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Modeling the Dynamics of The Second Wave of Corona Virus (COVID-19) Pandemic in Nigeria

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ABSTRACT

The resurgence of the dreaded coronavirus (COVID-19) pandemic is rapidly taking its toll across the globe. Like other nations of the world, the need to flatten the curves is now the top priority of both governmental and non-governmental organizations in Nigeria. Understanding the dynamics of the disease is crucial in making suitable preventive policies that will slow the spread and ultimately flatten the curves. In this work, a compartmental-based model for analyzing the dynamics of the pandemics' second wave in Nigeria is presented. The model is fitted to the available data accessible on the Wolfram Data Repository and the parameter values estimated with the use of Quasi-Newton algorithm. Efficiency of the current control policies is measured and projections of the dynamics of the disease in coming days are made. Recommendations on how to manage the resurgence of the disease are also suggested.

Keywords: Coronavirus; COVID-19; Pandemic; Second Wave; Compartmental Model; Nigeria

INTRODUCTION

The quest for standard and scientific methods in the provision of global solution to a pandemic is of great concern especially in recent times due to the resurgence of the novel CoronaVirus (COVID-19). Epidemiological models are particularly suitable in understanding the dynamics of an epidemic [5]. The use of compartmental-based models in epidemiological modeling has been shown to be effective for predicting, determining, validating and analyzing the rate of susceptibility, exposure, infection, recovery and mortality of a pandemic [5, 12, 13]. Due to the uniqueness of each occurrence of pandemic, assessing the impacts of responses and determining a number of qualitative parameters of the COVID–19 pandemic has made this work a bit complex. It is usually assumed that the incidence rate of a disease is given by an unspecified nonlinear function constrained by a few biologically motivated conditions. The resurgence of the pandemic in Nigeria has been meet with renewed enforcement of some social and health measures [14]. These measures are steps to reducing the contact parameter(s) [1, 16]. Epidemic models often make use of ordinary differential equations which are deterministic in nature [9, 10, 11, 12] to predict the dynamics of a disease by estimating the crucial parameters of the model [18]. As the number of cases increases, the need to understand the dynamics of the pandemic and hence, provide the best strategy to slow the spread and eventually flatten the curves is now a major concern in

Nigeria. Some models to visualize the geographical spread of the disease have been proposed [4, 6]. Several epidemiological models [2, 3, 7, 8, 15, 17] have been proposed in the efforts to estimate some parameters that can be used to project the severity of the outbreak, its duration, and the mortality rate. Data on the second wave of the pandemic for the period of December 01, 2020 to February 15, 2021 accessible on the Wolfram Data Repository was use in this research. In this work, we present a modified Susceptible-Exposed-Infectious-Recovered-Deceased (mSEIRD) model for analyzing the dynamics of the second wave of COVID-19 pandemic in Nigeria. The options for controlling the pandemic has been greatly reduced by the lack of vaccine. The country is currently focusing efforts on 'social distancing', 'mask usage' and 'personal hygiene' designed to reduce transmission of the virus. We introduce a control parameter $\mu \in [0,1]$ in the model to indicate the effectiveness of these efforts. Increase in the value of μ implies better effectiveness of the control efforts. The purpose of this model include: exploration of the impacts of the control strategies on the spread of the pandemic, measure the infection rate, average latent time, average infective time and average mortality rate. The basic reproduction number of the disease in Nigeria is also estimated. Projections of the dynamics of the disease in coming days are made. Recommendations on how to manage the resurgence of the disease are also suggested.

MODEL FORMULATION

In this work, we characterize the dynamics of the second wave of the COVID-19 pandemic by introducing a modified compartmental model consisting of five states - Susceptible $S(t)$, Exposed $E(t)$, Infected $I(t)$, Recovered $R(t)$ and Deceased $D(t)$ denoting at time t the respective number of the susceptible, exposed (infected but not yet infectious, in a latent period), infectious (with infectious capacity), recovered and deceased cases. We shall refer to this model as modified Susceptible-Exposed-Infectious-Recovered-Deceased (mSEIRD) model. The interactions between the categories are described by a system of ordinary differential equations formulated as;

$$\left.\begin{aligned}
\frac{dS}{dt} &= -(1-\mu)S(t)\left(\beta_1 \frac{E(t)}{N-D(t)} + \beta_1 \frac{I(t)}{N-D(t)}\right) \\
\frac{dE}{dt} &= (1-\mu)S(t)\left(\beta_1 \frac{E(t)}{N-D(t)} + \beta_1 \frac{I(t)}{N-D(t)}\right) - (\gamma + \delta_1 + \sigma_1) \\
\frac{dI}{dt} &= \gamma E(t) - (\delta_2 + \sigma_2) I(t) \\
\frac{dR}{dt} &= \delta_1 E(t) + \delta_2 I(t) \\
\frac{dD}{dt} &= \sigma_1 E(t) + \sigma_2 I(t)
\end{aligned}\right\} \quad (1)$$

where $N = S + E + I + R + D$ is the total population, $\mu \in [0,1]$ is the measure of the effectiveness of the current control policies and γ^{-1} is the average incubation time in days. The parameters $\beta_1, \delta_1, \sigma_1$ and $\beta_2, \delta_2, \sigma_2$ are respectively the infection, recovery, mortality rates of exposed and infected categories. Unlike other models discussed in the literature, this work assumes that an exposed person can infect a susceptible person and that some persons might have very mild symptoms and can move from the exposed category to the recovered category and will never get sick enough to be in the infectious category.

