https://doi.org/10.53656/nat2022-6.04

New Approaches

METEOROLOGICAL DETERMINANTS OF COVID-19 DISEASE: A LITERATURE REVIEW

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Abstract. The purpose of this investigation is to review the currently known studies on the meteorological preconditions of COVID-19, and analyze and synthesize the results from the existing research, with a view to further substantiating a methodological approach to assessing the daily meteorological factors of viral particles detention in the open air.

In pursuit of this goal, the present study attempts to derive and differentiate some findings of the recent research from all over the world about weather and climate factors of SARS-COV-2 dispersion in the atmosphere. The results are systematized according to the main climatic elements – air temperature, air humidity, solar radiation and wind speed. Some climatically sensitive social-demographic factors (such as gender, age structure, general morbidity and predisposition to chronic diseases, household conditions, personal habits, educational level and so on) that determine the resistance to COVID-19, are also commented in this study. Last but not least, the issue of scaling up and remote approaches to the study of the climate and COVID-19 relationship was also addressed.

Keywords: COVID-19; air temperature and humidity; solar radiation; wind speed; meteorological factors; social and demographic factors

Introduction

It is known that a number of environmental conditions, incl. climatic ones, are key to the emergence, life and behavior of microorganisms. They are directly related to the spread of diseases, transmitted in vector, water, air, nutritional and other ways. The climate impact on these processes is increasing even more in its changes, in which biotics and a-biotic mechanisms arise, some of which have already been studied and about some we will still learn. Climate change provokes the activity of the thermo-adaptation and immune system of macro-organisms, as well as these in the human body. Gradually, accumulated loads from the impact of these changes are just beginning to show in different, climatically conditioned bio-effects, and this is yet to grow with ever greater strength and in ever different ways. The Health Sector Report of the National Strategy for Adaptation to Climate Change (Mateeva 2019) establishes how diverse and surprising the health effects of climate change can be and how many diseases can be unlocked or exacerbated, as well as how little these impacts have been explored, especially for the highly climatic / meteorological diversity of Bulgaria.

For the factors, unlocked the current situation with the COVID-19 disease and the SARS-COV-2 virus causing it, as well as the influence of climate on this situation is known too little. At present, the World is at the beginning of meeting with COVID-19 and the knowledge of its nature and adaptation in co-habitation with humans is in a starting phase. The study and disclosure of the nature of COVID-19 is currently one of the most up-to-date research problems and involves scientists from all over the world. Is there a connection between the weather and resistance of the virus, and can climate contribute to the aggravation of the pandemic or vice versa - to overcome its spread, what is the behavior of the virus at lower or higher values and combinations of temperature, humidity, solar radiation, wind speed, the aerosol content in the air pool, etc., what is the amendment of this behavior in the conditions of climate change, is it possible to output algorithmically secured link “Climate → COVID-19” for to be predicted in a short or long-term order of meteorological / climatic increase in the presence of the virus in our surroundings? These are questions that are still expecting their scientific lighting and are the subject of interest in the current research.

The purpose of this work is to review and analyze the contemporary studies on the meteorological conditions of COVID-19, and to make a synthesis of the conclusions made in them, in view of the further justification of a methodological approach to assessing everyday weather prerequisites for detention of the viral particles in the air, and of forecasting to future time horizons on the climatic determinants of COVID-19.

For this purpose, the project is based on the working hypothesis that the transmission of the SARS-COV-2 virus (COVID-19 disease) from surfaces in our surrounding medium is not a leading factor (Nicastro, Sironi, Antonello et al. 2020). It is mainly carried out by aerosols and depending on the weather conditions it is able to accelerate transmission or slows down during the different periods of time.

In fulfilling of the objective, this study attempts to differentiate by basic climatic elements, as well as by some non-weather factors showing sensitivity to weather/climate and their changes, to make conclusions of previous studies on these issues.

1. COVID-19 climatic determinants

1.1 Air temperature

The air temperature is one of the main climatic elements. It is directly conditioned by the radiation and the thermal balance of a given place, which has a key impact on heat spending to heat the ground air. The thermal parameters of this air layer are essential for the bio-status of all living organisms.

A global study involving 166 countries (excluding China) reports a significant negative correlation between the air temperature and COVID-19 cases (McClymont & Hu 2021). The rise of the temperature by 1°C is associated with 3.08% (95% confidential interval (CI): 1.53 – 4.63%) decrease in conventional cases (Wu et al. 2020). In another global study of Yuan, Wu, Jing et al., (2021) analyze data from 188 countries. They discover that the average 24-hour air temperature is in a negative correlation with the number of new daily cases with COVID-19 and the 24-hour temperature amplitude shows a positive correlation with this number. These dependencies were more obvious when the 24-hour temperature was lower than its long-term mean and the temperature amplitude higher than that value.

