Influence of Humidity on the Evolution of COVID-19 Daily Cases in Romania — Data Based Study

Iulia Clitan, Vlad Muresan, Mihail Abrudean, and Andrei F. Clitan

***Abstract*—Upon an active research regarding the influence of environmental factors on the COVID-19 infection rate, that denoted a divided opinion between a positive or negative influence in term of humidity and the SARS COV-2 virus spread, the authors were able to obtain a quantification effect of relative humidity (RH) influence on the spread of SARS COV-2 virus, in Romania, and consequently the influence of RH on the future number of daily COVID-19 positive cases. The discussed quantification was validated by means of computer software, and the aid of a mathematical model that predicts the outcome of COVID-19 disease on a horizon of 28 days, based on a complex neural network structure, trained using consistent data tracking the evolution of daily COVID-19 cases from March 2020 till October 2020, tool designed by the authors themselves. The validated quantification revealed that the maximum influence of RH on the increase of daily COVID-19 infections is between 60% - 70%, due to the temperate climate, while zero influence occurs at a RH higher than 90%.**

***Index Terms*—Relative humidity, environmental factors, COVID-19 evolution, prediction model, neural network.**

I. Introduction

The first case of COVID-19 was reported in December 2019, in the region of Wuhan, China. COVID-19 is a disease due to the coronavirus SARS COV 2, that is a rapidly spreading virus, thus the coronavirus outbreak evolved into a pandemic on 11 March 2020 [1]. The COVID-19 patients suffer from mild to severe respiratory illness [2]. In Romania, the first case of COVID-19 was reported in 26 February 2020, and the national authorities imposed a national lockdown from 16 March to 14 May, that decreased the number of active cases in our country. From 15 May, our country is maintaining a state of alert, established by the President of Romania. However, with the relaxation of restrictions on the territory of our country, a first wave of infections appeared in April, followed in September by a second wave, reaching a much higher infection rate than at the beginning of the pandemic. Since then, our authorities have taken different actions to keep the pandemic under control.

The ascending allure on the evolution of COVID-19 daily cases, is depicted in Fig. 1, were it is represented the number of cases reported each day as COVID-19 positive, from 26 February 2020 until 1 March 2021, the web page https://covid19.geo-spatial.org being the source of data [3].

Manuscript received March 20, 2022; revised May 12, 2022.

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The red dotted vertical lines, from Fig. 1, represent restrictive measures imposed by the authorities, the green dotted vertical lines represent relaxation measures, while the blue dotted vertical lines represent national or religious holidays. `

Since, mainly the lock down measures imposed in order to slow the virus transmission rate, to relieve the pressure on the health care department and consequently decreasing the number of fatalities due to COVID-19, impacted the socio-economic and financial matters of the different countries of the world [4], many research is conducted on trying to understand and predict either the spread of the virus and the categories of vulnerable people, or the prediction of the effect of the virus, and the severity of the illness [5]-[7].

The authors are working on creating a predictive model, which will be incorporated into a web application [8], in order to predict the evolution of the daily number of COVID-19 cases in different scenarios, namely to analyze primarily the influence of measures taken by the authorities, either relaxation or compulsion. It is thus desired to obtain an aiding tool, to facilitate the local authorities in making the right decisions to maintain an equilibrium between controlling the transmission of COVID-19 and the impact on the socio-economic domain. The process of virus transmission is a biological process which has the particularities of having large number of input and output signals. Consequently, the studied process is a strong nonlinear MIMO (Multiple Input Multiple Output) process. For a correct assessment and prediction of the COVID-19 transmission (the increasing or decreasing number of cases), several factors were considered as inputs to the designed mathematical model, for example the number of daily infections, number of daily deaths, number of cures, number of quarantined persons, measures taken by the authorities, including the influence of environmental factors on the evolution of COVID-19 daily cases.

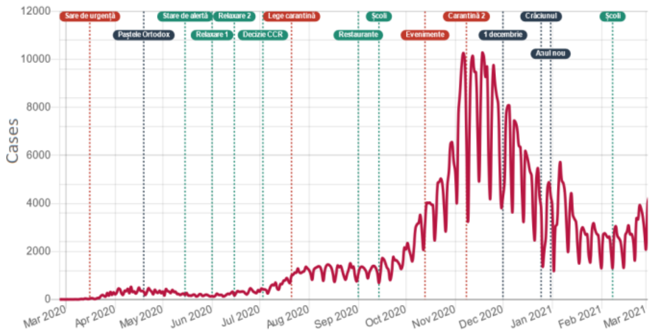

Fig. 1. Daily cases of COVID-19 infections in Romania according to geo-spatial.org [3].

