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Mathematical modeling for COVID-19 pandemic in Iraq

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Abstract

In this paper, we present the SIR pandemic model to evaluate the susceptible (R), infectious (I), and removed (R) for COVID-19 in Iraq for the period from the 22nd February 2020 to the 26th June 2020. We divided this period to three sub-periods, and for each sub-period, the real data has been cited from scientific trusted references to estimate the parameters that are required to solve the system of differential equations for the SIR pandemic model. Furthermore, the estimations are given by our model for the real active infection, recovery rate against case fatality rate, reproduction number $\mathcal{R}_0$ and the growth factor of the real accumulation infection have all shown significant similarities between the reported data and the estimations produced by our model.

Subject Classification: *[2010] 97Mxx, 97M10, 97M60.*

Keywords: *COVID-19 in Iraq, SIR model, Basic reproduction number, Effective contact rate, Removed rate.*

1. Introduction

The World Health Organization reported COVID-19 a pandemic on 11 March 2020, [1]. Worldwide it has exploded to 6,145,093 cases and caused

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370,412 deaths by 30 May 2020, [2]. In Iraq, the first case was announced on (22-Feb-2020) and had reported 6,179 cases and 159 deaths by 30 May 2020, [3].

As we know, readiness for the epidemic spread is fundamental public health anxiety for any health field. Epidemic recording of a disease is a significant event in knowing two main parameters in epidemiology, i.e. epidemic spread within a community and outgrowth at a society level.

Mathematical models, particularly those devised in a timely form, can present a fundamental part in giving health decision-makers with evidence-based knowledge. Modelling can, indeed, better help to explain many important things such as transmissibility of the disease, the highest level of infectiousness during infection, the severity of the infection.

In the literature, various mathematical models have been utilized to study the spread of COVID-19. The authors in [4], applied a mathematical model to judge if isolation and contact tracing can control onwards transmission from imported cases of COVID-19. A real-time predictions using the support-vector machine (SVM) model is presented in [5] to investigate the COVID-19 forecast of confirmed, deceased and recovered cases. A descriptive analysis of COVID-19 of India is displayed in [6] with analysing various features such as age, gender, travel history, contact type and current situation. In [7], a mathematical model is applied to predict the time needed to clear the backlog based on the level of progressed operating capacity. In [8], the authors develop a mathematical model for estimating the population-level influence of the control and reduction strategies the difficulty of COVID -19 depending on non-pharmaceutical interferences. In [9], an adjustment of the SEIR model has been utilized to investigate the impact of behavioural changes needed to lower community communication by proposing a time-varying contact rate. A mathematical model has been proposed in [10], concentrating on the approach of those who are concerned about contacting COVID-19 due to being in a health-related location. The authors in [11], utilised an enhanced mathematical model to investigate and predict the growth of the COVID-19 pandemic in countries worldwide. A compartmental SEIR model is produced in [12] using a collection of differential equations to show the impact of COVID-19 pandemic in India. The authors in [13] proposed an SEIR epidemic model with infectivity in the incubation period and homestead-isolation on the susceptible. In [14], the authors proposed a θ-SEIHRD mathematical model which is not a SIR or SEIR models for the spread of the COVID-19 disease in China. The mathematical modelling and dynamics of COVID-19 have been introduced in [15] to show the interaction among the people infections reservoir. The authors in [16] utilized a stochastic transmission model with data on cases of COVID-19 in Wuhan and international cases. In [17], the authors proposed the autoregressive time series (TP–SMN–AR) model to investigate the total number of confirmed and recovered COVID-19 cases in the world. The mathematical model [18] is utilized to compare the new characters of COVID-19 with those of SARS and MERS. The authors in [19] utilised the mathematical modelling and time-series occurrence data by dates to study the transmission potential of the COVID-19 outbreak aboard the Princess Cruises Ship. In [20], two mathematical models are applied to the COVID-19 pandemic in China. The first one includes infected persons in the exposed class before transmission is possible, and the second one includes a time delay in infected persons before transmission is possible. A mathematical model has been produced in [21] for evaluating the communitywide influence of mask used by the general. The authors in [22] introduced a mathematical model for the spread of the COVID-19 disease with a particular focus on the transmissibility of super-spreaders people. Mathematical models have been applied in [23] to describe fundamental aspects of the COVID-19 in South Korea, Italy, and Brazil. The authors in [24] proposed a mathematical model, including a quarantine class and governmental intervention measures to decrease disease transmission. A mathematical model has been constructed in [25] based on a SIR model to study the impact of COVID-19, with the addition of supplemental variables. The authors in [26] performed a study to obtain the solution for the model of nonlinear fractional differential equations describing the COVID-19 pandemic.

