Computers, Materials & Continua CMC, vol.65, no.3, pp.1945-1957, 2020

Awareness as the Most Effective Measure to Mitigate the Spread of COVID-19 in Nigeria

Isa Abdullahi Baba[1, *] and Dumitru Baleanu[2, 3]

Abstract: A mathematical model consisting of a system of four nonlinear ordinary differential equations is constructed. Our aim is to study the dynamics of the spread of COVID-19 in Nigeria and to show the effectiveness of awareness and the need for relevant authorities to engage themselves more in enlightening people on the significance of the available control measures in mitigating the spread of the disease. Two equilibrium solutions; Disease free equilibrium and Endemic equilibrium solutions were calculated and their global stability analysis was carried out. Basic reproduction ratio (R_0) was also obtained, in this research $R_0 = 3.0784$. Data obtained for Nigeria is used to conduct numerical simulations in order to support the analytic result and to show the significance of awareness in controlling the disease spread. From the simulation result, it was shown that to mitigate the spread of COVID-19 in Nigeria there is need for serious awareness programs to enlighten people on the available control measures; social distancing, self-isolation, use of personal protective equipment (such as face mask, hand globes, overall gown, etc.), regular hand washing using soap or sanitizer, avoiding having contact with person showing the symptoms and reporting any suspected case.

Keywords: COVID-19, model, equilibrium solution, basic reproduction ratio, stability analysis, numerical simulation, Nigeria.

1 Introduction

Starting from the end of 2019, coronavirus disease 2019 (COVID-19) epidemic, which is later declared pandemic [WHO (2020b)], caused by the severe acute respiratory syndrome coronavirus 2 [WHO (2020a)] hit Wuhan, the capital city of Hubei province in China [Wu, Hao, Lau et al. (2020)]. By March 23, 2020 the epicenter of COVID-19 has moved to Europe and Middle East, when the outbreak was almost controlled in China.

Number of confirmed cases is increasing rapidly in many countries [Bogoch, Watts, Thomas-Bachili et al. (2020); Lai, Bogoch, Ruktanonchai et al. (2020); Nishiura, Kobayashi, Yang et al. (2020); Wu, Leung and Leung (2020); Zhao, Zhuang, Ran et al. (2020); Zhao,

[1] Department of Mathematical Sciences, Bayero University, Kano, Nigeria.

[2] Department of Mathematics, Cankaya University, Ankara, Turkey.

[3] Institute of Space Sciences, Bucharest, Romania.

[*] Corresponding Author: Isa Abdullahi Baba. Email: iababa.mth@buk.edu.ng.

Received: 12 May 2020; Accepted: 28 July 2020.

Zhuang, Cao et al. (2020)]. The case-fatality-rate varies from one country to another. Globally as of 24 March 2020, over 400,000 people were infected with COVID-19 with more than 18,000 deaths [WHO (2020a, 2020c)].

In Africa the first case of COVID-19 occurred in Egypt on 14 February 2020 [WHO (2020c); Gilbert, Pullano, Pinotti et al. (2020)]. By 24th of March 2020, the cases in Africa reached more than 2300 with about 32 deaths [WHO (2020c)]. There is no doubt that African region is one of the most vulnerable with the COVID-19 infection [Gilbert, Pullano, Pinotti et al. (2020)]. This can be attributed to two reasons; 1. Africa is important commercial partner of China and therefore a lot of business person travel to the region; 2. Now that the epicenter is Europe, and due to the good relationship between African countries and Europe, the threat is bigger [Poletto, Gomes, Pastore et al. (2014); Sambala, Kanyenda, Iwu et al. (2008); Sands, Mundaca-Shah and Dzau (2016); Marston, Dokubo, van-Steelandt et al. (2017)].

On Feb 27, 2020, news broke that the first case of coronavirus landed in Nigeria from an Italian citizen. He landed at Lagos airport two days before the announcement on a flight from Italy, he then travelled from Lagos to Ogun State, western part of Nigeria, where he shows symptoms and was immediately isolated. Without much waste of time National Emergency Operations Centers were activated to trace out his contacts. Many suspected cases had been identified across five states (Edo, Lagos, Ogun, Federal Capital Territory, and Kano) by March 9, 2020. Some of them (27 to be precise) were confirmed to be positive with no deaths [NCDC (2020)].

Nigeria showed its readiness through intensifying its preparedness against COVID-19 importation, looking at the successes it recorded in controlling the recent epidemics related to Ebola and Polio [Unah (2020)]. This gives rise to the rapid deployment of high-quality surveillance, temperature screening, and collection of passengers' contact details and interviewing those arriving from COVID-19 hotspots, across Nigerian airports using equipment acquired during the Ebola epidemic [NCDC (2020)].

