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Epidemiology of chickenpox in Agona West Municipality of Ghana

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ABSTRACT

Chickenpox cases in recent time have increased in Agona West Municipality. The study showed that chickenpox is persistent in the municipality with $R_0 = 2$. The stability analysis of disease free and endemic equilibrium point of chickenpox transmission without vaccination was estimated to be a centre. Chickenpox in the Municipality can be prevented by reducing the rate at which people are exposed to the disease. Sensitivity analysis of the SEIR model showed that the latency rate was more sensitive to the model than the transmission rate (β) and the recovery rate (γ).

Keywords: Chickenpox, equilibrium, transmission, stability, disease, endemic.

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INTRODUCTION

The Agona West Municipal can be found in the eastern portion of the Central Region. It has a total land area of 540 sq. km. and a population of 160,000. The municipality is divided into eleven zones.

The area is bounded to the East and West by Effutu Municipal and Asikum/Odoben/Brakwa Districts, respectively. The municipal shares a border to the northeast with Akim West Municipal, to the northwest with Brim-South District and to the South, with Gomoa District.

Agona West Municipal is the capital and has a population of about 40,000. It lies to the north of Winneba and is about 40 km off the main Accra-Takoradi Highway. The location of the township makes it the commercial center or the region and a nodal point from which roads radiate to the rich cocoa growing countryside of the Region. Has a total land area of 667 km^2 (Agona West Municipal Featured).

The epidemiological dynamics of chickenpox (varicella) have been studied through mathematical models especially in developed countries with emphasis on the underlying process during the epidemic or endemic period for varicella, the morbidity effects of immunization against varicella and the seasonal variation in contact rates (Giraldo and Palacio, 2008). However, few studies have been done in developing countries like Ghana, whose tropical climate, demographic pattern and socio-economic conditions can influence the dynamical transmission of diseases.

A good understanding of some recent reported cases of chickenpox incidence in Ghana would be of interest in the SEIR epidemiology of chickenpox in Agona West Municipality, Ghana. According to the World Health Organization (WHO), chickenpox is one of the endemic diseases in the sub-Saharan country (PAO, 2012).

In 2008, 77,790 cases of chickenpox were recorded in the country,45,512 in 2004, and 19,614 in 2003 against 35,667 in 2002 (The Health sector in Ghana, 2010).

Information from Ghana (The Ghanaian Times, 2008) indicated that on 28th September, 2008, Times reported an outbreak of chickenpox in Accra Metropolis. The Times survey conducted in six medical centers revealed that about 600 chickenpox cases has been reported in first quarter of 2008. This includes three Hospitals and three Polyclinics. In 2007, 356 cases were reported during the first quarter at hospitals and clinics located in three sub-metros of Ayawaso, Kpeshie and Okaikoi within the Accra metropolitan area. The Times survey revealed that the new outbreak is more prevalent in densely populated areas.

La recorded 194 cases at its General Hospital, Maamobi 189 at the Sulemana Memorial Hospital, a private hospital and Nima 137 in the government clinic

according to the Times survey.

Ofori (2011) modelled the epidemiology of varicella in Ghana and concluded that chickenpox is endemic in Ghana with average patient contact rate of 1.4588 and the reproductive number $R_0 = 1.078$.

Chickenpox (Varicella) is a contagious viral disease characterized by vesicular skin lesions, fever, mild fatigue and general malaise. The primary infection with Varicella-Zoster Virus (VZV) causes chickenpox. The varicella-zoster virus (VZV) is one of eight herpes viruses that cause infections in humans. These viruses rapidly proliferate, invade and destroy infected cells like other herpes viruses and it is a double-stranded DNA virus that is closely related to herpes simplex virus types 1 and 2. The Varicella - Zoster Virus establish a latent infection in nerve ganglions and later reoccur as shingles, also known as Herpe Zoster that is characterized by a localized vesicular rash and often associated with pain. Elderly suffer more pain from Herpes Zoster than children which can persist for more than 3 months. The virus has a shorter survival time frame in the environment and the incubation period is normally between 14 and 16 days with exposure range of 10 and 21 days (NCIRS, 2009).

