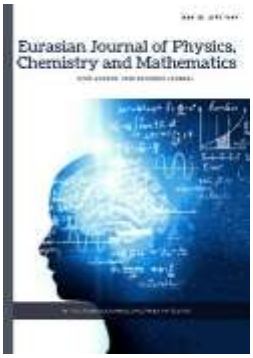

New Mathematical Model for the COVID-19 model in Wasit Province

Somaya Saad Faisal[1]

1) Department of Mathematics, College of Education for Pure Science, Wasit University, Iraq

Esam A. Alnussairy[2, a)]

2) Department of Biology, College of Science, Wasit University, Iraq
a) Corresponding author: eahmed@uowasit.edu.iq

ABSTRACT

Coronavirus disease 2019 (COVID-19) is a new viral disease that affected multiple organs in the body. Patients infected with SARS-CoV-2 develop arterial thrombosis including stroke, myocardial infarction and peripheral arterial thrombosis. The world wide spread of Covid-19 epidemic has instigated an unprecedented demand and supply of research related to this epidemic. Together with medical research for treatment and cure of the pandemic, efficient mathematical modelling of epidemics is the need of hour. In this thesis presented a new mathematical model and analyze it to understand the transmission dynamics of the COVID-19 pandemic in Wasit province, It is divided into ten compartmental classes, namely, Susceptible (S), Exposed (E) Symptomatically infected (I_s), Asymptomatically infected (I_a), Quarantined (Q), death (D), Recovered (R) and Hospitalized (H). Analytically solved using the Adomian decomposition method is carried out. The main advantage of this method is that it can be applied directly to all types of differential equations linear or non-linear, homogeneous or inhomogeneous, with constant or variable coefficients. Another important advantage is that, the method is capable of greatly reducing the size of computational work. The validation of the results by the analytical method shows that our model and adopted methodology are appropriate and accurate and could be used for further predictions for COVID-19. The graphical interpretation supports the efficient use of vaccination and quarantining proven infected persons, which significantly lowered the number of infected people. Furthermore, were note that, without vaccines and quarantine, the disease situation was much worse and the number of infected patients rose quickly.

Keywords: COVID-19, Wasit Province, pandemic, mathematical modeling

Introduction

Coronavirus (Covid-19) was a persistent global, epidemic of the Covid-19, which broke out, on December, 2019 in Wuhan city, China. On February 2020, it has been begun to spreading rapidly worldwide. The ASARS-COV-2 virus strain transmitted from infected animal to human, it causes the infection of 10 million people, and the death of hundred thousands of people worldwide. This is according, to statistics that reported, by country authorities, including the local Health Ministry [1-15]. The Covid-19 has 3 subgroups which are also known, as beta, gamma and alpha. There is also, another group that is called, delta SARS-CoV. Humans' coronavirus was first identified in 1960s [16]. The virus has mainly affects the elderly population [17]. The virus, that causes Covid-19, has mainly been transmitted through droplet generate once an infected persons exhales, sneezes and coughs. These symptoms are too heavy; to hang in air, and quickly, fall on surface or floor. Studies have been, tracked the spreads of this virus. They have been mobilized, to the speed innovative diagnostic. Many phenomena can be used in chemistry, engineering, physics, and mathematics. It can describe very successfully by model using the mathematical tool from the fractional calculus. For example, theory of derivatives, and integrals of the fractional (non-integer) order. The most fractional differential equation does not have exact the analytical solution Thus, that numerical technique and approximation method should be used. These models depict problems, which are linear and nonlinear phenomena have been played a crucial role in biology, mechanics, mathematics and physics. Thus, explicit solution to the nonlinear equation is fundamental importance to preserves the actual physical characters of the issue. Also, to deeply understand of the described process. It is necessary to apply efficient method including Adomian decomposition method (ADM) to solve these nonlinear issues [18]. Isaa and Alnussairy [19] in (2022), have been used the Adomian decomposition method(ADM) to calculate the influence of the angle of inclination on the air flow in human trachea under resting and normal breathing condition is presented.

Babies et al. [20] in (2021) have been developed a mathematical model about the spreads of the novel Covid-19. The model is a system of fractional differential equation in the sense of Caputo. The goal is to explain the mission of transmitting the Covid-19, and to investigate the effect of quarantine on reducing the rate of spreads of this virus in the country weather. The unique ability to solve the presented virus model is demonstrated. In addition, balance the point and reproduction numbers of the proposed model have discussed in two cases without and with taking into account the quarantine factors. It was by using the Adams-Bashforth-Moulton predictor corrected method.

Mehmet Yavuz et al. [16] in (2021) have been created a new virus models, taking into account vaccinations processes. They model us based on the dynamic of contact, with the Covid-19. The infection, of individual, who come into contact, the asymptomatic recovery or the virus. The exposure or absence, of the Covid-19 at the end, of vaccination process in individual who is not exposed, to this virus. Runge-Kota numerical chart of the fourth degree is applied to get results.

The aim of this study is to create a new mathematical model for Wasit province and to investigate the effect of the vaccine on Covid-19.

Model description and formulation

we will create a new mathematical model for Covied-19 in Wasit province with respect to a real data available from December 13, 2020 to March 14, 2021. The population of Wasit province was N(0)=1457000 persons for 2020 [21]. The mathematical model of COVID-19 transmission formulated in this study was motivated by the study of [32]. The model proposed in [32] was constructed from the SEIR model and is comprised of nine compartments with the infected compartment divided into three categories. However, in the present study, the model of Covied-19 with vaccination where the total population was subdivided into ten disjoint compartments, namely, Susceptible(S), Vaccinated with the first dose(V_1), Vaccinated with the second dose(V_2), Exposed (E), Asymptomatic infectious (I_a) Symptomatic infectious (I_s), Quarantine (Q), death (D) Hospitalized (H) and Recovered (R) compartments, respectively.