The rest portion of this paper has been designed in the following form: In section 2, we demonstrate the use of the SIR model to describe the spread of COVID-19. In section 3, we introduce a principal idea of the effective contact rate and the mean of infectious or removed period. In section 4, the system of ordinary differential equations of SIR model has been demonstrated. In section 5, all values of parameters required to solve the SIR model are estimated. Next, in section 6, we estimate real-world examples on COVID-19 of Iraq and derive some short term forecasting based on the suggested model. In the final section, we provide a thorough conclusion of our article.

2. Model for COVID-19 pandemic

We use the SIR model to describe the spread of COVID-19 in Iraq and use it to describe the outbreak of the virus in the whole country.

In this model, the population is split into three compartments S for the susceptible to catching the virus, I for the infected with the virus and capable of spreading it and R for the removed (recovered or died). The variables S, I and R represent the number of people in each category at time t.

3. Transition rate

For the complete specification of the model, the arrows between compartments are labelled with the transition rates. Between S and I, the transition rate is $\frac{\beta I}{N}$, where β is the effective contact rate, calculate as multiply a contact rate (number of contacts per person per time) by the risk of infection (probability of virus transmission in the contact between a susceptible and an infectious). $\frac{1}{N}$ is the part of the contact events that involve an infectious individual.

Between I and R, the transition rate is γ the removal rate (is the rate at which people stop being infected) defined as $(\text{removed period})^{-1}$, where the removed period (mean of infectious or death period) is how long it takes to removed (recovery or death) denoted γ^{-1}.

4. Governing Equations

The SIR model was first used by Kermack and McKendrick in 1927 [27]. This model has subsequently been applied to a variety of diseases, especially airborne childhood diseases, with lifelong immunity upon recovery. S, I and R represent the number of susceptible, infected, and recovered individuals, and

$$N = S + I + R \tag{1}$$

is the total population. In the deterministic form, the SIR model can be written as the following system ordinary differential equation (ODEs), [27]

$$\left.\begin{aligned} \frac{dS}{dt} &= -\frac{\beta SI}{N}, \\ \frac{dI}{dt} &= \frac{\beta SI}{N} - \gamma I, \\ \frac{dR}{dt} &= \gamma I, \end{aligned}\right\} \tag{2}$$

with the initial conditions $S(0) = S_0$, $I(0) = I_0$, and $R(0) = R_0 = 0$.

5. Estimating parameters

Estimating the value of parameters is often a difficult task. Without accurate parameter estimators, a model is less useful as a predictive tool. However, it may still be possible to deduce the general behaviour and therefore add insight into the possible processes underlying the model.

One approach for estimating parameters is to measure the value of the parameter directly for example, for the SIR model parameter γ has an interpretation that γ^{-1} the incubation period of the COVID-19 pandemic ranges from $(2-14)$ days [8], so we can take $\gamma = \frac{1}{7}$ as are estimated in the first period of the method, see Section (6.1).

Estimating the parameter β is more difficult. We can use the definition of the basic reproducing number $\mathcal{R}_0$, which defined as the expected number of cases directly generated by one patient in a population where all people are susceptible to infection, [28]. Furthermore, $\mathcal{R}_0$ values are usually calculated from mathematical models, and the evaluated values are dependent on the based model and values of the parameters in this model.

Suppose that infectious individuals make an average of β effective contact rate, with a mean infectious period of γ^{-1}.. Then the basic reproduction number is [29]

$$\mathcal{R}_0 = \frac{N\beta}{\gamma}, \tag{3}$$

this leads to

$$\beta = \frac{\gamma \mathcal{R}_0}{N}. \tag{4}$$

During an pandemic, typically the number of diagnosed infected $I(t)$ over time t is known. In the early stages of an pandemic, growth is exponential, with a logarithmic growth rate, [29]

$$K = \frac{d \ln[I(t)]}{dt}. \tag{5}$$

The second equation of the system (2), could be write as an initial value problem

$$\frac{dI}{dt} = \left(\frac{\beta S}{N} - \gamma\right) I,\ I(0) = I_0, \tag{6}$$

which has the analytic solution

$$I(t) = I_0 e^{\left(\frac{\beta S_0}{N} - \gamma\right)t}. \tag{7}$$

To find doubling time T_d, substituting $I(T_d) = 2I_0$ into Eq.(7), we obtain $2I_0 = I_0 e^{\left(\frac{\beta S_0}{N} - \gamma\right)T_d}$, then $2 = e^{\left(\frac{\beta S_0}{N} - \gamma\right)T_d}$, by assuming $K = \frac{\beta S_0}{N} - \gamma$, and take the ln for the both side leads to,