Complications of chickenpox infection occur in around 1% of all cases, with the most being secondary bacterial infection of the skin lesions. Pneumonia, encephalitis (inflammation of the brain) and cerebellar ataxia, thrombocytopenia and hepatitis are other complications associated with chickenpox (NCIRS, 2009).

Chickenpox starts with rashes with adults experiencing 1 to 2 days fever and malaise. In children, rash is often the first sign of the disease. The rash is associated with itching and pain that rapidly progresses from macules to papules to vesicles lesion that are 1 to 4 mm in diameter. The rash normally appears on the head, followed by the trunk (centripetal distribution). Lesions can occur on the mucous membrane of the respiratory tract, oropharynx, conjunctiva and the cornea. The rashes develop into blisters called vesicles and the vesicles are superficial and delicate with clear fluid on the erythematous base. Vesicles rupture or become purulent before they dry and crust. Successive crops appear over several days with lesions present in several days of development. Healthy susceptible children develop 200 to 500 lesions in 2 to 4 successive crops.

Clinical course in healthy children is generally mild, with malaise, itching and fever up to 102°F for 2 to 3 days but no respiratory or gastrointestinal symptoms. Complications occur most frequently in immune compromised persons, pregnant women and adults (Harpaz et al., 2008). Chickenpox cases in recent time have increased in Agona West Municipality and Mathematical models for the dynamics of the chickenpox with special emphasis in the municipality are uncommon. Based on this information, the study is focused on using SEIR model proposed by Anderson and May (1991) to model the spread and establish the endemicity of chickenpox in the Municipality.

METHODOLOGY

The population used for this study was from Agona West Municipal and the data was obtained from Agona West Municipal Health Directorate.

We used SEIR model proposed by Anderson and May (1991) to model the spread of chickenpox. Ordinary differential equations were used to formulate the model equations. Al-Showaikh and Twizell (2006) extended SEIR model to second order derivative for the transmission dynamics of measles to enable the geographic spread of the disease in a population which has not been vaccinated. In many facets of usages, differential equations' applications are embarked on extensively (Dontwi and Obeng-Denteh, 2011; Obeng-Denteh, 2011; Obeng-Denteh et al., 2012; Dontwi et al., 2013). Stability and sensitivity analysis are then performed on the model equations and Matlab software was used to draw simulation graphs.

Mathematical model

In the SEIR model, the total population is divided into four separate groups: Susceptible (S), Exposed (E), Infective (I) and Recovered (R). Susceptible people can contract the disease if they have been exposed to the chickenpox, while those in the exposed group are individuals infected with the chickenpox but not yet infectious and are not able to pass the chickenpox to others. Infective are the individuals who are infectious and capable of transmitting the infection to any susceptible that they come in contact with and those in the recovered compartment are individuals previously infected but now neither infected nor susceptible. They have an infection-acquired immunity (permanent immunity). The proportion of individuals in each compartment S, E, I and R at time t is given as S(t), E(t), I(t) and R(t). Figure 1 is the flow chart of the SEIR model without vaccination.

In this model, we assume that:

1. The members in the population mix homogeneously.
2. The disease spreads in a closed environment; there is no birth and death, emigration or immigration and so the total population N remains constant for all time. Thus:

$N = S(t) + E(t) + I(t) + R(t)$.

3. The number who are infected by chickenpox (infective individual) per unit time is proportional to the total number of Susceptible; β is proportional coefficient (Infection rate). So the total number of those infected by chickenpox (new infective) per unit time is given as $-\beta S(t)I(t)$, the negative sign indicates a decrease in the

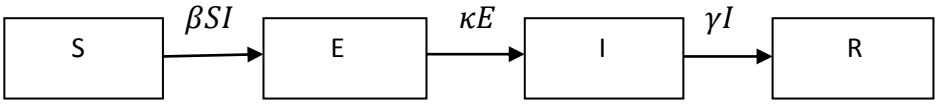

Figure 1. Flow chart of SEIR model of chickenpox without vaccination.

Table 1. Data obtained from the Agona West Municipal Health Directorate (GSS, 2010).

