Simple epidemic peaks of Coronavirus Disease in UAE, 2020

Research article

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Abstract

In 1927, the Susceptible Infected and Recovered (SIR) Mathematical Modelling originally studied by Kermack and McKendrick (A contribution to the mathematical theory of epidemics' in the Proceedings of the Royal Society London Ser. A), The paper became a classic in infectious disease epidemiology and has been cited innumerable times. Using the data offered by Ministry of Health and Prevention, the coefficient in the system of Ordinary Differential Equations that represent the United Arab Emirates' SIR Mathematical Modelling of COVID-19, using Microsoft Excel, and MATLAB Software is used consequently to solve and graph the solution. The idea may be extended to be website calculator or a Mobile Application giving the Infection Rate Ro, the Contact Ratio q, and the Maximum percentage of population expected to be infected linked to the daily official data website.

Keywords: COVID-19, contact ratio, infectious disease, infection rate, Mathematical modelling, susceptible

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Public Interest Statement

All over the world Covid-19 becomes a general issue and people would like to know the impact of the lockdown in attacking this virus. The most desired answer for everybody is the answer to the question "when do we get red of it?". In 2020, Oshikazu Kuniya published his paper entitled "prediction of the Epidemic Peak of Coronavirus Disease in Japan", where the well-known SIER –model (the susceptible, infective, exposed, and removed populations at time t). This article, the simpler SIR-model applied to the data from January 22 to December 23. Using Microsoft Excel, the value of the infection rate R_0 and the maximum percentage of expected infected in UAE population, $I_{Maximum}$ are calculated daily and weekly.

Introduction

The pandemic of Coronavirus disease 2019 (COVID-19 is caused by Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2). It first noticed in early of 2020 and has caught global attention in both developing and developed countries. The epidemic did not stop to that limit yet combined by a dramatic increase in the number of confirmed cases around the world. The World Health Organization (WHO) as a pandemic has announced the COVID-19 disease on March 11, 2020 [1]. Moreover, the SARS-CoV-2 pandemic contributed significantly to human destruction, paralyzing economic activities and an unprecedented increase in morbidity and mortality. At the time of writing this report, pandemic-19 is responsible for the deaths of about nine million people worldwide [2]. In the United Arab Emirates, the first case of COVID -19 was reported on January 29, 2020 with a steady increase in the number of laboratory-confirmed COVID-19 cases [3].

COVID-19 can infect people of all ages; however, current research shows that elderly people and patients with chronic diseases are more vulnerable to becoming severely ill if they are infected with the virus. Quarantines restrict the activities of healthy people for a period as determined by competent medical authorities. United Arab Emirates Health Ministry website supply Covid-19 information and awareness in text and videos. The effect of human mobility and control measures on the COVID-19 epidemic in China have been studied, [7], it shows that the drastic control measures implemented in China substantially mitigated the spread of COVID-19. Consequently, intensive control measures, including travel restrictions, have been implemented to limit the spread of the epidemic all over the world. The estimated total number worldwide of death until Sept 9, 2020 is 823,249 less than the Spanish Flue in 1918. The estimated number of deaths was at least 50 million worldwide [8].

The Ministry of Health and Prevention in UAE stressed its aim to continue expanding the scope of testing nationwide to facilitate the early detection of coronavirus cases and carry out the necessary treatment. For instant, on Tuesday August 29, it is announced that 88,803 additional COVID-19 tests were deducted over the past 24 hours. The total number of conducted tests until September 1 is 7,177,430 with diagnosed cases 70,805, recovered cases 61,491, active cases 8,930, and 431 death. The data from January 22 to December 23, 2020 [3], the weekly data is accumulated in Fig(1):

