Modeling the Effect of Education Based Intervention in the Control of Cholera

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Abstract: **In this work, mathematical epidemiological model for the transmission dynamics of Cholera with control strategies is presented and analyzed. The model formulated is designed into compartments which lead to a system of differential equations for the transmission dynamics of Cholera with control measures of water treatment, sanitation and education based intervention being proposed. It was assumed that in the model, Cholera is contracted when an individual comes into contact with and ingestion of contaminated water, food and unhygienic environment. The stabilities of the model are investigated at several instances. The results showed that the disease free equilibrium is locally asymptotically stable under assumed conditions on the parameters given in the model. It was then concluded from the results that treatment of water, with good sanitation and well based education are effective methods of controlling and eradicating Cholera when kept consistent.**

Keywords**: cholera, equilibrium, control strategies, stability.**
MSC 2010:

I. INTRODUCTION

Cholera is one of the most devastating infectious diseases in the world, infecting millions of people annually and is a major cause of mortality. It is an infectious disease that is a major concern in countries with inadequate access to clean water, proper sanitation and good health facilities. Cholera is an acute bacterial infection caused by Vibro-cholerae, non-invasive bacterium called Vibro or the "Comma bacillus "which lives in the small intestine [I]. It was discovered by Robert Knoch in 1883 during a Cholera outbreak in Egypt, which can be transmitted directly from human to human through unhygienic contact with Cholera patient's faece, vomit or corpse and indirectly from environment to human through ingestion of Vibro cholera bacteria from contaminated water and food [2, 12, 13]. The bacteria can brew in someone's system for up to twelve days before the person develops diarrhea, which can lead to dangerous dehydration. Most degeneration occur on the first day of illness and if not properly and immediately managed can lead to death [3].

Cholera has been a persistent epidemic and continues to be a global world health issue. Despite the studies on this disease for over one hundred years, it is estimated that approximately 120,000 people die from Cholera annually [4, 5, 6] and the dynamics of the disease indicate that it is intimately linked to serious inadequate access to clean water, improper treatment of human wastes and lack of access to essential health services.

Most cases of Cholera currently occur in developing countries. Currently, Cholera is endemic in India and Bangladesh near the Bay of Bengal as well as in coastal regions of South America [7]. Cases in these regions tend to have seasonal circles, generally associated with fluctuations in water temperature, zooplankton levels and monsoon cycles [8]. These epidemics tend to coincide with dry weather and higher water temperatures while cases are reduced in winter. In 2005, Nigeria had 4,477 cases and 174 deaths. There were reported cases of Cholera in 2008 in Nigeria in which there were 429 death cases out of 6,330 cases. 2,304 cases were reported in Niger State in which 114 were death cases [6]. Also in 2009, Nigeria reported 13,691 cases and 431 deaths [5, 7, 14]. Preventative measures include vaccination, drinking of clean water, and washing hands well- all of which is assumed that people have easy access to these resources but since most existing models exclude the use of education based intervention in passing down the aforementioned strategies in fighting against the propagation of infectious diseases, this work is aimed to better understand the effects of this measure so as to gain useful guidelines to the effective prevention and intervention strategies against Cholera epidemics.

II. MODEL FORMULATION

In this study, we consider the SIRP epidemiological model for Cholera transmission by making reasonable improvement on the work of Fatima and Isthrinayagy [8] with the incorporation of human treatment, water hygiene, environmental sanitation and education based intervention which is assumed to be the control strategies. Consequently, we introduce another compartment into the model: the concentration of Vibrio-cholera in water at time (t) denoted by $C_V(t)$. Let $S_H(t)$, $I_H(t)$, $R_H(t)$ and $P_H(t)$ represent the susceptible, the infected, recovered and the protected human populations respectively. The total human $N_H(t) = S_H + I_H + R_H + P_H$ is closed, which is a reasonable assumption for a relatively short period of time and for low mortality diseases like Cholera.

The Susceptible population is generated either through birth or through immigration at rate Λ_H.They acquire infection and move to infected class at the rate:

$$\alpha = \frac{q_1 C_V}{C_V + K} + q_2 I_H \quad (1)$$

Where $q_1 and\ q_2$ = rates of ingesting Vibro-cholera from the contaminated water and through human to human interaction respectively.

