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ORIGINAL ARTICLE

Statistical study on the impact of different meteorological changes on the spread of COVID-19 pandemic in Egypt and its latitude

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Abstract

More than 1 million illnesses and 70,000 deaths were reported due to novel COVID-19 by the end of the first quarter of 2020. In April 2020, the World Health Organization declared COVID-19 a pandemic. The striking resemblance between COVID-19 and its forerunners SARS and MERS, as well as earlier findings on the impact of meteorological conditions on the spread of SARS and MERS, prompted researchers to investigate the relationship between meteorological conditions and the spread of COVID-19. In this work, we statistically studied the effect of different meteorological parameters such as average temperature, humidity, dew point, and wind speed on the spread of COVID-19 pandemic in Egypt and its latitude (Algeria, Egypt, Iran, Saudi Arabia, Turkey). Our findings revealed that there is a correlation between several meteorological parameters and the spread of COVID-19, but that, contrary to popular belief, the virus does not disappear when the temperature rises. Our theory is that either the virus became active in Egypt and its latitude as the temperature rose, or the humidity became unstable when the temperature rose during the summer season. A log-linear quasi-Poisson regression model was used to estimate the relationship between the studied metrological parameters and the spread of COVID-19. The findings of the study will have ramifications for future control and prevention efforts in Egypt and its latitude.

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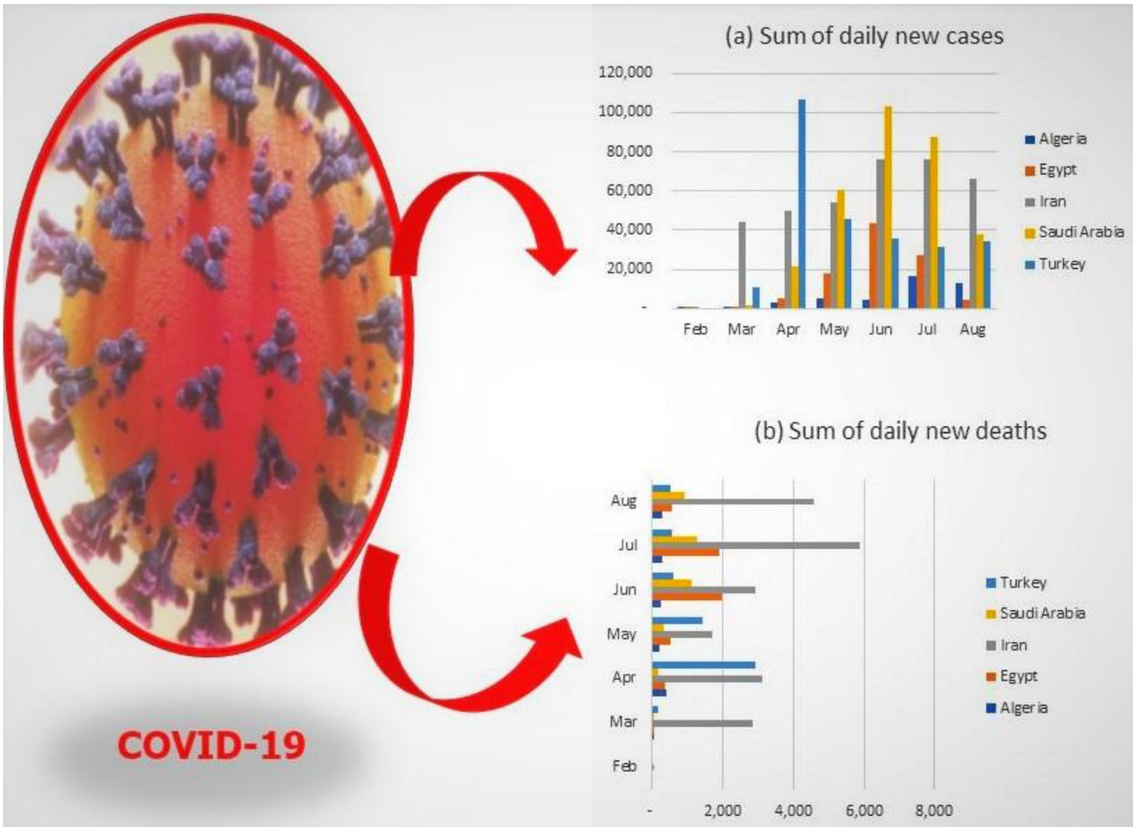
Graphic abstract