$$K = \frac{\ln 2}{T_d}. \tag{8}$$

If an individual after getting infected, infects exactly $\mathcal{R}_0$ new individuals only after exactly a time γ^{-1} has passed, the number of infectious individuals over time grows as $I(t) = I_0 \mathcal{R}_0^{t\gamma}$, then $\ln[I(t)] = \ln[I_0] + t\gamma \ln[\mathcal{R}_0]$. The underlying matching differential equation is

$$\frac{dI(t)}{dt} = I(t)\gamma \ln[\mathcal{R}_0],$$

or

$$\frac{d\ln[I(t)]}{dt} = \ln[\mathcal{R}_0]\gamma. \tag{9}$$

Substituting Eq.(5) into Eq.(9) leads to

$$K = \gamma \ln[\mathcal{R}_0],$$

or

$$\mathcal{R}_0 = e^{\frac{K}{\gamma}}. \tag{10}$$

6. SIR Simulation for COVID-19 outbreak in Iraq

6.1 *For the period from 22nd of Funerary to 21st of April.*

The spread COVID-19 was limited at the beginning of the pandemic in Iraq. However, the government imposed a lockdown on the people. By

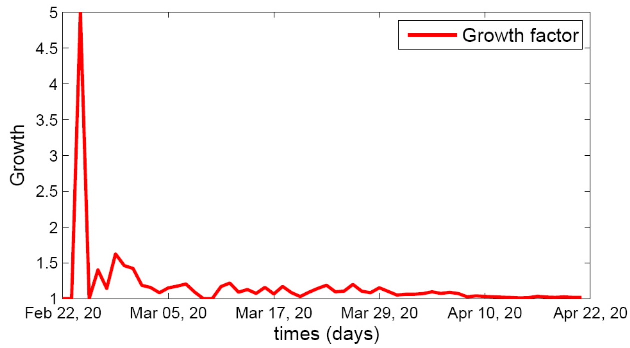

Figure 1

The growth factor of the real accumulation infective for the period from 22/2 to 21/4/2020 in Iraq.

using the real data of COVID-19 pandemic of Iraq [3], Fig. (1) illustrate the growth factor of the real accumulation infective for the period (22/2 to 21/4/2020).

We notice that the spread of the epidemic was relatively small. Setting the whole population in the country in the first period is not acceptable [30]. We nearly deduce the number of susceptible people in the compartment is 3500. The rough inference plays a role in determining the number of the max quantity of susceptible people. The initial infectious number for Iraq was 1, and the outbreak starts on 22/2/2020, [30]. Then we use the parameters of SIR model as they mentioned in Section (5) to draw the estimated active infective for this period. By using the information of real active infective of Iraq [3], we have taken in average of doubling time in this period i.e. [22/2- 21/4/2020] which is equal to 6 days, so that $T_d = 6$. From Eq. (4) we can obtain $K = \frac{\ln 2}{T_d} = \frac{0.69315}{6} = 0.11553$, $\gamma = \frac{1}{7} = 0.14286$ and from Eq. (4) and Eq. (10), $\beta = \frac{\mathcal{R}_0 \gamma}{N} = \frac{(2.24497)(0.14286)}{3500} = \frac{0.32071}{3500} = 9.16314 \times 10^{-05}$.

By substituting all theses parameters into Eq. (2) to obtain the following system

$$\left.\begin{aligned} \frac{dS}{dt} &= -9.16314 \times 10^{-05} SI, \\ \frac{dI}{dt} &= 9.16314 \times 10^{-05} SI - 0.14286 I, \\ \frac{dR}{dt} &= 0.14286 I, \end{aligned}\right\} \tag{11}$$

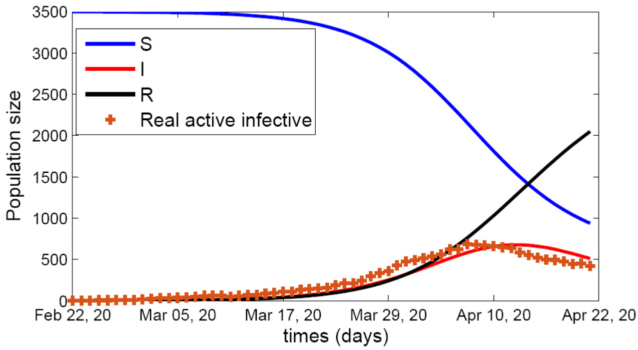

Figure 2

SIR estimation for the period from 22/2 to 21/4/2020 in Iraq, with $\gamma = 0.14286$, $\beta = 9.16314 \times 10^{-05}$, $S(0) = 3499$, $I(0) = 1$, $R(0) = 0$ and the real active data of infections.