Parameter Estimation

To estimate the parameters of the proposed model, we first solve (1) numerically in terms of the model parameters. The resulting values are then tuned manually to obtain the initial values needed in the curve fitting process. Initialized values of the parameters are given in Table 1.

Table 1: Initial parameter estimates

μ	β_1	β_2	γ	δ_1	δ_2	σ_1	σ_2
0.5089	0.3593	0.4451	0.0131	0.0025	0.0393	0.0001	0.0003

To fit the resulting curves obtained in the solution of (1) to the available data, we use the Quasi–Newton algorithm to obtain the best parameter estimates as given in Table 2.

Table 2: Model Parameter Table

Parameter	Estimate	Standard Error	t-Statistic	P-Value
μ	0.494067	0.068509	7.211702	8.330870×10^{-12}
β_1	0.319684	0.073152	4.370117	1.896874×10^{-05}
β_2	0.472738	0.055275	8.552538	1.870999×10^{-15}
γ	0.013754	0.001679	8.193423	1.911386×10^{-14}
δ_1	0.002360	0.000495	4.765542	3.379014×10^{-06}
δ_2	0.040699	0.001625	25.050530	5.093017×10^{-67}
σ_1	0.000127	0.000355	0.358572	7.202517×10^{-01}
σ_2	0.000553	0.001712	0.323081	7.469338×10^{-01}

Interpretation of Model Solution

The dynamics of the second wave of the pandemic is described by the proposed model (1). From the model solution, it can be seen that the turning point of the infection was determined to have occurred around the begining of February, 2021, the mortality curve started flattening around late January, 2021, the recovery curve is still on the rise. From Figure 1, it can be seen that effectiveness of the control measures is central in the quick peaking and fast–flattening of the curves. The effectiveness of the control policies was measured as 49.41%. Rates of infection by the exposed and infected categories are respectively measured as $\beta_1 = 0.319684$ and $\beta_2 = 0.472738$. The average incubation time was estimated as $\gamma^{-1} \approx 73\ days$. The rates of recovery of the exposed and infected persons are respectively estimated as $\delta_1 = 0.002360$ and $\delta_2 = 0.040699$, while the mortality rates among the exposed and infected categories are estimated as $\sigma_1 = 0.000127$ and $\sigma_2 = 0.000553$ respectively.

Sensitivity Analysis

To see how best the model fits the available data, we present the plot of the model solution curves compared with the observed data as given in Figure 1.