Keywords Covid-19 · Metrological factors · Average temperature · Average humidity · Average dew point · Average wind speed

Introduction

By the end of December 2019, many cases were reported to be infected by new virus strains known as COVID-19 (Coronavirus) in Wuhan city, China. Very soon the virus began to rapidly spread worldwide. Consequently, the world health organization (WHO) proclaimed an emergency state all over the world and reported COVID-19 as a pandemic. More than 1 million infected cases were confirmed and the number of deaths exceeded 70,000 by the end of April 2020 (WHO 2020). WHO reported different symptoms that could be considered a sign of the infection, for example, fever, coughing, and shortness of breath, while serious cases of pneumonia, acute respiratory syndrome, kidney failure, and even death revealed (Holshue and DeBolt 2020; Perlman 2020). The incubation period varied from 8 to 14 days based on a recent study (Qin et al. 2020). Although differences were found in the new virus stains, there is a noticeable similarity between the symptoms and signs of our new pandemic COVID-19 and those reported previously to SARS and MERS (Wang et al. 2020). As reported previously on the virus's survival, that both SARS and MERS transmission are affected by temperature and humidity (Cai et al. 2003; Casanova et al. 2010; Altamimi and Ahmed 2020). This similarity in symptoms and signs directed the attention of different researchers to find out the effect of different meteorological factors such as temperature, humidity, wind speed, and in some cases the particulate matter with a diameter less than 10 (PM10) and there effect on the COVID-19 pandemic spread (Qi et al. 2020; Şahin 2020; Tobías, et al. 2020). Expectations raised based on information reported on both SARS and MERS that the wide and rapid spread of COVID-19 may vanish as warming weather coming. Wallis and his co-author reported that SARS in Guangdong in 2003 gradually vanished as the weather temperature becomes warmer (Wallis and Nerlich 2005). As a result, many citizens all over the world waited with eagerness for the summer season to manumit them from the fear to be infected with COVID-19.

The authors employed descriptive statistics, basic correlation coefficients, and simple regression analysis to predict and model the spread of COVID-19 (Hridoy et al. 2021).

Because COVID-19 records are distinct count variables, using linear regression to model the relationship between meteorological variables and daily confirmed cases could result in inaccurate and biased results, which can lower the findings' dependability (Briz-Redón and Serrano-Aroca 2020; Hoffmann 2004; Long 1997). Also, negative values can be estimated using a linear regression model with Gaussian errors. The quasi-Poisson regression, an extended form of the Poisson regression, was employed as an alternative model for modeling over distributed count variables (Imai et al. 2015). The best fit of the relation between meteorological parameters and overspread diseases data was reported using a generalized linear model with quasi-Poisson regression (Joshi et al. 2016; Lin et al. 2013). Recently, a distributed log nonlinear model was used to correlate the temperature, relative humidity, and wind speed with the spread of SARS-CoV2 (DLNM) (Islam et al. 2020a, b). Also, a log-linear quasi-Poisson regression model was used to correlate the meteorological variables with the daily COVID-19 counts (Hridoy et al. 2021).

Here in Egypt, the first report on the COVID-19 case was in the middle of March 2020, after this report there was a nearly complete shutdown for all lifestyles to protest people from further virus transmission. As the temperature in Egypt exceeds 40 ^{0}C in the summer season, we conducted this study to be the first of its kind as we examine the effect of meteorological factors for more than 4 months on the spread of COVID-19 in Egypt and the latitude that Egypt located in (Algeria, Egypt, Iran, Saudi Arabia, Turkey) to explore which meteorological factor affects the spread of the pandemic.

Methods and modeling

Data collection

COVID-19 confirmed cases and deaths were downloaded from the world health organization (WHO) official website (WHO 2020). Daily temperature, dew points, humidity, and wind speed were collected from https://www.wunderground.com/.

The used data was for Egypt, Saudi Arabia, Algeria, Iran, and Turkey. The data were collected from February 14, 2020, to August 28, 2020 (197 days).