Time (year)	Susceptible	Exposed	Infective	Recovered
t = 0	60684	9	23	0
t = 1	55950	5	13	15
t = 2	58365	7	18	20
t = 3	48463	11	28	41
t = 4	31527	16	41	43

number of susceptible.
4. The rate at which individual leave the exposed compartment (E) into the infective (I) compartment at the time t is given by κE(t), where k is the latency rate of individual exposed to the chickenpox.
5. The number of individuals from the infective compartment to the recovered (R) at the time t is given as γI(t), where γ is the recovery rate coefficient of chickenpox and those who recovered from chickenpox gain permanent immunity.
6. Age, sex, color, social status and race do not affect the probability of being infected

The SEIR model for the spread of the disease can be written as a set of four coupled nonlinear ordinary differential equations as follows:

$$\frac{dS}{dt} = -\beta SI \quad (1)$$

$$\frac{dE}{dt} = \beta SI - \kappa E \quad (2)$$

$$\frac{dI}{dt} = \kappa E - \gamma I \quad (3)$$

$$\frac{dR}{dt} = \gamma I \quad (4)$$

Solving the four equations simultaneously, we obtain the equilibrium point as $S^*, E^*, I^*, R^* = (0, 0, 0, 0)$

We estimated the reproductive number (R_0) of chickenpox using the next generation matrix as $R_0 = \frac{\beta}{\gamma}$. The reproductive number is defined as the mean number of secondary infections caused by one infected individual during the mean course of infection in a totally susceptible population. The reproductive number (R_o) is a threshold that determines whether a disease will spread will die out in the population (Van Den Driessche and Watmough, 2002).

The stability analysis of the disease free and the in a population or dies out. Whenever R_o is >1, the disease will spread in a population. If $R_o < 1$, the disease endemic equilibrium point of the spread of chickenpox is given by:

$$J - \lambda I = \begin{vmatrix} -\lambda & 0 & -\beta & 0 \\ 0 & -k-\lambda & \beta & 0 \\ 0 & k & -\gamma-\lambda & 0 \\ 0 & 0 & \gamma & -\lambda \end{vmatrix}$$

The diagonal of the matrix gives us the eigenvalues of the disease free and the endemic equilibrium point of the spread of chickenpox as $\lambda = 0, \lambda = \kappa$ and $\lambda = \gamma$. Table 1 shows the summary of the data obtained from the Agona West Municipal Health Directorate.

RESULTS AND DISCUSSION

In this study, we estimated the parameter values from the data obtained from the Agona West Municipal Health Directorate as follows: Transmission rate $(\beta) = 0.026$, Latency rate $(\kappa) = 0.036$, Recovery rate $(\gamma) = 0.014$. From the studies, we observed that $R_0 = 2 > 1$ impling that on average two people will contract chickenpox in a year in the Municipality. The stability analysis of disease free and endemic equilibrium point of chickenpox transmission of the spread of chickenpox estimated to be a centre. By sensitivity analysis of the SEIR model, we observed that as transmission rate (β) varies from 0.08 to 0.90, the susceptible population decreases sharply with a sharp increase in the exposed population with more people contracting chickenpox, while the recovered population was asymptotic to the time axis. We observed that as the latency rate (κ) varies from 0.40 to 0.83, more

