Abstract- examining how a rumor spreads has been challenging, previous studies on social and psychological aspects of rumors have mainly been theory-driven and have relied on a small amount of manually collected anecdotal evidence. In this paper, a non-linear mathematical model for rumor spreading: vulnerability and its psychological effect has been proposed/developed and analyzed by using epidemiological approach, in which an ignorant individuals are refers to recruitment class and has a certain probability of becoming a spreader or stipler immediately upon hearing the rumor, and The whole population was assumed to be a constant and homogeneously mixed. The basic reproduction number $R_0$ is found. Equilibria have been analytically obtained and their local and global stability have been discussed. Conditions for the persistence of stipler have been determined. We mainly explore the mechanism of psychological effect in study of salt and water Ebola virus cure rumor of August 2014 in Nigeria. Finally, the obtained results are numerically validated and then discussed from both the mathematical and the sociological perspectives, and presented in the form of the graphics using Homotopy perturbation method.

Keywords- Epidemic approach, Equilibria, Mathematical model, Psychological effect, Rumor spreading, Reproduction number and stability.

I. INTRODUCTION

Rumors are an inevitable social phenomenon. According to Warren Peterson, Noel and Gist, a rumor is “an unverified account or explanation of events circulating from person to person and pertaining to an object, event, or issue in public concern” [1]. From this point of view, a rumor is a certain form of communication, transferring information amongst society. However, the content and purpose of a rumor cannot be verified, while this character discriminates rumors from illusive propaganda, as well as gossip and slander, which have certain purposes and targets [2]. This definition clarifies the connotations and boundaries of rumors; however, it does not give any clue about how rumors spread. “Traditionally, rumors are propagated by word of mouth. Nowadays, with the emergence of the Internet, rumors spread by instant messengers, emails or publishing bloggings and social media that provide a faster speed of transmission”[2]. Once a rumor spreads, the truth is at risk of being distorted in the public sphere.

Some modelling studies have been conducted regarding the rumor spreading and Daley and kendall are among the earliest researchers to propose a rumor spread model that has some properties in common with epidemic model [3]. Also Cane [4] showed that deterministic forms of models for the spread of an epidemic and of a rumor are similar. Recently, Thompson et al. [5] explored the dynamics of rumor spreading in chat rooms. Bettencourt et al. [6] applied models similar to epidemiology to the spread of ideas. Kawachi [7] proposed deterministic models for rumor transmission with constant and variable rumor in an age-independent. Kawachi et al. [8] explored the effects of various contact interactions in a rumor transmission model. Piqueira [9] examined an equilibrium study of a rumor spreading model according to propagation parameters and initial conditions. Huang [10] studied the rumor spreading process with denial and skepticism. Wang and Wood [11] adopted an epidemiological approach to model viral meme propagation. Meme, as defined in their paper, is any cultural entity that appears to exhibit self-replication. Huo et al. [12] analyzed the dynamics of a rumor transmission model with incubation. Zaho et al. [13] proposed a mathematical model for exploring the interplay of authorities, information, rumor dissemination and the evolution of emergency, aiming to give more insights on effective strategies for rumor management. The symbolic achievement of psychological research on rumor was done by Allport and Postman [14] as there was some formative research in the following. Homans [15] points to a variety of theories concerning interpersonal relationships that are relevant to the sociability of people exposed to rumor. Rosnow [16] posits the idea that there are three stages to the phenomenon of rumor transmission: parturition, diffusion, and control. Pendleton [17] revisited previous research on rumor

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and make suggestions as to how the focus of rumor research needs to be expanded. According to Homans, when two people communicate with each other, collective result is rewarding to both. By sharing a rumor with another person, the rumor disseminator may be attempting one-upmanship, looking for social approval for exchanging such important information and/or expecting the recipient to reciprocate at a later time. At the initial stage, most people do not have much information about emergency event, and spreadsers could gain much satisfaction from telling the rumors; it was a major motive power for the spreading of news. The more people knew the rumor, the lower spreaders’ grades and levels of personal contentment are. Rumors expired because people grow weary of an issue and stop talking or thinking about it. Problem solving rumors should dissipate when interests are drawn toward other news events or if attention turns from a problem out of boredom or frustration. Rumors should also terminate if the underlying tensions are played out. The recent outbreak of the rumors propagated for salt and water Ebola virus cure rumor of August 2014 in Nigeria. Had such psychological effects on the general public, and the significant of studying the dynamics of rumors spreading and ideas lies in understanding a way to change perception, to persuade others, to generate predictions regarding product adoption, to predict what the public may find interesting in the future, and to influence decision making and public opinion.