The susceptible compartment comprises individuals living in the Wasit province or who have recently returned before the border's closure. The individuals exposed to COVID-19 and show signs of symptoms are moved to the symptomatic infectious compartment. In contrast, individuals who show no sign of symptoms are moved to the asymptomatic infectious compartment there is a reduction in the risk of infection for the individuals in the susceptible compartment since they practice preventive measures such as social distancing, wearing a mask, and refraining from mass gatherings or meetings. Individuals move to the recovery compartment through recovery from both the quarantined and infected compartments, respectively. The parameters α_s and α_a, respectively, represent the effective contact rate (contacts capable of leading to COVID-19 transmission) for individuals in the symptomatically infectious and asymptomatically infectious compartments. The proportion of individuals who wear face masks correctly within a community is denoted as $0 < \psi \leq 1$ while $0 < \xi \leq 1$ represent the expected decrease in the risk of infection due to the face mask's use. The progression rate of exposed individuals is denoted as h where $h = \beta \frac{\tau I_a + I_s}{N-(Q+H)}$. A proportion $0 < \rho \leq 1$ of exposed individuals showed no clinical symptoms of COVID-19 (and move to the compartment (I_a) at the end of the incubation period. Due to the vaccine efficacy, individuals in $V_1$and V_2 class are relatively less infected than the fully susceptible ones: they will get infected with reduced vulnerability of $(1 - \eta_1)$ and $(1 - \eta_2)$ respectively. η_1 measures the efficacy of the first dose vaccine, whereas η_2 measures the efficacy after the second dose. Majority of the vaccines approved by WHO are given in two doses with an average recommended time interval between the two doses. We considered this scenario in our model. Susceptible individuals get vaccination (the first dose) at the rate of p_1 and those who got the first dose will get the second dose after an average $1/\alpha$ period of time with the rate p_2. In this study we did not fix a particular vaccine type therefore the value of $1/\alpha$ represents the average time needed to take the second dose. ρ proportion of exposed individuals will move to asymptomatic class and the rest, $(1-\rho)$ proportion will move to the symptomatic class after they finish the incubation period of $1/e$ day, where e is the infection rate. Mostly the symptoms of COVID-19 are similar to other respiratory diseases like common cold and flu, so all symptomatic individuals do not quarantined. Those only tested and confirmed can go to quarantine. Symptomatic individuals get tested and quarantine at the rate of δ. Those quarantined may develop serious illness, in this case they go to hospital at the rate of q_h. Individuals in I_a, I_s, Q and H will recover from the disease at the rate of r_a, r_s, r_q and r_h respectively. Similarly, γ_s and γ_a are the isolation rate of individuals. Finally, the parameters δ and q_h represent the COVID-19-induced mortality rate for individuals in the asymptomatic infectious and quarantined compartments, respectively. Asymptomatic are individuals with less pain and assumed will not die due to the disease. As a consequence, individuals in I_s, Q and H classes die due to the disease at the rate of d (assumed to be equal). People in all compartments will die naturally at the rate of μ and Λ is the recruitment rate to the susceptible compartment. The total population size at time t is denoted by $N(t)$

Where $N(t) = S(t) + V_1(t) + V_2(t) + E(t) + I_a(t) + I_s(t) + Q(t) + D(t) + H(t) + R(t)$

The model flow diagram is shown in Figure 1.

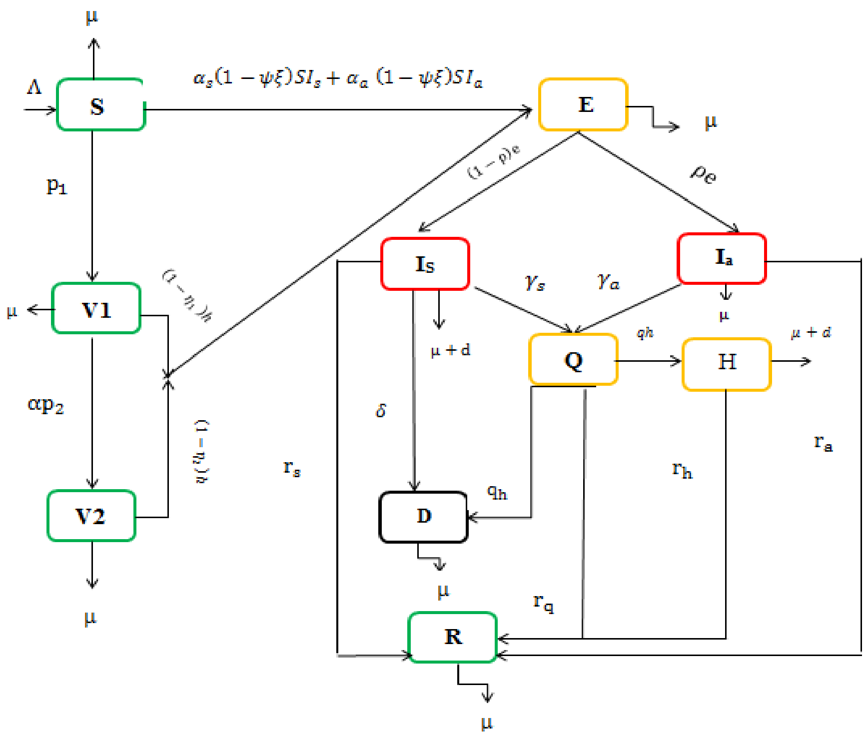

Figure 1: Flow diagram of the model

From the schematic diagram (Figure 1) the following system of differential equation is obtained by

$$\frac{dS}{dt} = \Lambda - \alpha_s(1-\psi\xi)SI_s - \alpha_a\,(1-\psi\xi)SI_a\; - \;\mu S$$

$$\frac{dV_1}{dt} = p_1 S - (\alpha p_2 + \mu + (1-\eta_1)h)V_1$$

$$\frac{dV_2}{dt} = \alpha p_2 V_1 - (\mu + (1-\eta_2)h)V_2$$

$$\frac{dE}{dt} = \alpha_s(1-\psi\xi)SI_s + \alpha_a\,(1-\psi\xi)SI_a + (1-\eta_1)hV_1 + (1-\eta_2)hV_2 \quad - (\mu + e)E$$

$$\frac{dI_a}{dt} = \rho e E - \left(r_a + \gamma_a + \mu\right)I_a$$

$$\frac{dI_s}{dt} = (1-\rho)eE - \left(r_s + \mu + \gamma_s + d\right)I_s$$

$$\frac{dQ}{dt} = \gamma_s I_s \;+ \gamma_a I_a \;- (\mu + r_q + q_h)Q$$

$$\frac{dD}{dt} = \delta\, I_s + q_h Q$$

$$\frac{dH}{dt} = q_h Q - (\mu + d + r_h)H$$

$$\frac{dR}{dt} = r_a I_a + r_s I_s + r_q Q + r_h H \; - \mu R$$

With initial conditions

$S(0) \geq 0, V_1 \geq 0, V_2 \geq 0, E(0) \geq 0, I_a(0) \geq 0, I_s(0) \geq 0, Q(0) \geq 0,$
$D(0) \geq 0, H(0) \geq 0$ and $R(0) \geq 0$

Since each component of the given model system considers a human population, it is necessary to show that all variables $S(t), V_1(t), V_2(t), E(t), I_a(t), I_s(t), Q(t), D(t), H(t)$ and $R(t)$ are positive for all $t \geq 0$.