Statistical methods

Descriptive statistics

Such as Mean, Variance, Standard deviation, skewness, and kurtosis, etc. used to describe the basic features of the data.

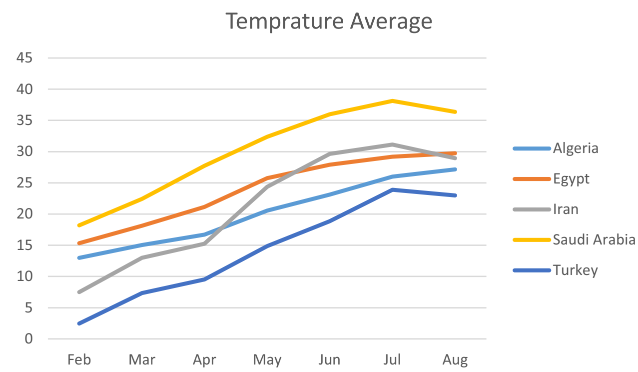


Fig. 1 The average temperature in five countries (Egypt, Turkey, Saudi Arabia, Iran, Algeria)

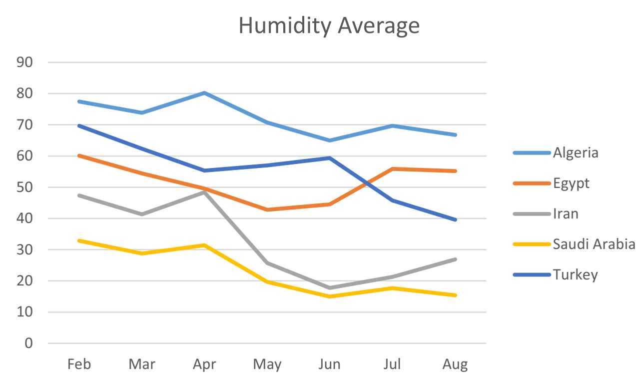


Fig. 2 The average humidity in five countries (Egypt, Turkey, Saudi Arabia, Iran, Algeria)

Normality Tests

To test if the data follow the normal distribution, so we can decide which kind of statistical tests we will use to analyze the data, parametric or non-parametric tests. We used the Kolmogorov Smirnov test.

Non-parametric tests

The non-parametric test Spearman correlation test was used to decide if there is any relation between the number of cases and any other variable.

Regression analysis

Regression analysis was used to measure the impact of the independent variables of the study on the confirmed cases and deaths of COVID-19.

Quasi-Poisson model

The quasi-Poisson regression is considered as s typical model for modeling over distributed count variables (Imai et al. 2015). Recently a log-linear quasi-Poisson regression model is used to correlate the climate variables and daily counts (Hridoy et al. 2021). The quasi-Poisson model as a function of the meteorological parameters can be given by the following equation:

$$\log\text{ (U)} = Y = \alpha_o + \alpha_1\left(T_C\right) + \alpha_2(\text{hum}) + \alpha_3(\text{DP}) + \alpha_4\left(\text{v}_{\text{wind}}\right) + \text{ DOW} + \text{ LD} + \log(\text{P})$$

where log(U) refers to the logarithmic of the daily new cases, Y is the fitting model, β0 is the overall coefficient, and α_o, $\alpha_1(T_C)$, α_2 (hum), α_3 (DP), and α_4 (v_{wind}) represent coefficients for mean temperature (°C), relative humidity (%), dew point (°C), and wind speed (km/h) respectively. DOW refers to a variable that indicates the day of the week to account for any seasonal effects that might exist or a changing trend over time. LD = 1 for lockdown days and 0 otherwise. Log(P) is the log of population density.

Results and discussion

In this study, we selected Egypt and countries located in the same latitude (Algeria, Egypt, Iran, Saudi Arabia, Turkey) to figure out the effect of these meteorological factors on the spread of the pandemic. This unique work aims to help in drawing an obvious map for these effects.

