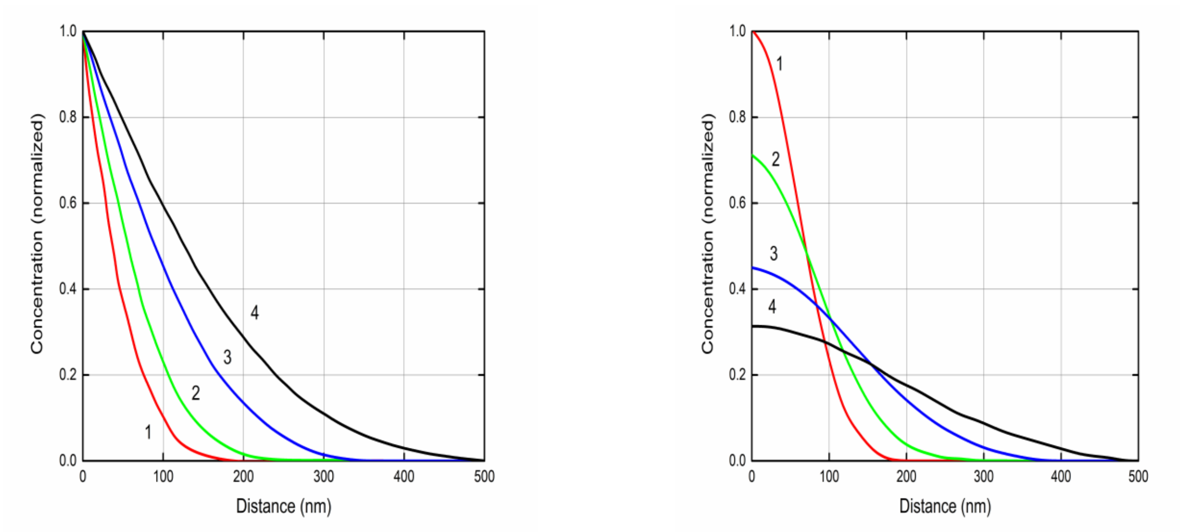

Fig. 2 Diffusion profiles of boron in silicon at the temperature 1100 ^{o}C. Curves 1 – 4 correspond to the duration of diffusion of 1, 2, 5, and 10 min. Left: diffusion from an unlimited source of admixture. Right: diffusion from a limited source [3].

Notions derived from the kinetic theory of gases

In the course of April 2020, the relatively little infected southern belt of Slovakia (Fig. 1) changed into a mosaic of the more or less affected districts. This can be interpreted by both an invasive and a locally reproduced infection. The situation in the Roma settlements may serve as an example. We may resort to the kinetic theory of gases when seeking an analogy between the movement of the molecules of an ideal gas and the movement of people. The basic relation of the theory [4]

$$\langle mv^2/2 \rangle = 3\mathrm{k}T/2 \qquad (6)$$

relates the mean kinetic energy of the translational motion of the gas molecules $\langle mv^2/2 \rangle$ to the gas temperature T. (Temperature is absolute, in units of Kelvin.) Mass of a molecule is m, speed is v, and k is the Boltzmann constant. The most probable speed of a molecule is

$$v_p = (2\,kT/m)^{1/2} \tag{7}$$

Let us imagine that the virus spreads via the local movements and chance encounters – in the language of the molecular theory through collisions – of individual persons. The gas temperature we may personify as the "temperature" of the social environment. We may consider several sources and forms of this temperature.

• First, it is the temperature that characterizes the mechanical motion and its derived frequency of "collisions." It goes up during the weekends and holidays and during the events like weddings and funerals.

• A second type of temperature may characterize the temperament of a given ethnic group. (Warmer climate = more emotional people is a supposition that Montesqieu articulated already in 1748 [6]). It is not inconceivable that the serious virus problems in Southern Europe have something to do with that fact.

• A third type of temperature has to do with the economic strength of the country. In Slovakia, according to our opinion, is the activity of people and along with it the temperature lower than in the wealthy western countries.

Kinetic theory of gases prods us to keep lowering the social temperature. The success of Slovakia in controlling the current pandemic may perhaps be caused by our more balanced temperament and by the concerns that the national health care would not be able to handle a large-extent pandemic, as it will be discussed later. Localization does produce desirable results. On the other hand, it affects the quality of life and it may be offset by depressions and by the lower immunity. But one thing seems to be certain: ignoring the localization regime opens the door to the diffusive spreading of the disease to larger distances.