In the present study, we assume that individuals of ignorant class are susceptible to both the rumor spreading class, like in epidemics, where two infective classes and one susceptible class have been considered [18].

Keeping above in view, in this paper, we study a qualitative behavior of a model of a constant rumor spreading in a population with constant immigration and emigration. We studied the limit system of the model by reducing the model to a system of two ordinary differential equations, and investigate qualitative study of the mathematical model, the stability of the rumor-free equilibrium and the rumor-endemic equilibrium. In study of salt and water Ebola virus cure rumor of August 2014 in Nigeria.

II. MATHEMATICAL MODEL

Let N be the total population, which is assumed to be a constant and homogeneously mixed. This total population has been divided into three classes: (i) Ignorant class (I), (ii) Spreader class (S), and (iii) Stifler class (Q) which represent , those not aware of the rumor, those know the rumor and spread it actively and those knows the rumor and do not spread it respectively. Due to the assumption of a constant population size we assume that per capita exit rate is equal to the per capita entering rate into the rumor spreading system. Hence we assume that individuals enter into the Ignorant class automatically with the rate, where \( \mu \) is the rate at which individuals enter or leave the rumor spreading system. Due to the inactiveness and death, individuals exit from the rumor spreading system from each class with the rates \( \mu_I, \mu_S \) and \( \mu_Q \) respectively. In the modeling process, it is considered that the individuals of Ignorant class (I) are susceptible to both the rumor spreading class Sand Q. The individuals of both the rumor spreading class S and Q contact the individuals of the I class and try to convince them to join them on the basis of rumor’s ideology. Let \( k_1 \) be the average number of contacts of individuals of rumor spreading class S with rumors per unit time, and \( p_1 \) be the probability of convincement per contact by a Ignorant with a individual of rumor spreading class S then the per capita recruitment rate in rumor spreading class S is \( \beta_1 = p_1 k_1 \). Thus the individuals in I class may decide to join the rumor spreading class S at a rate \( \beta_1 I (S/N) \) where \( S/N \) is the chance of coming into contact with the individuals of rumor spreading class S. Similarly we may find the per capita recruitment rate \( \beta_2 \) in rumor spreading class Q as \( p_2 k_2 \), where \( k_2 \) is the average number of contacts of individuals of rumor spreading class Q with rumors per unit time, and \( p_2 \) be the probability of convincement per contact by a ignorant with a individuals of rumor spreading class Q. So the individuals in I class may decide to join the rumor spreading class Q at a rate \( \beta_2 I (Q/N) \), where \( Q/N \) is the chance of coming into contact with the individuals of rumor spreading class Q.

We also assumed that individuals move from one rumor class to another when they are being contacted by the individuals of the other rumor spreading class. Let \( \theta_1 \) and \( \theta_2 \) be the per capita recruitment from rumor spreading class S to Q and from Q to S respectively. Thus the individuals of rumor spreading class S leave their class with the rate \( \theta_1 S (Q/N) \) and join the class Q with the same rate. Similarly individuals of class Q leave their class with the rate \( \theta_2 Q (S/N) \) and join the rumor class S with the same rate.

The nonmonotone function \( g(S) \) has been used to describe the psychological effects in the process of rumor spreading. The function \( g(S) \) is increasing when \( s \) is small and decreasing when \( S \) is large. We will focus on

\[
g(S) = \frac{k S}{1 + \alpha s^2} \quad (1)
\]

Consider the existence and nonexistence of limit cycles in system, which is crucial to determine the existence of a persistence region of the rumor. In the equation (1), \( k S \) measures the probability of news rumor infection and \( 1/(1 + \alpha s^2) \) measures the inhibition effect from the behavioral change of the ignorant individuals when their number increases or from the weary effect of the others. It describes the psychological effect of the behavioral change of the
susceptible individuals when the numbers of infective individuals change in an emergency event. Notice that when $\alpha = 0$, the nonmonotone incidence rate becomes the bilinear incidence rate. Parameter $k$ is the probability infection of the rumor, and parameter $\alpha$ describes the psychological quality of the general public toward the infective. The flow diagram of the model system is shown in Fig. 1

Fig. 1. Flow Diagram of the Model.