with the initial conditions $S(0) = 3499$, $I(0) = 1$, and $R_0 = 0$. We modified the Matlab code [31] to solve SIR model as shown in Eq. (11) by using Mtlab 14a. We have run the estimation process and Fig. (2) illustrates how the number of the compartment can be changed over time, according to the SIR model. The real active infective is included to show that the SIR estimation is compatible with the real data in this period.

In Fig. (3), the estimated active infection and the real active infection are compared together for the first period explored in this research. The estimated curve is close to the real points, which shows the accuracy of the estimation. The first part of the graph displays an exponential growth, with cases increasing slowly at the start of March due to COVID-19

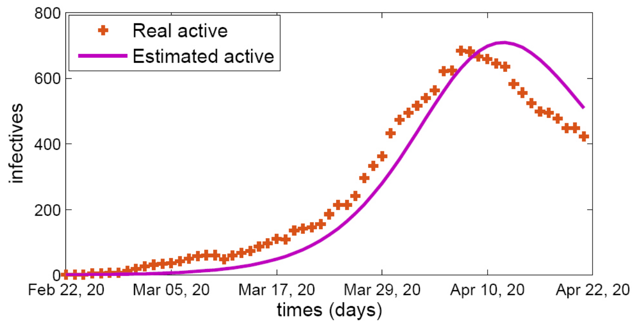

Figure 3

The real active and the estimated infectives for the period from 22/2 to 21/4/2020 in Iraq.

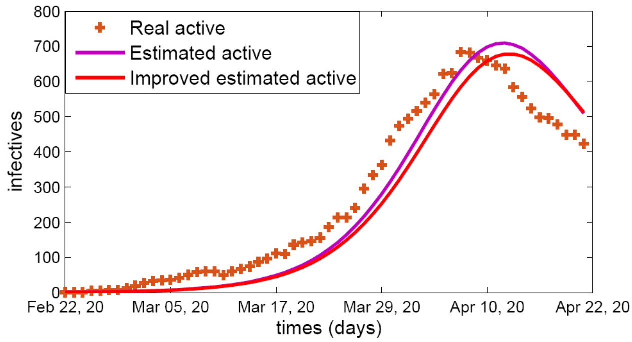

Figure 4

The real active, the estimated and the improved estimated infectives for the period from 22/2 to 21/4/2020 in Iraq.

reaching Iraq, then it accelerates rapidly as time passes by. The cases reach a maximum on April 13, after which, cases start to decline gradually.

To find the best (estimated) parameters β and γ so that the improved estimated infective coincides with the actual infective, we utilize the least square method to minimize the following function ([32], pp. 352)

$$s(\beta,\gamma)=\sum_{i=1}^{N}\left(I(t_i-\hat{I}_i)\right). \tag{12}$$

Where $I(t_i)$ is the number of infectives predicted by the model at the time $t_i, i=1,2,\cdots,N$ by solving the second differential equation as in Eq. (11).

Fig. (4) adds on to Fig. (3) by the addition of an improved estimation of the active infection cases. This development enhances the accuracy of the estimation as the difference between the estimated, and the real cases is now smaller. The least squares procedure has calibrated the model with the estimated parameters $\beta=9.13314\times10^{-05}$ and $\gamma=0.14575$.

6.2 *For the period from 22nd of April to 1st of June.*

In this period, we notice that the infective increases after the date (22 April) because of the lifting of the lockdown by the government and the people's lack of concern for safety, social distance and security instructions. Fig. (5) illustrates the fluctuations in the growth factor for the second period in this study. The reason a second period has been introduced is for the rise in contact between people due to the lift of the lockdown, which increased the growth factor compared to being in lockdown.

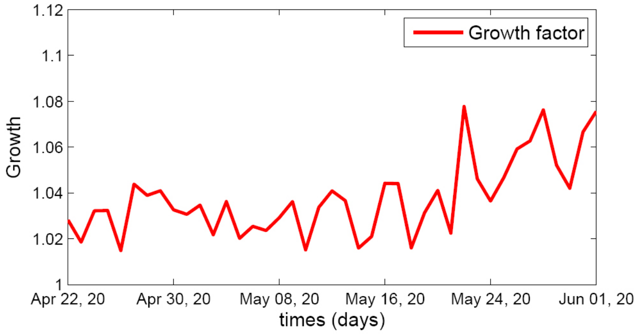

Figure 5

The growth factor of the real accumulation infective for the period from 22/4 to 1/6/2020 in Iraq.