Descriptive statistics

Independent variables

Effect of average temperature Figure 1 illustrates the average temperature in five countries (Egypt, Turkey, Saudi Arabia, Iran, Algeria) starting from February since the first case reported in Egypt till August as usually, the temperature starts to decrease after the end of August. The figure showed an ordinary increase in the temperature as we go from February till August the temperature starts to be fixed then going down. The temperature in Egypt ranged from a minimum of 12 °C to a maximum of 37 °C. The median value was 26 °C. At 37 °C around 1465 new daily cases were reported in Egypt. Temperature showed a consistently increasing trend from February (16.6 ± 2.4 °C) to July (29.1 ± 1.0 °C), Which becomes almost constant in August (29.8 ± 1.0 °C). This trend is similar to Turkey's temperature ranges (Şahin 2020).

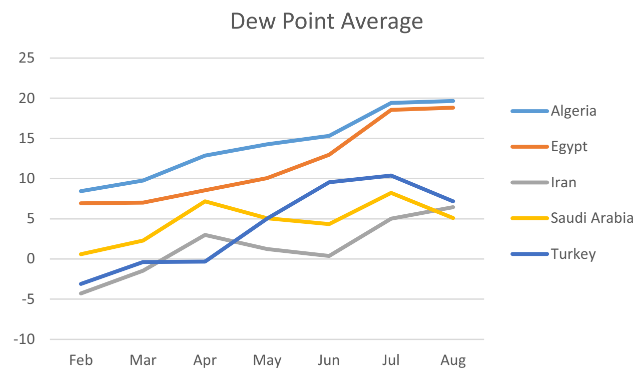


Fig. 3 The average dew point in five countries (Egypt, Turkey, Saudi Arabia, Iran, Algeria)

Effect of average humidity Figure 2 shows the trend in average humidity in the same five countries within the same period. As it is clear there is a significant decrease in the average humidity as we go deeper into the summer season. The average humidity in Egypt ranged from a minimum of 15% to a maximum of 98%. The median value was 53%. As it is clear from Fig. 2, there is a noticeable change in the trend of average humidity starts in April. The observed variations are similar to those observed in the average humidity of turkey (Şahin 2020). The average humidity is decreased starting from February (65.5 ± 11.3). Then, there is a sudden increase in April before decreasing again to 55.5 ± 4.4. We believe that this sudden change affects the number of cases that appeared in this month, which will appear in the discussion of the dependent variables.

Effect of average Dew Point The dew point is a temperature measured after clouds formed due to air saturation. Figure 3 shows a significant increase in the average dew point from February (8.6 ± 1.9) till August (18.9 ± 1.3). This is similar to the trend of Turkey's dew point ranges that were reported previously (Şahin 2020). The dew point in Egypt ranged

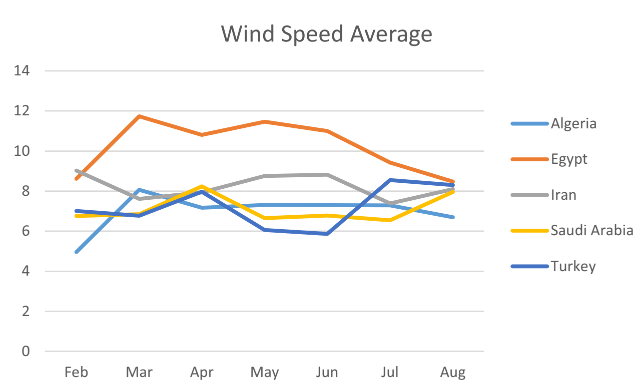


Fig. 4 The average wind speed in five countries (Egypt, Turkey, Saudi Arabia, Iran, Algeria)

Table 1 Correlation between New Cases and other variables

Variable	Algeria	Egypt	Iran	Saudi Arabia	Turkey	General
Temperature	0.767[b]	0.598[b]	0.595[b]	0.714[b]	− 0.300[b]	0.392[b]
Dew Point	0.752[b]	0.389[b]	0.273[b]	0.183[a]	− 0.233[b]	− 0.364[b]
Humidity	− 0.155[a]	− 0.315[b]	− 0.410[b]	− 0.605[b]	0.102	− 0.555[b]
Wind Speed	0.020	0.133	0.159[a]	− 0.142	− 0.154[a]	− 0.086[b]

[a]Correlation is significant at the 0.05 level (2-tailed), [b]Correlation is significant at the 0.01 level (2-tailed)

from a minimum of -1 °C to a maximum of 21 °C. The median value was 11 °C.