Analytical Solution by Adomian Decomposition Method for COVID-19 in Wasit Province

The nonlinear system of ordinary differential equations can be solve using the ADM with the initial conditions.

Let l be an operator that is given by $l_t = \frac{d}{dt}$ and inverse of this operation is $l_t^{-1} = \int_0^t (.)\,dt$, then by applying l_t^{-1} for both sides of equation and we obtain:

$$S(t) - S(0) = l_t^{-1}(\Lambda - \alpha_s(1-\psi\xi)S(t)I_s(t) - \alpha_a\,(1-\psi\xi)S(t)I_a(t) - \mu S(t))$$

Where $S_0 = 50$

$$V_1(t) - V_1(0) = l_t^{-1}(p_1 S(t) - (\alpha p_2 + \mu + (1-\eta_1)h)V_1(t))$$

Where $V_{1_0} = 0$

$$V_2(t) - V_2(0) = l_t^{-1}(\alpha p_2 V_1(t) - (\mu + (1-\eta_2)h)V_2(t))$$

Where $V_{2_0} = 0$

$$E(t) - E(0) = \\ = l_t^{-1}(\alpha_s(1-\psi\xi)S(t)I_s(t) + \alpha_a\,(1-\psi\xi)S(t)I_a(t) + (1-\eta_1)hV_1(t) + (1-\eta_2)hV_2(t) - (\mu+e)E(t)\ )$$

Where $E_0 = 2$

$$I_a(t) - I_a(0) = l_t^{-1}\left(\rho e E(t) - \left(r_a + \gamma_a + \mu\right)I_a(t)\right)$$

Where $I_{a_0} = 1$

$$I_s(t) - I_s(0) = l_t^{-1}((1-\rho)eE(t) - \left(r_s + \mu + \gamma_s + d\right)I_s(t))$$

Where $I_{s_0=}1$

$$Q(t) - Q(0) = l_t^{-1}\left(\gamma_s I_s + \gamma_a I_a - (\mu + r_q + q_h)Q(t)\right)$$

Where $Q_0 = 0$

$$D(t) - D(0) = l_t^{-1}(\delta\, I_s(t) + q_h Q(t)\ )$$

Where $D_0 = 0$

$$H(t) - H(0) = l_t^{-1}(q_h Q(t) - (\mu + d + r_h)H(t)\ )$$

Where $H_0 = 0$

$$R(t) - R(0) = \\ = l_t^{-1}(r_a I_a(t) + r_s I_s(t) + r_q Q(t) + r_h H(t) - \mu R(t))$$

Where $R_0 = 0$

The above equations equivalent the following East:

$$S_{k+1} = l_t^{-1}\left(\Lambda - \alpha_s(1-\psi\xi)S_k I_{s_k} - \alpha_a\,(1-\psi\xi)S_k I_{a_k} - \mu S_k\right), k \geq 0$$

$$V_{1_{k+1}} = l_t^{-1}\left(p_1 S_k - (\alpha p_2 + \mu + (1-\eta_1)h)V_{1_k}\right), k \geq 0$$

$$V_{2_{k+1}} = l_t^{-1}\left(\alpha p_2 V_{1_k} - (\mu + (1-\eta_2)h)V_{2_k}\right), k \geq 0$$

$$E_{k+1} = l_t^{-1}(\alpha_s(1-\psi\xi)S_k I_{s_k} + \alpha_a\,(1-\psi\xi)S_k I_{a_k} + (1-\eta_1)hV_{1_k} + (1-\eta_2)hV_{2_k} - (\mu+e)E_k\ )\ , k \geq 0$$

$$I_{a_{k+1}} = l_t^{-1}\left(\rho e E_k - \left(r_a + \gamma_a + \mu\right)I_{a_k}\right), k \geq 0$$

$$I_{s_{k+1}} = l_t^{-1}\left((1-\rho)eE_k - \left(r_s + \mu + \gamma_s + d\right)I_{s_k}\right), k \geq 0$$

$$Q_{k+1} = l_t^{-1}\left(\gamma_s I_{s_k} + \gamma_a I_{a_k} - (\mu + r_q + q_h)Q_k\right), k \geq 0$$

$$D_{k+1} = l_t^{-1}\left(\delta\, I_{s_k} + q_h Q_k\ \right), k \geq 0$$

$H_{k+1} = l_t^{-1}(q_h Q_k - (\mu + d + r_h)H_k), k \geq 0$

$R_{k+1} = l_t^{-1}\left(r_a I_{a_k} + r_s I_{s_k} + r_q Q_k + r_h H_k - \mu R_k\right), k \geq 0$

The general form of the nonlinear terms A_k. and B_k should be:

by Using the Alternative Method

$A_k = \left(\sum_{n=0}^{\infty} S_n\right)\left(\sum_{n=0}^{\infty} I_{sn}\right). k = 0.1.2. \dots$

$A_k = (S_0 + S_1 + S_2 + \cdots)\left(I_{s_0} + I_{s_1} + I_{s_2} + \cdots\right).$

$= S_0 I_{s_0} + S_1 I_{s_0} + S_2 I_{s_0} + \cdots + S_{0I_{s_1}} + S_1 I_{s_1} + S_2 I_{s_1} + \cdots + S_0 I_{s_2} + S_1 I_{s_2} + S_2 I_{s_2} + \cdots$

$B_k = \left(\sum_{n=0}^{\infty} S_n\right)\left(\sum_{n=0}^{\infty} I_{an}\right). k = 0.1.2. \dots$

$B_k = (S_0 + S_1 + S_2 + \cdots)\left(I_{a_0} + I_{a_1} + I_{a_2} + \cdots\right).$