In the same manner as in Section (6.1), we can find all parameters K, $\mathcal{R}_0$, and β of SIR model in order to draw the estimated infective. From the data of COVID-19 pandemic of Iraq [3], T_d has been estimated to be 23. Therefore, where $K = \frac{\ln 2}{T_d} = \frac{0.69315}{23} = 0.03014$.

Relying on the data of COVID-19 pandemic of Iraq and using the correct formula, which is announced in [3], to calculate the case fatality rate (CER)

$$CER = \frac{\text{Death at day X}}{\text{Case at day}(X-T)}, \tag{3}$$

where T refers to the time period from confirmation to death with a conservative estimated of $T = 7$ days, as the average time period from case the confirmation to death.

In the same idea, we can calculate the recovery rate (RR), such that

$$RR = \frac{\text{Recovery at day } X}{\text{Case at day } (X-T)}. \tag{14}$$

Then we compute the summation of CER and RR for all days of this period, i.e. from the 22nd of April to 1st of June to have

$$CER_{sum} = \sum_{22/4}^{1/6/2020} CER, \tag{15}$$

$$RR_{sum} = \sum_{22/4}^{1/6/2020} RR. \tag{16}$$

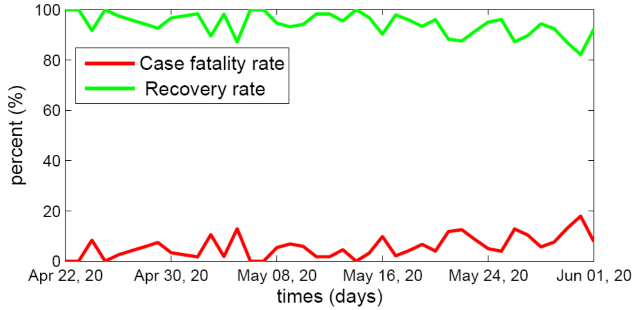

Figure 6

Recovery rate against case fatality rate for the period from 22/4 to 1/6/2020 in Iraq.

Eventually, the average of CER and RR are estimated by the following formula

$$CER_{av} = \frac{CER_{sum}}{N_1}, \tag{17}$$

$$RR_{av} = \frac{RR_{sum}}{N_1}, \tag{18}$$

where N_1 indicates to the numbers of days for this period from the 22nd of April to 1st of June. The recovery rate and case fatality rate of this period is shown in Fig. (6)

By the determination of removed period to be the mean of infectious or death period as in Section (3), γ can be estimated as

$$\gamma = CER_{av} + RR_{av}, \tag{19}$$

where $CER_{av} = 0.00357$ and $RR_{av} = 0.06863$. So, $\gamma = 0.07220$, then $\mathcal{R}_0 = e^{\frac{K}{\gamma}} = e^{0.41741} = 1.518027$, and $\beta = \frac{\mathcal{R}_0 \gamma}{N} = \frac{0.10960}{40{,}000{,}000} = 2.74003 \times 10^{-09}$. For all theses parameters, we get the following system

$$\left.\begin{aligned} \frac{dS}{dt} &= -2.74003 \times 10^{-09} SI, \\ \frac{dI}{dt} &= 2.74003 \times 10^{-09} SI - 0.07220I, \\ \frac{dR}{dt} &= 0.07220I, \end{aligned}\right\} \tag{20}$$

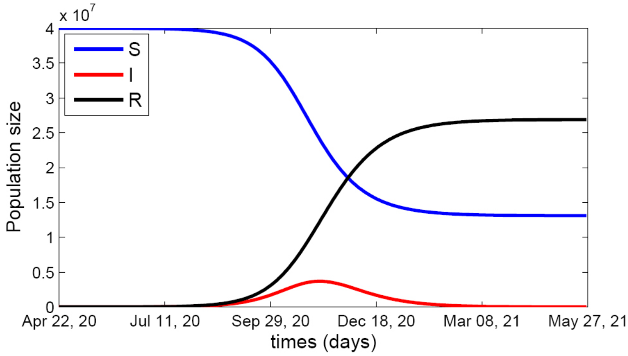

Figure 7

SIR estimation for a long time in Iraq with $\gamma = 0.07220, \beta = 2.74003 \times 10^{-09}, S(0) = 39998452, I(0) = 402$, and $R(0) = 1146$.

with the initial conditions $S(0) = 39998452$, $I(0) = 402$, and $R(0) = 1146$, where $I(0)$ and $R(0)$ represent the infectious and removed numbers at the last day (21st of April) of the previous period. By applying Eq. (1), $S(0) = N = I(0) - R(0)$ where N is the population of Iraq in 2020 [33]. The same Matlab code [31] is used to solve the SIR model as shown in Eq. (20) by using Matlab $14a$. Due to the SIR model, Fig. (7) shows the changing of the compartment over a long time.