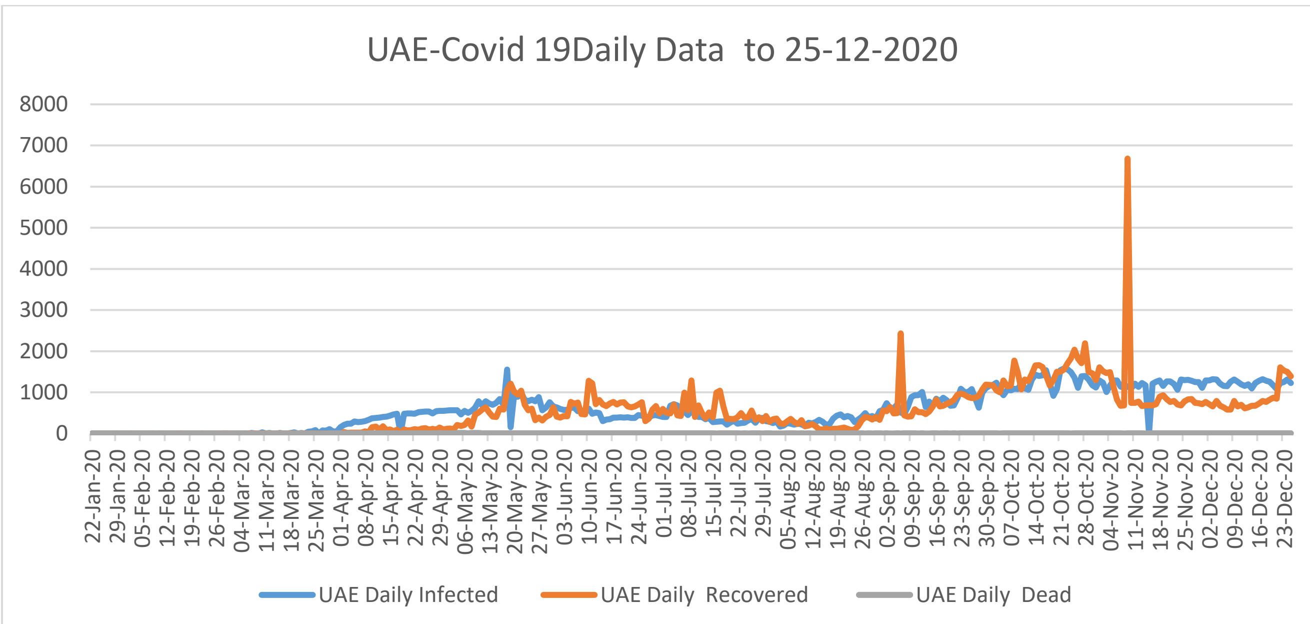


Fig (1)

2. Methods

Prediction of the Epidemic Peak of Coronavirus Disease in Japan, where the well-known SIER –model (the susceptible, infective, exposed, and removed populations at time t) [4]. Here the simpler SIR-model applied to the data from January 22 to December 23, 2020 as well as the Numerical Central First Order Derivative for S(t), I(t), and R(t), the susceptible, infected, removed populations at time t (the sum of the Recovered and Dead). Using Microsoft Excel, the value of the infection rate R_0 and the maximum percentage of expected infected in UAE population, $I_{Maximum}$ are calculated daily and weekly.

2.1. Model

[5] became a classic in infectious disease epidemiology and has been cited innumerable times, where the well-known SIR Mathematical has been used to study the epidemic. Then, Roy Anderson reprinted it, with a discussion, in a special issue 'Classics of theoretical biology' (part two) in the Bulletin of Mathematical Biology [6].

$$\frac{dS}{dt} = -rSI, \qquad (1)$$
$$\frac{dI}{dt} = rSI - aI\ , \qquad (2)$$
$$\frac{dR}{dt} = aI, \qquad (3)$$

where S(t), I(t), R(t), r and a is denote the susceptible, infected, removed populations at time t (the sum of the Recovered and Dead), the transmission rate, and the recovery rate respectively. Their values at the starting time t=0 denoted by $S(0) = S_0,\ I(0) = I_0,\ R(0) = 0$. The ratio

$$q = \frac{r}{a}, \qquad (4)$$

is called the contact ratio and the ratio

$$R_0 = \frac{rS_0}{a} = qS_0, \qquad (5)$$

called the Infection Rate, the number of people each infected person passes the virus on to, on average. If it is 2 then 10 infected people would pass it onto 20 others. Nevertheless, if is 0.5 then 10 infected people pass it onto 5 others. If $R_0 > 1$, then there could be a "second peak" in cases and this is what everyone are trying to avoid. This R_0 plays the major rule in the spread of the epidemic increasing (if $\frac{dI}{dt} < 0$). Matlab cannot find the explicit theoretical solution of SIR. So, to find the numerical centered first derivative for R, S, and I with a step equal to 1 (one day for the daily data and one week for the weekly data). Then the Least Square Method used to determine the coefficient r and a in (2) and (3). Dividing (1) by (2), we get the Ordinary Differential Equation