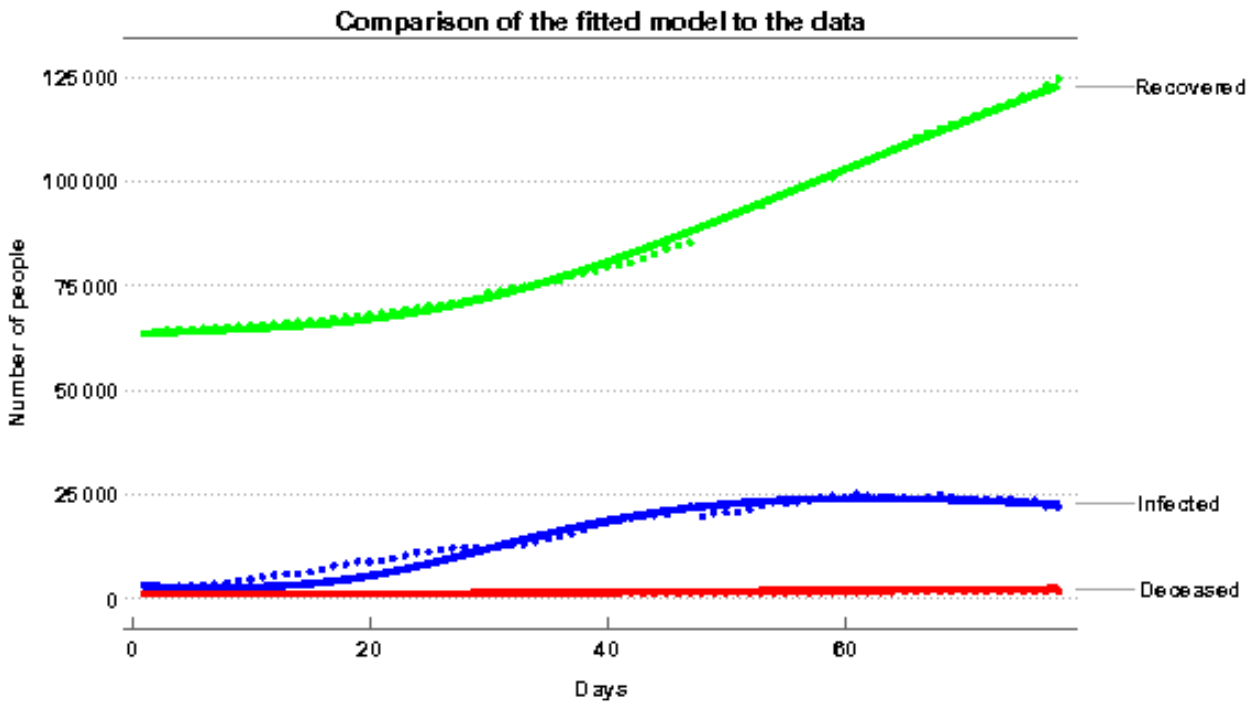


Figure 1: Nigeria COVID–19 Pandemic Second Wave Fitted Curve

Figure 1 shows how well the proposed model fits the Covid–19 data. A two–week projection of the dynamics of the pandemic is presented in Figure 2.

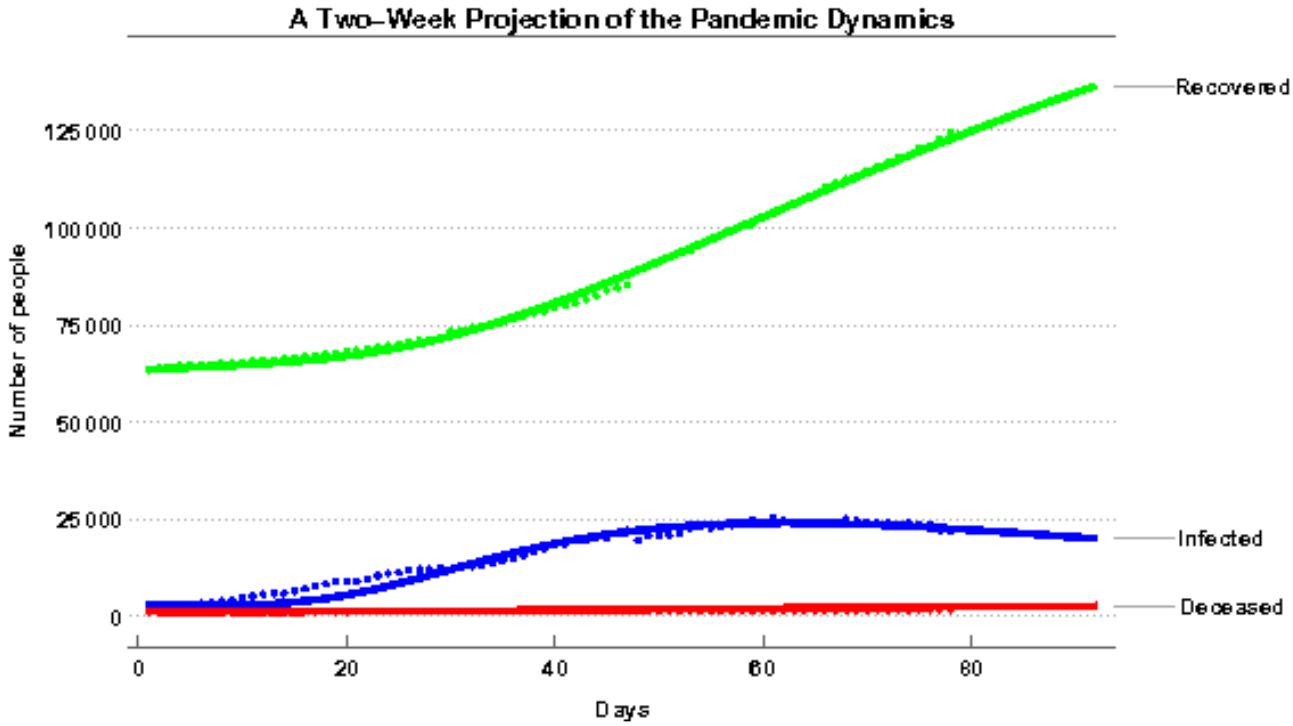


Figure 2: A Two–Week Projection of COVID–19 Pandemic in Nigeria

CONCLUSION AND RECOMMENDATION

The mSEIRD model (1) presented in this work has been used in estimating the major parameters influencing the dynamics of the disease in Nigeria. The model fits the deceased category well. It can also be seen that the recovered category recovers almost as fast as the data. The model reveals that the second wave of the disease has peaked and the curves are fast flattening. It also reveals that the overall effectiveness of the control policies in Nigeria is just 49.41%. This is an indication that control policies are not properly adhered to and thus requires an improvement.

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