A systematic literary review of McClymont & Hu (2021) shows that the temperature is reported as a significant meteorological element as analyzed in the largest number of studies. The incidence of the COVID-19 disease increases by lowering the temperature, and the highest frequency is in the temperature range of 0 – 17°C. Of all publications assessing the relationship between temperature and COVID-19, only three studies conducted in Canada, Spain and Australia (To, Zhang, Maguire et al. 2020; Ward, Xiao & Zhang 2020; Briz-Redón & Serrano-Aroca 2020) did not show a significant relationship. As an optimal temperature range for the disease occurred, is from 0 to 17°C average 24-hour temperature. The number of cases is lower in the warm areas (i.e., with an average temperature above 17°C) (Bukhari, Massaro, D'Agostino et al. 2020). It is found that 60% of cases occurred at a temperature between 5 and 15°C and the peak reached at 11.5°C (Huang, Huang, Gu et al. 2020). Most studies in this review report a significant correlation between the temperature and cases of COVID-19, with a part of them observing a negative correlation and, in another part, positive correlation. This is probably associated with a certain temperature optimum around which the correlation is positive, but beyond - negative.

According to a study on cities in China (Liu et al. 2020), there is a significant negative correlation both in terms of the average air temperature and the 24-hour temperature amplitude. The authors report that the reduction in the number of daily cases reached 80% (95% CI: 75-85%) and 90% (95% CI: 86 – 95%) at an increase of 1°C of the average daily temperature and at a 1% increase in the 24-hour of the air temperature (McClymont & Hu 2021). For

Hubey province, it is found that every 1°C increase in the average temperature there is a reduction in daily confirmed cases by 36-57%. Shi, Dong, Yan et al. (2020) reported that the lowest morbidity was observed at -10°C and the highest at 10°C. Xie & Zhu (2020) report that at temperatures below 3.0°C there is a significant positive correlation with COVID-19 cases in Chinese cities. Each increase of 1°C was associated with 4.861% (95% CI: 3.209 – 6.513) increase of cases. Liu et al. (2020) analyze data from continental China, Hong Kong and Singapore and discover that high temperature reduces the transmission of the disease.

Research held in Africa reports that with each increase with 1°C of the average daily temperature, daily cases decrease by 13.53%, with delay decrease in the incubation and infectious periods (Adekunle, Tella, Oyesiku et al. 2020; McClymont & Hu 2021).

In a study by India for the period 1 April - 10 May 2020, the effect of temperature varies in the 11 country states. The connection between the frequency of COVID-19 and the average temperature is reported as significant in four of the included states, namely Madhya Pradesh ($r = 1.43$, $p \leq 0.05$), Maharashtra ($r = 2.76$, $p \leq 0.05$), Punjab ($r = 1.49$, $p \leq 0.05$) and Tamil Nadu ($r = -15.9$, $p \leq 0.05$). The maximum temperature is reported as significant with respect of COVID-19 in two regions - Maharashtra ($r = -0.32$, $p <0.05$) and Tamil Nadu ($r = 0.43$, $p \leq 0.05$). The minimum temperature is significant in two states - Gujarat ($r = 0.21$, $p < 0.05$) and Uttar Pradesh ($r = 0.18$, $p < 0.05$) (Goswami, Bharali & Hazarika 2020). In another Indian study concerning the regions of Maharashtra, Rajasthan and Cashmere, a significant positive connection between the temperature and frequency of COVID-19 is reported. This is found in Rajasthan and Cashmere ($r = 0.76$, $p \leq 0.0001$ and $r = 0.76$, $p \leq 0.0001$ respectively). Maharashtra is missing a significant connection ($r = 0.093$) (Meraj, Farooq, Singh et al. 2021; McClymont & Hu 2021).

For Saudi Arabia (Alkhowailed, Shariq, Alqossayir et al. (2020)) find a significant correlation in the new casual cases both in terms of the average temperature ($r = -0.162$, $p < 0.05$) and the maximum temperature ($r = -0.211$, $p < 0.01$).

In Spain, it was found a decrease in COVID-19 frequency by 1 – 2% for each percentage increase in temperature (Paez, Lopez, Menezes et al. 2021; McClymont & Hu 2021).

In a study for eight of the most affected regions and towns in South America, Zhu, Liu, Huang et al., (2020) report that the average daily temperature has a strong negative correlation with the daily confirmed cases of COVID-19. The power of this correlation varies depending on the region, as it is highest in the town of Santiago ($p < 0.01$), Valparaiso and Lambayeque. No significant connection with the temperature is reported. Prata, Rodrigues, Bermejo (2020) report a linear negative link between the temperature and cases of COVID-19 in major cities in Brazil, and at a temperature below 25.8°C each 1°C increase of the temperature is associated with a 4.9% decline in COVID-19 cases (McClymont & Hu 2021).