However, unlike Ebola and Polio, COVID-19 has neither a vaccine nor treatment. Moreover, Gilbert et al. labeled Nigeria as vulnerable to exposing its population of more than 200 million to COVID-19, due to moderate capacity to control the outbreak [Gilbert, Pullano, Pinotti et al. (2020)]. This assessment questions Nigeria's capacity to provide sufficient bed space and associated clinical care to support those who could need isolation and quarantine if local cycles of transmission of COVID-19 occur in the country.

As scientists all over the world are busy trying to develop a cure and vaccine, all hands must be on deck to support and comply with the standard recommendations that lower the transmissions of the disease, as such the following measures must be taken: social distancing, self-isolation, use of personal protective equipment (such as face mask, hand globes, overall gown, etc.), regular hand washing using soap or sanitizer, avoiding having contact with person showing the symptoms and reporting any suspected case [Institute of Medicine (US) Forum on Microbial Threats (2007)].

Most of these measures were taken in Nigeria. From the early outbreak Nigerian authorities banned all social (or religious) gathering and local (or international) trip except for an essential purpose, start contact tracing and isolation of infected individuals, begin fumigating exercises, and impose lockdown to stay at home. These measures are believed to be at the moment the most reliable methods of curbing the spread of the disease if they were to be applied successfully. However, in order to apply such measures in an underdeveloped country like Nigeria there is need for relevant authorities to engage in widely public orientation exercise for sensitization and enlightenment.

Numerous epidemiological studies have been conducted to understand the transmission dynamics of COVID-19, which is quantified in two key parameters, the basic reproduction number (the expected number of secondary cases that may be caused by a typical primary case during his/her infectious period in a wholly susceptible population, R_0) and the serial interval (time delay between the symptom onset of a primary case and his/her secondary case, SI). High reproductive number and short serial interval imply rapid growth. In the initial phase, the epidemic (number of new cases over time) typically exhibited exponential growth [Zhao, Lin, Ran et al. (2020); Ma (2020); Nishiura, Linton and Akhmetzhanov (2020); Riou and Althaus (2020); Shen, Peng, Xiao et al. (2020); Read, Bridgen, Cummings et al. (2020)]. None of these papers study the impact of awareness campaign in controlling the disease.

Our aim in this paper is to study the dynamics of the spread of COVID-19 in Nigeria and to show the effectiveness of awareness and the need for relevant authorities to engage themselves more in enlightening people on the significance of the available control measures in curtailing the spread of the disease.

The paper is constructed as follows; the first chapter is the introduction, second is construction of the model, third is equilibrium solution and its analysis, fourth is the numerical simulations and fifth is the Summary and conclusions.

2 Construction of the model

Let the total population be $N(t)$. The population is broadly divided into three compartments; the general susceptible population $S(t)$, the infective population $I(t)$ and susceptible population with awareness $S_A(t)$. The cumulative density of the awareness programs is given by $A(t)$. The growth rate of the density of the awareness program is assumed to be proportional to the number of Infectives. Fig. 1 is the schematic diagram of the model and meaning of parameters are given in Tab. 1.