C_v =Concentration of Vibro-cholera in contaminated water.

K = Concentration of Vibro-cholera in water that yields 50% chance of getting it.

I_H = Total number of infected individuals.

The number of infected individuals decreases through natural recovery from the disease at the rate of β_H and Z_H is the recovery due to the use of treatments. μ_H is natural death of an individual andd_H is the death rate induced by the disease. ρ_H Is the loss rate of immunity by the recovered individuals, ε is the rate of contribution of each infected person to the population of Vibro-cholera in the aquatic environment. ω is the net death rate of Vibro-cholera gotten by ω = m – n, where m is the Vibro-cholera growth rate and n is the Vibro-cholera loss rate.

Variables

S_H = Total number of susceptible individuals.

I_H = Total number of infected individuals.

R_H =Total number of recovered individuals.

P_H = The human population called the protected population.

N_H =Total population of humans.

C_V= Concentration of Vibro-cholera in contaminated water.

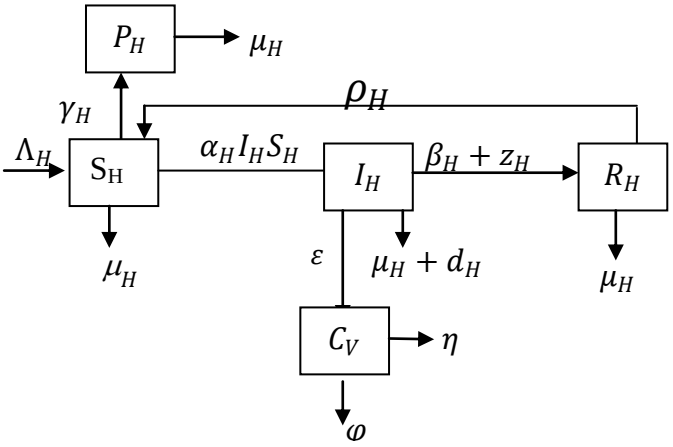
Parameters	
Symbols	Definitions
Λ_H	Per capital birth rate of humans.
μ_H	Per capital natural death rate of humans.
d_H	Cholera induced death rate.
α_H	Rate of exposure to contaminated water.
ρ_H	Loss rate of immunity by recovered individuals.
β_H	Natural recovery rate.
ε	Rate of contribution of each infected person to the population of Vibro-cholera in the aquatic environment.
z_H	Recovery due to the use of antibiotics in the aquatic environment.
M	Vibro-cholera growth rate.
N	Vibro- cholera loss rate.
φ	Net death rate of Vibro-cholera ie m-n.
γ_H	ate of exposure to education and its compliance.
η	death of Vibro-cholera as a result of water treatment.
K	Concentration of Vibro-cholera in water that yield 50% chance of getting it.
$q_1$andq_2.	Rates of ingesting Vibro-cholera from the contaminated water.

2.1 The Compartmental Diagram

The model assumptions are as follows:

a. Susceptible individuals acquire Cholera at a constant rate.
b. The death in the Infectious class is not only due to the infection but also natural.
c. Water treatment leads to the death of the Vibro-cholera.
d. All parameters are considered non- negative.

The following diagram illustrates the compartmental flow diagram.



From the analysis and assumptions the following system is obtained:

$$\frac{dS_H}{dt} = \Lambda_H + \rho_H R_H - (\mu_H + \gamma_H) S_H - \frac{q_1 C_V}{C_V + K} S_H - q_2 I_H S_H \quad (2)$$

$$\frac{dI_H}{dt} = \frac{q_1 C_V}{C_V + K} S_H + q_2 I_H S_H - (\mu_H + d_H + \beta_H + z_H + \varepsilon) I_H \quad (3)$$

$$\frac{dR_H}{dt} = \beta_H R_H + z_H R_H - \mu_H R_H - \rho_H R_H \quad (4)$$

$$\frac{dP_H}{dt} = \gamma_H S_H - \mu_H P_H \quad (5)$$

$$\frac{dC_V}{dt} = \varepsilon I_H - (\varphi + \eta) C_V \quad (6)$$

Invariant Region: All state variables remain non-negative all the time such that

$$S_H(0) \geq 0, I_H(0) \geq 0, R_H(0) \geq 0, P_H(0) \geq 0, C_V \geq 0. \text{and} q_1 > q_2 \quad (7)$$

2.2 Existence of solution

The following theorem validates the existence of solution of the above models

Theorem 2.1 Derrick and Groosman [10].