In New York for the period from March 1 to April 12, 2020 a significant relationship between the minimum temperature ($r = 0.335$, $p < 0.1$) and the average temperature ($r = 0.289$, $p < 0.05$) cases of COVID-19 is reported (Bashir, Ma, Bilal et al. 2020; McClymont & Hu 2021). In another US-based study, Chien and Chen (2020) show that the average temperature significantly correlates with cases of COVID-19, with RR% -0.21 (95% CI: -0.26, -0.15). For further modeling, a 15.3°C threshold is determined, where over this threshold RR% turns from negative in positive and reaches a peak at 20.3°C, and decreases to 29.2°C.

In a Jakarta study (Indonesia), where the average temperature varies between 26.1°C and 28.6°C, Tosepu, Gunawan, Effendy et al. (2020) observes a significant correlation between the temperature and cases of COVID-19 ($r = 0.392$, $p < 0.01$) has been found. A study of (Hridoy, Mohiman, Tusher et al. 2021) conducted in Bangladesh finds that SARS-COV-2 can be transmitted at high temperatures and humidity, which, according to the authors, contradicts previous studies in many other countries.

In Oslo, Norway, both the maximum temperature ($r = 0.347$; $p = 0.005$) and the average temperature ($r = 0.293$, $p = 0.019$) were significantly positive correlated with COVID-19 cases (Menebo 2020; McClymont & Hu 2021).

Pani, Lin, RavindraBabu et al. (2020) discover that for the period from 4 February to 31 May 2020 the average temperature $r = 0.4$, $p < 0.01$) and the minimum temperature ($r = 0.32$, $p < 0.01$) show a significant positive correlation with new cases. With the overall number of cases of COVID-19 during this period, while the maximum temperature ($r = 0.40$, $p < 0.01$), the minimum temperature ($r = 0.39$, $p < 0.01$) and the average temperature ($r = 0.47$, $p = 0$) show a strong bond in the initial phase of the outbreak of the epidemic (McClymont & Hu 2021).

In Poland Bochenek, Jankowski, Gruszczynska et al. (2021) find that the increase in temperature and solar hours lead to a reduction in the number of COVID-19 cases confirmed. The study was conducted based on data from 55 synoptic stations, data on the daily number of laboratory confirmed cases of COVID-19 and the number of deaths related to COVID-19.

In England, Nottmeyer & Sera (2021) conduct a 54 cities-based study and establish a non-linear relation between case of COVID-19 cases with the temperature. At 11.9°C, the authors observe 1.62 times higher risk of transmitting COVID-19 compared to that at a temperature of 21.8°C when the corresponding risk was significantly lower (95% CI: 1.44 – 1.81%).

The studies mentioned here do not give unambiguous results on the relationship between air temperature and the number of cases of COVID-19. Such a conclusion also reaches the most comprehensive systematic study conducted by Briz-Redon & Serrano Aroca (2020), which explores a total of 1357 reports and publications, sifting them under different criteria. Finally, 61 of them are selected on the basis of which the following conclusions are drawn: Most studies (33 out of 61) suggest a negative correlation between COVID-19 and the temperature (Figure 1). Negative correlation is detected in globally-based research of Arumugam, Menon & Narayan (2020), Caspi, Shalit, Kristensen et al. (2020), Chiyomaru & Takemoto (2020), Notari (2020), Pirouz, Golmohammadi, SaeidpourMasouleh et al., (2020), Sajadi, Habibzadeh, Vintzileos et al. (2020), Wu, Nethery, Sabath. et al., (2020), Yu (2020), as well as such concerning of them individual countries or parts as California (Gupta & Gupta 2020), Japan (Ujiie, Tsuzuki & Ohmagari 2020), Ghana (Abdul, Appiahene, & Kessie 2020), Spain (Abdollahi & Rahbaralam 2020; Tobías & Molina 2020), Italy (Livadiotis 2020), China (Oliveiros, Caramelo, Ferreira et al. 2020; Oi et al. 2020; Shi, Dong, Yan et al. 2020; Sil & Kumar 2020) etc. Other studies (6 out of total 61), however, reach the opposite conclusion, namely the existence of positive relation between COVID-19 and the temperature in Jakarta (Tosepu, Gunawan, Effendy et al. 2020) and New York (Bukhari, Massaro, D'Agostino et al. 2020), or lack of any connection (9 out of 61) in countries such as Spain (Briz-Redón & Serrano-Aroca 2020), Iran (Ahmadi, Sharifi, Dorosti et al. 2020; Jahangiri, Jahangiri & Najafgholipour 2020), Nigeria (Taiwo & Fashola 2020) and in global research (Jamil, Alam, Gojobori et al. 2020). Two globally based analyses (Kassem 2020) and one in China (Shahzad, Shahzad, Fareed et al. 2020) establish unclear relation between the temperature and COVID-19, or connection depending on the temperature range (11 out of 61) in countries such as Brazil (Auler, Cássaro, da Silva et al. 2020; Prata, Rodrigues, Bermejo 2020), China (Shu & Xie 2020) and India (Dangi & George 2020).