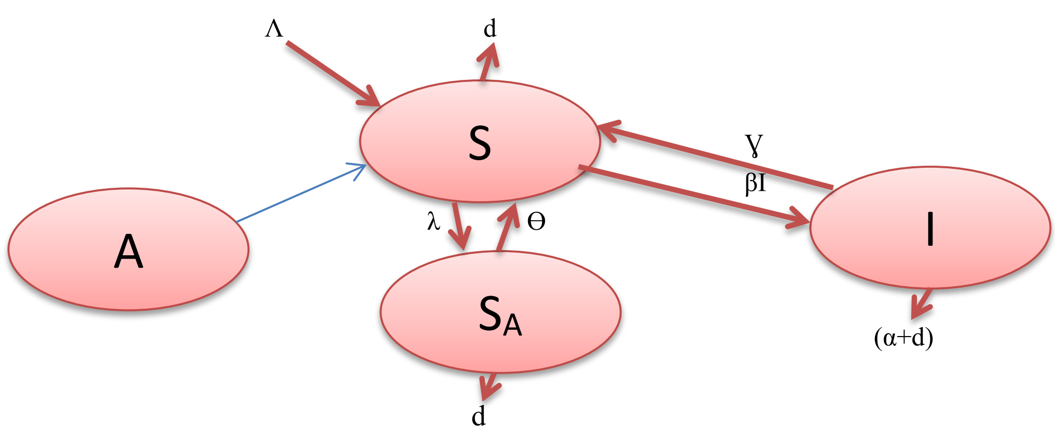

Figure 1: Schematic diagram of the model

$$\frac{dS}{dt} = \Lambda - \beta SI - \lambda SA - dS + \gamma I + \theta S_A$$
$$\frac{dI}{dt} = \beta SI - \gamma I - \alpha I - dI \qquad (1)$$
$$\frac{dS_A}{dt} = \lambda SA - dS_A - \theta S_A$$
$$\frac{dA}{dt} = \mu I - \phi A$$

Table 1: Meaning of parameters

Parameters	Meaning
Λ	Recruitment rate
β	Infection contact rate
λ	Dissemination rate of awareness
Ɣ	Recovery rate
α	Death rate due to infection
d	Natural death rate
Ɵ	Rate of transfer of aware individuals to susceptible class
μ	Rate of implementation of the awareness program
ϕ	Rate of depletion of the program due to social problems and ineffectiveness

3 Boundedness, equilibrium solution and stability analysis

3.1 Boundedness

Let

$$N(t) = S(t) + I(t) + S_A(t) \qquad (2)$$

Then,

$$\frac{dN}{dt} = \frac{dS}{dt} + \frac{dI}{dt} + \frac{dS_A}{dt}$$
$$= \Lambda - d(S + I + S_A) - \alpha I \qquad (3)$$

This implies,

$$\frac{dN}{dt} \le \Lambda - dN \qquad (4)$$

Solving the differential inequality as $t \to \infty$, we get

$$N(t) \le \frac{\Lambda}{d} \qquad (5)$$

3.2 Equilibrium solution

We have two equilibrium solutions; the disease free equilibrium (E_0) and endemic equilibrium (E_1).

$$E_0 = \left(S^0, I^0, S_A^0, A^0\right) = \left(\frac{\Lambda}{d}, 0,0,0\right) \quad (6)$$

$$E_1 = (S^1, I^1, S_A^1, A^1) \quad (7)$$

where,

$$S^1 = \frac{\alpha + \text{Ɣ} + d}{\beta} \quad (8)$$

$$I^1 = \frac{\phi[\Lambda\beta d + \Lambda\beta\theta - (\text{Ɣ}d^2 + \theta\text{Ɣ}d + \alpha d^2 + \theta\alpha d + \theta d^2 + d^3)]}{\beta\phi\alpha d + \beta\phi\alpha\theta + \beta\phi d^2 + \beta\phi d\theta + \lambda\text{Ɣ}\mu d + \lambda\alpha\mu\theta + \lambda\mu d^2} \quad (9)\ (10)$$

$$S_A^1 = \frac{\lambda\mu(\alpha + \text{Ɣ} + d)(\Lambda\beta - d\text{Ɣ} - d\alpha - d^2)}{\beta(\beta\phi\alpha d + \beta\phi\alpha\theta + \beta\phi d^2 + \beta\phi d\theta + \lambda\text{Ɣ}\mu d + \lambda\alpha\mu\theta + \lambda\mu d^2)} \quad (11)$$

$$A^1 = \frac{\mu[\Lambda\beta d + \Lambda\beta\theta - (\text{Ɣ}d^2 + \theta\text{Ɣ}d + \alpha d^2 + \theta\alpha d + \theta d^2 + d^3)]}{\beta\phi\alpha d + \beta\phi\alpha\theta + \beta\phi d^2 + \beta\phi d\theta + \lambda\text{Ɣ}\mu d + \lambda\alpha\mu\theta + \lambda\mu d^2}$$

It can easily be seen that I^1, S_A^1 *and* A^1 are biologically meaningful only if

$$\frac{\Lambda\beta}{d(d + \alpha + \text{Ɣ})} > 1 \quad (12)$$

Define R_0 (basic reproduction ratio) to be $\frac{\Lambda\beta}{d(d+\alpha+\text{Ɣ})}$. Thus the endemic equilibrium E_1 exists only if $R_0 = \frac{\Lambda\beta}{d(d+\alpha+\text{Ɣ})} > 1$.