$= S_0 I_{a_0} + S_1 I_{a_0} + S_2 I_{a_0} + \cdots + S_0 I_{a_1} + S_1 I_{a_1} + S_2 I_{a_1} + \cdots + S_0 I_{a_2} + S_1 I_{a_2} + S_2 I_{a_2} + \cdots$

The nonlinear terms of A_0 *and* B_0. as the following:

$A_0 = S_0 I_{s_0} = 50 \times 1 = 50$

$B_0 = S_0 I_{a_0} = 50 \times 1 = 50$

When *k=0*

Substituting for all A_0 and B_0 , by Eq., to obtain*:*

$S_1 = l_t^{-1}(\Lambda - \alpha_s(1 - \psi\xi)S_0 I_{s_0} - \alpha_a\,(1 - \psi\xi)S_0 I_{a_0} - \mu S_0)$

Substituting for all A_0 and B_0 by Eq., to obtain:

$E_1 = l_t^{-1}(\alpha_s(1 - \psi\xi)S_0 I_{s_0} + \alpha_a\,(1 - \psi\xi)S_0 I_{a_0} + (1 - \eta_1)hV_{1_0} + (1 - \eta_2)hV_{2_0} - (\mu + e)E_0\,)$

From Eqs. we get:

$V_{1_1} = l_t^{-1}\left(p_1 S_0 - (\alpha p_2 + \mu + (1 - \eta_1)h)V_{1_0}\right)$

$V_{2_1} = l_t^{-1}\left(\alpha p_2 V_{1_0} - (\mu + (1 - \eta_2)h)V_{2_0}\right)$

$I_{a_1} = l_t^{-1}\left(\rho e E_0 - \left(r_a + \gamma_a + \mu\right) I_{a_0}\right)$

$I_{s_1} = l_t^{-1}\left((1 - \rho)e E_0 - \left(r_s + \mu + \gamma_s + d\right) I_{s_0}\right)$

$Q_1 = l_t^{-1}\left(\gamma_s I_{s_0} + \gamma_a I_{a_0} - (\mu + r_q + q_h)Q_0\right)$

$Q_1 = l_t^{-1}\left(0.2 \times 1 + 0.2 \times 1 - \left(\frac{1}{70 \times 365} + 0.05 + 0.015\right) \times 0\right)$

$Q_1 = l_t^{-1}(0.4) = \int_0^t 0.4\,dt = 0.4\,t$

$D_1 = l_t^{-1}\left(\delta\, I_{s_0} + q_h Q_0\,\right)$

$H_1 = l_t^{-1}(q_h Q_0 - (\mu + d + r_h)H_0)$

$R_1 = l_t^{-1}\left(r_a I_{a_0} + r_s I_{s_0} + r_q Q_0 + r_h H_0 - \mu R_0\right)$

Now we find $S_2.E_2.I_{a_2}.I_{s_2}.V_{1_2}.V_{2_2}.Q_2.D_2.H_2$ and R_2

The nonlinear borders of A_1 and B_1 are given in the following formula:

$A_1 = S_1 I_{s_0} + S_0 I_{s_1}$

$B_1 = S_1 I_{a_0} + S_0 I_{a_1}$

When *k=1*,

Substituting for all by A_1 and B_1, to obtain:

$S_2 = l_t^{-1}((\Lambda - \alpha_s(1 - \psi\xi)(S_1 I_{s_0} + S_0 I_{s_1}) - \alpha_a\,(1 - \psi\xi)(S_1 I_{a_0} + S_0 I_{a_1}) - \mu S_1)$

$(\mu + e)E_1\,)$

And also, from Eqswe get:

$V_{1_2} = l_t^{-1}\left(p_1 S_1 - (\alpha p_2 + \mu + (1 - \eta_1)h)V_{1_1}\right)$

$V_{2_2} = l_t^{-1}\left(\alpha p_2 V_{1_1} - (\mu + (1-\eta_2)h)V_{2_1}\right)$

$I_{a_2} = l_t^{-1}\left(\rho e E_1 - \left(r_a + \gamma_a + \mu\right) I_{a_1}\right)$

$I_{a_2} = l_t^{-1}\left(0.5 \times 0.1 \times 9.299921722\, t - \left(0.1 + 0.2 + \frac{1}{70 \times 365}\right) \times -0.200039138\, t\right)$

$I_{a_2} = l_t^{-1}(0.52501565\, t) = \int_0^t 0.52501565\, t dt = 0.2625078284 t^2$

$I_{s_2} = l_t^{-1}\left((1-\rho)eE_1 - \left(r_s + \mu + \gamma_s + d\right) I_{s_1}\right)$

$Q_2 = l_t^{-1}\left(\gamma_s I_{s_1} + \gamma_a I_{a_1} - (\mu + r_q + q_h)Q_1\right)$

$D_2 = l_t^{-1}(\delta\, I_{s_1} + q_h Q_1)$

$H_2 = l_t^{-1}(q_h Q_1 - (\mu + d + r_h)H_1)$

$R_2 = l_t^{-1}\left(r_a I_{a_1} + r_s I_{s_1} + r_q Q_1 + r_h H_1 - \mu R_1\right)$

When *k=2*

At the same previous steps, the nonlinear borders of A_2. and B_2 , are given as:

$A_2 = S_2 I_{s_0} + S_1 I_{s_1} + S_0 I_{s_2}$

$B_2 = S_2 I_{a_0} + S_1 I_{a_1} + S_0 I_{a_2}$

When *k=2*,

Substituting for all by A_2 and B_2 Eq. (3.36) and Eq.(3.39), to obtain:

$S_3 = l_t^{-1}((\Lambda - \alpha_s(1-\psi\xi)(S_2 I_{s_0} + S_1 I_{s_1} + S_0 I_{s_2})$
$\quad -\alpha_a(1-\psi\xi)(S_2 I_{a_0} + S_1 I_{a_1} + S_0 I_{a_2}) - \mu S_2)$

$E_3 = l_t^{-1}(\alpha_s(1-\psi\xi)(S_2 I_{s_0} + S_1 I_{s_1} + S_0 I_{s_2}) + \alpha_a(1-\psi\xi)(S_2 I_{a_0} + S_1 I_{a_1} + S_0 I_{a_2}) + (1-\eta_1)hV_{1_2} + (1-\eta_2)hV_{2_2} - (\mu + e)E_2)$