Regarding the influence of environmental factors, a more detailed analysis is caried out regarding the relative humidity's influence on the transmission of COVID-19, and a quantifying of the influence of humidity on the evolution of the number of daily cases of illness in our country resulted. The proposed quantification is validated based on the comparison between the predicted output (future number of daily cases) and a part of the available number of daily cases set, that was used to test the predictive model.

II. Research on the Influence of Humidity on the Transmission of the SARS-CoV-2 Virus

In addition to population mobility and human-to-human contact, environmental factors can influence droplet transmission and virus survival.

Humidity is the amount of water vapor contained in a sample of air. There are three ways to express humidity: absolute humidity, relative humidity, and specific humidity. Absolute humidity is the amount of water vapor (in grams) contained in a volume of air equal to one unit. Relative humidity (RH) is the ratio between the partial pressure of water vapor under given conditions and the partial pressure of vapor under equilibrium conditions at the same temperature. Relative humidity depends on temperature and pressure [9].

If in terms of temperature, the studies are consistent and have denote a negative effect on the influence of the increase in outdoor temperature on the spread of SARS-CoV-2 virus, in terms of the influence of humidity on the spread of the virus, opinions are divided [10]-[16]. This is based on limited climate variables at national or regional level and is probably due to the time-limited range used in previous research, focusing on the onset of the pandemic.

In comparative studies conducted in several countries, it was obvious that the climatic conditions specific to each region are essential, when analyzing the influence of meteorological factors on the rate of transmission of SARS-CoV-2 virus. Moreover, the association of COVID-19 incidence with temperature seems more obvious and much stronger than the one with relative humidity. However, the vast majority of studies have shown a negative influence on the spread of SARS-CoV-2 when there is an increase in humidity. RH being closely related to the temperature value. In a study conducted in January-April 2020 in China, it was found that RH favors the transmission of the virus at low temperatures (below 5%) but tends to reduce transmission when temperatures are high (above 25°C) [11]. At low temperatures: with an increase in RH by 1%, the number of daily infections from a patient increases by 0.001 [11].

An analysis of previous studies led to the following conclusions [12]: SARS-CoV-2 may be less stable in environments with high temperature and high relative humidity. Second, the moisture in expired bioaerosols evaporates rapidly at low relative humidity, forming droplet nuclei that remain in the air longer, thus increasing the likelihood of transmitting the pathogen. The data, analyzed from 166 countries [12], led to the hypothesis that temperature and humidity are inversely correlated with the number of daily cases of illness (in terms of RH the study found that for each increase in humidity by 1%, the daily number of cases is reduced by 0.85%, but without presenting the RH reference value used). In [13], the authors report that high temperature and high relative humidity reduce the viability, stability, survival, and transmission of COVID-19, while low temperature, wind speed, dew point/frost, precipitation and surface pressure prolong activation and virus infectivity. It resulted from statistical analyzes that increasing RH by 1% will decrease the number of confirmed cases by approximately 0.08% (considering the average value of RH as 73.7%, and the maximum value being 100%, value reached in the analyzed data). High RH values lead to decreased viability and persistence of the virus, and at low values coronaviruses can last up to 14 days, thus prolonging their viability and stability on contaminated surfaces.

An analysis of the pandemic evolution in New Jersey, USA, and the link between the number of daily cases and environmental factors, showed a positive influence of RH on daily illnesses [14]. The percentage increase in humidity, with each percentage, led to an increase in the number of COVID-19 cases by 2.28%.

An analysis of the influence of humidity and temperature on the evolution of the Bangladesh pandemic showed the following: the peak of COVID-19 spread occurred at an average temperature of 26°C and a humidity of 55%, then gradually decreases as temperature and humidity increase. The highest number of cases were grouped in the average temperature range 26°C - 28°C (84.2%) and in the humidity range 55% - 65% (82%). High RH helps prevent infection in another way by keeping the membranes of the nose and throat moist, allowing them to trap dirt, bacteria, and viruses before they reach the lungs [16]. This is corroborated by the fact that at high RH, small respiratory droplets would take water, increase in size, and settle faster in the air [17].

It was observed that most published articles focused on the influence of relative humidity on the transmission of SARS-CoV-2 virus.

Another study on the influence of climate on COVID-19 transmission, carried out on 228 cities around the world grouped according to their geographical location in three climate zones, was published in October 2020 [10]. The climatic classification was made as follows: tropical (0 – 23°26′11.9″ N/S), subtropical (23°26′11.9″ N/S - 40° N/S), and temperate (40° N/S - 60° N/S). Unlike other articles, this study contains data on the evolution of the number of cases by areas of variation of RH and temperature (93 cities), respectively, for temperate, tropical, or sub-tropical countries. The results from [10] show that the average temperature (42.9%) and the average RH (25.9%) were the main factors that contributed to explain the differences in COVID-19 transmission in the temperate zone. At the same time, the average daytime interval (52.2%) and the temperature season (30.8%) were the most significant determinants of this viral community transmission in the tropics. In the subtropical area, the role of average temperature (61.7%) and relative humidity (17.5%) was the largest of the selected predictors. The results show that, in the countries of temperate zones, the average temperature contributed major to the number of cases, and the optimal RH for spreading was found in the range of 60-70%.