In this way, all surveys discussed in the above-mentioned systematic review have received contradictory results and none has found clear evidence that increasing the temperature reduces the number of COVID-19 cases. Yet, most studies set a negative connection between COVID-19 and the temperature, which in combination with test laboratory experiments for the temperature of the virus (Chin, Chu, Perera et al. 2020) suggests that the summer time can reduce the transmission of COVID-19 to some extent, but probably insufficient to stop the pandemic. However, these findings must be interpreted cautiously, given the existing diversity of COVID-19 data and the possible impact of the statistical and model framework on results.

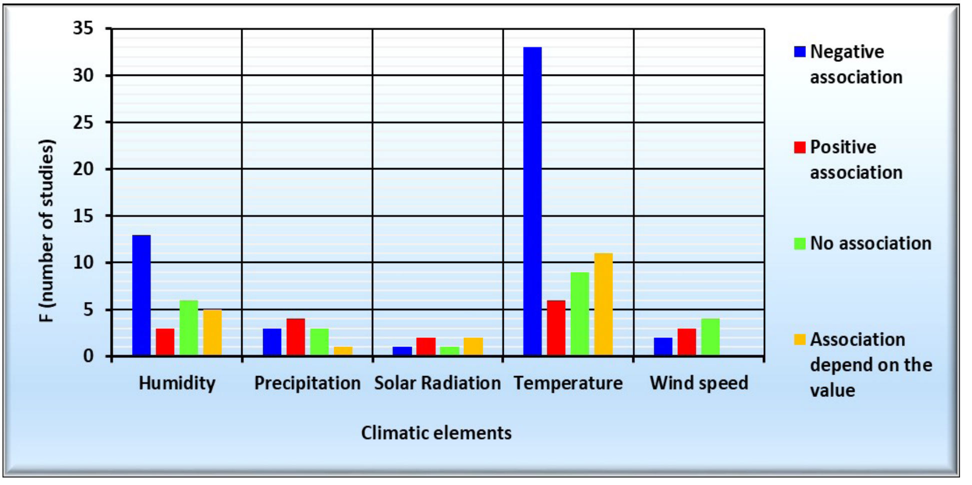

Figure 1. Studies (F) establishing different type of associations (negative, positive, no association, and association depending on value) between climate elements (humidity, precipitation, solar radiation, temperature and wind speed) and COVID-19 persistence (The figure is developed after Briz-Redon & Serrano Aroca (2020) data)

1.2. Air humidity

According to the literary review, made by McClymont & Hu (2021), the humidity is also associated significantly with the frequency of COVID-19, although reported results are mixed, taking into account both positive and negative correlation. Twelve studies (75%) reported significant relationships with relative humidity, absolute humidity or both, with four studies reporting a positive correlation and six studies - negative correlation.

A global study involving 100 countries as well as those carried out in Africa, New York, USA, Jakarta and Indonesia do not find a significant relationship between humidity and COVID-19 (Meyer, Sadler, Faverjon et al. 2020; Bashir, Ma, Bilal et al. 2020; Adekunle, Tella, Oyesiku et al. 2020; Tosepu, Gunawan, Effendy et al. 2020; McClymont & Hu 2021).

Goswami, Bharali & Hazarika (2020) reported mixed results in India‘s regions, as positive links reported in Madhya Pradesh ($r = 1{,}211$, $p < 0.05$) and Punjab ($r = 0.584$, $p < 0.05$), while in Tamil Nadu connection is negative ($r = -6.79$, $p < 0.05$). The authors also reported a significant interaction between temperature and relative humidity (McClymont & Hu 2021).

Qi, Xiao and Shi, Dong, Yan et al. (2020) reports a substantial negative connection with the relative humidity and cases in China, where in every 1% increase in relative humidity, daily cases decreased in the range of 11 – 22% when the average temperature is in the range of 5.04°C to 8.2°C. The authors also report interaction between relative humidity and the average temperature. In multivariate analysis in New South Wales, Australia, which assesses the relative humidity at 9:00 and 15:00 there is a significant connection with humidity, as a 1% increase in humidity at 9 am can increase the number of COVID-19 cases with 6.11% (Ward, Xiao & Zhang 2020; McClymont & Hu 2021).