$$\frac{dI}{dS} = \frac{rSI - aI}{-rSI} = \frac{1}{qS} - 1. \qquad (6)$$

The theoretical solution of this Ordinary Differential Equation is

$$I + S - \frac{1}{q}\ln(S) = I_0 + S_0 - \frac{1}{q}\ln(S_0) \qquad (7)$$

The maximum number $I_{Maximum}$ occurs when $\frac{dI}{dS} = 0$ or $q = \frac{1}{S}$, therefore

$$I_{Maximum} = I_0 + S_0 - \frac{1}{q}(1 + \ln(qS_0)) = I_0 + S_0 - \frac{1}{q}(1 + \ln(R_0)), \qquad (8)$$

$I_{Maximum}$ is clearly depends on the contact ratio q and $R_0 = q \times S_0$. Using the provided daily data [3] for susceptible, infected and death. Using the numerical central first derivative, to get the numerical values of $\frac{dI}{dt}$, and $\frac{dR}{dt}$ to use the least square method to compute, up to the date t

$$a = \frac{\sum R'}{\sum I}, \qquad r = \frac{\sum I' + a \sum I}{\sum IS}. \qquad (9)$$

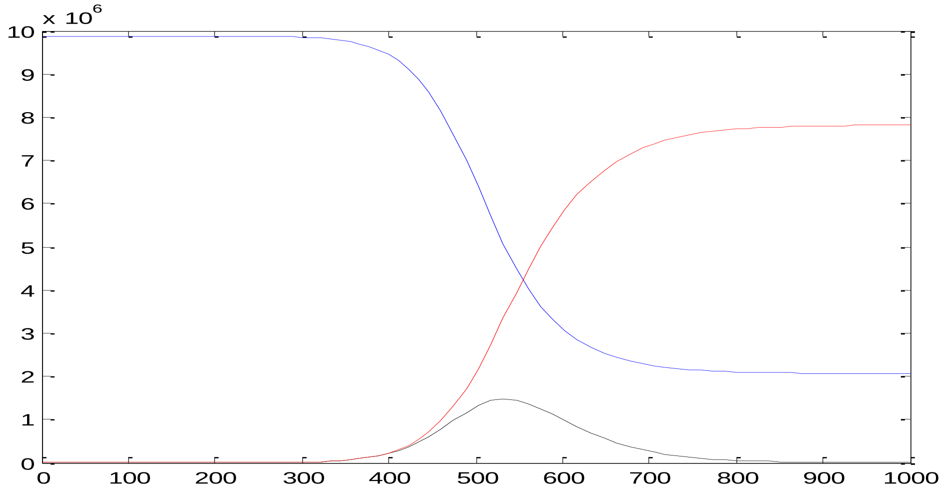
Some calculated values for a and r are given in table(1):

Date	a	r
September first, 2020	0.027421686	5.49078×10^(-9)
October 7, 2020	0.048086522	9.21622×10^(-9)
November 18, 2020	0.022317591	5.65665×10^(-9)
December 16, 2020	0.02189182	5.40211×10^(-9)

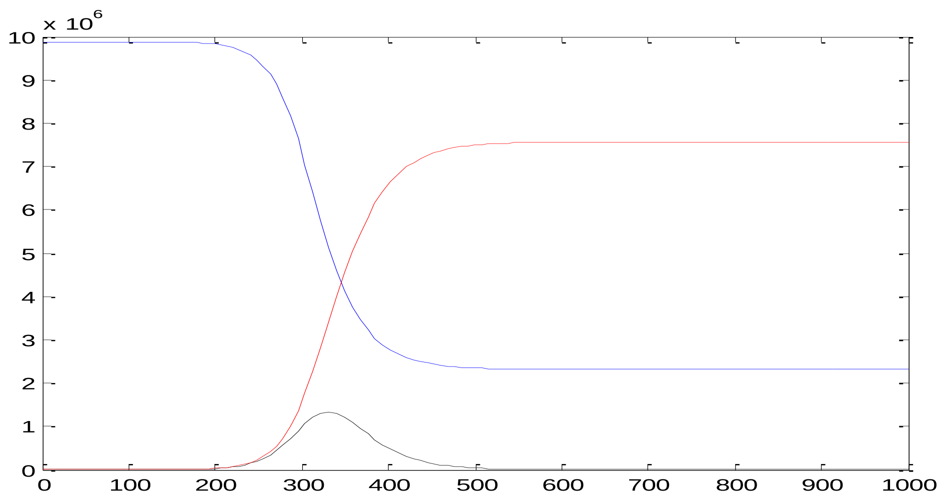
Table(1)

