The model of the spread of virus COVID-19 in Moscow

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<u>Analysis of situation monitoring data</u>

The simulation is based on statistics on the spread of the virus, presented on the site [1]. Below, figures 1 and 2 show some of these data (at the interval of time until April 30).

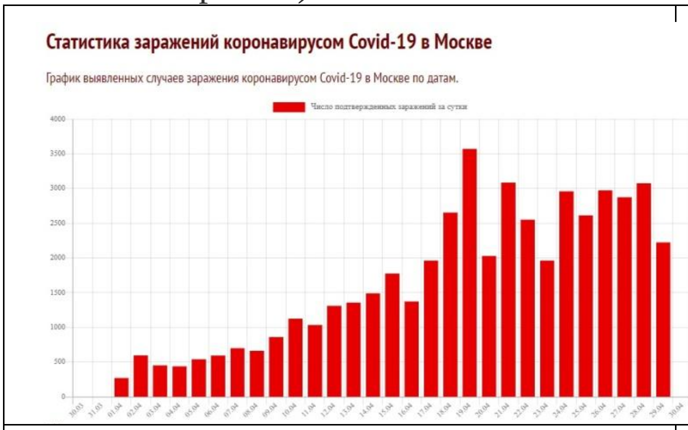

Figure 1. Daily increase in the number of infected residents

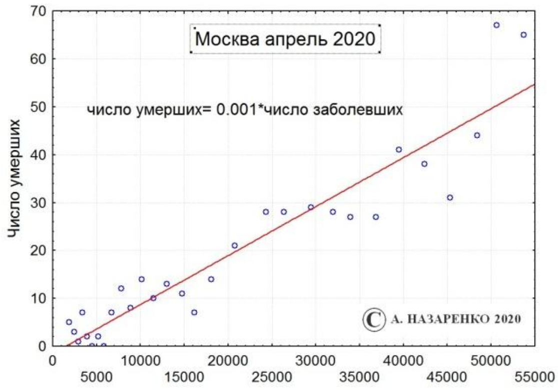

Figure 2. Link the number of deaths and the number of people who have been contagious

Figure 1 data are characterized by the fact that the growth of the daily number of sick residents actually stopped after April 18 and stopped at the level of 2,500 cases per day. Figure 2 shows a proportional dependence on the number of deaths and the number of people who have fallen. On average, there is one dead per 1 000 inhabitants.

Consider the results of monitoring the number of infected residents in Moscow. They are presented in Figure 3.

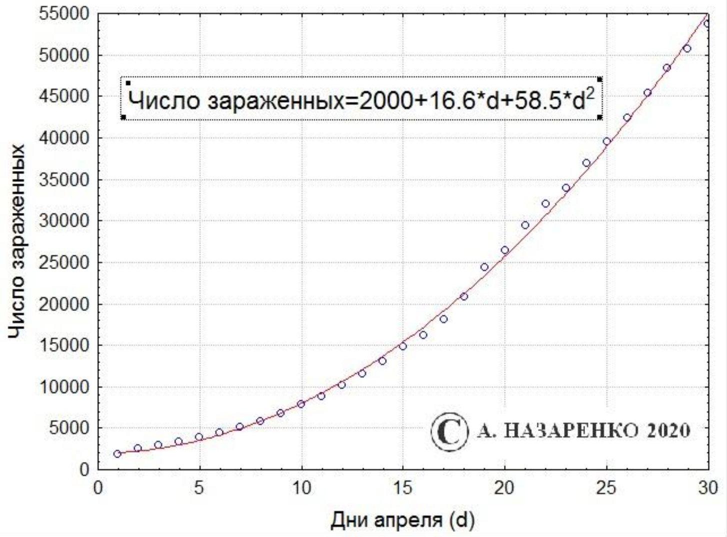

Figure 3. Data from the epidemic monitoring in Moscow

This picture also presents the results of the approximation of experimental data by parabolic dependence on time:

$$x(d)=2000+16.6\times d+58.5\times d^2 \, . \qquad (1)$$

The derivative of this function

$$dx(d)/dd=16.6+2\times 58.5\times d \quad . \qquad (2)$$

makes sense of the daily increase in the number of sick residents

$$(dx(d)/dd)_{d=30}=16.6+2\times 58.5\times 30=3526. \qquad (3)$$

At the last point of the time interval considered (*d-30*), this value was 40% higher than the above-mentioned estimate of the daily increase in the number of sick residents (2500 per day). The reason for this discrepancy is due to the fact that at the entire interval examined, the quadratic approximation does not quite correspond to the actual pattern. This is confirmed by the calculation of the derivative at point d=19

$$(dx(d)/dd)_{d=19}=16.6+2\times 58.5\times 19=2240, \qquad (4)$$

that was close to the above-mentioned daily growth rate of 2,500 per day.