In Fig. (8), the estimated and real active infection are presented for the second period, starting from 22nd of April 2020 to 1st of June 2021. The graph shows a positive correlation, with both predicted and real data demonstrating a steady increase in active infection over time. The estimated

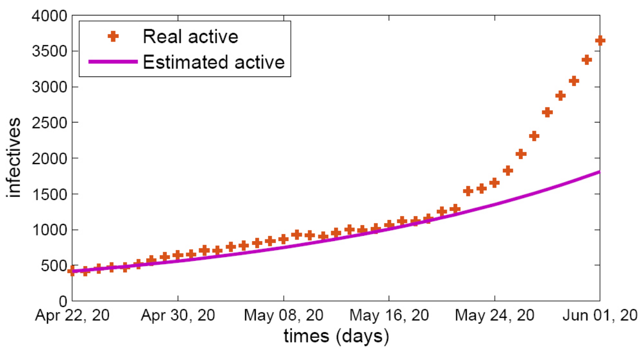

Figure 8

The real active and the estimated infectives for the period from 22/2 to 1/6/2020 in Iraq.

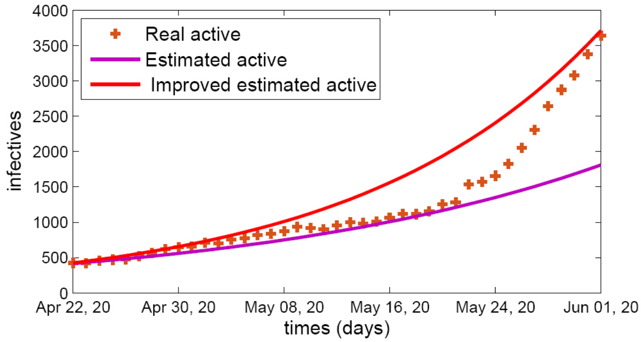

Figure 9

The real, the estimated, and the improved estimated infectives for the period from 22/2 to 1/6/2020 in Iraq.

and real active infection are very close most of the period. However, the real active infection shows a surge in infections starting at May 23, which continues increasing as opposed to the estimation curve, which shows a steady constant increase that does not change throughout the graph

As in Eq. (12), we can use the method of least square to find the improved estimated infective that can coincide with the real active data of infectives, where $\gamma = 0.08542$ and $\beta = 3.52874 \times 10^{-09}$. Fig. (9) improves the estimation of active infection provided in Fig. (8). There is a crucial difference as the new estimation curve is steeper compared to the previous one. This increases the accuracy as the new estimation curve is closer to the real data points.

6.3 *For the period from 2nd of June to 26th of June.*

In this period, we observe that the infective is highly increasing among the people. The main reason for considering this period is because of the increasing the reproducing number $\mathcal{R}_0$ which affect the number of real active infective. Fig. (1) shows that the changing values of $\mathcal{R}_0$ with time (days). In previous period, we computed the average value of $\mathcal{R}_0$ to be 1.518027 while the average value of $\mathcal{R}_0$ reaches to 2.

In the same manner, as in Sections (6.1) and (6.2), we can find all parameters K, γ, $\mathcal{R}_0$, and β of SIR model in order to draw the estimated infective. Fom the data of COVID-19 pandemic of Iraq [3], T_d has been computed to be 10. Therefore, where $K = \frac{\ln 2}{T_d} = \frac{0.69315}{10} = 0.06931$. Fig. (11) shows that the similarity of the case fatality rate and recovery rate in this period with the previous section as in Fig. (6).