3.3 Local stability analysis of the equilibrium solutions

Consider the following Jacobian matrix from Eq. (1);

$$J = \begin{bmatrix} -\beta I - \lambda A - d & -\beta S + \gamma & \theta & -\lambda S \\ \beta I & \beta S - (\alpha + \gamma + d) & 0 & 0 \\ \lambda A & 0 & -(d + \theta) & \lambda S \\ 0 & \mu & 0 & -\phi \end{bmatrix} \quad (13)$$

Theorem 1: Disease free equilibrium is locally asymptotically stable when $R_0 < 1$.

$$J(E_0) = \begin{bmatrix} -d & -\beta(\frac{\Lambda}{d})+\gamma & \theta & -\lambda(\frac{\Lambda}{d}) \\ 0 & \beta(\frac{\Lambda}{d})-(\alpha+\gamma+d) & 0 & 0 \\ 0 & 0 & -(d+\theta) & \lambda(\frac{\Lambda}{d}) \\ 0 & \mu & 0 & -\phi \end{bmatrix} \tag{14}$$

Proof: Consider the above Jacobian matrix at disease free equilibrium, then we have;
The eigenvalues are;

$-d,\ \beta(\frac{\Lambda}{d})-(\alpha+\gamma+d),\ -(d+\theta)\ and - \phi.$

Hence, it is locally asymptotically stable if

$\beta(\frac{\Lambda}{d})-(\alpha+\gamma+d)<0$. Which implies $R_0 < 1$.

Theorem 2: Endemic equilibrium is locally asymptotically stable if $R_0 > 1$.
Proof: Consider the above Jacobian matrix at endemic equilibrium, then we have;

$$J(E_1) = \begin{bmatrix} -(\beta I_1+\lambda A_1+d) & -(\alpha+d) & \theta & -\lambda S_1 \\ \beta I_1 & 0 & 0 & 0 \\ \lambda A_1 & 0 & -(d+\theta) & \lambda S_1 \\ 0 & \mu & 0 & -\phi \end{bmatrix} \tag{15}$$

The eigenvalues are;

$-\phi, -(\theta+d),$

$$\frac{-\beta I_1-\lambda A_1-d \pm \sqrt{\beta^2 I_1^2+2\beta\lambda I_1 A_1-2\beta I_1 d+\lambda^2 A_1^2+2\lambda A_1 d+d^2-4\beta\alpha I_1}}{2} \tag{16}$$

The eigenvalues are all negative if;

$$\frac{-\beta I_1-\lambda A_1-d \pm \sqrt{\beta^2 I_1^2+2\beta\lambda I_1 A_1-2\beta I_1 d+\lambda^2 A_1^2+2\lambda A_1 d+d^2-4\beta\alpha I_1}}{2} < 0 \tag{17}$$

Which is true only if I_1, A_1 are positive. But $I_1, A_1 > 0$ only if $R_0 > 1$.

3.4 Global stability analysis of the equilibrium solutions

In this chapter we study the stability analysis of the solutions of the model. The global stability analyses of the disease free and endemic equilibriums are given by the following two theorems;

Theorem 3: Disease free equilibrium E_0 is globally asymptotically stable when $\frac{\mu}{\alpha+d} \leq 1$.

Proof: Consider the Lyapunov function, defined as;

$$V(S, I, S_A, A) = g\left(\frac{S}{S^0}\right) + S_A + I + A \tag{18}$$

where $g(x) = x - 1 - lnx$, which is positive function, therefore $V \geq 0$. It suffices to show $\dot{V} < 0$.

$$\dot{V} = \left(1 - \frac{S^0}{S}\right)\dot{S} + \dot{I} + \dot{S_A} + \dot{A}$$

$$= \left(1 - \frac{S^0}{S}\right)[\Lambda - \beta SI - \lambda SA - dS + \gamma I + \theta S_A] + (\beta SI - \gamma I - \alpha I - dI) + (\lambda SA - dS_A - \theta S_A) + (\mu I - \phi A \;)$$

$$= \Lambda - \frac{\Lambda S^0}{S} - dS + \beta IS^0 + \lambda AS^0 + dS^0 - \frac{\gamma IS^0}{S} - \frac{\theta S_A S^0}{S} - \alpha I - dI + \mu I - \phi A$$

Since $S^0 = \frac{\Lambda}{d}$

$$= dS^0\left(2 - \frac{S^0}{S} - \frac{S}{S^0}\right) - \left(-\beta I - \lambda I + \frac{\gamma I}{S} + \frac{\theta S_A}{S}\right)S^0 - (\alpha + d - \mu)I - \phi A$$

$$\leq dS^0\left(2 - \frac{S^0}{S} - \frac{S}{S^0}\right) - (\alpha + d - \mu)I \tag{19}$$

By the relation between arithmetic and geometric means $2 - \frac{S^0}{S} - \frac{S}{S^0} < 0$. Therefore, $\dot{V} < 0$ if $\frac{\mu}{\alpha+d} \leq 1$.