Given IV $Px' = f(t, x),\ x(t_0) = x_0$ (8)

Let **D** denotes region $|t - t_0| \leq a, \|x - x_0\| \leq b, x = (x_1, x_2, \ldots, x_n)$ and suppose that $f(t, x)$ satisfies the Lipchitz condition

$$\|f(t,x_1) - f(t,x_2)\| \leq k\|x_1 \quad (9)$$

Whenever the pairs $(t,x_1)$and(t,x_2) belong to**D**, wherek is a positive constant. Then, there is a constant $\delta > 0$ such that there exists a unique continuous vector solution x(t) of the system in the interval $|t - t_0| \leq \delta$. T he condition (9) is satisfied by the requirement that $\frac{\partial f_i}{\partial x_j}, i.j = 1,2,\dots,n$ be continu0ous and bounded in D.

Theorem 2.2 (Uniqueness of solution) [9, 15, 16]

Let **D** denotes the region defined by $1 \leq \varepsilon \leq R$ such that$0 < R < \infty$,hold, then the solution of (2)-(6) is unique and bounded in the region**D**.

Proof

Let

$$f_1 = \Lambda_H + \rho_H R_H - (\mu_H + \gamma_H)S_H - \frac{q_1 C_V}{C_V + K} S_H - q_2 I_H S_H. \quad (10)$$

$$f_2 = \frac{q_1 C_V}{C_V + K} S_H + q_2 I_H S_H - (\mu_H + d_H + \beta_H + Z_H + \varepsilon)I_H. \quad (11)$$

$$f_3 = \beta_H R_H + Z_H R_H - \mu_H R_H - \rho_H R_H. \quad (12)$$

$$f_4 = \gamma_H S_H - \mu_H P_H \quad (13)$$

$$f_5 = \varepsilon I_H - (\varphi + \eta)C_V \quad (14)$$

It suffices to show that $\frac{\partial f_i}{\partial x_j}, i, j = 1,2,\dots.5$ are continuous.

Consider the partial derivatives:

Forf_1;

$$|\partial f_1/\partial S_H| = |-(\mu_H + \gamma_H)|.$$

$$|\partial f_1/\partial I_H| = 0 < \infty = |\partial f_1/\partial R_H| = |\partial f_1/\partial P_H| = |\partial f_1/\partial C_V|.$$

Similarly;

$$|\partial f_2/\partial I_H| = |-(\mu_H + d_H + \beta_H + Z_H + \varepsilon)|.$$

$$|\partial f_2/\partial S_H| = 0 < \infty = |\partial f_2/\partial R_H| = |\partial f_2/\partial P_H| = |\partial f_2/\partial C_V|.$$

Similarly;

$$|\partial f_3/\partial R_H| = |\beta_H + Z_H - \mu_H - \rho_H|.$$

$$|\partial f_3/\partial S_H| = 0 < \infty = |\partial f_3/\partial I_H| = |\partial f_3/\partial P_H| = |\partial f_3/\partial C_V|.$$

Similarly;

$$|\partial f_4/\partial P_H| = |-\mu_H|.$$

$$|\partial f_4/\partial S_H| = 0 < \infty = |\partial f_4/\partial I_H| = |\partial f_4/\partial R_H| = |\partial f_4/\partial C_V|.$$

Finally;$|\partial f_5/\partial C_V| = |-\varphi|$.

$$|\partial f_5/\partial S_H| = 0 < \infty = |\partial f_5/\partial I_H| = |\partial f_5/\partial R_H| = |\partial f_5/\partial P_H|.$$

It is clearly seen that the partial derivatives are continuous and bounded, implying that the solutions for (2)-(6) exists and are unique in the region D. Thus, the proof is complete.