With respect to the above assumptions, the equations of the model may be written as follows

$$\frac{dI}{dt} = \mu N - \frac{kIS}{1 + \alpha s^2} + \beta S + \frac{s}{N} \cdot N - \beta_1 I \cdot \mu I \cdot N \beta_1 \cdot I \cdot \frac{s}{N} \cdot N - \beta_2 I \cdot Q - \mu I$$

$$\frac{dS}{dt} = \beta_1 I \cdot \frac{s}{N} + \frac{kS}{1 + \alpha s^2} + \theta I - \theta S - \theta S - \mu$$

$$\frac{dQ}{dt} = \beta S \cdot \frac{Q}{N} + \theta Q - \theta S - \mu Q$$

Where $0 > 0$, $S(0) \geq 0$, $Q(0) \geq 0$. Adding all the three equations of model system (2), we have $dN/dt = 0$ Showing that the total population $N$ is constant over time and $I + S + Q = N$. Now we can obviously observe that the net shifting of individuals will be either from rumor class $S$ to class $Q$ or vice versa. Let us set $\theta_1 = \theta_2 = 0$ So that, the above system model (2) can reduces to:

$$\frac{dI}{dt} = \mu N - \frac{kIS}{1 + \alpha s^2} + \beta S + \frac{s}{N} \cdot N - \beta_1 I \cdot \mu I \cdot N \beta_1 \cdot I \cdot \frac{s}{N} \cdot N - \beta_2 I \cdot Q - \mu I$$

$$\frac{dS}{dt} = \beta_1 I \cdot \frac{s}{N} + \frac{kS}{1 + \alpha s^2} + \theta I - \theta S - \theta S - \mu$$

Thus, we may assume that $\theta > 0$. This assumption implies that net rate of movement of rumor class individuals is from rumor spreading class $S$ to class $Q$. We now defined new variables $i, s, q$ as proportions of the total rumor population $N$. Let $i = I/N$, $s = S/N$ and $q = Q/N$ denotes the proportionate variables of our system. Then the above system reduces to the following form:

$$\frac{di}{dt} = \mu i - \frac{kis}{1 + \alpha s^2} - \beta_1 i s - \beta_2 i q - \mu i$$

$$\frac{ds}{dt} = \beta_1 i s + \frac{kis}{1 + \alpha s^2} - \theta s - \mu s$$

$$(4)$$

$$\frac{dq}{dt} = \beta_2 i q + \theta s - \mu q$$

We first consider the existence of four equilibria in the model system (5), as follows:

(i) Rumor free equilibrium $E_0(0; 0)$. This equilibrium always exists without any condition. In term of sociological/psychological aspects, this corresponds to a situation where there is no any rumor in existence.

(ii) Single rumor class equilibria $E_1(1 - \mu/\beta_1, 0)$ and $E_2(0, 1 - \mu/\beta_2)$. In this case there exist two equilibria. The equilibrium $E_1(1 - \mu/\beta_1, 0)$ exists if the condition $\beta_1 > \mu$ holds, whereas the equilibrium $E_2(0, 1 - \mu/\beta_2)$ exists if $\beta_2 > \mu$. In the equilibrium $E_3(1 - \mu/\beta_1, 0)$, rumor spreading class $S$ exists whereas individuals in the rumor class $Q$ are zero. Similar explanation also holds for the equilibrium $E_2(0, 1 - \mu/\beta_2)$, in reverse order.

(iii) Interior/endemic equilibrium $E_3(s^*, q^*)$. This equilibrium may be obtained by solving the algebraic equations:

$$\beta_1(1 - s - q) + g - \theta q - \mu = 0$$

$$\beta_2(1 - s - q) + \theta s - \mu = 0$$

From equations (6) and (7), the values of $s^*$ and $q^*$ may be written as follows:

$$s^* = \frac{\mu(\beta_1 - \beta_2) - \theta(\beta_2 - \mu)}{\theta(\beta_1 - \beta_2 + \theta)}$$

$$q^* = \frac{k(1 - \mu)(\beta_1 - \beta_2) + \theta(\beta_2 - \mu)}{\theta(\beta_1 - \beta_2 + \theta)(1 + \alpha s^2)}$$

Let $(i^*, s^*, q^*)$ be the equilibrium of the above model then $i^* = I^*/N$, $s^* = S^*/N$ and $q^* = Q^*/N$, where $(I^*, S^*, Q^*)$ are equilibrium of the unreduced system (3).