Theorem 4: Endemic equilibrium E_1 is globally asymptotically stable if $\frac{\mu}{\alpha+d} \leq 1$ and $R_0 > 1$.

Proof: Consider the Lyapunov function, defined as;

$$V(S, I, S_A, A) = g\left(\frac{S}{S^1}\right) + g\left(\frac{I}{I^1}\right) + g\left(\frac{S_A}{{S_A}^1}\right) + g\left(\frac{A}{A^1}\right) \tag{20}$$

where $g(x) = x - 1 - lnx$, which is positive function, therefore $V \geq 0$. It suffices to show $\dot{V} < 0$.

$$\dot{V} = \left(1 - \frac{S^1}{S}\right)\dot{S} + \left(1 - \frac{I^1}{I}\right)\dot{I} + \left(1 - \frac{{S_A}^1}{S_A}\right)\dot{S_A} + \left(1 - \frac{A^1}{A}\right)\dot{A}$$

$$= \left(1 - \frac{S^1}{S}\right)[\Lambda - \beta SI - \lambda SA - dS + \gamma I + \theta S_A] + \left(1 - \frac{I^1}{I}\right)[\beta SI - \gamma I - \alpha I - dI] + \left(1 - \frac{{S_A}^1}{S_A}\right)[\lambda SA - dS_A - \theta S_A] + \left(1 - \frac{A^1}{A}\right)[\mu I - \phi A]$$

$$= \Lambda - dS - \frac{S^1}{S} + dS^1 - (-\beta SI - \lambda SA + \gamma I + \theta S_A)S^1 - (\lambda SA - dS_A - \theta S_A){S_A}^1$$

$$-(\mu I - \phi A)A^1 - \alpha I - dI - dS_A - \phi A + \mu I \tag{21}$$

This implies $\dot{V} < 0$ by the relationship between arithmetic and geometric means, if $\frac{\mu}{\alpha+d} \leq 1$, and if $S^1, I^1, {S_A}^1$ and A^1 are positive. We know $S^1 > 0$ and $I^1, {S_A}^1, A^1 > 0$ if $R_0 > 1$.

4 Numerical simulations

In this chapter we use data obtained for Nigeria to support the analytic result and to show the significance of awareness in controlling the disease spread. Consider Tab. 2 for the values of variables and the parameters and Tab. 3 for the COVID-19 related cases in Nigeria.

Table 2: Values of variables and parameters for the simulation

Variables/ Parameters	Values	References
N (0)	200×10^6	[Gilbert, Pullano, Pinotti et al. (2020)]
S (0)	199996855	Estimated
I (0)	3145	[NCDC (2020)]
A (0)	200	Estimated
S_A (0)	19999685.5	Estimated
Λ	400	[Misra, Sharma and Shukla (2011)]
β	0.0000157	[Tahir, Shah, Zamzn et al. (2019)]
λ	0.0002	[Misra, Sharma and Shukla (2011)]
Ɣ	0.16979	[NCDC (2020)]
α	0.03275	[NCDC (2020)]
d	0.0096	[NPC (2009)]
Ɵ	0.2	[Misra, Sharma and Shukla (2011)]
μ	0.0005	[Misra, Sharma and Shukla (2011)]
ϕ	0.06	[Misra, Sharma and Shukla (2011)]
R_0	3.0784	Calculated

Table 3: COVID-19 related cases in Nigeria

Population of Nigeria	1,959,000	[NPC (2009)]
No. of Active Cases	15682	[NCDC (2020)]
No. of Recovered Cases	5101	[NCDC (2020)]
Death Confirmed Cases	407	[NCDC (2020)]