2.3 Equilibrium state of the model

To show the disease-free equilibrium for the system (2)-(6), here, setting$\frac{N_H}{dt} = 0$, implying

$$\frac{dS_H}{dt} = \frac{dI_H}{dt} = \frac{dR_H}{dt} = \frac{dP_H}{dt} = \frac{dC_V}{dt} = 0$$

For disease-free state,

$$I_H = R_H = C_V = 0.$$

So that (2)-(6) has a disease free equilibrium state of the form:

$$E_0 = (S_H, I_H, R_H, P_H, C_V) = \left(\frac{\Lambda_H}{\mu_H + \gamma_H}, 0, 0, \frac{\gamma_H \Lambda_H}{\mu_H(\mu_H + \gamma_H)}, 0\right) \quad (15)$$

2.4 Estimation of the Basic Reproduction Number

The basic reproduction number denoted by $R_0$is an important parameter used to study the behavior of epidemiological model,this is defined as the expected number of secondary cases produced in a completely susceptible population, by a typical infective individual. This is a threshold that determines whether or not; an infection will spread through a given population.

$$n = 1, m = 3 \text{ so that } x = (I_H), Y = (S_H + R_H + P_H)$$

Where

$$X = \{x_1, x_2, \dots, x_n\} \text{ represents n} - \text{infected host compartments.}$$

$$Y = \{y_1, y_2, \dots, y_n\} \text{ represent m} - \text{other host compartments.}$$

$$\frac{dx_i}{dt} = F_i(x,y) - V_i(x,y),\ i = 1,\dots,n,\ \frac{dy_j}{dt} = G_j(x,y),\ j = 1,\dots,m$$

F_i = rate at which new infected enter compartment i.

V_i= rate at which transfer of individuals out of and into ith compartments.

$$\frac{dx}{dt} = F(x) - V(x)$$

$$F_i = \left(\frac{q_1 C_V}{C_V + K} + q_2 I_H\right)S_H;\ V_i = (\mu_H + d_H + \beta_H + Z_H + \varepsilon)I_H$$

$$G_1 = \Lambda_H - \rho_H R_H - \left(\mu_H + \gamma_H + \frac{q_1 C_V}{C_V + K} + q_2 I_H\right)S_H$$

$$G_2 = (\beta_H + Z_H)R_H - (\mu_H + \rho_H)R_H$$

$$G_3 = \gamma_H S_H - \mu_H P_H$$

$$F = \begin{pmatrix} q_2 S_H & \frac{q_1 K S_H}{(C_V + K)^2} \\ 0 & 0 \end{pmatrix} (16)$$

$$V = \begin{pmatrix} \mu_H + d_H + \beta_H + Z_H + \varepsilon & 0 \\ \varepsilon & (\varphi + \eta) \end{pmatrix} \quad (17)$$

$$R_0 = FV^{-1}$$

$$= \begin{pmatrix} q_2 S_H & \frac{q_1 K S_H}{(C_V + K)^2} \\ 0 & 0 \end{pmatrix} \begin{pmatrix} \frac{1}{\mu_H + d_H + \beta_H + Z_H + \varepsilon} & 0 \\ \frac{\varepsilon}{(\mu_H + d_H + \beta_H + Z_H + \varepsilon)} & \frac{1}{(\varphi - \eta)} \end{pmatrix}$$

The reproduction number with control measure is given *as*:

$$R_0 = \frac{q_1 k S_H}{(C_V + k)^2 (\varphi + \eta)} \qquad (18)$$

if $R_0 < 1$ ⇒Asymptotically stable, $R_0 > 1$ ⇒ unstable.

III. LOCAL STABILITY OF THE DISEASE-FREE EQUILIBRIUM (DFE)

In what follows, the local stability of the DFE is established

Theorem 3.1[15, 16, 17]

The disease free-equilibrium of (2)-(6) is locally asymptotically stable if $R_0 < 1$ and unstable otherwise.

Proof

The variational (Jacobian matrix) of the system formed by (2)-(6) at $E_0 = \left(\frac{\Lambda_H}{\mu_H + \gamma_H}, 0, 0, \frac{\gamma_H \Lambda_H}{\mu_H (\mu_H + \gamma_H)}, 0\right)$ is given by:

$$\frac{\partial f_1}{\partial S_H} = -(\mu_H + \gamma_H), \quad \frac{\partial f_1}{\partial I_H} = -q_2 S_H, \quad \frac{\partial f_1}{\partial R_H} = \rho_H, \frac{\partial f_1}{\partial C_V} = \frac{q_1 K S_H}{(C_V + K)^2}$$

