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Analysis of Cholera Outbreak between 2000 and 2010 in Wudil Region Using a Mathematical Model

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Abstract

Prevalence of Cholera outbreak is a recursive event in our society. Analysis of cholera outbreak in Wudil region utilizing a mathematical model derived in [1]was presented. Thestudy and analysis of the occurrence of cholera outbreak in Wudil region was based on the data (2000 to 2010) obtained from Wudil General Hospital.

Keywords: strongly correlated electrons; superconductivity; specific heat; half-filling; coupling regime; on-site Coulombic repulsion.

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1.0 Introduction

According to [1, 2], Wudil local government area of Kano state Nigeria is located on latitude $11,8.2127^0$N and longitude $8,5^0$ E of the Greenwich meridian. Wudil region contains some parts of the local governments bounded with Wudil local government like GarinDau in Warawa Local Government. Wudil Local Government is surrounded by Warawato the North, Gaya to the East, Garko and Albasu to the South. The population of Wudil Local Government is 185,189 by the 2006 census and with estimated area of $458km^2$. Wudil town is the local government headquarters which is strategically located on River Wudil (known as River Hadejia). It was reported in [2]that the mean annual temperature of the region is about 26^0C, and mean monthly values range between 21^0C in the coolest months of December/January and 31^0C in the hottest months of April/May. The annual rainfall is about 850mm. Sources of water supply in the region classified into four (4) major sources namely: pipe borne, well water, borehole and streams (or river). The dwellers of the region depend on well and river water through water vendors who supply to households. This is as a result of inconsistencies of pipe borne water which pumps from Wudil water works. Also boreholes are inadequate in the region.The practice of open defecation also exercise in the region especially in Wudil city defecation along the road sides is common and in most cases people use river bank for dumping of refuse, rotten substances and other sewage materials from the toilets of some houses.

In this region sanitation status is on fair (by observation). Food stuff spruces in the regions mostly in rainy season are cereals like Guinea corn, millet e. t. c. and in dry season are beverages like Tomatoes, Pepper, Onion, and Lettuce e. t. c. Famers in dry season depend on river for watering their farms and washing their farm products during harvest and when taking to market. The region depends on only one general hospital (Governmental) and two other private hospitals both in Wudil city and other primary health care centres in some villages.

Cholera is a disease that causes frequent vomiting and diarrhea (gastro enteritis problem). Mostly outbreak of this disease occurs in community with poor sanitation exercise. Cholera is a water borne and food borne diseases.Cholera has killed millions of people since it emergence. Historically there is total of eight (8) cholera pandemics in the world from 1800s as stated [3]. It was suggested that the bacterium that causes the diseases called “vibrio cholerae" is prevalent in regions of the world where sanitation is poor, clean water is unavailable, or food is contaminated [4].The first cholera pandemic of 1817-1823 spread from India to Southeast Asia, the Middle East and Russia leaving hundreds of thousands of people dead.As also reported in [3] the number of cholera deaths in recent pandemics has still been high with many tens of thousands dying, the numbers are nonetheless considerably lower than the pandemics of the 1800s when many hundreds of thousands of people would die.As a result of the contribution of biological and social sciences to the pandemiology of cholera in the world led to the decrease in the number of death.

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It was also reported that the Italian doctor FilippoPacini was the first to discover the cholera bacteria (vibrio cholerae) in 1854 when cholera hit France.In [5], it was shown persons can become long-term carriers of vibrio cholerae.

Analysis of cholera outbreak in Wudil region is presented here based on adata set obtained from Wudil General Hospital. The mathematical model is utilized.

2.0 The Mathematical Model

The Mathematical model used is in two stages; initial stage when$t = 0$ and $t \neq 0$. These two stages contain three equations (equations of susceptible, infection and bacteria) and the threshold used as a scale for prediction (at each stage) and also result comes at the end of each stage. The equations of susceptible and infection are given respectively by

$$\frac{ds}{dt} = n\,(H - S) - a\lambda\,(B)\,S \qquad (1)$$

$$\frac{dI}{dt} = a\lambda(B)S - rI \qquad (2)$$

And the threshold

$$Sc = \frac{rK(mb-nb)}{ae} \qquad (3)$$

where

n - is the rate of birth and death in the region (assumed constant).
H - is the population of the region.
S- is the number of susceptible persons in the region.
a- is the rate of contact with untreated water in the region.
λ(B)- is the probability that 50% of the persons to catch cholera while contact with untreated water and therefore computed using

$$\lambda(B) = \frac{B}{K + B}$$

B - is the number of cells of vibrio cholerae required to contaminate water
K - is the concentration of vibrio cholerae in the river water.
r - is the rate of infection of cholera in the region.
I - is the number of infected persons in the region.
nb - is the local growth of bacteria (or population increase).
mb- is the control of bacteria (or population decrease).
e - is the rate of poor sanitation in the region.

3.0 Analysis

The rate or percentage of reproduction/local growth, death/control of bacteria and the rate of contact with untreated water and rate of poor sanitation are considered constants. Therate of birth and death in the region is alsoassumed to be constant. According to [1] water only needs 7cells of vibrio cholerae in each milliliter (7cells ml^{-1}) to be contaminated and hazard for cholera.

