Mathematical modeling of COVID-19 pandemic waves in Ukraine and Poland

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ABSTRACT

Background. The threats of the COVID-19 pandemic require the mobilization of scientists, including mathematicians. To understand how the number of cases increases versus time, various models based on direct observations of a random number of new cases and differential equations can be used. Complex mathematical models contain many unknown parameters, the values of which must be determined using a limited number of observations of the disease over time. Even long-term monitoring of the epidemic may not provide reliable estimates of its parameters due to the constant change of testing conditions, isolation of infected and quarantine. Therefore, simpler approaches should also be used, for example, some smoothing of the dependence of the number of cases on time and the known SIR (susceptible-infected-removed) model. These approaches allowed to detect the waves of pandemic in different countries and regions and to make adequate predictions of the duration, hidden periods, reproduction numbers, and final sizes of its waves. In particular, seven waves of the COVID-19 pandemic in Ukraine were investigated.

Objective. We will detect epidemic waves in Ukraine and Poland; estimate the epidemic characteristics with the use of generalized SIR model. Some predictions of the epidemic dynamics and estimations of the vaccination efficiency will be presented .

Methods. In this study we use the smoothing method for the dependence of the number of cases on time; the generalized SIR model for the dynamics of any epidemic wave, the exact solution of the linear differential equations and statistical approach developed before.

Results. Eight epidemic waves in Ukraine were detected and the reasons of their appearance were discussed. The optimal values of the SIR model parameters were calculated. The prediction for the COVID-19 epidemic dynamics in Ukraine is not very optimistic: new cases will not stop appearing until June 2021. Similar research can be done for Poland.

Conclusions. New waves of COVID-19 pandemic can be detected, calculated and predicted with the use of rather simple mathematical simulations. The expected long duration of the pandemic forces us to be careful and in solidarity.The governments and population must strictly adhere to quarantine measures in order to avoid fatal consequences.

The text of the lecture is available in:

1. Nesteruk I. Waves of COVID-19 pandemic. Detection and SIR simulations. MedRxiv. 2020 Aug. doi: https://doi.org/10.1101/2020.08.03.20167098
https://www.medrxiv.org/content/10.1101/2020.08.03.20167098v1

2. Nesteruk I. Нові хвилі пандемії COVID-19 в Україні. New waves of COVID-19 pandemic in Ukraine. (In Ukrainian). [Preprint.] ResearchGate. 2020 Aug. DOI:10.13140/RG.2.2.26172.26244 https://www.researchgate.net/publication/343979510_Novi_hvili_pandemii_COVID-19_v_Ukraini_New_waves_of_COVID-19_pandemic_in_Ukraine

3. 1. Nesteruk I. COVID-19 pandemic dynamics in Ukraine after September 1, 2020. [Preprint.] ResearchGate. 2020 Dec. DOI: 10.13140/RG.2.2.27942.75848 https://www.researchgate.net/publication/347521678_COVID-19_pandemic_dynamics_in_Ukraine_after_September_1_2020

The details will be available in the book:

I. Nesteruk. COVID-19 Pandemic Dynamics. Mathematical Simulations. Springer, to be punlished in March 2021. DOI 10.1007/978-981-33-6416-5

https://www.springer.com/us/book/9789813364158

Biography of Igor Nesteruk

Leading Researcher in Institute of Hydromechanics National Academy of Sciences of Ukraine, Head of Laboratory of Biomedical Electronics at *Igor Sikorsky Kyiv Polytechnic Institute* . He earned his M.S Degree in Aircraft Engineering from Moscow Institute of Physics & Technology in 1977; Ph.D. Degree in Mechanics of Liquid, Gas and Plasma form Moscow State University in 1982, Dr. Science degree in the same subject in 2005. His main research interests are Inverse Non-steady Problems of Fluid Mechanics, Supercavitation, Flow Control, and Biomedical signal processing. In frames of two Horizon 2020 projects (EUMLS and AMMODIT) he worked on mathematical simulations of infectious diseases, post-processing the 4D MRI data, has proposed an algorithm for the automatic segmentation of the vessel lumen and started developing an user-friendly interface.