Wu et al. (2020) report feedback between relative humidity and global daily new cases where in each 1% increase in humidity, new casual cases decreased by 0.85% (95% CI: 0.51 – 1.19%). Alkhowailed, Shariq, Alqossayir et al. (2020) report about low positive correlation between 24-hours medium relative humidity and new cases in Saudi Arabia ($r = 0.194$, $p < 0.01$). Chien and Chen (2020) also report a significant positive connection with the US relative humidity (RR 0.07 95% CI: 0.05 – 0.09). In Spain, Paez, Lopez, Menezes et al. (2021) report a significant negative relationship between relative humidity and everyday cases, with a 3% reduction of incidences of cases with a 1% humidity increase.

All studies for assessing absolute humidity reported a significant relationship with COVID-19.

Bukhari, Massaro, D'Agostino et al. (2020) report an optimal absolute humidity range, with most of the cases of COVID-19 been reported at humidity between 1-9 g/m^3. Huang, Huang, Gu et al. (2020) report 73.8% of the confirmed cases in regions with absolute humidity in the range of 3 – 10 g/m^3. Liu et al. (2020) report a negative correlation between absolute humidity and the confirmed number of cases in 17 cities in China and when absolute humidity increases by 1 g/m^3, cases are reduced. Zhu, Liu, Huang et al., (2020) report different results for the absolute humidity, with significant negative correlation for daily confirmed cases for Pichincha ($p < 0.05$) and Rio de Janeiro ($p < 0.01$) and significant positive correlation in Santiago ($p < 0.05$).

In Singapore Pani, Lin, RavindraBabu et al. (2020) reported poor positive correlation with the minimum, maximum and median relative humidity ($r = 0.19$, $r = 0,20$ and $r = 0.21$) and COVID-19 cases ($p < 0.05$) without a significant effect during the early phases of the February to March epidemic, and this effect has increased when the relative humidity increased (80 ± 4%) in May. The maximum ($r = 0.27$) and the mean absolute humidity ($r = 0.59$) have a stronger positive correlation with the number of COVID-19 cases compared to the relative humidity ($p < 0.01$) (McClymont & Hu 2021).

According to Bochenek, Jankowski, Gruszczynska et al. (2021) the high humidity has caused an increase in the number of cases of COVID-19 14 days later. Nottmeyer & Sera (2021) find that the risk of transmission of COVID-19 is 1.62 times higher in absolute humidity (95% CI: 1.41 – 1.83) of 6.6 g/m^3 compared to humidity of 15.1 g/m^3. When adjusting with the temperature, the relative humidity shows a 1,41-fold increase in the risk of COVID-19 frequency (95% CI:

1.09 – 1.81) at 60.7% compared to 87.6%. According to Liu et al. (2020) high relative humidity promotes COVID-19 transmission when the temperature is low, but tends to reduce transmission when the temperature is high. Yuan, Wu, Jing et al., (2021) discover that the relative humidity is in a negative correlation with the everyday new cases of COVID-19.

These studies do not give unambiguous results on the relationship between air humidity and the number of cases of COVID-19. To such a conclusion also reaches the above-mentioned systematic study conducted by Alvaro Briz-Redon et al. (2020). According to him, many of the studies presented in Figure 1 show a negative connection between COVID-19 and humidity (13 out of 27) in a global context (Wu et al. 2020), the mainland of China (Oi et al. 2020), Ghana (Abdul, Appiahene, & Kessie 2020), Iran (Ahmadi, Sharifi, Dorosti et al. 2020) and Iraq (Jebril 2020). However other studies show a positive link between COVID-19 and humidity (3 out of 27) in China (Luo, Majumder, Liu et al. 2020) and globally (Pedrosa 2020) or lack of connection (6 out of 27) in New York (Bashir, Ma, Bilal et al. 2020) and Jakarta (Tosepu, Gunawan, Effendy et al. 2020).

Therefore, it can be summed up that the effect of temperature and humidity on COVID-19 transmissibility is too variable, although the general trend is assessed as negative. Absolute humidity as well as temperature correlate with the number of cases with COVID-19 in an exponential way reflecting the presence and negative and positive relationship. Climate factors in addition to a direct effect on the pathogen, may also have an indirect effect on host behavior (masks / clothing / residence), which also affect transmission.

1.3. Solar radiation

Solar radiation is one of the most important climate elements with great impact on the biota. Its significance is expressed in two main aspects: as a source of heat and as a source of ultraviolet radiation (UV), the latter being highly microbicidal.

According to the length of the waves and their respective physiological impact on organisms, ultraviolet radiation is divided into three types: “C” ($\lambda < 280\eta$ m) – possessing the most powerful microbicidal and lethal action but it is swallowed by ozone in the high layers of the atmosphere and therefore does not normally reach the earth’s surface; “B” ($\lambda = 280 - 315\eta$ m) – characterized by a lesser microbicidal action, but in a clear sky and sufficient sun height for 1 hour can deactivate SARS-COV-2 to 99%; “A” ($\lambda = 316 - 400\eta$ m) which is significantly less biologically active.