Effect of average wind speed The average wind speed showed limited variations during the period under test. Figure 4 shows the average values of wind speed for the five countries during the period from February to August. The average wind speed ranged from a minimum of 4 mph to a maximum of 20 mph. The median value was 10 mph. The average values of the wind speed are 7.3 ± 2.9, 7.0 ± 2.7, 10.3 ± 2.9, 7.1 ± 2.6, and 8.3 ± 3.1 for Turkey, Algeria, Egypt, Saudia Arabia, and Iran over the studied period.

Dependent variables

Figure 5 (a and b) shows the number of new cases and new deaths in each country as we move from February to August. The new cases as well as the number of deaths increases day after day. Starting from April there is a sudden jump in the number of new cases and deaths, this sudden increase appears in all countries under test. We believe that the changes in humidity and dew point affect directly the number of new cases and deaths. Tables 1 and 2 illustrated the values of the correlation between these meteorological factors and the number of new cases and deaths. It is clear from the data in Tables 1 and 2 that there is a significant correlation between temperature, dew point, and humidity and the number of new cases and deaths. However, the temperature is more effective than the other parameters, especially in Saudi Arabia and Algeria. Although all expectations predicted that as temperature increases the number of new cases and deaths

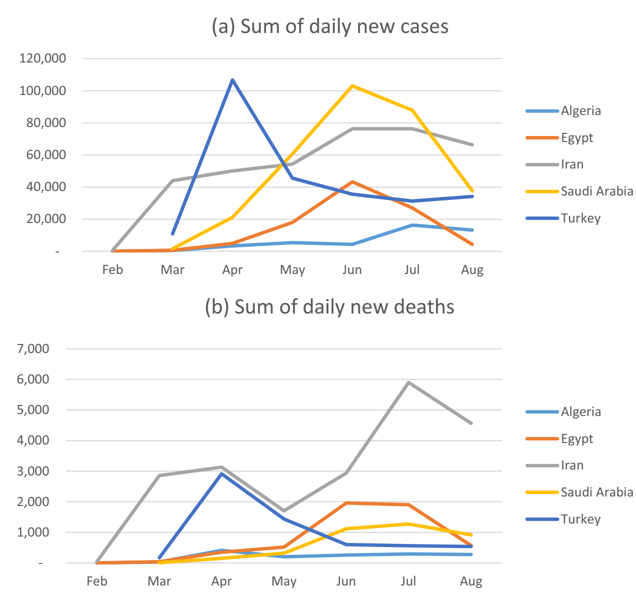


Fig. 5 **a** Sum of daily new cases, **b** sum of daily new deaths in five countries (Egypt, Turkey, Saudi Arabia, Iran, Algeria)

Table 2 Correlation between New Deaths and other variables

Variable	Algeria	Egypt	Iran	Saudi Arabia	Turkey	General
Temperature	0.424[b]	0.701[b]	0.457[b]	0.815[b]	– 0.352[b]	0.246[b]
Dew point	0.424[b]	0.572[b]	0.536[b]	0.145	– 0.338[b]	– 0.265[b]
Humidity	– 0.028	– 0.172[a]	– 0.163[a]	– 0.708[b]	0.099	– 0.391[b]
Wind speed	– 0.080	0.025	0.049	-0.047	– 0.141	0.010

[a]Correlation is significant at the 0.05 level (2-tailed), [b]Correlation is significant at the 0.01 level (2-tailed)