Thus, we may assume that $i + s + q = 1$ for the reduced system (4). From this fact, the reduced model (4) given rise the following differential equations

$$\frac{ds}{dt} = \beta_1(1 - s - q)s + q - \theta s - \mu s$$

$$\frac{dq}{dt} = \beta_2(1 - s - q)q + \theta s - \mu q$$

The study of this model (5) is equivalent to the study of model system (2). Keeping this in View we study the model system (5). The governing equations in the model system (5) are ecological type equations. Now we analyze the above system (5) like ecological models and interpret the results in terms of sociological perspectives.

III. EQUILIBRIUM OF THE MODEL

The study of this model (5) is equivalent to the study of model system (2). Keeping this in View we study the model system (5). The governing equations in the model system (5) are ecological type equations. Now we analyze the above system (5) like ecological models and interpret the results in terms of sociological perspectives.
Notethat $i^* = 1 - s^* - q^* = 0/(\beta_1 - \beta_2 + \theta)$. For all $i^* \in (0,1]$ this implies that $\beta_1 > \beta_2$. If we take $\beta_1 = \beta_2$, then $i^* = 1$ and $s^* = q^* = 0$. As in the case of rumor free equilibrium. Thus for the existence of interior equilibrium we set $\beta_1 > \beta_2$, so that the equilibrium $E_3(s^*,q^*)$ exists provided parameters of the model system (4) satisfy the following two more conditions:

$$\mu(\beta_1 - \beta_2) - \theta(\beta_2 - \mu) > 0 \quad (10)$$

$$k(1 - s - q)(\beta_1 - \beta_2 + \theta) - (\alpha s^2)\mu(\beta_1 - \beta_2) + \theta(\beta_1 - \mu) > 0 \quad (11)$$

In this case the two rumor class S and Q dominate the whole population. The basic reproduction number $R_0$ is defined in epidemiological models to be the average number of new infections caused by one infected individual [19]. Here $R_0$ means the average number of new rumor spreading. The basic reproduction number reflects a significant role when designing control interventions for a system. To find $R_0$ of system (5), we use the method of next-generation matrix [19]. The system has a Rumor free equilibrium $E_0(0,0)$. Taking the infected compartments to be $s$ and $q$ give

$$F = \begin{pmatrix} \beta_1 & i \\ 0 & 0 \end{pmatrix}, \quad V = \begin{pmatrix} (\theta q + \mu)s \\ -\beta_2 s - (\mu - \theta s)q \end{pmatrix}$$

Hence

$$F = \begin{pmatrix} 0 & \beta_1 \\ 0 & 0 \end{pmatrix}, \quad V = \begin{pmatrix} (\theta q + \mu) & 0 \\ -\beta_2 & (\mu - \theta s) \end{pmatrix}$$

$$k = FV^{-1} = \begin{pmatrix} \beta_1 & 1 \\ 0 & 0 \end{pmatrix} \begin{pmatrix} 1 \\ -\beta_2 \end{pmatrix} = \begin{pmatrix} \beta_1 & 1 \\ 0 & 0 \end{pmatrix} \begin{pmatrix} \beta_1 \mu - \theta s \\ \mu - \theta s \end{pmatrix}$$

Note that $D = 0$, $\lambda_{max} = \frac{r}{2} + \sqrt{(\frac{r^2}{4}) - D}$ and when $D = 0$ then $\lambda_{max} = T$.

Therefore, the reproduction number of the system (5) is the spectral radius of matrix, that is, $FV^{-1}$. $R_0 = \rho(FV^{-1}) = \frac{\beta_1 \beta_2}{(\theta q + \mu)(\mu - \theta s)}$.