To characterize the ultraviolet radiation regime from a bioclimatic point of view, the stream of erythem rays is evaluated, i.e. those of “B” type. They represent only 0.1% of the UV solar radiation, which in turn represents only about 3 – 4% of the total solar radiation flow reaching the earth‘s surface. It depends on geographic and astronomical factors such as latitude and time of the year i.e., on the rotation of the Earth around the Sun and gets in half-day altitudes of the Sun, greater than 25^0 above the horizon. On average for Bulgaria falling in the latitude between $41^0$14`and $44^0$13`, the sun rises above this height around the middle of January and goes below it at the beginning of December (Mateeva 1999). Therefore, in 320 days of the year, the territory of the country has a potential opportunity to receive the UV required doses. In real conditions, however, this possibility is reduced depending on the current power of the ozone layer in the high parts of the atmosphere, on its transparency, weather conditions, in particular the character of cloudiness.

The effect of UV-radiation on one- and two-chain RNA and DNA viruses and the possible role it plays on seasonality of epidemics is relatively poorly explored (Lytle & Sagripanti 2005; Lubin & Jensen 1995; Martinez 2018). Nicastro, Sironi, Antonello et al. (2020) justify assumptions that the evolution and power of the COVID-19 pandemic may be modulated by the intensity of UV-B and UV-A solar radiation streams that ‘hit’ with different power separate parts of the surface of the Earth, depending on the height of the Sun and respectively – from the latitude, the annual period and time of the day. The study shows that the seasonality of viral respiratory diseases as well as their geographic distribution within latitude can be fully explained by the virucidal properties of UV-B and UV-A and the solar photon forcing mechanism induced daily. Such induced periodicity can continue in practice from dozens to hundreds of cycles and even in the presence of internal dynamics (loss of host immunity), much slower than seasonal, it will generate seasonal fluctuations for a long period.

When administering UV-C radiation, damaging RNA of SARS-COV-2, the virus may become non-infectious.

1.4. Wind speed

The wind speed is mentioned in relatively fewer studies concerning the climatic conditionality of COVID-19 (McClymont & Hu 2021). Wu et al. (2020) and Xie & Zhu (2020) input the wind speed in a computer model as one of the COVID-19 climatic factors studied and do not detect significant results. Of 7 studies that include wind speed as weather variable, three report a significant connection between wind speed and cases of COVID-19. Adekunle, Tella, Oyesiku et al. (2020) report a significant positive connection with the wind speed, where a 1% increase of wind speed was associated with an increase in COVID-19 with 11.21% cases (95% CI: 0.51 – 1.19) in African countries. Pani, Lin, RavindraBabu et al. (2020) report a significant negative correlation between wind speed and COVID-19, as with the increase in wind speed was associated with a reduction in COVID-19 cases ($r = -0.6$, $p < 0.001$). Alkhowailed, Shariq, Alqossayir et al. (2020) also report a significant negative correlation with the maximum and average wind speed ($p < 0.001$ and $P < 0.01$ respectively). Bashir, Ma, Bilal et al.

(2020), Bukhari, Massaro, D'Agostino et al. (2020), Menebo (2020) and Zhu, Liu, Huang et al., (2020) do not find a significant connection between the wind speed and the daily cases of COVID-19.

1.5. Precipitation

In the comprehensive review of Wu et al.2020 concerning the connection between meteorological factors and COVID-19 precipitation (overall) rainfall is included in 6 studies (26.1%, n = 6/23), as those from New York, USA, Jakarta, Indonesia and New South Wales, Australia do not find any significant relation (Bashir, Ma, Bilal et al. 2020; Ward, Xiao & Zhang 2020; Tosepu, Gunawan, Effendy et al. 2020; McClymont & Hu 2021). To, Zhang, Maguire et al. (2020) include rainfall as a control variable and also does not find a connection.

Chien and Chen (2020) report a significant negative correlation between rainfall and COVID-19 cases in the United States, with daily cases increasing with rain between 1.27 and 1.74 inches and decreasing with rainfall over 1.77 inches (< 0.00001).

The relationship between rainfall and incidence with COVID-19 is also influenced by unexplored behavioral factors, for example the majority of people remain indoors in these meteorological conditions, etc.

Meteorological conditions are only a part of the factors determining the behavior of the SARS-COV-2 virus and the COVID-19 disease caused by it in natural conditions. In order to distinguish the factor-determining role of the meteorological elements with respect to the virus, a series of experiments in laboratory environment have been held. They aim to establish the ecological stability of SARS-COV-2 on types of surfaces under controlled temperature, moisture and light. The information on such a study conducted by SA Health (Riddell, Goldie, Hill et al., 2020) testifies that in a particular relative humidity and variable temperature (from 20 to 40 degrees), the virus can be retained by different duration on different types of surfaces. The experiments were conducted in the dark to eliminate the effects of solar radiation.