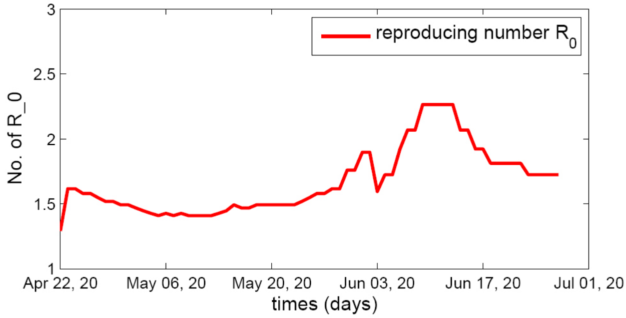

Figure 10

Basic reproducing number $\mathcal{R}_0$ for the period from 22/4 to 26/6/2020 in Iraq

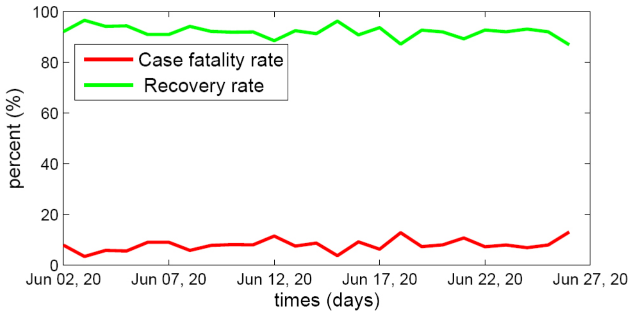

Figure 11

Recovery rate against case fatality rate for the period from 2/6 to 26/6/2020 in Iraq.

In this period, we evaluated $CER_{av} = 0.00780$ and $RR_{av} = 0.09822$, then $\gamma = 0.10602$. $\mathcal{R}_0 = e^{\frac{\kappa}{\gamma}} = e^{0.65376} = 1.92276$, and $\beta = \frac{\mathcal{R}_0\gamma}{N} = \frac{0.20386}{40{,}000{,}000} = 5.09648\times 10^{-09}$. For all theses parameters, we get the following system

$$\left.\begin{aligned} \frac{dS}{dt} &= -5.09648\times 10^{-09} SI, \\ \frac{dI}{dt} &= 5.09648\times 10^{-09} SI - 0.10602 I, \\ \frac{dR}{dt} &= 0.10602 I, \end{aligned}\right\} \tag{21}$$

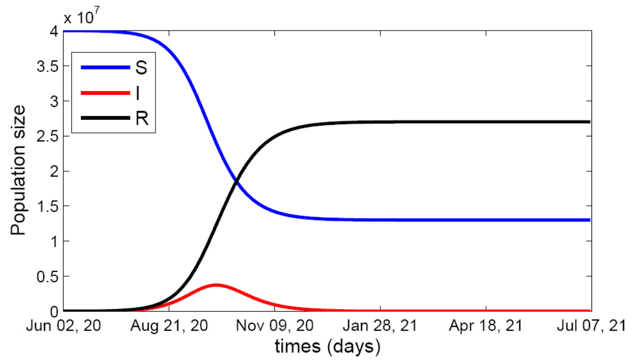

Figure 12

SIR estimation for a long time in Iraq with $\gamma = 0.10602, \beta = 5.09648 \times 10^{-09}, S(0) = 39998452, I(0) = 3644$, and $R(0) = 3508$.

with the initial conditions $S(0) = 39998452$, $I(0) = 3644$, and $\mathcal{R}_0 = 3508$, and $S(0)$, $I(0)$ and $R(0)$ refer to the susceptible, infectious and removed numbers at the last day (1st of June) of the previous period as in Section (6.2). The same Matlab code [31] is used to solve SIR model as shown in Eq. (21) by using Matlab 14*a*. Due to the SIR model, Fig. (12) shows the changing of the compartment over a long time.

The third period is presented in Fig. (13). Both real and estimated active infection increases over time. The estimation curve shows exponential growth. The real active infection is very close to the estimation curve in the

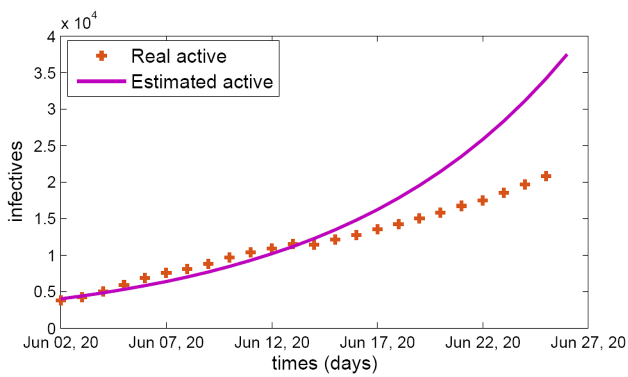

Figure 13

The real active and the estimated infectives for the period from 2/6 to 26/6/2020 in Iraq.