IV. STABILITY OF THE EQUILIBRIUM

The general Jacobian matrix $J$ of the model system (5) is given as follows:

$$J = \begin{pmatrix} \beta_1 & (1 - 2s - q) - \alpha s - \beta_1 s - \theta s \\ -\beta_2 q + \alpha \beta_2 s & (1 - 2s - q) - \beta_2 s - \theta s \end{pmatrix}$$

We now investigate the stability of various equilibria by finding eigenvalues of Jacobian matrix $J$ corresponding to each equilibrium. Let $J_1$ be the Jacobian matrix evaluated at the equilibrium $E_1(i = 0,1,2,3)$. It is obvious to see that the eigenvalues of the matrix $J_1$ are $\beta_1 - \mu$ and $\beta_2 - \mu$ since for the existence of equilibrium $E_1(1 - \mu/\beta_1,0)$, $\beta_1 > \mu$ and for the existence of equilibrium $E_2(0,1 - \mu/\beta_2), \beta_2 > \mu$. Thus $E_0(0,0)$ is unstable whenever equilibrium $E_1$ or $E_2$ exists. The eigenvalues of the matrix $J_1$ are $(-\beta_1 - \mu)$ which is negative and $\theta(\beta_1 - \mu - \mu(\beta_1 - \beta_2)) / \beta_1$, which is positive for the existence of equilibrium $E_3$ (see condition (9)). Thus $E_4(1 - \frac{\mu}{\beta_1},0)$ is unstable whenever interior equilibrium $E_3(s^*,q^*)$ exists. Moreover the eigenvalues of the matrix $J_2$ are $\mu(\beta_1 - \beta_2 - \theta) / \beta_2$, which is positive for the existence of equilibrium $E_3$ (see condition (8)) and $-\beta_2 - \mu$, which is negative. Since one eigenvalue of matrix $J_2$ is positive, thus $E_2(0,1 - \mu/\beta_2)$ is unstable whenever interior equilibrium $E_3(s^*,q^*)$ exists.

The local stability behavior of $E_3(s^*,q^*)$ model (5) is established by finding the roots of characteristic equation of the Jacobian matrix evaluated at $E_3(s^*,q^*)$. The global stability result has been proved by using the divergency criterion [20].

Theorem 1. The equilibrium $E_3(s^*,q^*)$ whenever exists, is locally asymptotically stable without any condition.

Proof: The matrix $J_3$ (evaluated at $E_3$) is given as follows:

$$J_3 = \begin{pmatrix} -\beta_1 s - \beta_1 s^* - \theta s \\ -\beta_2 + \theta \theta q - \beta_2 q^* \end{pmatrix}$$

From the above matrix, we observe that trace $(\text{tr}) = -\beta_1 s^* - \beta_1 s^* - \beta_2 q^* - \theta s$ is negative and $\det = -\beta_1 s^* - \beta_1 s^* - \beta_2 q^* - \theta q$, which is positive (since $\beta_1 > \beta_2$). This implies that both the eigenvalues of the matrix $J_3$ will be either negative or having negative real part. Thus $E_3(s^*,q^*)$ whenever exists, is locally asymptotically stable without any condition.

Theorem 2. Model (5) does not have any limit cycle in the interior of the positive quadrant of the $sq$-plane.

Proof. Let us consider the following function

$$H(s,q) = \frac{1}{sq},$$

which is positive in the interior of the positive quadrant of the $sq$-plane. Define by

$$h_1(s,q) = \beta_1 q (1 - s - q) - \alpha sq - \mu s$$

$$h_2(s,q) = \beta_2 q (1 - s - q) - \alpha sq - \mu q \triangleq q \alpha q H$$

Then we have:

$$\Delta(s,q) = \frac{\partial}{\partial q} (h_1 H) + \frac{\partial}{\partial q} (h_2 H) = 0.$$

This shows that $\Delta(s,q)$ does not change sign and is not identically zero in the interior of the positive quadrant of the $sq$-plane. Therefore, by Bendixson–Dulac criterion, it follows that there is no closed

to the interior of the positive quadrant of the sq-plane.

Theorem 3. The model (5) is uniformly persistent if the condition of existence of the equilibrium $E_4(s^*,q^*)$ holds.