How to explain the trend of daily increase in the number of patients to a stable level? Using an analysis of the situation in Moscow, the author concluded that this is due to the gradual transition to an even distribution of the number of patients across the city. As a result, the likelihood of infection becomes constant. The other picture was before the stabilization. During this period, areas with an increased level of patients occupied part of the city. Over time, they expanded. Therefore, the daily growth rate increased. This is typical of a large rather isolated city with a large population, such as Moscow.

Thus, recommendations follow from the above analysis of the curve $x=f(d)$:

- At the interval of time until April 20, use the approximation (1).
- Once the derivative *dx/dd* reaches 2500 per day this value is taken a constant value at the interval of further forecast.

<u>Consider the algorithm of epidemic modeling in Moscow</u>

Below outlined an updated method of modeling the development of the epidemic, which, compared to the previous version of the epidemic, made a number of improvements:

- Taken into account the dependence (1) of the increase in the number of sick residents from time to time;
- The number of people dying of natural causes unrelated to the epidemic is taken into account;
- The impact of possible preventive measures to prevent infection has been taken into account.
- The effect of seasonal effect has been enhanced.

The number of residents at the current time t

x - the number of sick residents

y - the number of people who have recovered

z1 - the number of inhabitants who have died from the virus

z2 - the number of residents who have died for other reasons

$w=x-y-z1$ - the current number of patients (5)

u - the number of residents with whom preventive measures

Sum - the total number of residents of the city, the number of residents of the city, the number of residents of the city, the number of residents of the city, prone to infection

$$Sumt=sum-x-z1-z2-z2-u. \quad (6)$$

Data on daily increase

q - number of patients who have arrived

n - number of sick residents

m - number of residents with prevention

s - number of recovered

r - number of deaths

$$dx/dt=q+n$$
$$dy/dt=s \quad (7)$$
$$d(z1+z2)/dt=r$$
$$du/dt=m$$

Model parameters and their influence

p_n - effect are the proportion of new infected, which is calculated on the basis of the ratio (1).

kt - *seasonal ratio of the number of infected*

$$kt=1+0.6*sin(t+90°) \quad (8)$$

t – days from the beginning of the year

$$n= Sumt *kt*p_n \quad (9)$$

p_s - *the share of new recovered*

$$s= w *p_s \quad (10)$$

p_r - *the proportion of new deaths from the epidemic and other causes of the epidemic*

$$r= w *p_{r1} +Sumt *p_{r2} \quad (11)$$

p_m - *increase in the number of residents with prevention*

$$m= p_m \quad (12)$$

Ratios (5 -12) is the model of the evolution of the epidemic with the parameters of q, p_n, 0.6, p_s, p_{r1}, p_{r1}, p_m.

d = the interval of the forecast

$t=t_0+d$ - the time (days) from the beginning of the year (13)

Model parameters are specified according to the published data of monitoring the situation.

The results of the simulation

In the *first* phase the modeling the spread of coronavirus in April 2020 and updating the set the parameters of the model were executed based on published monitoring data. The result of this stage is presented in Figure 4.