The expected infection peak shown in the graphical solution, , of the SIR-Model (1), (2), and (3), found using the values in Table(1) and the initial values $I(0) = 5$, $S(0) = 9882275$, $R_0 = 0$. The following MATLAB code used with replacing $S = x(1), I = x(2), R = x(3)$ to get Fig(2-a), Fig(2-b), Fig(2-c), and Fig(2-d):

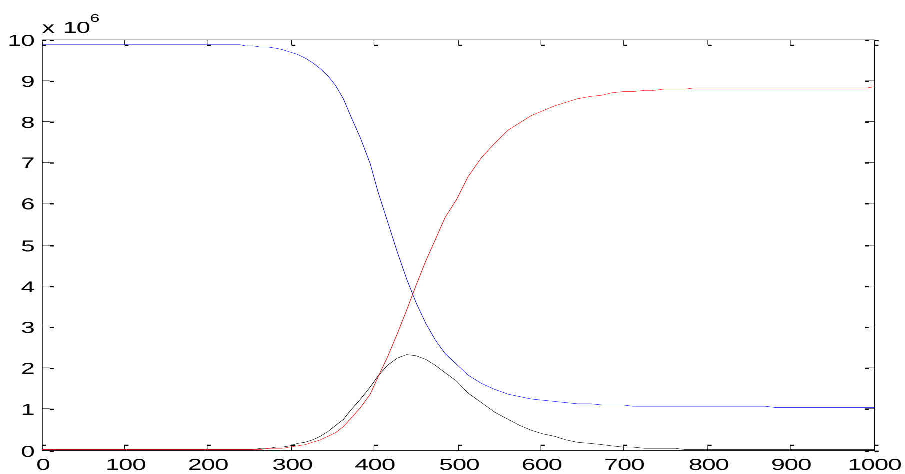
```
f = @(t,x) [-r*x(1)*x(2); r*x(1)*x(2)- a*x(2); a*x(2)]
[t,xa]=ode45(f,[0 1000], [S(0)  I(0)  0.0]); plot(t,xa(:,1))
 hold on
 plot(t,xa(:,2),'k')
 plot(t,xa(:,3),'r')
 hold off
```



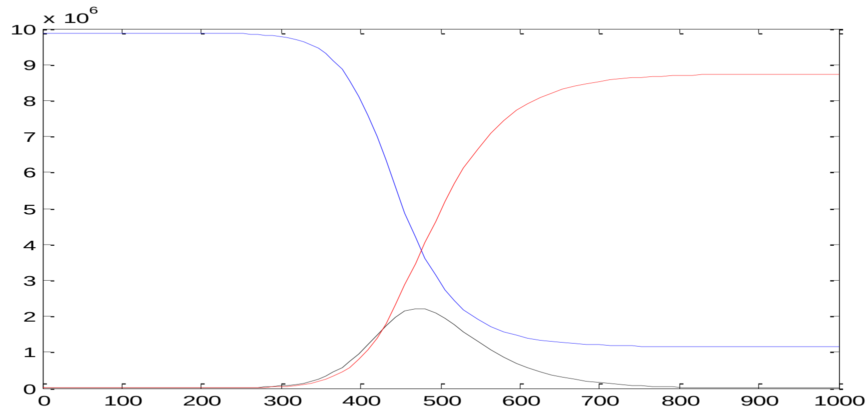
On September first, 2020 Fig (2a)



On October 7, 2020-Fig (2b



On November 18, 2020 -Fig (2c)



On December 16, 2020-Fig (2d)