The results of these experiments show the following:

- On banknotes and paper SARS-COV-2 can be kept up to 28 days at 20°C; to 20 days at 30 ° C; and up to 48 hours at 40°C.
- On cotton fabric SARS-COV-2 resistance is significantly lower: within 14 days at 20°C, up to 3 days at 30°C and up to 24 hours at 40°C.
- On steel SARS-COV-2 is the most stable and can last up over 28 days at 20°C. With a temperature rise, the virus becomes much more unstable – up to 7 days at 30°C and up to 48 hours at 40°C.
- On glass surfaces SARS-COV-2 remains up to 22 days at 20°C, up to 7 days at 30°C and less than 48 hours at 40°C.

2. Non-Metheorologic Factors For Covid-19, Sensitive To Weather And Climat

In the study of the meteorological factors of the COVID-19, some authors also pay attention to the fact that these factors can strengthen the effects of COVID-19 by indirectly affecting non-soft economic matter sensitive to meteorology. For example, the extreme events of the weather determine the idle time of people indoors (refer to the stay in indoor spaces with reduced ventilation such as restaurants and other places for social contacts), which in turn can help spread the virus as host saturation is a decisive factor for the transmission of viruses (Dalziel, Kissler, Gog et al. 2018). At the same time, increased home stays lead to reverse effects since the ability to transmit the virus significantly decrease.

In a number of studies looking for the indirect influence of weather and climate on SARS-COV-2's transmittance, different aspects of socio-economic factors are considered, seen through the climate prism. It is about increasing vulnerability to adverse climatic impacts depending on the social status, the overall level of development of different territorial units and groups of population, gender, age structure, general morbidity and predisposition to chronic diseases, household conditions, personal habits, educational level and so on (Kollamparambil & Oyenubi 2020).

Some studies pay attention to ethnic composition and social status of the population (in the US) by concluding that the spread of the virus has an asymmetric nature in urban and rural areas. More affected are the counties with high numbers of colorful population, the counties with lower educated population. In these counties both higher morbidity and higher mortality resulting from coronavirus is observed (Paul, Englert & Varga 2021).

Scientists from South Africa indicate as most affected by the pandemic small and medium-sized enterprises, focusing on the most vulnerable households, incl. lonely parents and poor people (UNDP 2021). Social status has also been taken into account in a number of other research works on the topic. According to a team of Italian scientists, higher morbidity is observed in the poorer layers of the population, while such dependence is lacking in hospitalization and mortality (Urdiales, Fabiani, Rosano et al. 2021).

Some of the studies are dedicated to the economic aspects of tackling pandemic at national level, paying attention to direct and indirect costs and their dependence on the length of the lockdown period (Kolbin, Belousov, Gomon et al. 2020).

A study for Africa focusing on the spatial aspect of a pandemic concludes that the infection usually starts from major urban centers to suburban areas and subsequently to less populated areas (Bamweyana, Okello, Ssengendo et al. 2020).

3. Scaling and Remote Approaches to Studying the Relationship of Climate and COVID-19

In his extensive study Alvaro Briz-Redon et al. (2020), states that the choice of a particular geographic unit as a basis for epidemiological analysis is a major issue that affects the study results. When choosing a geographic unit, a number of varied criteria can be followed, such as biological significance, data availability, homogeneity and compactness inside the unit, etc. (Arsenault, Michel, Berke et al. 2013). The selection of a unit for the Climate- COVID-19 pandemic relationship analysis depends mostly on data availability. Most of the previous studies have been done at state level or at regional level, as in most of them at this stage of the pandemic data in a large spatial scale are not sufficient. Some of the studies, however, apply city level analyzes (Auler, Cássaro, da Silva et al. 2020; Prata, Rodrigues, Bermejo 2020; Liu et al. 2020). They are useful as they can explain the rapid spread of the pandemic in cities with a high population number, density and overwhelming disease events. The choice of a very comprehensive geographic unit (characterized by many of the studies) prevents researchers from taking into account specific phenomena that are only observed in a large scale.

In principle, small-area studies should be preferred in order to better characterize any geographical unit involved in the analysis of meteorological conditions, non-soft economic factors and specific effects. For greater spatial units, the details may be unintentionally missed. At the same time, some details such as, for example some extreme values can result in distortion of the mean results. For this reason, the choice of scale should be carefully considered, depending on the objectives of the study.

In the cases of large scale, the most frequent obstacle is the availability of relevant data. In this context, it is expected that the remote and re-analytical methods of generating climatic data will be increasingly used. Based on their application, the territories can be explored in meso- and micro-climatic aspects. This is particularly true when identifying urban thermal islands and urban areas characterized by individual climate specificity.