And also, from Eqs we get:

$V_{1_3} = l_t^{-1}\left(p_1 S_2 - (\alpha p_2 + \mu + (1-\eta_1)h)V_{1_2}\right)$

$V_{2_3} = l_t^{-1}\left(\alpha p_2 V_{1_2} - (\mu + (1-\eta_2)h)V_{2_2}\right)$

$I_{a_3} = l_t^{-1}\left(\rho e E_2 - \left(r_a + \gamma_a + \mu\right) I_{a_2}\right)$

$I_{s_3} = l_t^{-1}\left((1-\rho)eE_2 - \left(r_s + \mu + \gamma_s + d\right) I_{s_2}\right)$

$Q_3 = l_t^{-1}\left(\gamma_s I_{s_2} + \gamma_a I_{a_2} - (\mu + r_q + q_h)Q_2\right)$

$D_3 = l_t^{-1}(\delta\, I_{s_2} + q_h Q_2)$

$H_3 = l_t^{-1}(q_h Q_2 - (\mu + d + r_h)H_2)$

$R_3 = l_t^{-1}\left(r_a I_{a_2} + r_s I_{s_2} + r_q Q_2 + r_h H_2 - \mu R_2\right)$

The Adomian decomposition method assumes that the unknown functions $S(t), E(t), I_s(t), I_a(t), V_1(t), V_2(t), Q(t), D(t)$, $H(t)$ and $R(t)$that can be written by series as follows:

$$S(t) = \sum_{k=0}^{\infty} S_k,\quad E(t) = \sum_{k=0}^{\infty} E_k,\quad I_s(t) = \sum_{k=0}^{\infty} I_{s_k}.$$

$$I_a(t) = \sum_{k=0}^{\infty} I_{a_k}, V_1(t) = \sum_{k=0}^{\infty} V_{1_k}, V_2(t) = \sum_{k=0}^{\infty} V_{2_k},\quad Q(t) = \sum_{k=0}^{\infty} Q_k.$$

$$D(t) = \sum_{k=0}^{\infty} D_k,\quad H(t) = \sum_{k=0}^{\infty} H_k, R(t) = \sum_{k=0}^{\infty} R_{k,}$$

And using parameters values from a table 1 and table 2 we get

Table (1): Variables description used in the new model in Wasit province

Variables in the model	Meaning
S	The susceptible compartment
V_1	The Vaccinated with the first dose
V_2	The Vaccinated with the second dose
E	The exposed compartment
I_a	The asymptomatic infectious compartment
I_s	The symptomatic infectious compartment
Q	The quarantined compartment
D	The death compartment
H	The Hospitalized
R	The recovered compartment

Table (2): Parameter description and their baseline values used in the new model in Wasit province

Parameter	Description	Value	Sources
Λ	Recruitment rate	52	Calculated
μ	Natural death rate	$\frac{1}{70 \times 365}$	Calculated
h	The progression rate of exposed individuals	0.0000003	Calculated
p_1	First dose Vaccination rate	$8.157\times 10^{-7}\ days^{-1}$	[23]
p_2	Second dose Vaccination rate	0.974 $days^{-1}$	[23]
β	Transmission rate	0.513 $days^{-1}$	[23]
τ	Infectivity factor for asymptomatic individuals	0.116	[23]
η_1	Efficacy of first dose vaccine	0.8	[23]
η_2	Efficacy of second dose vaccine	0.95	[23]
α	Inverse of average time needed to take the second dose	0.14 $days^{-1}$	[23]
ρ	Fraction of infections that become asymptomatic	0.5	[22]
e	The rate of progression from the exposed compartment to the infectious compartment	0.1	[22]
r_s	Recovery rate for individuals with symptom	0.1	[22]
r_a	Recovery rate for asymptomatic individuals	0.1	[22]
r_q	Recovery rate for quarantined individuals	0.05	[22]
r_h	Recovery rate for individuals in hospital	0.213 $days^{-1}$	[22]
δ	The COVID-19 disease mortality rate for individuals in the infectious	0.015	[22]

	compartment		
d	Disease induced death rate	0.738	Calculated
q_h	The COVID-19 disease mortality rate for individuals in the quarantined compartment	0.015	[22]
α_s	The effective contact rate	0.1	[22]
α_a	The effectiveness of social distancing	0.1	[22]
γ_s	The isolation rate for individuals in the symptomatically infected compartment	0.2	[22]
γ_a	The isolation rate of asymptomatically infectious individuals	0.2	[22]
ψ	The proportion of individuals who use a face mask	0.1	[22]
ξ	The efficacy of face masks	0.5	[22]