The blue curve is the population, which has not yet had the disease S, the black curve is the infected population I and the red curve is the population, which has recovered R. The expected infection peak on September 1, 2020 was around 550 days from the starting day January 22, 2020. Then reduced to be within 350 days on October 7, 2020, and increased to be around 450 days on both November 18 and December 16, 2020. The incubation period for COVID-19, which is the time between exposure to the virus (become infected) and symptom onset, is, on average, 5-6 days. However, it can be up to 14 days. During this period, also known as the "pre-symptomatic" period, some infected persons can be contagious. Therefore, transmission from a pre-symptomatic case can occur before symptom onset [5]. As the occupation period is around two weeks, so within this, we calculate by equation (4), (5), (9) and (8) the values this of R_0 and the maximum estimated infected percentage of the UAE's population as shown in Fig (3), Fig (4), Fig (5), and Fig (6)

Daily Calculation:

As the daily results are too many, selected days chosen

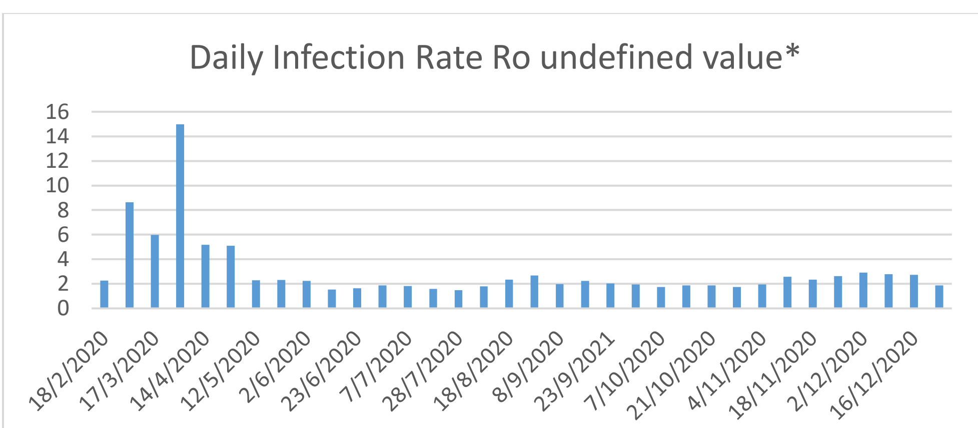


Fig (3)

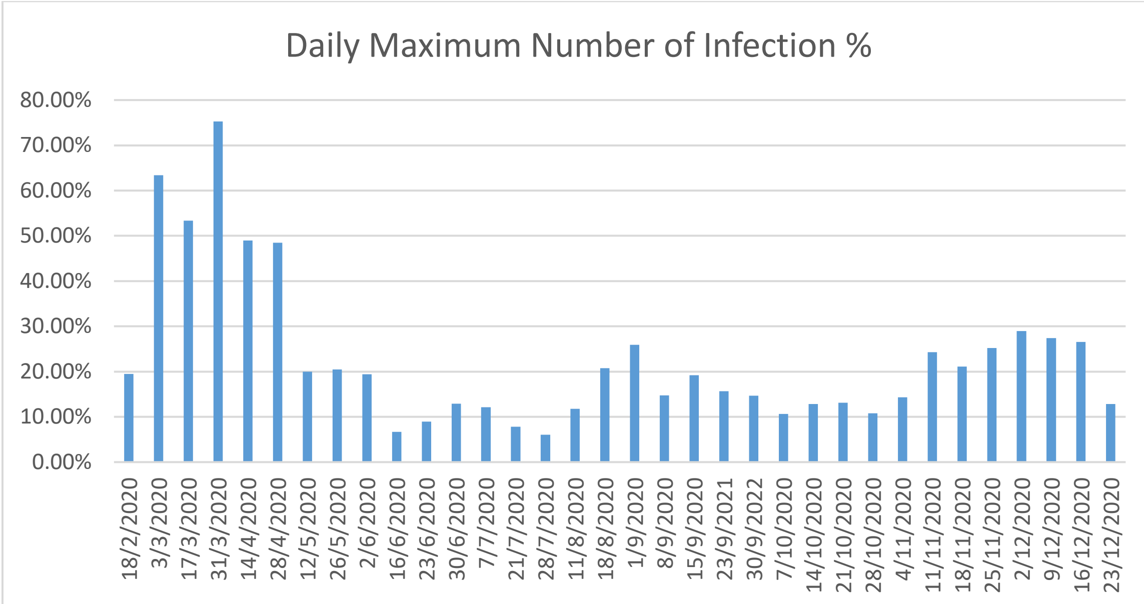


Fig (4)