Proof: Let the average Lyapunov function for model system (5) be

$$\sigma(A) = spq^r, p > 0, r > 0. \text{ Then } \sigma(A) \text{ is a nonnegative } Q^1 \text{ function in } R^2. \text{ And not that}$$

$$\psi(A) = \frac{1}{\sigma} \frac{d}{dt} = p[\beta_1(1-s-q) - \theta q - \mu] + r[\beta_2(1-s-q) - \theta q - \mu].$$

Since there is no periodic orbit in the interior of the positive quadrant of the sq-plane (see Theorem 2). Thus, to show the uniform persistence of the system it is sufficient to show that $\psi(A) > 0$ for all equilibria $E_0, E_1, E_2, E_3, E_4$. Hence the divergence criterion [20] implies that all periodic solutions must be orbit stable. This is impossible, since $E_3(s^*,q^*)$ is locally asymptotically stable. Thus, the system (5) has no periodic orbit in $R^2$. since the equilibria $E_0(0,0)$, $E_1(1-\mu/\beta_1,0)$, $E_2(0,1-\mu/\beta_2)$ are unstable equilibria, the theorem follows immediately.

V. DATASETS OF THE PRACTICAL PROBLEM

As West Africa was agog with fear of the deadly Ebola hemorrhagic fever, multiple recipes of potential “folk” have flooded the minds of Nigerians. Particularly, persistent suggestion that bathing in or drinking hot water and salt solution prevents and/or cures Ebola virus disease has been circulating widely among the public, at the tick of dawn on 8 August, 2014. In actual sense, shouldn’t we all exhibit some form of anxiety at that mysterious illness which spares no mortals and spares no time in claiming its victims? The salt and water Ebola virus cure rumor of August 2014 in Nigeria, which made more than five peoples lose their life and live many hospitalized, seriously impacted peoples psychology and triggered a chain of disorders. The rumor messages advising Nigerians to take their bath with hot water mixed with salt in order to avoid the Ebola Virus Disease (EVD) went viral overnight, and the ‘salt antidote’ has claimed more lives than the dreaded disease itself.

Yet the crux of the matter is that in such national health emergencies, when the right public health messages and accurate awareness is not quickly spread by the relevant authorities, Rumour, with its all-knowing fangs would ride high on the crescendo of public ignorance. And, in that case, when people still run the risk of having the Ebola virus spread to various parts of the country people have continue to drench themselves with salt; the salt packaging companies have been proverbially smile their salted ways to the banks and telecommunications companies, with pockets bulging with bulks accrued from frightened calls and SMSs, would look down and guffaw at our ignorance. Ebola rumor, alas, turns adults - educated or otherwise - to victims long before their time. At recession period, the spread scope of the true crisis information gets more and more widely, and government agencies as well as authority media begin to join the true information spreading ranks, which strengthens the crisis information, identify capacity of the public; then, after receiving the true information, the public will not be confused by the rumors. The public show steady decline needs for the crisis information and gradually lose interest for rumor.
TABLE 1: Rumor spreading datasets of the studied with f=frequency and p=percentage.