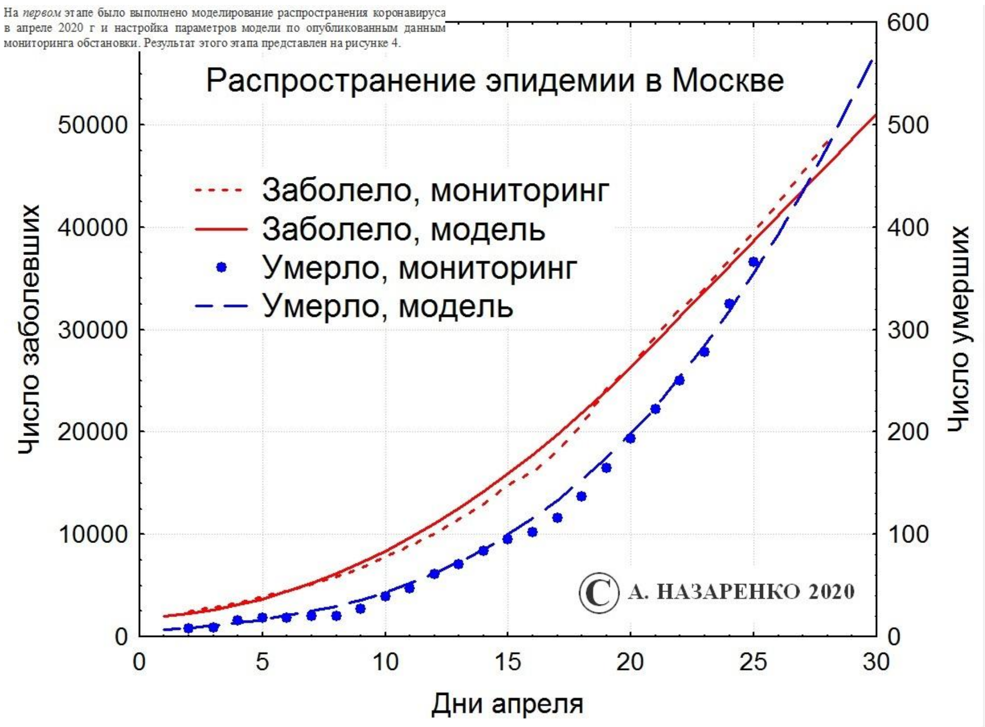

Figure 4. Comparison of the results of modeling and monitoring of the situation

The data of picture shows that on such characteristics as the number of sick and deceased residents of Moscow, a very good correspondence of model and real data has been achieved. Below, Table 1 shows the data from the last line of the output file.

Table 1. Model results of the situation on the monthly interval of time until April 30, 2020

Date	K(t)	Number of cases	Daily increase	Number of recovered	Number of recove-red from the virus	Number of deaths not from the virus
30	0.75	51058	2471	5259	573	5097

During the month reviewed, the number of deaths as a result of coronavirus infection was 9 times lower than the number of deaths for other causes.

In the *second* phase, the epidemic was predicted at the annual interval starting may 1, 2020. The first (pessimistic) scenario allowed that no preventive measures would be taken to reduce the number of cases. In the second scenario, preventive measures were expected to be taken to prevent coronavirus infection. Namely, it was accepted that such events will be held daily with 3,000 patients. The results are presented in Figure 5.

These results show an important conclusion that the number of sick and deceased residents will continue to rise steadily. In a year's time, the corresponding estimates will be:

The number of cases (680 – 770) thousand of inhabitants.

The number of dead (155 – 167) thousand of inhabitants.

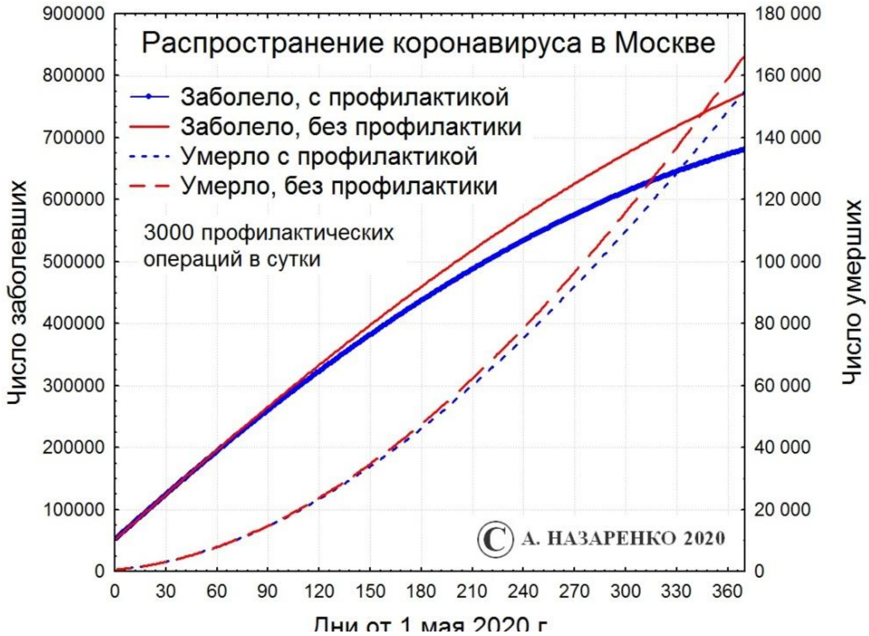

Figure 5. Forecast of epidemic development at one-year interval

The above-mentioned preventive measures (3,000 inhabitants per day) do not have a significant impact on the development of the epidemic. Another important conclusion is that **the increase in the number of sick residents of Moscow will continue for more than one year!**

Reference

1. Site https://coronavirus-monitor.info/country/russia/moskva/
2. А.И. Назаренко. «Модель распространения коронавируса в Москве», Site satmotion.ru, part “News”
3. А.И. Назаренко. Задачи стохастической астродинамики. Математические методы и алгоритмы решения. М: URSS, 2017. 352 стр.

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