Weekly Calculation: Selected weeks chosen

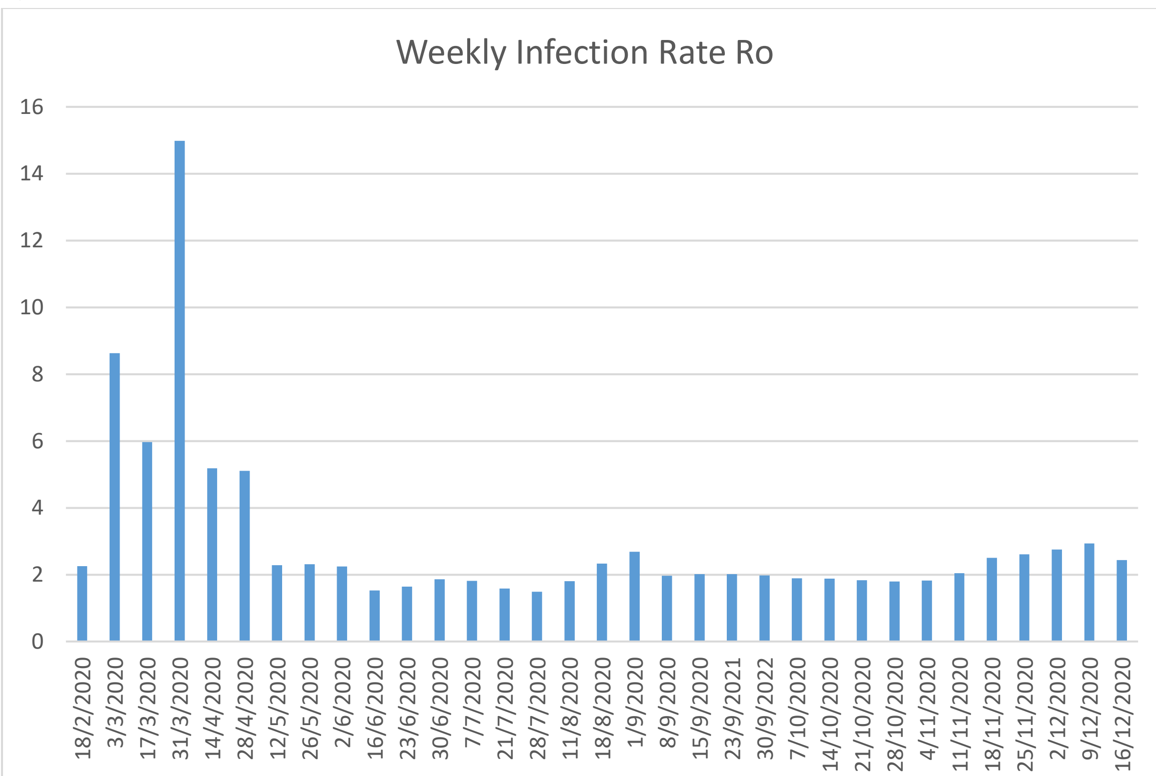


Fig (5)