According to [6, 7] the concentration of vibrio cholerae in river water is ranges from 103cells ml^{-1} to 106cells ml^{-1} (from 52 up to 800 microorganisms per liter).the rate of infection of cholera in the region, according to data given by Wudil General Hospital in 2011, the number of cholera infected persons in the period of eleven years (11yrs) is 3318 persons out of this number of infected, 64 persons died and 3254 persons recovered by hospitalization. The rate of recovered is

$$\frac{3254}{3318} \times 100 \approx 98.07\%$$

It stated that vibrio cholerae was able to grow extensively in freshwater and multiplied in river water and lake water. The population of vibrio cholerae was difficult to determine because reproduction of bacteria may not take time since is binary fission. The important factor in reproduction and growth of vibrio cholerae is temperature, Vital also suggested that vibrio cholerae reproduce and grow in temperature rangebetween 20^0c to 30^0c (optimal growth). Therefore it is higher in hottest months in the region ($nb > 0$) and moderate or lower in coolest months of the region ($nb \leq 0$). Also Etowa reported that the control of bacteriaand other diseases carriers is by using improved sanitation facilities but more than half of the Nigerians they are not using improved sanitation facilities. The natural forces mostly affecting mbis (like *nb*) in hottest months in the region mb decrease to the lower rate ($mb < 0$) but in the coolest months in the region mb increase to the moderate or higher rate ($mb \geq 0$). It was reportedthat about 103 millions of Nigerians are not using improved sanitation facilities [7]. The rate of poor sanitation is

$$\frac{103}{150} \times 100 \approx 68.21\%$$

According to [8], the susceptible person is a carrier of the disease but does not show any sign of infection in the body of the persons.

4.0 Discussions

CASE I: (*t = 0*)

$H = S = 185{,}189$

$e = 68.21\%$

$a = 42.67\%$

$r = 0$

$S = e \times \mathrm{H} = \frac{68.21}{100} \times 185189 = 126317.$

$I = 3318$

$nb = 0$

$mb = 0$

$nisconstant.$

$B = 7cellsml^{-1}$

$K = 103$

$\lambda(B) = \frac{B}{K+B} = \frac{7}{103+7} \approx 0.0636$

$a\lambda(B)S = 0.4267 \times 0.0636 \times 185189 = 5026$

$\frac{ds}{dt} = n(H-s) - a\lambda(B)S = n(185189 - 185189) - 5026 = -5026$

$\frac{dI}{dt} = a\lambda(B)S - rI = 5026 - 3254 = 1772$

$\frac{dB}{dt} = B(nb - mb) + eI = 0(0-0) + 0(3318) = 0(3318) = 0$

The threshold $Sc = \frac{rK(mb-nb)}{ea} = \frac{103(0-0)}{0.6821 \times 0.4267} = 0$

The resultshows the value of susceptible is negative (-5026), and that of threshold is zero (0).The result shows that the community will not be expecting an outbreak in this case, $t < 0$. It is also noted from this result that infection in the community may start with 1772 personsinfected, and the required population of bacteria to contaminate water is zero (0). Therefore this case serves as a control.

CASE II ($\boldsymbol{t} > 0$)

$H = 185{,}189$

$S = 126{,}317$

$nisconstant$

$n(H-S) = 185{,}189 - 126{,}317 = 58872$

$a\lambda(B)S = 0.4267 \times 0.0636 \times 126{,}317 = 3428$

$r \approx 0.9807 I = 3318.$

$e \approx 0.6821 \qquad B \neq 0 \quad nb \neq 0 \quad mb \neq 0$

$\frac{ds}{dt} = n(H-s) - a\lambda(B)S = 58{,}872 - 3{,}428 = 55{,}444$

$\frac{dI}{dt} = a\lambda(B)S - rI = 3{,}428 - 0.0177 \times 3318 = 3{,}428 - 58.73 = 3{,}428 - 59 = 3{,}369$

$\frac{dB}{dt} = B(nb - mb) + eI = B(nb - mb) + 0.6821 \times 3{,}318 = B(nb - mb) + 2263$

The threshold $Sc = \frac{rK(mb-nb)}{ae}$

$= \frac{0.0177 \times 103 \times (mb-nb)}{0.4267 \times 0.6821}$

$= \frac{1.8231(mb-nb)}{0.2911}$

Here the number of the susceptible persons increases from 5,028 persons to 55,444 persons.Similarly, the infected persons increase from 1,772 persons to 3,369 persons.Also the population of bacteria exists (from 0 to positive number greater than 2263 cells).The result of threshold is base on the number of *nb* (reproduction of bacteria) and *mb* (death of bacteria). Reproduction of bacteria mostly depends on the temperature of the place at a time.If $mb = nb$ shows the threshold SC is zero (0). This implies no infection and in turns no outbreak. Similarly, if $mb > nb$ shows there is mild infection and there may be no serious case of cholera outbreak. The worth situation is when $mb < nb$. These cases of bacteria reproduction and their death could be verified using laboratory analysis on water sampled in the region.

5.0 Conclusion

Analysis of cholera outbreak in Wudil region utilizing a data set and a mathematical model is presented. Three cases are discussed intensively.

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