$S(t) = \sum_{k=0}^{\infty} S_k = S_0 + S_1 + S_2 + S_3 + \cdots$
$S(t) = 50 + 47.49804305t + 57t - 1.810307696\, t^2 + 57\, t - 5.41611546\, t^2 + 0.27184321\, t^3$
$S(t) = 50 + 161.4980t - 7.2264231t^2 + 0.27184321\ \ t^3$
$E(t) = \sum_{k=0}^{\infty} E_k = E_0 + E_1 + E_2 + E_3 + \cdots$
$E(t) = 2 + 9.299921722t + 0.00000001\, t + 1.344200104t^2 + 40.415t^2 - 0.3166438047t^3$
$E(t) = 2 + 9.2999217t + 41.7592001t^2 - 0.31664380t^3$
$I_S(t) = \sum_{k=0}^{\infty} I_{SK} = I_{S0} + I_{S1} + I_{S2} + I_{S3} + \cdots$
$I_S(t) = 1 + 0.21196086t + 0.0899637t^2 + 0.0769883\, t^3$
$I_a(t) = \sum_{k=0}^{\infty} I_{ak} = I_{a0} + I_{a1} + I_{a2} + I_{a3} + \cdots$
$I_a(t) = 1 - 0.200039138\, t + 0.262507828\, t^2 + 0.00000000025t^2 +\ 0.020649858t^3 + \cdots$
$I_a(t) = 1 - 0.200039138\, t + 0.00001659\, t^2 + 0.020649858t^3 + \cdots$
$V_1(t) = \sum_{k=0}^{\infty} V_{1k} = V_{10} + V_{11} + V_{12} + V_{13} + \cdots$
$V_1(t) = 0 + 0.000040785\, t + 0.00001659055t^2 + 14.25t^2 - 0.3017187\, t^3 + \cdots$
$V_1(t) = 0.00004078\, t + 14.2500165t^2 - 0.3017187t^3$
$V_2(t) = \sum_{k=0}^{\infty} V_{2k} = V_{20} + V_{21} + V_{22} + V_{23} + \cdots$
$V_2(t) = 0 + 1 - 0.00001679t^2 - 0.0000122922\, t^3 +$
$Q(t) = \sum_{k=0}^{\infty} Q_k = Q_0 + Q_1 + Q_2 + Q_3 + \ldots..$
$Q(t) = 0 + 0.4\, t - 0.1268156t^2 + 0.088207095t^3 +$
$D(t) = \sum_{k=0}^{\infty} D_k = D_0 + D_1 + D_2 + D_3 + \ldots$
$D(t) = 0 + 0.015\, t - 0.0040352\, t^2 + 0.00029627155\, t^3 +$
$H(t) = \sum_{k=0}^{\infty} H_k = H_0 + H_1 + H_2 + H_3 + \cdots$
$H(t) = 0 + 1 + 0.003\, t^2 - 0.9510391t + 0.35095205\, t^2 - 0.00043511t^3 \ldots$
$H(t) = 1 - 0.9510391t + 0.35395205t^2 - 0.00043511t^3$
$R(t) = \sum_{k=0}^{\infty} R_t = R_0 + R_1 + R_2 + R_3 + \cdots$
$R(t) = 0 + 0.2t + 0.213t - 0.04690782\, t^2 - 0.1012898356t^2 + 0.030828903\, t^3 + \cdots$
$R(t) = 0 + 0.413\, t - 0.1481976556\, t^2 + 0.030828903t^3$

Results and Discussion

In this figure 2 we notice a decrease in the curve for the group of people who are not infected with the epidemic S When iteration 300 days, as a result of the rapid spread of the epidemic as well as the failure to adhere to the instructions of the World Health Organization. Also, in this figure, we notice a rise in the curve that represents people infected with the epidemic, with and without symptoms, due to frequent mixing between people. As for the category of people who were removed from the infection list R, we notice a clear increase in this group significantly as a result of the demand for taking the vaccine and commitment to social distancing...etc. Finally, there is a noticeable increase in the curve of the group of people who took the second dose V_2 of the vaccine against this pandemic, after which the curve stabilizes and becomes stable until the end of the study period.

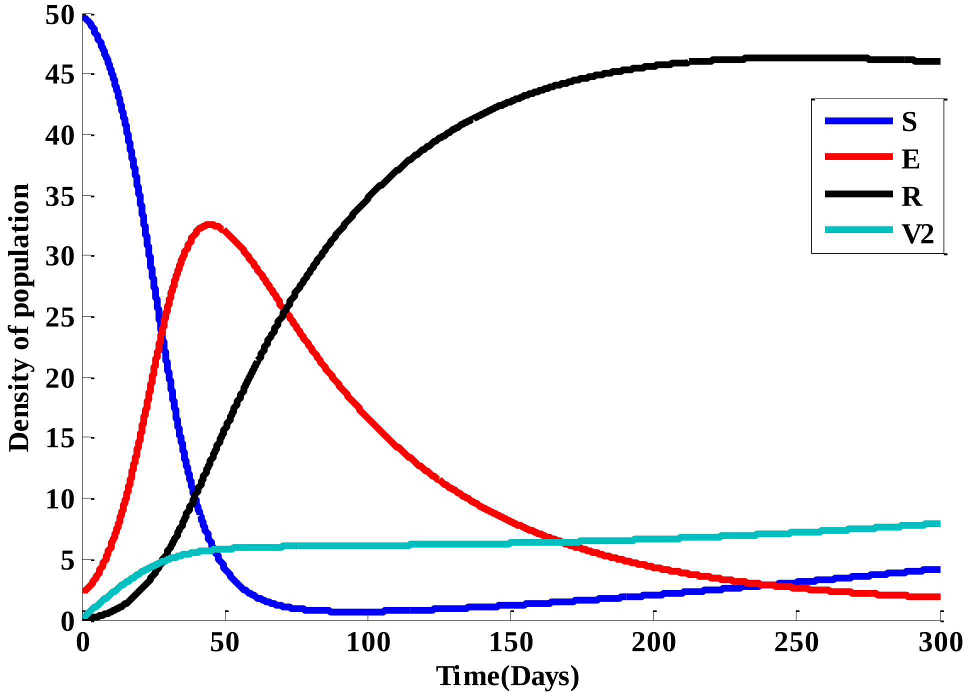

Figure 2: ADM analytical results of the COVID-19 model for S, E , R and V_2 during 300 days

In the figure 3 we notice a gradual decrease in the curve of the group of uninfected people S gradually at 300 repetitions to maintain the same level as a result of adherence to the instructions of the World Health Organization. We also notice that the curves of infected people who do not suffer from I_a symptoms and those infected with I_s symptoms converge at a certain point, then the I_a curve gradually decreases, noting that the Q curve for people isolated in quarantine gradually increases at a certain level, as a result of people's commitment to global health instructions. It is noted that the I_s curve increases gradually as a result of the frequent mixing of people