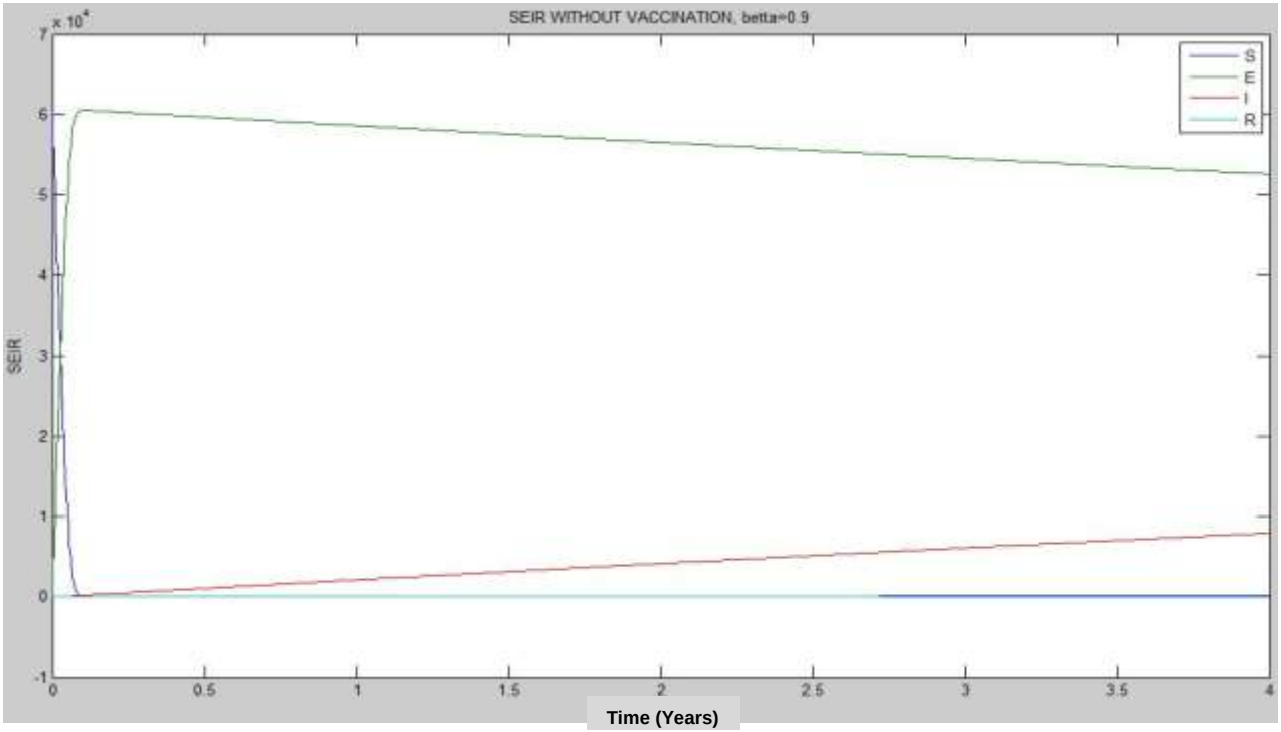

Figure 2. SEIR without vaccination, beta = 0.9.