For countries in the temperate zone, like our country, a more complex association is found between the number of COVID-19 cases and RH, although it was a less influential factor in temperate and sub-tropical areas. The probability of transmitting the disease increased after the threshold of about 60%, resulting in a peak in the range of 60% - 70% RH.

Based on the presented studies, a quantification of the influence of RH on the number of daily infections was obtained by the authors. This quantification resulted from the correlation of all the analyzed studies with the data from, considered by us, the more consistent study [18]. The proposed RH quantification is given in Table 1, where a value of 0 means no influence whatsoever while a value of 100 means a maximum RH influence on the increase of future cases.

TABLE I: QUANTIFICATION OF RELATIVE HUMIDITY

Relative Humidity Level (RH %)	Quantification granted
< 30	5
30 - 59	20
60 - 70	100
71 - 90	30
> 90	0

III. INFLUENCE OF RELATIVE HUMIDITY ON THE EVOLUTION OF COVID-19 DAILY CASES IN ROMANIA

The testing and further, the validation of relative humidity, as a climate factor, on the evolution of daily cases in Romania is based on the neural network prediction model designed by the authors and intended as an aiding tool for the national authorities to control the spread of the virus by analyzing the influence of different measures (relaxations or compulsions) combined for instance with the seasonal climatic chances.

A. Testing the Influence of Relative Humidity on the Evolution of Daily Cases in Romania Based on a Neural Network Prediction Model

First, the model proposed by the authors for the prognosis of virus transmission dynamics is a MIMO type model since it is a complex model, having large number of input and output signals that must be analyzed and taken into consideration, with strong nonlinear input-output interdependencies [8].

The large number of input-output signals are being grouped by the authors in different categories (as briefly presented in Fig. 2). The input signals considered for the proposed model are grouped in three main categories such as: of type SAIS – Set of Active Input Signals (for example the legislation in the domain of the COVID-19 issue); of type SEIS – Set of Exogenous Input Signals (for example the climatic conditions including the influence of humidity on the SARS-CoV-2 virus spread); or of type SENIS – Set of Endogenous Input Signals (for example the social and demographic aspect of the pandemic). The proposed model will provide the prediction of the Set of Output Signals (SOS) considered as the future daily cases of infections, the future daily active cases and the future number of fatalities, thus providing an overall look on the rising or descending allure of future infections, on a time span of 28 days.

The prediction model is implemented using neural structures containing different types of parallel neural networks, having large number of hidden layers of significant high sizes, depending on the input-output dependency types associated to the model. The identification of such a model is based on processing large databases containing experimental data, thus the usage of neural networks becomes an asset as to determine (learn) the dynamics of the SARS-CoV-2 virus transmission process, over time.

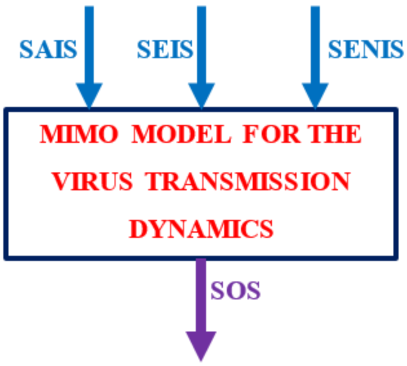

Fig. 2. The proposed architecture of the prediction MIMO model for the virus transmission dynamics [8].

The neural network was trained using a large portion of the COVID-19 databases containing experimental data, such as the daily number of cases from 26Th of February 2020 till 31 of October 2020, considered as the learning time interval. This is a time series database, considering day 1 as the 26Th of February 2020.

Using the proposed prediction model, and the designed complex neural network, the information about the influence of relative humidity on the evolution of COVID-19 cases was tested. The results of the SOS generated by the trained neural network structure without adding the proposed RH influence, were compared to real experimental data, that were not included in the learning procedure (for November 2020).

Figure 3 shows the different results obtained between the experimental data and the predicted ones, by training the neural network without adding the environmental factors' effect (including the RH influence), thus without considering the proposed RH quantified effect. Further, the quantified effect of RH on the virus transmission is added to the mathematical model and the network is retrained.