Inspiration by the gravitational model

The gravitational model is an analogy of the Newton's gravitational law. We write: $F = \kappa\, Mm/r^2$, where M and m are masses, F is the force between them, r is their mutual distance, and κ is the gravitational constant. In the social systems the relation is adapted to the geographic or demographic purposes; it is then expressed in the logarithmic form. For instance [20]

$$\log F_d = \mathrm{a} \log P_1 + \mathrm{b} \log P_2 - \mathrm{c} \log r + \mathrm{d} \log X \tag{8}$$

where F_d is the demographic force that measures the social interaction, e.g. the migration flow; P_1, P_2 are the populations in the interacting centers; the quantity X expresses additional variables such as the GDP, the level of employment, and so on; and a, b, c, d are the constants that follow from fitting the data. Note that $\mathrm{c} \geq 0$. The gravitational model introduces the factor of distance between the interacting subjects. In our further analysis we will attempt to estimate the determining influence on the spread of the infection. That influence is decisive in defining the safe distances, isolating the infected persons, quaranting the potential disseminators, eliminating the transfer "traps".

We will use our model to compare occurences of the contagion in Bratislava and in the metroplitan cities Prague, Vienna, New York (Tab. 3). Those cities belong in the category of the national agglomerations, with large universities, governmental offices, country-wide medical institutions. We assume the potential of contagion to be proportional to the population P. Let us assume that the potential of infection is inversely proportional to the mean distance L between citizens; further, let the dependence be exponential, with the exponent α. We envision the citizens to be placed in the knots of a square net. Then $L = 1/(\sigma)^{0.5}$, where σ is the population density in the given city. We express L as a dimensionless quantity normalized to the length of 1 meter, since the safe distance as a rule is set at 2 meters. The following relation gives the number of infected N

$$\log N = a + \log P - \alpha \log L_1 \qquad (9)$$

where a is the constant obtained from the fitting exercise.

Tab. 3 Numbers of the infected citizens in the selected cities, with the related demo- and geographic quantities. Date: 5 May – 6 May 2020

City	***P* (2019)**	**σ [km^{-2}]**	**L_1**	***N***
Bratislava	437 725	1 190,5	29,0	206
New York	8 399 000	10 715	9,7	181 034
Prague	1 294 513	2 582	19,7	1 782
Vienna	1 897 776	4 326	15,2	2 204

Data in columns 2, 3, 5 come from the web pages of the respective cities and from the national maps of the COVID-19 pandemic spreading. See, e.g., [21].

We apply the model to several combinations of the cities Bratislava, New York, Prague, and Vienna. The data relevant to the chosen pairs we substitute into (9). This yields two eqations in two unknowns, **a** and **α**. The resulting values of the exponent α are shown in Tab. 4. The large values of α demonstrate considerable impact of the population density; also, that it is necessary to maintain safe distances.

Tab. 4 Exponent **α** for the combinations of cities in Tab. 3

Combination	**Exponent α**
Bratislava – New York	3,4
Batislava – Prague	2,8
Bratislava - Vienna	1,4
Prague – New York	4

Similarity with the recombination of the charge carriers in semiconductors

Important for the functioning of the semiconductor devices is the generation of the electron-hole pairs under the influence of photon absorption [10]. After a certain time, the pairs join again together – they recombine. In semiconductors such as GaAs, with the so called direct band structure, the radiative bimolecular recombination takes place. This is accompanied with the emission of radiation – e.g., in the LED devices. In the most often used semiconductor – silicon, with the indirect band structure, more complicated recombination takes place. This is accompanied with the release of a photon and a phonon – a thermal quantum. Recombination is facilitated by traps. We speak about the Shockley-Read-Hall mechanism. Traps are created by doping or they are imperfections in the crystal lattice. A trap absorbs the impulse difference between the recombining carriers in silicon.

This, for a layman uninteresting passage, points to the fact that it is not sufficient to eliminate the bimolecular interactions; in other words, it is not sufficient for people not to touch each other while using the public transportation or shopping in the supermarkets. It is necessary to avoid the transfer of the virus by means of a trap – an object made out of metal or plastic or some other material to which the virus sticks for hours or even days. Food packaging may act as a trap. Customers may have touched merchandise wrapped in this manner, without actually purchasing it. Thus they created a real "trap." Face masks, respirators, distancing protect us from infection of the bimolecular type. Gloves, disposable and available in the markets, protect us from infection through the traps. It does not do any harm to disinfect the packagings of the food items that we bring home.

Contribution of the theory of percolation

The importance of percolation theory deserves attention that is beyond the scope of this paper. Here we present an illustrative result of the work [12] that corresponds to the calculation using a gravitational model. Generalized knowledge from the theory of percolation applied to virus transmission indicates a critical population density of 1000/km^2. Under this condition the nucleus of the infection growth and spreads rapidly. This is documented in Fig. 3. Based on this, it was recommended [12] to move people to less populated areas.