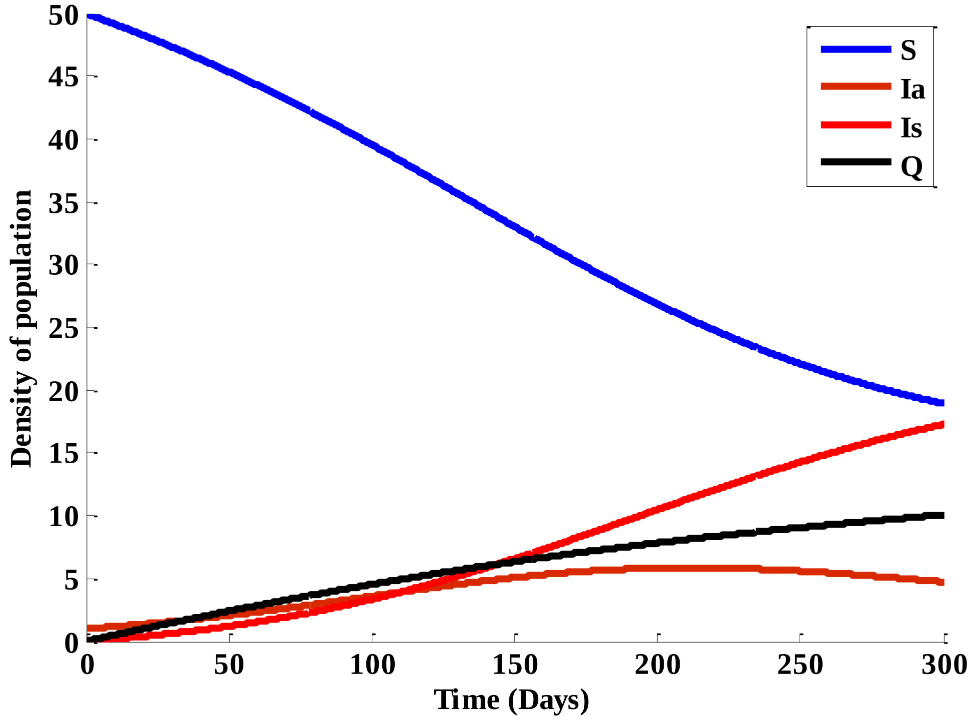

Figure 3: ADM analytical results of the COVID-19 model for ,I_a, I_s, Q during 300 days

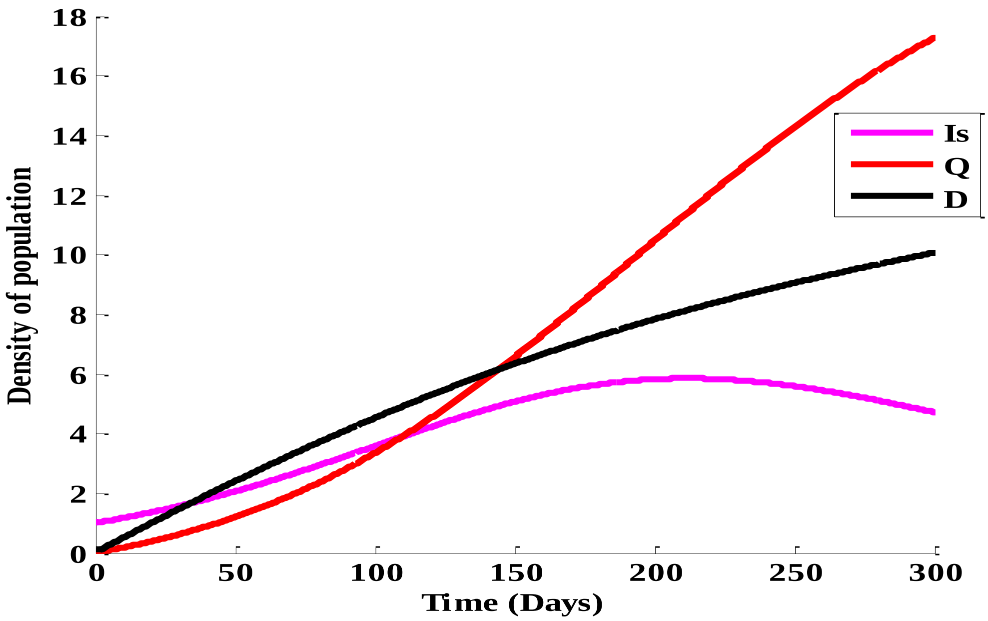

Figure 4: ADM analytical results of the COVID-19 model for Is, Q, D during 300 days

In the figure 5 we discuss the curves for the community groups when the repetition is 300, and we notice that the S curve began to decrease significantly as a result of the vaccination campaign. We note that the curve of people associated with the first dose of the pandemic vaccine V_1 gradually rose at a specific point and remained at the same level, with a clear and noticeable decrease in the curve of infected people who suffer from I_s symptoms and the curve of infected people who do not suffer from I_a symptoms, significantly as a result of the demand for taking the vaccine and adhering to distancing social. Finally, the curve of the group of recovered people R began to rise and gradually increase, then stabilized at the same level.

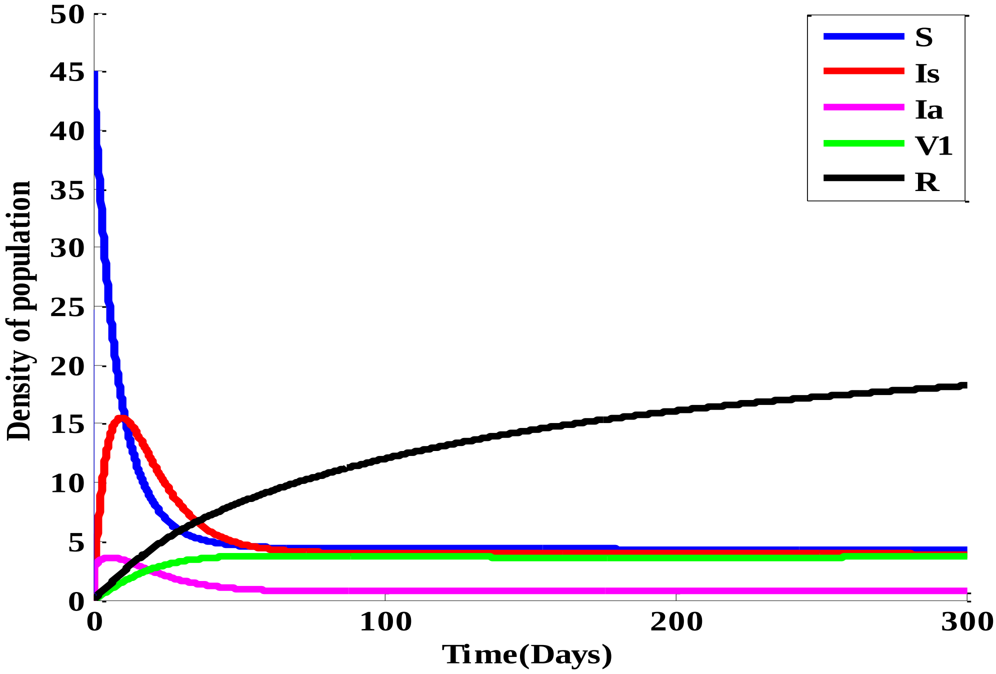

Figure 5: ADM analytical results of the COVID-19 model for shapes ▯, I_s, I_a, V_1, R during 300 days

Conclusion

The study concludes a new mathematical model of Covied -19 epidemic. The mathematical model is presented and analyzed to understand the transmission dynamics of the Coronavirus (COVID-19) epidemic in Wasit provience. It is divided into ten segmented categories, namely susceptible (S), exposed (E), and symptomatic (Is). Asymptomatic infection (Ia), quarantined (Q), death (D), recovery (R) and hospitalization (H). It was solved analytically using the Adomian decomposition method. The main advantage of this method is that it can be applied directly to all types of differential equations linear or nonlinear, homogeneous or inhomogeneous, with fixed or variable coefficients. Another important advantage is that the method is able to significantly reduce the amount of computational work.