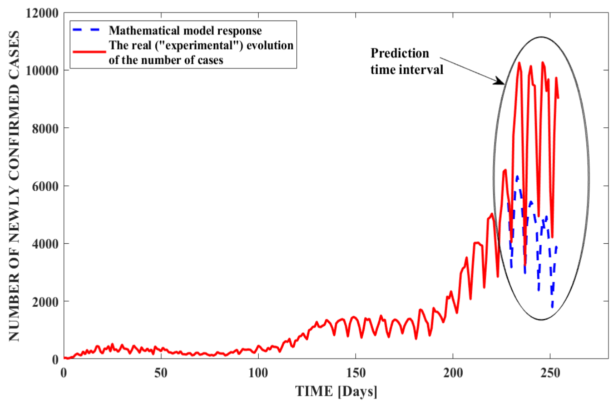

Fig. 3. The results obtained by training the neural network without considering the environmental factors effect.

B. Validating the Influence of Relative Humidity on the Evolution of Daily Cases in Romania

The above network training and testing revealed a direct correspondence between the relative humidity and the spread of SARS COV 2 virus, meaning the evolution of COVID-19 cases.

The result of the SOS generated by the trained neural network structure with the proposed RH influence included (the estimated number of future COVID-19 cases) were also compared to real the experimental data of November 2020. The data related to this time interval was considered as the prediction time interval.

Using such a relative humidity influence (the proposed quantification) as one of the model's SEIS inputs, generated the comparative graph between the experimental curve of COVID-19 daily cases and the response of the main SOS solution provided by the neural network (given in Fig. 4). The high accuracy of the obtained neural model, and thus validating the correct humidity influence an COVID-19 transmission for a temperate climate country, results directly from Fig. 4, since the two responses are almost completely overlapped.

The insignificant value of the quality indicator MSE (Mean Square Error) validates the influence of relative humidity on the evolution of daily COVID-19 cases in Romania.

The even more important aspect is the fact that on the prediction interval (November 2021), the answer of the determined mathematical model keeps the allure of the real evolution of the number of confirmed cases and approximates with high accuracy this evolution. This aspect demonstrates the correctness of the obtained mathematical model, respectively the influence of relative humidity on the evolution of the pandemic.

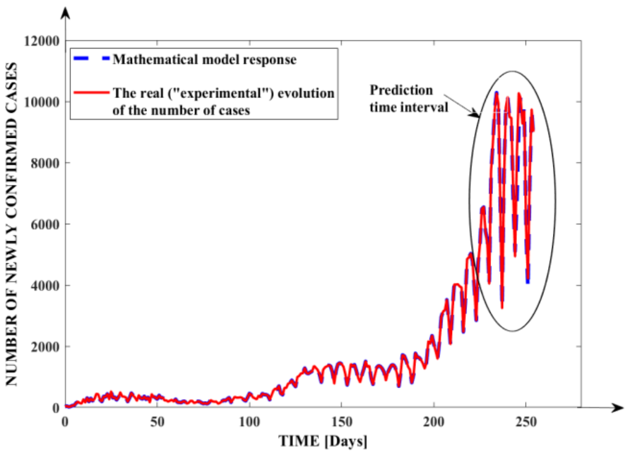

Fig. 4. Validating graph of the relative humidity influence an COVID-19 transmission for a temperate climate country

IV. Conclusion

The authors are elaborating a prediction model, for the prognosis of COVID-19 daily future cases, to aid the national authorities in pandemic related decision making. The model is based on a complex neural network structure, since it deals with a MIMO type model associated to a process of virus transmission. The authors analyze, by means of the proposed model, the influence of environmental factors on the outcome of COVID-19 evolution.

In terms of temperature, studies are consistent on the negative effect on the influence of the increase in outdoor temperature on the spread of SARS-CoV-2 virus while in terms of the influence of humidity on the spread of the virus, opinions are divided into positive or negative effects on the virus transmission rate. The authors found a more consistent study carried out on 166 countries, that analyzes the environmental factors influence on the COVID-19 infections evolution based on the climate position of each country.

Based on the review and analysis of previously published studies, a quantification of the influence of relative humidity on the number of daily infections was obtained by the authors. The maximum influence on the increase of COVID-19 cases occurs for a relative humidity between 60% and 70%, for temperate climate countries, while for a relative humidity higher than 90% the influence is zero.

The RH quantification vas validated by means of simulation, since for the prediction interval of 1 month (November 2020) the predicted number of daily COVID-19 positive cases coincides with the real data regarding the COVID-19 cases, on a graphical analysis. If the influence of humidity is not taken into account, or another influence is considered, than the quantified one, the evolution predicted during a month no longer coincides with the real values, for the prediction interval.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

I. Clitan conducted the research; V. Muresan developed the prediction model and its architecture; M. Abrudean analyzed the data. A. Clitan proofread the paper and contributed to the elaboration of the paper; all authors had approved the final version.

Acknowledgment

The research was supported by the research project no. 10Sol / 2020, "*Dinamica transmiterii virusului SARS-CoV-2 pe teritoriul României (*Dynamics of SARS-CoV-2 virus transmission in Romania*)*", Project PN-III-P2-2.1-SOL-2020-0157, Coordinating institution Technical University of Cluj-Napoca, Romania.

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