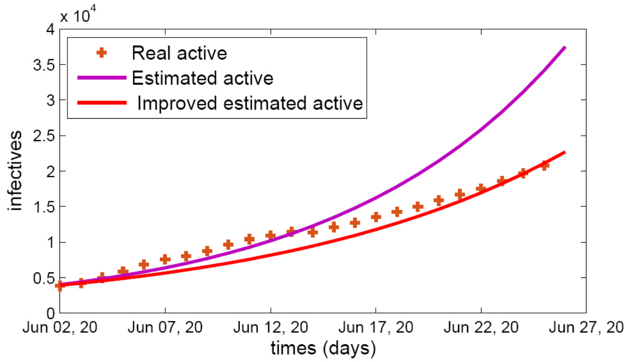

Figure 14

The real, the estimated, and the improved estimated infectives for the period from 1/6 to 26/6/2020 in Iraq.

first half of the graph, but this changes in the second half as the estimation curve starts to drift from the real active infection points.

As in Sections (6.1) and (6.2), the least square method is employed to find the improved estimated infective that can coincide with the real active data of infectives, where $\gamma = 0.11602$ and $\beta = 4.80025 \times 10^{-09}$. Fig. (14) establishes an improved estimation curve to the one introduced in Fig. (13). There is a significant difference between the two, as the new estimation curve is closer to the real active infection data points compared to the previous one. This enhances the accuracy of the estimation.

Fig. (15) illustrates a prediction of the active infective cases over a prolonged period of time in Iraq. The real active cases since COVID-19

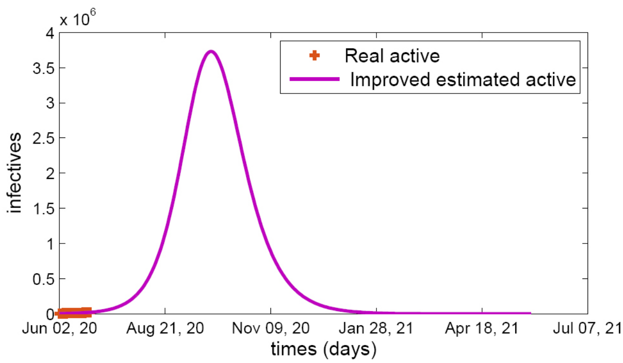

Figure 15

The real active and the improved estimated active infectives for a long time in Iraq.

reached Iraq matches with the curve of the predicted active infection cases. It is estimated that cases will increase over time, reaching a maximum of approximately 3.5 million on October/November, after which, the cases would start to decrease to reach a minimum level. It is estimated that COVID-19 would disappear by 7th of July 2021.

7. Conclusion

In this work, we developed the SIR epidemic model which represents the system of (ODEs) to the characteristics of COVID-19 in Iraq. This model considers some important characteristics of the COVID-19, such as the infectious people.

The first patient was reported on February 22, 2020, since then, the COVID-19 outbreak in Iraq has resulted in many confirmed cases. We divide our study into three periods depending on the value of the reproducing number R_0 and its implications for identifying the speed of the epidemic. In the first period (22/2 to 21/4/2020), the growth factor for COVID-19 was stable with the number being less than 1. We considered the incubation period to be the same as the removal period to calculate the removal rate due to the lack of information related to the recovered patients so this would implies $\mathcal{R}_0$ would slightly higher than the expectations. However, after the lockdown ended in Iraq, which is the second period (22/4 to 1/6/2020) where $\mathcal{R}_0 = 1.518027$, the growth factor started to show a fluctuating increase, and the daily infected number changed from being in the tens to be in hundreds, with a maximum of 416 cases. In the third period (2/6 to 26/6/2020) , we notice that $\mathcal{R}_0$ jumped to be 2 in the first week of June. The daily infected number was in the thousands.

Our model predicts that the maximum peak of the accumulated infection number to be 3.5 million by October/November, and the death cases to be approximately 30 thousand by October/November. This prediction is in line with the American study published in , which predicted the death cases would reach between $12-40$ thousand by October/November. We also deduced, from Fig. (11) that the recovery rate same to be 9 times more than case fatality rate which would mean the recovered cases would be approximately 2700000 cases. It is estimated that COVID-19 in Iraq would disappear by 7th of July 2021. This is the first paper to discuss COVID-19 in Iraq as our model predicts a considerable increase of infected people so this paper acts as a warning for both society and the government to be more cautious and practice safety methods.

In order to develop this model in the future, the birth and death cases unrelated to COVID-19 could be included. This is usually ignored in past pandemics research as pandemics used to last for a short period, as opposed to COVID-19.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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