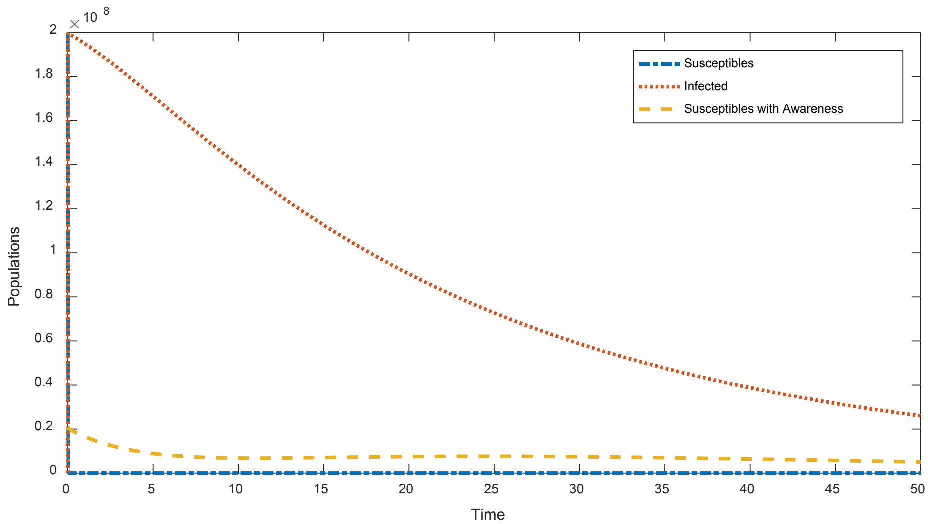

Figure 2: Dynamics of COVID-19 in Nigeria with $\mu = 0.0005$ and $\phi = 0.06$

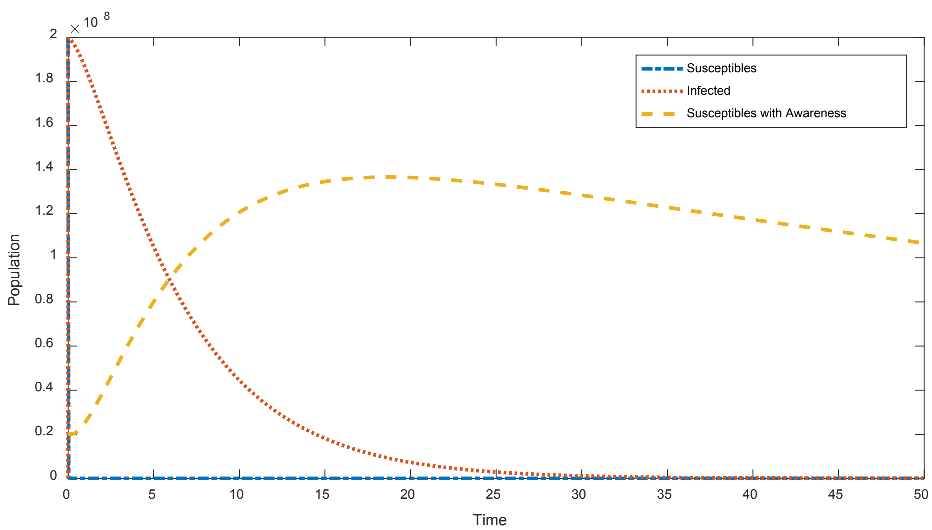

Figure 3: Dynamics of COVID-19 in Nigeria with $\mu = 0.06$ and $\phi = 0.0005$

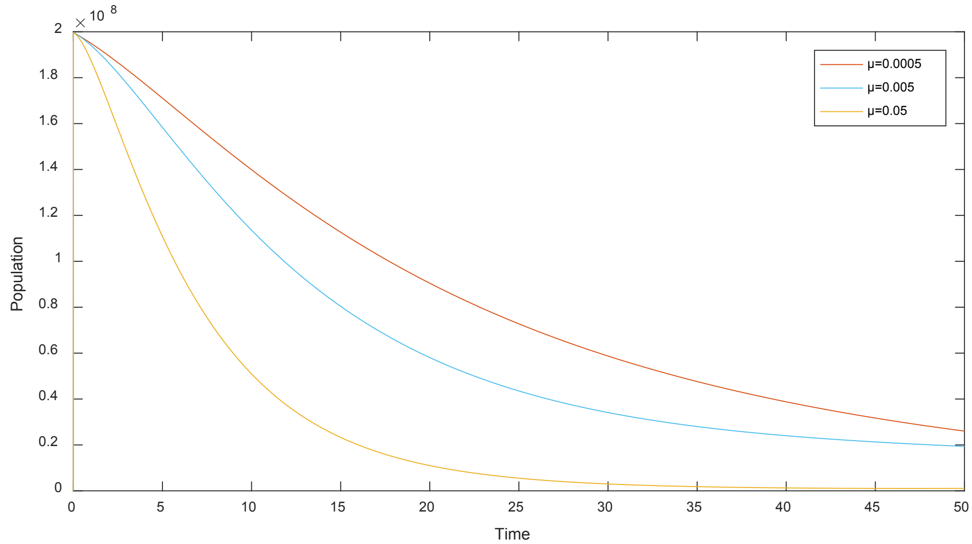

Figure 4: Variation of infected population with time for different values of μ

5 Discussion and conclusion

In this paper, a mathematical model consisting of a system of four nonlinear ordinary differential equations is constructed. Our aim is to study the dynamics of the spread of COVID-19 in Nigeria and to show the effectiveness of awareness and the need for relevant authorities to engage themselves more in enlightening people on the significance of the available control measures in curtailing the spread of the disease.