<table>
<thead>
<tr>
<th>S/N</th>
<th>QUESTIONS</th>
<th>YES</th>
<th>NO</th>
<th>NOT SURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Do you believe that Ebola virus disease is real?</td>
<td>203</td>
<td>90</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>68.2</td>
<td>23.4</td>
<td>8.1</td>
</tr>
<tr>
<td>2</td>
<td>Have you heard about water and salt Ebola Virus cure rumor of August 2014?</td>
<td>311</td>
<td>60</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.0</td>
<td>15.6</td>
<td>3.4</td>
</tr>
<tr>
<td>3</td>
<td>Did you hear the rumor at the early stage? That is, on that very night?</td>
<td>765</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60.0</td>
<td>76.0</td>
<td>5.0</td>
</tr>
<tr>
<td>4</td>
<td>Do you believe/accept the rumor and drink/bath with salt and water?</td>
<td>173</td>
<td>392</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>44.8</td>
<td>50.0</td>
<td>5.2</td>
</tr>
<tr>
<td>5</td>
<td>Did you passed/spread the rumor to someone actively?</td>
<td>173</td>
<td>392</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>44.8</td>
<td>50.0</td>
<td>5.2</td>
</tr>
<tr>
<td>6</td>
<td>Did you evaluate its credibility or trust-worthiness Before deciding whether to pass the rumor message on to others?</td>
<td>150</td>
<td>194</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>39.1</td>
<td>50.5</td>
<td>10.4</td>
</tr>
<tr>
<td>7</td>
<td>Did the drinking or bathing with salt and water harm or affected you?</td>
<td>08</td>
<td>264</td>
<td>68.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25.5</td>
<td>68.8</td>
<td>5.7</td>
</tr>
<tr>
<td>8</td>
<td>Did you lose someone as a result of drinking or bathing with salt and water?</td>
<td>08</td>
<td>264</td>
<td>68.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20.8</td>
<td>75.0</td>
<td>4.2</td>
</tr>
<tr>
<td>9</td>
<td>Did you think that the psychological factor of anxiety, importance, credibility and uncertainty are implicated in the transmission of the Ebola virus cure rumor of August, 2014?</td>
<td>223</td>
<td>114</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>58.1</td>
<td>29.7</td>
<td>12.2</td>
</tr>
<tr>
<td>10</td>
<td>Do you think that social media is the main platform for rumor spreading?</td>
<td>289</td>
<td>61</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>75.3</td>
<td>17.9</td>
<td>8.8</td>
</tr>
<tr>
<td>11</td>
<td>Through which medium you got the rumor information?</td>
<td>Phone calls:</td>
<td>Social media:</td>
<td>Face to face:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25.4%</td>
<td>14.0%</td>
<td>21%</td>
</tr>
<tr>
<td>12</td>
<td>When did you alerted that the rumor is not true?</td>
<td>Early stage:</td>
<td>Medium stage:</td>
<td>Late stage:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27.9%</td>
<td>59%</td>
<td>10%</td>
</tr>
</tbody>
</table>
| 13  | Why did you decide to passed/spread the rumor?                           | Fair panic: | Protection/ save life: | Lack awareness of:
|     |                                                                           | 14% | 42.7% | 7.6% |

After August 8th, the Nigeria government have increased awareness of rumor prevention efforts and spread scientific knowledge that bathing in or drinking hot water and salt cannot prevents and/or cures Ebola virus disease. The scare- bathing in or drinking emergency is under control when the rumor is debunked. The datasets was reliable coverage of the events being studied. As described in Table I, the rumors studied were drawn from Bauchi state metropolis and across a diversity of areas. Data collection was aimed at gathering rumor highly related to the events under study.

Actually, the collective behavior caused by Ebola virus cure rumor crisis in Nigeria, it was described as psychological effect with nonmonotone and nonlinear incidence in rumor spreading model, and that is the main innovation in this paper.
VI. DISCUSSION AND NUMERICAL SIMULATION

The basic idea of the game is inspired by rumor spreading observations and by the insights obtained through questionnaire/interviews. We support the analysis regarding existence conditions and stability of various equilibria, by hypothetical parameter values/data obtained from the field work so as the existence conditions are satisfied in model (2). We may assume that persons are involved in rumor spreading only between the ages of 18–78 years old, thus we may take $\mu \approx 1/60$. Because ignorant are susceptible to both rumor class. Thus for the above situation we have the following set of parameter values from dataset in model system (2):

$$\beta_1 = \frac{60}{173}, \beta_2 = \frac{60}{192}, \theta_1 = \frac{195}{173}, \theta_2 = \frac{173}{195}$$

(15)

For the above set of parameter values, we note that $\theta_1 > \theta_2$ and $\theta_1 - \theta_2 = \theta = 0.23999$. It may also be checked that for these parameter values, the conditions of existence of interior equilibrium $E_3(s^*, q^*)$ of model system (5) are satisfied.

We have made the simulation analysis of our model system (2) for the above set of parameter values. In Fig. 3 and 4, we have shown the variations of rumor spreading class $S$ (spreaders) and $Q$ (stippler) with respect to the time $t$. From this figure it is easy to observe that if both Spreaders and stippler have started with same number of individuals then for some time spreaders will lead over stipplers but after some time result will be reversed i.e. stiplers will lead over Spreaders. Similarly, in Fig. 2,3 and 4, from the trajectories it may be noted that as time increases the variation of Ignorant class approaches to its steady state values while spreaders and stiplers class approach negetive as a time goes to infinity, the rumor dies out.