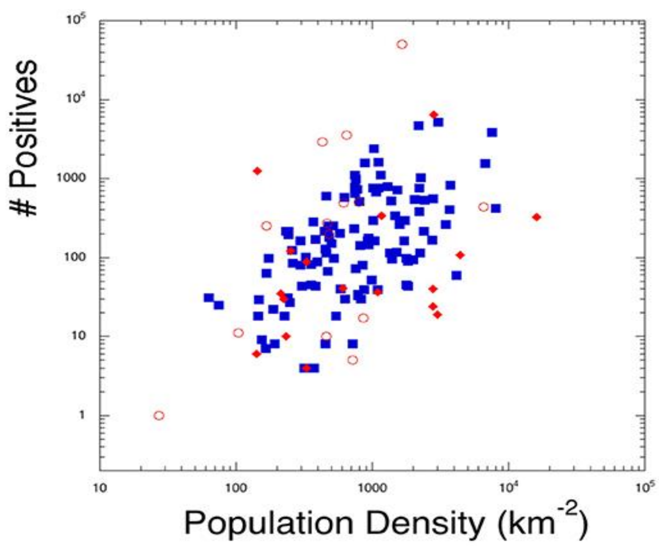

Fig 3. Number of positive cases (20 March 2020) as a function of population density in Italian provinces (full squares), regions of the Republic of Korea (diamonds) and some regions of China (empty circles). Credit A. Bonasera [12].

These calculations can be generalized using data on the degree of urbanization of EU countries [22]. Its values, i.e. the share of the population living in cities in 2020 ranges from 98.1 % in Belgium to 53.8 % in Slovakia. EU-27 average urbanization level is 73.8 %. According to [23] the mean population density in Slovak cities is 398/km^2 and in the countryside it is 61/km^2. Since population density is an accepted factor of infection transmission, the low rate of urbanization can be considered as advantage of Slovakia in the COVID-19 case. In addition, the World Health Organization has drawn attention to the worse living conditions in cities [24]; in connection with COVID-19, air pollution should be mentioned.

Social contexts of the battle against the pandemic in Slovakia

Slovakia’s results in combatting the COVID-19 are ascribed to the decisiveness of governmental authorities, but mainly to the consistent behavior of the people. What motivations should be sought behind all of this? Government has been apprehensive about the failure in the management of the epidemic and disruption of economics. Citizens feared for their lives and for their economic survival. There are several related factors in Slovakia‘s situation; we select four of them:

1. The condition of Slovak health care system and its potential to control a pandemic
2. Indebtedness of the Slovak households
3. Decline in industrial production
4. Internetization of EU countries

Ad 1. The Slovak healthcare system traditionally operates in a state of indebtedness, emigration of physicians, missing medication, etc. We verify hypothesis no. 1 as follows: for the sake of simplicity, the EU-27 countries (after Brexit) will be grouped into eight triplets and one pair according to the steadily declining expenditure on health care, expressed as a percentage of GDP per capita in 2019. Data are in US dollars [25]. (Luxembourg with anomalous high GDP per capita will be omitted as an outlier). Average values V will be compared to the average number of infectious N_i in the groups as of 6 May 2020. It turns out that the values of the seven groups (with the exception of Portugal – Italy – Spain – number of infected 153 654 and France – Germany – Sweden – number of infected 128 768) can be approximated by a straight line translated by the least squares method (Fig. 4).

$$N_\mathrm{i} = 4{,}36\ V – 36 \qquad (10)$$

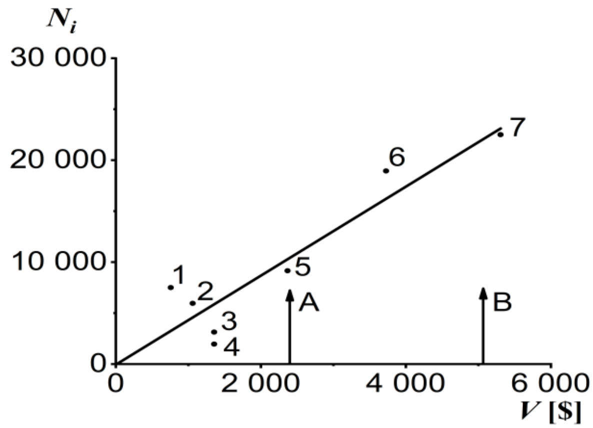

Fig. 4 Number of infected in EU vs. health care expenditure per citizen averaged for six triplets of countries, points 2 – 7 and one pair – point 1. Slovakia forms a triplet with the Czech Republic and Cyprus (point 3).. Point 7 has the Austria-Netherlands-Denmark group. Arrows A and B indicate the position of the triplets Portugal et al. and France et al.