The model consists of four compartments; Susceptibles, Infectives, Susceptibles with Awareness and the cumulative density of the awareness programs. Two equilibrium solutions; Disease free equilibrium and Endemic equilibrium were calculated and their global stability analysis was carried out. Basic reproduction ratio (R_0) was also obtained, and we were able to show that the global stability of the endemic equilibrium depends on the magnitude of the basic reproduction ratio. If $R_0 > 1$, the endemic equilibrium is globally asymptotically stable, in this research $R_0 = 3.0784$.

Data obtained for Nigeria is used to conduct numerical simulations in order to support the analytic result and to show the significance of awareness in controlling the disease spread. In Fig. 2, it can be seen that if the rate of implementation of the awareness program is very small ($\mu = 0.0005$) compared to the rate of depletion of the program due to social problems and ineffectiveness ($\phi = 0.06$) the disease persist. In Fig. 3, it can be seen that if the rate of implementation of the awareness program is bigger ($\mu = 0.06$) compared to the rate of depletion of the program due to social problems and ineffectiveness ($\phi = 0.0005$) the disease dies out. In the first figure it can be seen that only a small portion from the population of the susceptible aware people is touched, while, in the second figure, the population of the susceptible aware people shoots up due to very effective awareness program. In Fig. 4, the significance of strengthening the awareness program is shown. It is clear that increasing the value of μ from $0.0005\ to\ 0.005\ to\ 0.05$ leads to significant decrease in the number of infective.

In conclusion, to mitigate the spread of COVID-19 in Nigeria there is need for serious awareness programs to enlighten people on the available control measure; social distancing, self-isolation, use of personal protective equipment (such as face mask, hand globes, overall gown, etc.), regular hand washing using soap or sanitizer, avoiding having contact with person showing the symptoms and reporting any suspected case.

Acknowledgment: We thank the reviewers for their valuable contributions.

Funding Statement: The author(s) received no specific funding for this study.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

References

Bogoch, I. I.; Watts, A.; Thomas-Bachili, A.; Huber, C.; Kraemer, M. U. G. et al. (2020): Pneumonia of unknown aetiology in Wuhan, China: potential for international spread via commercial air travel. *Journal of Travel Medicine*, vol. 27, no. 2.

Gilbert, M.; Pullano, G.; Pinotti, F.; Valdano, E.; Poletto, C. et al. (2020): Preparedness and vulnerability of African countries against importations of COVID-19: a modelling study. *The Lancet*, vol. 395, no. 10227, pp. 871-877.

Institute of Medicine (US) Forum on Microbial Threats (2007): Ethical and legal considerations in mitigating pandemic disease: workshop summary. Washington (DC): National Academies Press (USA). https://www.ncbi.nlm.nih.gov/books/NBK54163/.

Lai, S.; Bogoch, I.; Ruktanonchai, N.; Watts, A.; Lu, X. et al. (2020): Assessing spread of risk of Wuhan novel coronavirus within and beyond China, January-April 2020: a travel network-based modelling study. MedRxiv, 2020.02.04.20020479.

Ma, J. (2020): Estimating epidemic exponential growth rate and basic reproduction number. *Infectious Disease Modeling*, vol. 5, no. 1, pp. 129-141.

Marston, B. J.; Dokubo, E.; van-Steelandt, A.; Martel, L.; Williams, D. et al. (2017): Ebola response impact on public health programs, west Africa, 2014-2017. *Emerging Infectious Diseases*, vol. 23, no. 13. https://dx.doi.org/10.3201/eid2313.170727.

Misra, A. K; Sharma, A.; Shukla, J. B. (2011): Modelling and analysis of effect of awareness programs by media on the spread of infectious diseases. *Mathematical and Computer Modeling*, vol. 53, no. 5-6, pp. 1221-1228.

NCDC (2020): COVID-19 outbreak in Nigeria: situation report. https://ncdc.gov.ng/diseases/sitreps/?cat=14&name=An%20update%20of%20COVID-19%20outbreak%20in%20Nigeria.