$$\frac{\partial f_2}{\partial S_H} = \left(\frac{q_1 C_V}{C_V + K} + q_2 I_H\right), \quad \frac{\partial f_2}{\partial I_H} = q_2 S_H - (\mu_H + d_H + \beta_H + Z_H + \varepsilon),$$

$$\frac{\partial f_2}{\partial C_V} = \frac{q_1 K S_H}{(C_V + K)^2}, \quad \frac{\partial f_3}{\partial R_H} = \beta_H + Z_H - \mu_H - \rho_H$$

$$\frac{\partial f_4}{\partial S_H} = \gamma_H, \quad \frac{\partial f_4}{\partial P_H} = -\mu_H$$

$$\frac{\partial f_5}{\partial I_H} = \varepsilon, \quad \frac{\partial f_5}{\partial C_V} = -(\varphi + \eta)$$

At disease free state E_0:

$$\begin{pmatrix} -(\mu_H + \gamma_H) & \frac{-q_2 \Lambda_H}{\mu_H + \gamma_H} & \rho_H & 0 & 0 \\ 0 & \frac{q_2 \Lambda_H}{\mu_H + \gamma_H} - (\mu_H + d_H + \beta_H + z_H + \varepsilon) & 0 & 0 & 0 \\ 0 & 0 & \beta_H + z_H - \mu_H - \rho_H & 0 & 0 \\ \mu_H & 0 & 0 & -\mu_H & 0 \\ 0 & \varepsilon & 0 & 0 & -(\varphi + \eta) \end{pmatrix}$$

The characteristic equation using $|A - 1\lambda|$, we obtain

$$-(\mu_H + \gamma_H + \lambda) \begin{vmatrix} \frac{q_2 \Lambda_H}{\mu_H + \gamma_H} - (\mu_H + d_H + \beta_H + z_H + \varepsilon + \lambda) & 0 & 0 & 0 \\ 0 & \beta_H + z_H - \mu_H - \rho_H - \lambda & 0 & 0 \\ 0 & 0 & -(\mu_H + \lambda) & 0 \\ \varepsilon & 0 & 0 & -(\varphi + \eta + \lambda) \end{vmatrix} = 0$$

From which the following eigenvalues are obtained $\lambda_1 = -(\mu_H + \gamma_H)$, $\lambda_2 = -\mu_H$, $\lambda_3 = (\varphi + \eta)$, $\lambda_4 = \beta_H + Z_H - \mu_H - \rho_H$

So that

$$\left(\frac{q_2 \Lambda_H}{\mu_H + \gamma_H} - (\mu_H + d_H + \beta_H + Z_H + \varepsilon)\right) < 0 \qquad (19)$$

so that

Dividing both side of (19) by $(\mu_H + d_H + \beta_H + Z_H + \varepsilon)$ we obtain

$$\frac{q_2 \Lambda_H}{(\mu_H + \gamma_H)(\mu_H + d_H + \beta_H + Z_H + \varepsilon)} < 1 \qquad (20)$$

Biologically, by *Theorem 3.1*, cholera can be removed from the community (when $R_0 < 1$) if the initial mass of the population of the model are in the basin of attraction of E_0. To ensure that elimination of cholera is independent of the initial sizes of the populations. It is necessary to show that the disease-free equilibrium is globally asymptotically stable.

IV. CONDITIONS FOR GLOBAL STABILITY OF THE DISEASE FREE-EQUILIBRIUM.

In this section, conditions that if met, guarantee the global asymptotic stability of the disease free state are listed. Set the model equation in the form:

$$\frac{dx}{dt} = \mathrm{F(X,Z)}(21)$$

$$\frac{\mathrm{dz}}{\mathrm{dt}} = \mathrm{G(X,Z)},\ \ \mathrm{G(X,0)} = 0.$$

Where $\mathrm{X} \in \mathrm{R}^{\mathrm{m}}$ denotes the number of uninfected individuals and $\mathrm{Z} \in \mathrm{R}^{\mathrm{n}}$ denotes the number of /infected individuals including the latent, infectious etc.$\mathrm{U}_0 = (\mathrm{x}^*, 0)$ denotes the disease free equilibrium of this system.

The conditions (H1) and (H2) below must be met to guarantee local asymptotic stability.

(H1)$\frac{\mathrm{dx}}{\mathrm{dt}} = \mathrm{F(X,0)}$, x^* is globally asymptotically stable.