In parallel with numerous remote sensing (RS) sensors, in the scientific circles a variety of methods of studying the urban temperature of the ground surface (TGS) are emerging. For example, in the literature there are descriptions of energy balance models (Oke, Spronken-Smith, Jauregui et al. 1999), models connected to laboratory research (Cendese & Monti 2003), three-dimensional simulations (Saitoh, Shimada & Hoshi 1996), as well as methods such as "Single-Channel", "Split-Window" and "Dual-Angle Algorithms" described by Roy, Dwivedi & Vijayan (2010). Previous studies are mainly focused on biophysical and geometric factors such as built-up areas and height (Bottyán & Unger 2003), urban and street geometry (Eliasson 1996), LULC (Land Use & Land Cover) (Dousset & Gourmelon 2003; Popov, Baymakova, Vaseva et al. 2020; Popov, Dimitrov, Borisova et al. 2019) and vegetation. The interconnection between the TGS and the plant cover is predominantly investigated using vegetation indices such as the NDVI - Normalized Difference Vegetation Index, which provides information on green vegetation (Carlson, Gillies & Perry 1994; Gillies, Kustas & Humes 1997; Lo, Quattrochi &

Luvall 1997; Weng 2001), the NDMI index - Normalized Difference Moisture Index, which is used to retrieve water bodies data and moisture content, Index NDBI – Normalized Difference Built-Up Index, giving information about sealed areas (Guha, Govil, Dey et al. 2018). More multispectral imaging techniques such as Tasseled Cap Transformations can be used to determine sealed areas, which convert images into three "greenness, wetness, brightness" indices, and soil sealing can be estimated using regression models (Homer, Huang, Yang et al. 2004). This in turn is an additional prerequisite for a more accurate definition of the urban heat island (UHI). Described developments of complete tools and working procedures can be found in the literature, presented in specialized software for direct calculation of TGS (Avdan & Jovanovska 2016).

The latest achievements include development and use of quantitative surface descriptors to assess the interaction between urban building materials and urban heat behavior (Weng, Lu & Schubring 2004; Weng & Lu 2008). Landscape ecology methods are also used to assess the connection between TPP and LULC and establish the thermal landscape units (Weng, Liu & Lu 2007).

From this point of view, the contributory factors for increasing the TGS and formation of a UHI described by EPA, United States Environment Protection Agency (Heat Island Compendium, 2012). These factors can be classed in the following groups: Reducing vegetation in urban areas; Characteristics of urban materials with reduced reflection values; Geometry of cities and creating open and indoor spaces; Generation of additional anthropogenic heat; Local features and climatic features; Geographical location.

4. Findings

On the basis of the extensive literary review, to which this study is devoted, the following conclusions may be drawn up:

- The majority of research currently establishes significant climatic connectivity with COVID-19 cases.
- The virus SARS-COV-2 is mainly transmitted by air, which predetermines the significance of meteorological/climatic conditions as one of the factors in the spread of the virus.
- Some climatic elements show positive and other negative correlation with regard to morbidity from COVID-19.
- In a number of cases, the same climate element under certain conditions is in a positive connection, and under other conditions in a negative connection with COVID-19. This in most cases proves rather complex, polynomial nature of the dependence than lack of such.
- The existing research emphasizes the study of mono-parametric dependencies of COVID-19 of the meteorological factor - with respect to the individual climatic element.

– The effects of temperature and humidity are most common studied. Less attention is paid to solar radiation, wind speed and precipitation.
– Global and regional studies take precedence over local meso- and micro-climatic studies in terms of morbidity from COVID-19.
– Rich research approaches and techniques are available to conduct terrestrial and remote climate and weather studies, but for the latter we do not find much evidence of studying the Climate-and-COVID-19 connectivity.
– The object of interest in research is not only the direct impacts of weather and climate on the dissemination and transmission of SARS-COV-2, but also the indirect effects mediated by socio-economic and behavioral parameters, also sensitive to climatic influences.

On the basis of these findings, we can conclude that further research on the Climate-and- COVID-19 relationship should continue the study of:

1. The individual climatic elements - temperature, humidity, precipitation, wind speed, adding a special emphasis on solar radiation (and especially its UV components) as well as the combined effects of climatic elements;
2. The impact of weather and climate on COVID-19 in a large, local meso and micro-climatic plan;
3. The possibilities for use not only ground methods, but also of remote methods in the study of climatic effects on COVID-19;
4. Socio-economic and behavioral prerequisites contributing to amplification of climatic influences on COVID-19.

Acknowledgements

This article is developed under the research project "Development of a Methodological Approach for National Monitoring, Analysis and Assessment of the Climate / Climatic Change - COVID-19 System" under contract КП-06-ДК-1/1, funded by the Research Fund at the Ministry of Education and Science, Republic of Bulgaria.

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