References

[1] Nave, O., Shemesh, U., & HarTuv, I. (2021). Applying Laplace Adomian decomposition method (LADM) for solving a model of Covid-19. Computer Methods in Biomechanics and Biomedical Engineering, 24(14), 1618-1628.

[2] Ndaïrou, F., Area, I., Nieto, J. J., & Torres, D. F. (2020). Mathematical modeling of COVID-19 transmission dynamics with a case study of Wuhan. Chaos, Solitons & Fractals, 135, 109846.

[3] Samui, P., Mondal, J., & Khajanchi, S. (2020). A mathematical model for COVID-19 transmission dynamics with a case study of India. Chaos, Solitons & Fractals, 140, 110173.

[4] Hernandez-Vargas, E. A., & Velasco-Hernandez, J. X. (2020). In-host mathematical modelling of COVID-19 in humans. Annual reviews in control, 50, 448-456.

[5] Giordano, G., Blanchini, F., Bruno, R., Colaneri, P., Di Filippo, A., Di Matteo, A., & Colaneri, M. (2020). Modelling the COVID-19 epidemic and implementation of population-wide interventions in Italy. Nature medicine, 26(6), 855-860.

[6] Abdulkadhim, M. M., & Al-Husseiny, H. F. (2020). Global stability and bifurcation of a COVID-19 virus modeling with possible loss of the immunity. In AIP conference Proceedings (Vol. 2292, No. 1, p. 030003). AIP Publishing LLC.

[7] Zumla, A., & Niederman, M. S. (2020). The explosive epidemic outbreak of novel coronavirus disease 2019 (COVID-19) and the

persistent threat of respiratory tract infectious diseases to global health security. Current opinion in pulmonary medicine.

[8] Yao, S. Y., Lei, C. Q., Liao, X., Liu, R. X., Chang, X., & Liu, Z. M. (2021). Integrated Chinese and Western medicine in treatment of critical coronavirus disease (COVID-19) patient with endotracheal intubation: a case report. Chinese journal of integrative medicine, 27(4), 300.

[9] Mandal, M., Jana, S., Nandi, S. K., Khatua, A., Adak, S., & Kar, T. K. (2020). A model based study on the dynamics of COVID-19: Prediction and control. Chaos, Solitons & Fractals, 136, 109889.

[10] Kaur, S. P., & Gupta, V. (2020). COVID-19 Vaccine: A comprehensive status report. Virus research, 288, 198114.

[11] Zhang, R., Gao, Y., Xie, D., Lian, R., & Tian, J. (2021). Characteristics of systematic reviews evaluating treatments for COVID-19 registered in Prospero. Epidemiology & Infection, 149.

[12] Babaei, A., Ahmadi, M., Jafari, H., & Liya, A. (2021). A mathematical model to examine the effect of quarantine on the spread of coronavirus. Chaos, Solitons & Fractals, 142, 110418.

[13] Mandal, S., Bhatnagar, T., Arinaminpathy, N., Agarwal, A., Chowdhury, A., Murhekar, M., & Sarkar, S. (2020). Prudent public health intervention strategies to control the coronavirus disease 2019 transmission in India: A mathematical model-based approach. The Indian journal of medical research, 151(2-3), 190.

[14] Liu, L., Hong, X., Su, X., Chen, H., Zhang, D., Tang, S., & Shi, Y. (2020). Optimizing screening strategies for coronavirus disease 2019: A study from Middle China. Journal of Infection and Public Health, 13(6), 868-872.

[15] Kiran, R., Roy, M., Abbas, S., & Taraphder, A. (2020). Effect of population migration and punctuated lockdown on the spread of SARS-CoV-2. arXiv preprint.

[16] Yavuz, M., Coşar, F. Ö., Günay, F., & Özdemir, F. N. (2021). A new mathematical modeling of the COVID-19 pandemic including the vaccination campaign. Open Journal of Modelling and Simulation, 9(3), 299-321.

[17] Zeb, A., Alzahrani, E., Erturk, V. S., & Zaman, G. (2020). Mathematical model for coronavirus disease 2019 (COVID-19) containing isolation class. BioMed research international, 2020.

[18] Wazwaz, A. M.: “Partial Differential Equations:Methods And Applications”. Taylor Francis, (2 2).

[19] Isaa, H., & Alnussairy, E. (2022). Mathematical Modelling of Airflow in an Inclined Main Trachea: Using Adomain Decomposition Method. Wasit Journal of Pure sciences, 1(2), 102-117.

[20] Babaei, A., Ahmadi, M., Jafari, H., & Liya, A. (2021). A mathematical model to examine the effect of quarantine on the spread of coronavirus. Chaos, Solitons & Fractals, 142, 110418.

[21] Bontempi E, Coccia M, Vergalli S. (2021) Can commercial trade represent the main indicator of the COVID-19 diffusion due to human-to-human interactions? A comparative analysis between Italy, France, and Spain. Environ. Res. 201: 111529

[22] Riyapan, P., Shuaib, S. E., & Intarasit, A. (2021). A mathematical model of COVID-19 pandemic: A case study of Bangkok, Thailand. Computational and Mathematical Methods in Medicine, 2021.

[23] Sharbayta, S. S., Desta, H. D., & Abdi, T. (2022). Mathematical modelling of COVID-19 transmission dynamics with vaccination: A case study in Ethiopia. Discrete Dynamics in Nature and Society, 2023.