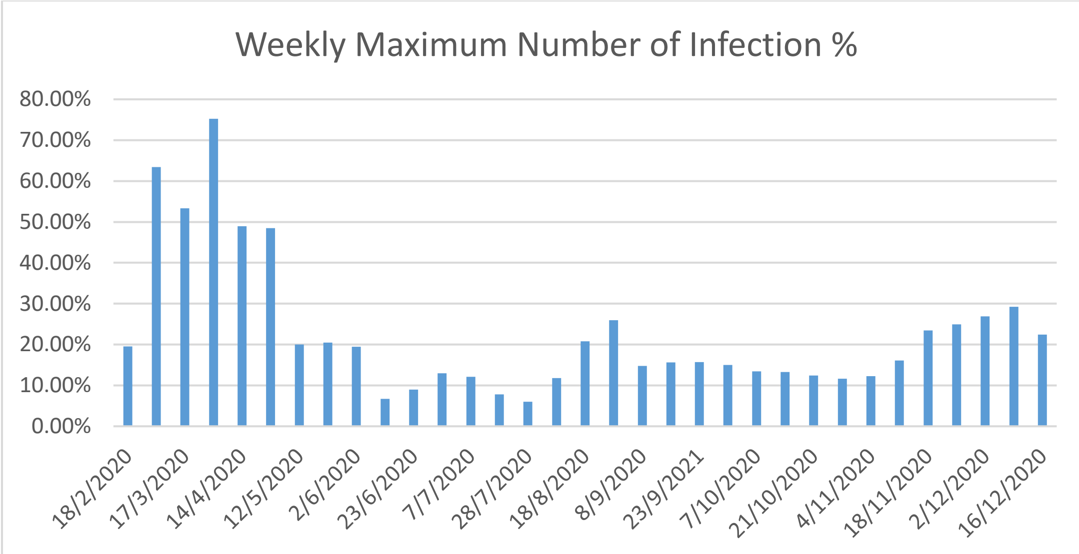


Fig (6)

On June 24, 2020, the lock down ended, also after the beginning of the academic year on August 23, 2020, so more contact and consequently the infection rate increased R_0 and the estimated percentage of the maximum number of infected $I_{Maximum}$ increased. The significant increase before May 12, 2020 due to the lack citizens' awareness of Covid-19. Now for question, "How long will the epidemic last?" and why on June 24, announced the lock down ended in United Arab Emirates. Back to a differential equation involving time in (1). Plugging in the formula for I as a function of S from (7), we get

$$\frac{dS}{dt} = -rS(-S + \frac{1}{q}\ln(S) + C), \qquad (10)$$

where $$C = I_0 + S_0 - \frac{1}{q}\ln(S_0). \qquad (11)$$

To solve this differential equation using separation of variables, write

$$T_{end} = \int_{S_0}^{S_T} \frac{dS}{rS^2 - \frac{rS}{q}\ln(S) - rSC} = \int_{S_0}^{S_T} \frac{dS}{rS^2 - aS\ln(S) - rSC}. \qquad (12)$$

Unfortunately, we do not know an antiderivative for the right side: there probably is not a formula for it and theoretically, the time of the epidemic is infinite unless there is no infection, the infected people becomes zero for at least more than the occupation period of Covid-19. For Daily Calculation on Sept 1, 2020, we get the coefficienta $=$ 0.014791101, $\mathrm{r} = 2.40989\mathrm{x}10^9$, and $\mathrm{q} = \mathrm{a/r} = 0.0061376664495\ \mathrm{x}10^9$, therefore $C = I_0 + S_0 - \frac{a}{r}\ln(S_0) = -8.8973\ \mathrm{x}10^7$.

So, by (12),

$$T_{end} = \int_{9819857}^{9882275} \frac{dS}{2.40989\text{E}-09\, S^2 - 0.014791101\, S \ln(S) - (2.40989\text{E}-09)(-8.8973\text{E}+007)\, S} \qquad (13),$$

the result by MATLAB is NaN (which means the result is not a number) which is also the same result for the weekly-accumulated data. This mean that the Covid-19 will last for long if the susceptible, infection, recovered rate settled high.

Conclusion

On June 24, 2020, the lock down ended, also after the beginning of the academic year on August 23, 2020, so more contact and consequently the infection rate increased R_0 and the estimated percentage of the maximum number of infected $I_{Maximum}$ increased (Fig(3)-Fig(6)). The answer for "How long will the epidemic last?" is unknown based on the result of (13) is indefinite.

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Conflicts of Interest: The authors declare no conflict of interest.

Author Biography

Rewarded a Ph.D. in Mathematics from East Anglia University, United Kingdom 2000, where I was working as a teaching assistant for 5 years. Teaching Mathematics and statistics using most of the linked software package (Computer Algebra System-CAS) help me teaching with more interactive way with my students offline and online. Recently, I focused on the method of teaching Mathematics and Statistics that ease the concepts understanding and saving time in calculation without ignoring the critical thinking and the problem solving with creation and innovation. In 2002, I came to the United Arab Emirates to teach in Ajman University in Fujairah campus. Recently, I am working in the University of Science & Technology of Fujairah.

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