(H2)$\mathrm{G(X,Z)} = \mathrm{AZ} - \hat{\mathrm{G}}\mathrm{(X,Z)},\quad \hat{\mathrm{G}}\mathrm{(X,Z)} \geq 0$ for$(\mathrm{X,Z}) \in \Omega$.

Where $\mathrm{A} = \frac{\partial \mathrm{G}}{\partial \mathrm{Z}}(\mathrm{X}^*, 0)$ is an M-matrix (the off diagonal elements of Aare nonnegative) and Ω is the region where the model makes biological sense.

Then the disease free-disease equilibrium $\mathrm{x}_0 = (\mathrm{X}^*, 0)$ is globally asymptotically stable provided that $\mathrm{R}_0 < 1$.

Let

$$\mathrm{X} = (\mathrm{S_H}, \mathrm{R_H}, \mathrm{P_H}),\ \ \mathrm{Z} = (\mathrm{I_H}, \mathrm{C_V})^{\mathrm{T}}$$

$$\mathrm{F(X,0)} = \begin{pmatrix} \Lambda_{\mathrm{H}} - (\mu_{\mathrm{H}} + \gamma_{\mathrm{H}})\mathrm{S_H} \\ R_H(\beta_H + Z_H) - R_H(\mu_H + \rho_H) \\ \gamma_{\mathrm{H}} S_H - \mu_H P_H \end{pmatrix}$$

Checking out for linearity of$\mathrm{F(X,0)}$, we obtain:

$$\mathrm{S_H(t)} = \mathrm{e}^{-\int_0^t(\mu_H+\gamma_H)\mathrm{dt}}(\mathrm{S_H(0)} + \int_0^s \Lambda_{\mathrm{H}}\mathrm{e}^{\int_0^t(\mu_H+\gamma_H)\mathrm{dt}}\mathrm{ds}), \mathrm{R_H}$$

$$= \mathrm{R_H(0)e}^{\int_0^t((\beta_H+Z_H)-(\mu_H+\rho_H))\mathrm{dt}}$$

$$P_H(t) = e^{\int_0^t \mu_H dt}(P_H(0) + \int_0^s \gamma_H S_H\, e^{\int_0^t \mu_H dt}\, ds).$$

Next we show that condition (H2) is less than or equal to zero as follows:

$$\mathrm{G(X,Z)}$$

$$= \begin{pmatrix} \frac{\mathrm{q_1 C_V}}{\mathrm{C_V + K}}\mathrm{S_H} + \mathrm{q_2 I_H S_H} - (\mu_{\mathrm{H}} + \mathrm{d_H} + \beta_{\mathrm{H}} + \mathrm{z_H} + \varepsilon)\mathrm{I_H} \\ \varepsilon \mathrm{I_H} - (\varphi + \eta)\mathrm{C_V} \end{pmatrix}$$

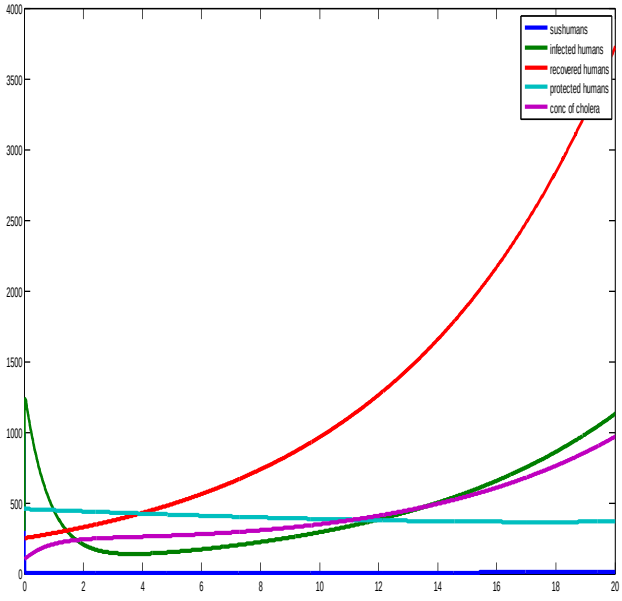
$$\mathrm{AZ} = \begin{pmatrix} \mathrm{q_2 S_H} - (\mu_{\mathrm{H}} + \mathrm{d_H} + \beta_{\mathrm{H}} + \mathrm{z_H} + \varepsilon) & \frac{\mathrm{q_1 K S_H}}{(\mathrm{C_V + K})^2} \\ \varepsilon & -(\varphi + \eta) \end{pmatrix} \begin{pmatrix} I_H \\ C_V \end{pmatrix}$$

$$\hat{\mathrm{G}} = \begin{pmatrix} \frac{\mathrm{K}}{(\mathrm{C_V + K})^2} \\ 0 \end{pmatrix}$$