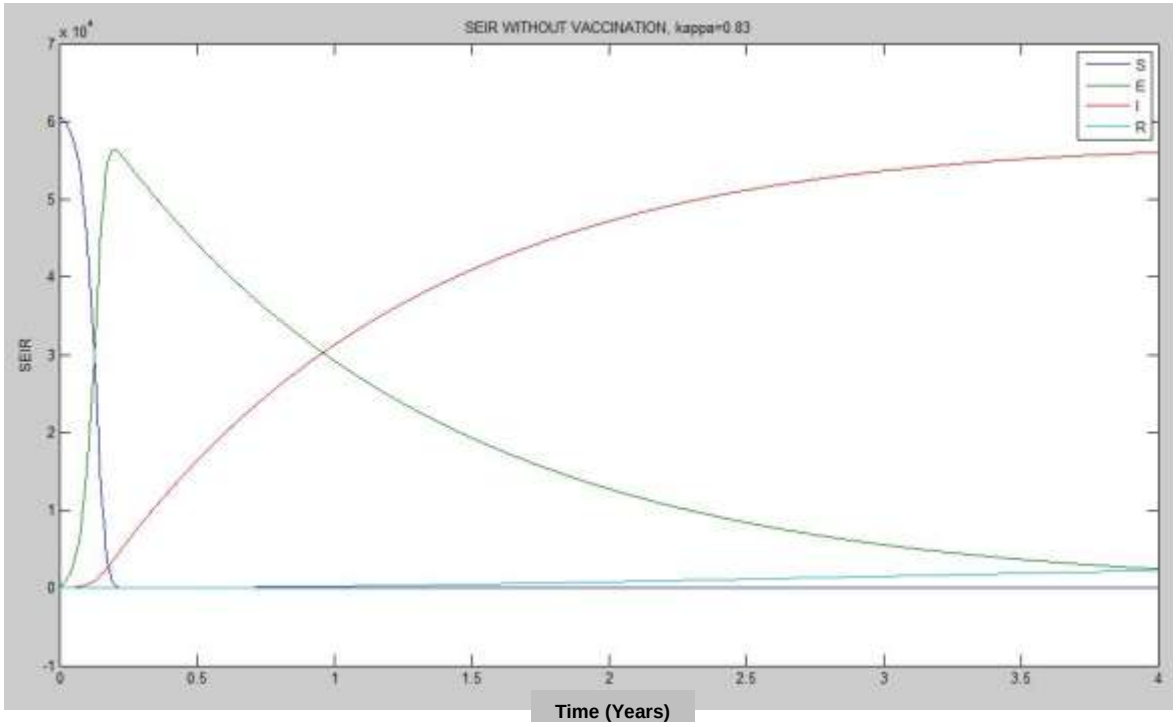

Figure 3. SEIR without vaccination, beta = 0.83.

people become exposed to chickenpox and as a result chickenpox patient rose from approximately 46,000 to 56,000 with no significant change in the recovered population as shown in Figures 2, 3 and 4.

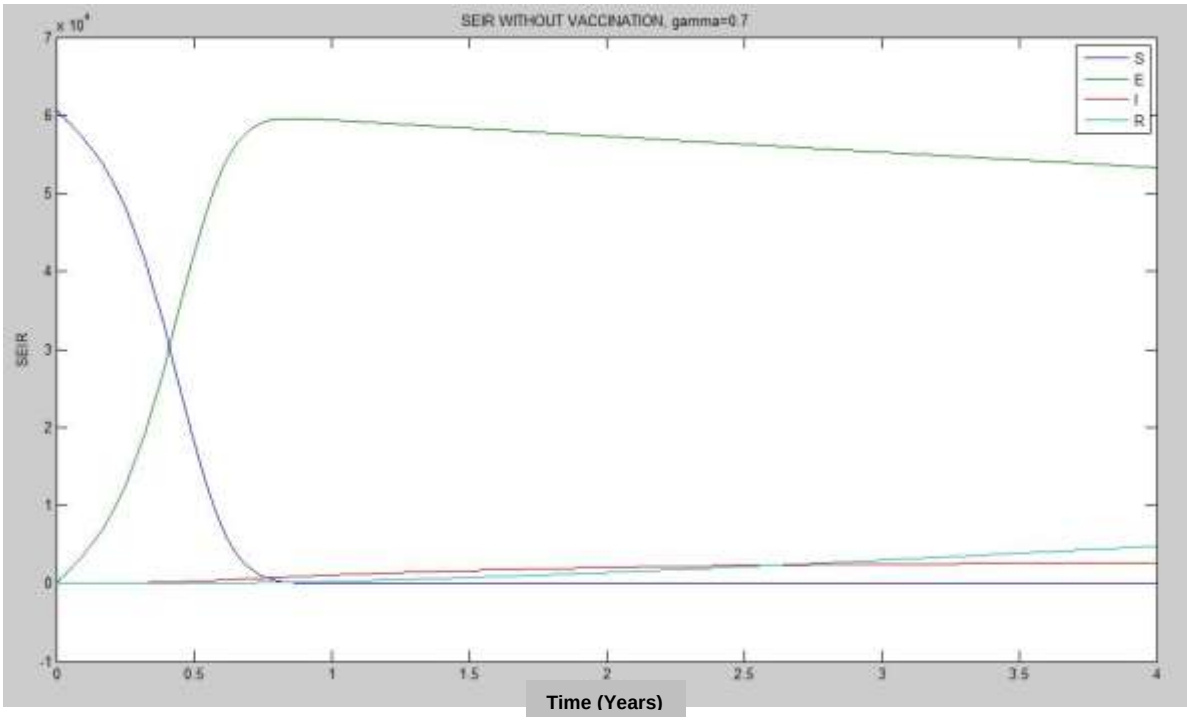

Figure 4. SEIR without vaccination, gamma 0.7 = 0.9.

We observed that as the recovered rate (γ) varies from 0.007 to 0.70, people who contracted chickenpox decreases with more people recovering and also saw that the latency rates (κ) is more sensitive to the model than the transmission rate (β) and the recovery rate (γ).