will decrease, but our results showed unexpected observations as shown in Fig. 6 a. This figure showed a 3D colormap theme of cumulative cases versus temperature and number of days. The increase in temperature as we go through the summer season corresponds to an increase in the number of new cases and deaths. Our hypothesis that this unexpected correlation may be due to the first reports and the spread of viruses synchronized with an increase in the temperature. Therefore, the incubation period of the virus started with the summer season starting. Finally, wind speed has a weak correlation with the number of new cases and deaths. The weak correlation may be ascribed to widespread progression, extended time-series data, and the nonlinear behavior of COVID-19 counts. The correlation between meteorological factors and the spread of the pandemic has been reported previously (Poole 2020; Şahin 2020). Figure 6b showed the cumulative cases in Egypt that predicated from the quasi-Poisson model versus WHO data. As the number of cases increased the predicated number become more close to the real cases. Error% is very high at low numbers of cases. But error% becomes less than 10% for number of cases > 63. Our results regarding the correlation between the spread of COVID-19 and temperature are in agreement with prior literature by Bashir et al. (2020), Pedrosa (2020), and Tosepu et al. (2020) in India, Kafieh et al. (2020), and Islam et al. (2020a; b) in Bangladesh. Regarding the humidity effect, our data are in agreement with previous literature by Sajadi et al. (2020), Luo et al. (2020), Goswami et al. (2020), and Islam et al. (2020a; b)).

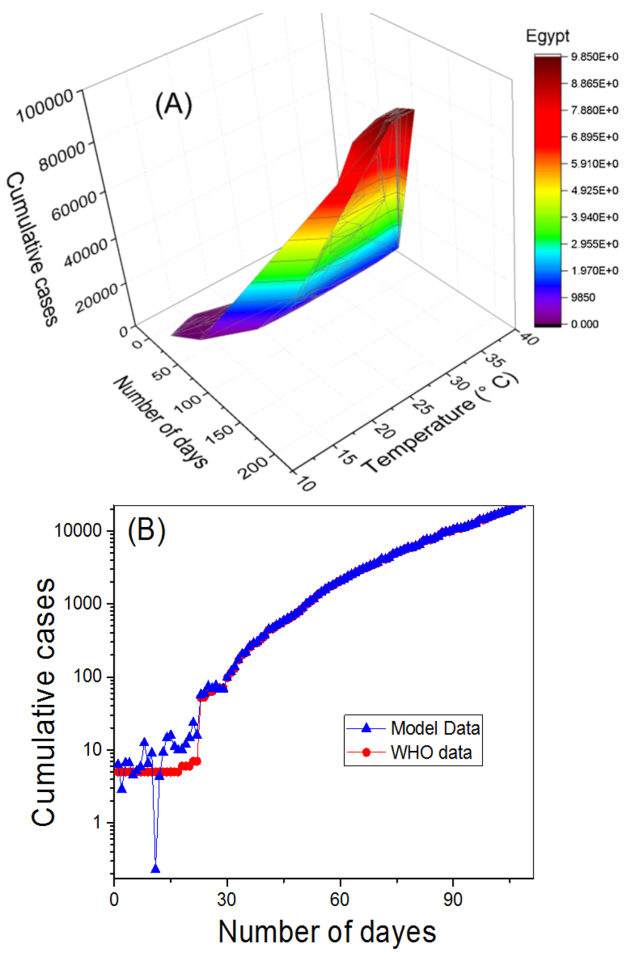


Fig. 6 **A** 3D colormap Theme of cumulative cases versus temperature and number of dayes, **B** cumulative cases in Egypt from model versus WHO data

Conclusion

This study illustrated the total number of new cases and deaths in Egypt and its latitude during the summer season in correlation with a number of meteorological factors such as average temperature, humidity, dew point, and wind speed. The results showed an observed increase in the number of new cases and deaths till the middle of June, then these numbers started to decrease again. There was a clear correlation between the studied meteorological factors and the increase in the number of new cases and deaths. However, the temperature is more effective than the other parameters, especially in Saudi Arabia and Algeria. The increase in temperature does not limit the virus's spread. The quasi-Poisson model was used to predicate the number of cases in correlation with the studied metrological factors. This model became more accurate as the number of cases and temperature increased, whereas the error% became less than 10% for numbers of cases > 63. The outcomes of this study may have consequences for future control and prevention efforts in Egypt and its latitude.

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Future work After the second wave of COVID-19 started to appear in Egypt, we noticed that some territories recorded more cases than others. We are going to focus on the number of cases recorded in the first wave and those recorded nowadays in different territories to figure out if the previously infected territories will record other infections or not.

Authors' contributions AH: Writing-original draft, Writing—review & editing. DEA: data analysis, and results interpretation. AAPK: Review & editing, MS: Writing—original draft, Writing—review & editing. KAA: review & editing, AMA: review, editing & Supervision.

Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Not required.

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