Here, $K > 0$. Clearly, $\frac{\mathrm{K}}{(\mathrm{C_V+K})^2} > 0$, so that $\hat{\mathrm{G}} \geq 0$, thus satisfying H2. It is also clear that x^* is a g.a.s equilibrium if $\frac{dx}{dt} = F(x,0)$. Hence, by the above theorem U_0 is g.a.s.

Table 2: Parameter, Description, Value and Reference.

Parameter	Description	Value	Reference
Λ_H	Per capital birth rate of humans.	0.500(day^{-1})	14
μ_H	Per capital natural death rate of humans	0.021(day^{-1})	14
d_H	Cholera induced death rate	0.480(day^{-1})	10
α_H	Rate of exposure to contaminated water	0.500	11
ρ_H	Immunity waning rate	0.414(day^{-1})	11
z_H	Rate of recovery of individuals due to treatment	0.550(day^{-1})	11
β_H	Natural recovery rate	0.020(day^{-1})	13
H	Death rate of vibro cholera due to water treatment.	0.020	13
E	Rate of contribution of each infected person	0.150	13
Φ	Netdeathrate of Vibro cholera	0.033	10
γ_H	Rate of exposure to education and its compliance	0.800	Estimated
q_1 and q_2	Rates of ingestion of Vibro cholera	0.017(day^{-1})	14
H	Death of Vibro cholera due to water treatment	0.250	Estimated
d_H	Disease induced death rate.	0.048 (day^{-1})	14
$S_H(0)$	Susceptible individuals in the population	1000	Estimated
$I_H(0)$	Infected individuals in the population	100	Estimated
N_H	Total human population	1100	Estimated
C_V	Concentration of Vibro cholera in water	0.002	13
K	Half saturation of Vibro cholera in water	100	10



The graph of education based intervention on a population prone to cholera at time t.

V. RESULT AND DISCUSSION

Numerical results of this model are in a graph form. Using parameter values stated in table 2, matlab software(ode45) was used to run the test and the graph below which shows that proper enlightenment on personal hygiene, environmental sanitation and water treatment on the population prone with cholera disease will reduce the spread of the infection thereby bringing the population to a healthy state.

We noticed from the graph that when the population is exposed and well educated on the do's and don'ts to imbibe, the recovery rate of the infected humans grows exponentially leading to a drastic reduction on the number of people infected with the disease and on the concentration of the vibro- cholera bacteria in the environment. With this, the protected humans who are knowledgeable are not dragged into the struggle of living right since the understand it's effect. Consistency on this practice eventually leads to gradual dying out of the disease, bringing the population to a healthy state.

VI. CONCLUSION

In this research work, we modeled education base intervention as an added control measure alongside with water treatment and environmental sanitation in the dynamics of Cholera in humans, there exists a disease free-equilibrium state $E_0 = (S_H, I_H, R_H, P_H, C_V) = \left(\frac{\Lambda_H}{\mu_H+\gamma_H}, 0,0, \frac{\gamma_H \Lambda_H}{\mu_H(\mu_H+\gamma_H)}, 0\right)$. From the findings, the equilibrium point is stable when $R_0 < 1$, and unstable when $R_0 > 1$. Showing that the control recommended will help to eradicate the emergence of new infectious disease.

This research work extends the model of Fatima and Isthrinayagy Krishnarajah, 2014)by bringing in the education based intervention measure. We proved the existence of the model and it having a unique solution. Using the next generation matrix method, we determined the basic reproduction number R_0. We showed that the disease free equilibrium is locally asymptotically stable when $R_0 < 1$ causing the disease to disappear. Numerically we proved that educating the people should not be a program that should be done skeletally but with intense responsibility so as to achieve effectiveness in curbing cholera from any population under the invasion.

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