CONCLUSION

From the studies, we observed that chickenpox is endemic with $R_0 = 2 > 1$. We observed that if vaccine for chickenpox is not given in Agona West Municipality and the latency rates (κ) is reduced significantly, chickenpox will be under control. This means that people who have contracted chickenpox should reduce their exposure to the susceptible population. Comparing with others, we had situations in 1995, where there were 2934 verified cases reported in Antelope Valley, CA, 3130 cases in Travis County and 1197 cases in West Philadelphia. The number of cases declined in all sites in 1996 and remained stable until 1998. In 1999, the number of cases began to dramatically decrease and in 2000, there were 837, 491 and 250 cases in Antelope Valley, Travis County, and West Philadelphia, respectively. Between 1995 and 2000, the total number of cases in the three surveillance areas declined 71 to 84%, with the most considerable reduction in preschool children (1 to 4 year olds). By 2005, the number of cases declined by about 90% in both Antelope Valley and West Philadelphia combined (Guris et al., 2008). This buttresses the study that the problem can be salvaged.

RECOMMENDATIONS

We call on all stakeholders in the health sector to come together to ensure that there is a law that enforces all the health sector to keep up to date on all the diseases reported at the various hospitals, clinics and the health centers due to the difficulties in obtaining data for research.

We recommend further studies on:

1. SEIR model using non constant population and incorporation of age.
2. Researchers and students can extend the model to non constant population size and to unequal birth/death rate.

REFERENCES

Al-Showaikh FNM, Twizell EH, 2006. One-dimensional measles dynamic. Appl Math Comput, 156:169-194.

Anderson RM, May RM, 1991. Infectious Diseases in Human: Dynamics and Control. Oxford University Press. Oxford.

Dontwi IK, Obeng-Denteh W, Bilson Darku F, Tackie-Otoo F, Batsa Tetteh F, Ewoenam K, Owusu-Mensah I, Amoah-Mensah J, 2013. Modeling memorization and forgetfulness using differential equations. Prog Appl Math, 5(2):1-12.

Dontwi K, Obeng-Denteh W, 2011. Using differential equations to model the number of bats in a habitat. Cont J Appl Sci, 6(2):29-33.

Ghana Statistical Service, 2010. Available on www.ghanadistricts.com

(accessed on 11th November, 2012)
Giraldo JO, Palacio DH, 2008. Deterministic SIR (Susceptible – Infected – Recovered) Models Applied to Varicella Outbreak. Epidemiol Infect, 136(5):679-687
Guris D, Jumaan AO, Mascola L, Watson BM, Zhang JX, Chaves SS, Gargiullo P, Perella D, Civen R, Seward JF, 2008. Changing varicella epidemiology in active surveillance sites—United States, 1995-2005. J Infect Dis, 197(Suppl 2):S71-5.
Harpaz R, Orstega Sanches IR, Seward JF, 2008. Prevention of herpes zoster. Recommendations of the advisory Committee on Immunization Practices (ACIP),
National Centre for Immunization Research and Surveillance (NCIRS) Fact Sheet, 2009. Varicella-zoster (chickenpox) vaccines for Australian Children. Available on http: www.ncirs.edu.au (accessed on 12th December, 2012).
Obeng-Denteh W, 2011. Modelling students' affinity for pure mathematics using differential equations: The case of students of Kwame Nkrumah University of Science and Technology. Cont J Appl Sci, 6(2):34-40.
Obeng-Denteh W, Kodua-Nana O, Owusu AS, Kwame AR, Quashie NA, 2012. Modelling students' affinity for lecture attendance using differential equations: The case of students of Kwame Nkrumah University of Science and Technology. Br J Educ Soc Behav Sci, 2(4):389-401.
Ofori MM, 2011. Mathematical modeling of the epidemiology of varicella. Kwame Nkrumah University of Science and Technology Kumasi, Ghana.
Providential Aid Organization, 2012. Rural Health and Education Programme. Available on http: www.pao-gh.com (accessed on 21st December, 2012).
The Ghanaian Times, 28th September 2008. Available on www.ghanhealthservice.org/articles (accessed on 3rd November, 2012).
The Health Sector in Ghana, Fact and Figures, 2010. Available on http; www.moh-ghana.org (accessed on 4th November, 2012).
Van Den Driessche P, Watemough J, 2002. Reproduction number and sub-threshold endemic equilibria for compartmental models. Math Biosci, 180:29-48.