In Fig. 7, we have shown the global stability of interior equilibrium $E_3(s^*, q^*)$. We have made the trajectories with respect to the equation 5 and it may be noted that the trajectory are approaching to the interior equilibrium, which shows the global stability of the equilibrium $E_3(s^*, q^*)$. In model system (5), $\theta$ is a very sensitive parameter. In Fig. 5 and Fig. 6, we made the graphs of variation of spreaders and stipplers with respect to time $t$ for different values of $\theta$. From these figures it is clearly shows that as the value of $\theta$ increases the individual of spreaders class decreases whereas an individual in stiplers class increases.

The analysis of model shows that if the net rate of shifting of individuals from spreaders class to stiplers class (i.e. $\theta$) is greater than $\mu(\beta_1 - \beta_2)/(\beta_2 - \mu)$, then spreaders will die out. On the other hand as we
have taken that recruitment from ignorant class to spreaders class is greater than stiflers class (i.e. $\beta_1 > \beta_2$) so if $\theta < \mu(\beta_1 - \beta_2)/(\beta_1 - \mu)$, then stiflers will die out. So the existence of the rumor spreading class Q (stiflers) $\theta$ must lie in the open interval $\mu(\beta_1 - \beta_2)/(\beta_1 - \mu)$.

We recall that the parameter $\alpha (\alpha > 0)$ describes the psychological quality of the general public toward the infectives, in the relationship between rumor spreading and the psychological effect. Though the basic reproduction number $R_0$ does not depend on $\alpha$ explicitly, numerical simulations indicate that when the rumor is endemic, the steady state value $s^*$ of the infectives decreases as $\alpha (\alpha > 0)$ increases (see Figure 3). When $\alpha > 0$ the steady state value $s^*$ will decline and it will remain steady. This shows that the stronger the psychological effect, Based on the above one can draw a conclusion that the parameter $\alpha$ describes the psychological quality of the general public with respect to the infectives; it would be a significant risk factor in the process in the rumor spreading/transmission. We believe that the psychological quality to be absolutely essential to minimize the bad influence of rumors. With the increased psychological quality, we can also see that the population of spreaders seem to approach zero to a closer degree than population with the poor mental quality levels. From the steady state expression (9), we can see that $s^*$ approaches zero as $\alpha$ tends to infinity. Larger $\alpha$, the better psychological quality one in emergency event; the people with high psychological quality has good resistance to rumor spreading, while the ones with low psychological quality are vulnerable to rumor spreading.

CONCLUSIONS

In this paper, a nonlinear mathematical model for rumor spreading has been proposed and analyzed in an epidemiological approach, we also developed/show that the nonmonotone and nonlinear incidence rate of the form $g(S) = kS/(1 + \alpha S^2)$, can be used to interpret the psychological effect with rumor spreading/transmission in emergency: the number of effective contacts between infective individuals and ignorant individuals decreases at high infective levels due to the quarantine of infective individuals or due to the protection measures by the ignorant individuals. The people pay more and more attention to crisis information form authenticity and decrease the interest for rumor. Three valuable conclusions/recommendations drawn from our analysis.

(1) To reduce the probability of new infection value of the rumor spreading, authorities will intensify propaganda and direct public views by controlling rumor spreading and take some actions to relax public vigilance, reducing the focus of attention of rumors, and it is the important task for the authorities to avoid the negative effects for rumor spreading in emergency management. Generally, it can also enhance the transparency of the information in an emergency event, and then the rumor spreading/transmission can be controlled by implementing those strategies. Sometimes information disclosure can achieve management aims for rumor spreading/transmission more effectively and at far lower cost than traditional/political regulation.

(2) The Parameters $\alpha$ for psychological quality have effect on the final size of a rumor infective. To decrease rumors impact on society, developing excellent psychological quality is essential in emergency management. The recommendations are to provide effective immunity against rumor through the timely publicity and popularize scientific knowledge. Excellent psychological quality provides the public with strong mental power and the ability to control rumor in emergency event.

(3) The constitutional authorities can propose efficient measures to control the rumor spreading to keep the stabilization of society and development of economy. And to control the rumor spreading, it will not only need to control the rate of change of the spreader class, but also need to control the change of the information about rumor in medium which has larger influence. Moreover, Government should enhance the management of internet/social media, and relevant legal institutions for punishing the rumor creator and spreader on internet/social media who’s tracked can be possibly established.

REFERENCES

Rumor Spreading Model: Vulnerability and its Psychological Effect in Study of Salt and Water Ebola Virus Cure Rumor of August 2014 in Nigeria


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