NPC; ICF Macro (2009): *Nigeria: Demographic and Health Survey 2008-Key Findings.*

Nishiura, H.; Linton, N. M.; Akhmetzhanov, A. R. (2020): Serial interval of novel coronavirus (COVID-19) infections. *International Journal of Infectious Disease*, vol. 93, no. 1, pp. 284-286.

Nishura, H.; Kobayashi, T.; Yang, Y. Hayashi, K.; Miyama, T. et al. (2020): The rate of under ascertainment of novel coronavirus (2019-nCov) infection: estimation using Japanese passengers data on evacuation flights. *Journal of Clinical Medicine*, vol. 9, no. 2, pp. 419.

Poletto, C.; Gomes, M. F. C.; Pastore, Y.; Piontti, A.; Rossi, L. et al. (2014): Assessing the impact of travel restrictions on international spread of the 2014 West African Ebola epidemic. *Euro Surveillance*, vol. 19, no. 42.

Read, J. M.; Bridgen, J. R.; Cummings, D. A.; Ho, A.; Jewell, C. P. (2020): Novel coronavirus 2019-nCoV: early estimation of epidemiological parameters and epidemic predictions. MedRxiv, 2020 2020.2001.2023.20018549.

Riou, J.; Althaus, C. L. (2020): Pattern of early human-to-human transmission of Wuhan 2019-nCoV. BioRxiv, 2020 2020.2001.2023.917351.

Sambala, E. Z.; Kanyenda, T.; Iwu, C. J.; Iwu, C. D.; Jaca, A. et al. (2008): Pandemic influenza preparedness in the WHO African region: are we ready yet? *BMC Infectious Diseases*, vol. 18, no. 567.

Sands, P.; Mundaca-Shah, C.; Dzau, V. J. (2016): The neglected dimension of global security-a framework for countering infectious-disease crises. *The New England Journal of Medicine*, vol. 374, no. 1, pp. 1281-1287.

Shen, M.; Peng, Z.; Xiao, Y.; Zhang, L. (2020): Modelling the epidemic trend of the 2019 novel coronavirus outbreak in China. BioRxiv, 2020;2020 2001.2023.916726.

Tahir, M.; Shah, S. I. A.; Zamzn, G.; Khan, T. (2019): Stability behavior of mathematical model of MERS Corona virus spread in population. *Filomat*, vol. 33, no. 12, pp. 3947-3960.

Unah, L. (2020): 'Nigeria will deal with this': high alert after coronavirus case. https://www.aljazeera.com/news/2020/03/deal-highalert-coronavirus-case.

WHO (2020a): Coronavirus disease (COVID-19) pandemic. https://www. who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports/.

WHO (2020b): Director-general's remarks at the media briefing on COVID-19-11 March 2020. https://www. who.int/dg/speeches/detail/who-directorgeneral-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020.

WHO (2020c): Coronavirus disease (COVID-19) situation reports. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports/.

Wu, J. T.; Leung, K.; Leung, G. M. (2020): Nowcasting and forecasting the potential domestic and international spread of the 2019-nCoV outbreak originating in Wuhan, China: a modelling study. *Lancet*, vol. 2020, no. 395, pp. 689-697.

Wu, P.; Hao, X.; Lau, E. H.; Wong, J. Y; Leung, K. S. M. et al. (2020): Real-time tentative assessment of the epidemiological characteristics of novel corona virus infections in Wuhan, China as at 22 January 2020. *Euro Surveillance*, vol. 25, no. 3.

Zhao, S.; Lin, Q.; Ran, J.; Musa, S. S.; Yan, G. et al. (2020): Preliminary estimation of the basic reproduction number of novel coronavirus (2019-nCoV) in China, from 2019 to 2020: a data driven analysis in the early phase of the outbreak. *International Journal of Infectious Disease*, vol. 92, no. 2, pp. 214-217.

Zhao, S.; Zhuang, Z.; Cao, P.; Ran, J.; Gao, D. et al. (2020): Quantifying the association between domestic travel and the exportation of novel coronavirus (2019-nCov) cases from Wuhan, China in 2020: a correlation analysis. *Journal of Travel Medicine*, vol. 27, no. 2.

Zhao, S.; Zhuang, Z.; Ran, J.; Lin, J.; Yang, G. et al. (2020): The association between domestic train transportation and novel coronavirus (2019-nCov) outbreak in China from 2019 to 2020: a data driven correlation report. *Travel Medicine Infectious Diseases*, vol. 33, no. 1, 101568.