For the Czech-Slovak-Cyprus triplet, we get 6020 infected by calculation, the reality is 3139. So, point 3 lies below the line. The Slovenia-Greece-Bulgaria triplet (point 4) is also below the line, while Romania-Latvia group (point 1) is over it.. Southern Europe is influenced by Italy, where the pandemic began, in Western Europe, confidence in one's own economy could weigh on. If we disregard groups A, B, it is clear that the number of infected people increases paradoxically with the increase of health care expenditures, which in turn indicates the caution of citizens of countries where health care is at a lower level.

Ad 2. The indebtedness of the household in the EU-27 in 2012 – 2018 can be found in [26]. To facilitate comparison, the data are expressed in % GDP. In the first group we have countries whose debt has been declining. It's a total of 19 countries. The indebtedness grew in Belgium, the Czech Republic, France, Luxembourg, Poland, Slovakia, Finland and Sweden. Growth was within 10 %, in the case of Slovakia the ratio coefficient reached 1.49. It can be assumed that the concerns of Slovak households about family bankruptcy increase caution in times of crisis.

Ad 3. The current decline in industrial production in the world is due to the spread of the epidemic. We used two types of data: a) year-on-year percentage decrease in industrial production *IP* in May 2020 compared to May 2019, b) percentage decrease in *IP* in March 2020 compared to February 2020 plus a decrease in April compared to March 2020. These data are influenced by the first wave and they enable to estimate the situation of the country in the second wave. The values of individual countries range from a few percentage points up to 50%. Slovakia is in a bad situation in both cases, in the first case it has a decrease of 33.5%, in the second one 47.2% [27].

We take the first case and compare *IP* with the percentage of infected people N_i in a given country, recalculated to the population size. The values range from 0.47% for Spain, to 0.026% for Slovakia. When we show the individual countries in the x-y coordinate system, we find that in the rectangle

$0 \leq IP \leq 20\%$
$0 \leq N_i \leq 0.2\%$

there are Bulgaria, Denmark, Greece, Estonia, Finland, Croatia, Malta, Lithuania, Latvia, Poland and Slovenia. These countries are managing well in terms of the downturn in the industry. They are successful in tourism, they foster green economy and some of them are Baltic countries that do not climb on the main transport routes. If we include losses in tourism, the picture will change, but in case of Finland and Denmark no so much. In a rectangle

$20 \leq IP \leq 40\%$
$0.2 \leq N_i \leq 0.5\%$

there are countries that have suffered heavy losses in the pandemic, such as Spain, Italy, Portugal, Germany and France. Let's look also at the strip along the x-axis

$0 \leq IP \leq 40\%$
$0 \leq N_i \leq 0.04\%$

Bulgaria, Lithuania, Hungary and Slovakia are located in it. However, Slovakia has the largest year-on-year decline in industrial production. If we characterize these countries by the product of IP x N_i, which speaks of the success of individual countries in facing the epidemic with a small decline in industry, the values are as follows: Lithuania 0.305, Bulgaria 0.417, Hungary 0.883, Slovakia 1.340. For comparison, Spain has 11.750.

Ad 4. The Internet exerts an important influence on the control of the pandemic. It is the pillar of the *home office* form of work. Access to the Internet has been approaching 100 % in Western Europe, 90 % in Central Europe and Visegrad 4, and 80% in the Balkans. Hence, the differences are relatively law to influence the situation considerably.

Conclusion

Application of the particularly chosen physical theories and models to the spreading of the SARS-CoV-2 virus in Slovakia and perhaps also elsewhere yields the following lessons. The diffusion mechanism leads to a relatively fast spreading of the infection. This is confirmed by the estimated diffusion coefficient of ≥ 12 km^2/day, even though that value is lower than the diffusion coefficient of migration to Europe in the current decade. The kinetic theory of gases tells us that it is necessary to keep lowering the "virtual temperature" of the social system. That temperature may be related to the national temperament of the individual ethnic groups or nations. A principal lesson follows from the gravitational model, namely that the infectivity steeply grows as the mean distance between citizens in residential neighbourhoods is reduced. Our models indicate that the growth could reach the fourth power. The calculations based on the theory of percolation are congruent with these findings. Analogy with the recombination of the charge carriers in semiconductors points to the danger posed by the stationary traps. They make the spreading of the virus feasible even when a large distance between persons has eliminated the chance for a direct transfer. Good results of fighting the COVID-19 epidemic in Slovakia may be ascribed to the vigilance of the population. Two possible sources of this vigilance are identified: the poor state of the national health care and the indebtedness of the households.

Dedication

In this work written during the EASA 2020 elections we want to appreciate the merits of the founders of the Academy, many years of Professor F. Unger's work as President and to wish Professor K. Mainzer and his team the fulfillment of their program for the further development of the institution.

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