Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 4(1): 73-76
© Scholarlink Research Institute Journals, 2013 (ISSN: 2141-7016)
jeteas.scholarlinkresearch.org

Estimating the Proportion of a Community Infected by a Contagious Disease

[1]R. A. Adeleke and [2]S. O. Olagunju

[1]Department of Mathematical Sciences,
Ekiti State University, Ado-Ekiti.
[2]Department of Mathematics,
Adeyemi College of Education, Ondo.

Corresponding Author: R. A. Adeleke

Abstract

We earlier considered a stochastic model for estimating the velocity and acceleration of spread of a (contagious) disease in any community when given the initial susceptible population and previous short-period infection record. This paper considers the estimation of the proportion of the community that may have been infected at a point in time. This need arises with the view to estimate the needed space and materials that will be required, given the need to relocate the citizens, as well as ascertaining the expected speed of action necessary in curtailing such a disease. With the fact that we already estimated the velocity and acceleration of spread, and bearing in mind that victims are randomly selected, the purpose of this paper is to estimate the proportion of the community that has been infected as this will be useful in determining the need to relocate the remaining citizens or just cleansing their existing abode, and the urgency with which such actions should be carried out. This brings into focus the need for a justified model for the estimation of the proportion the community infected as illustrated using existing data.

Keywords: stochastic model, proportion, velocity, acceleration, contagious diseases, infection record.

INTRODUCTION

In some earlier publications, we discussed that diseases are disorders which adversely affect Human or Animal health, thereby causing reduction in productivity, resulting in economic disorder. Going by Sikorski and Peters (2008), some diseases are infectious while others are not. While infectious diseases are usually caused by agents such as bacteria or viruses which penetrate into the body's natural defense mechanisms after contacting an already infected human or animal, non-infectious diseases are caused by factors such as diet, environment, injury or heredity;. Infectious diseases include Cholera, Tuberculosis, Measles, HIV/AIDS, Gonorrhea, etc. [Barlett (1960) and Anderson (1992)]

In another focus, Kannan (1979) explained that objects, processes or situations requiring study may be represented by symbols, diagrams, relations or combination of all these; and are referred to as Models. However, models, according to Olowofeso *et' al* (1997), are said to be mathematical, when translation of physical or chemical \situations into systems of Mathematical Symbols and Relations are involved; and are deterministic when dealing with situations based on certain laws and assumptions in order to predict their outcomes. This was supported by Olagunju *et' al* (2007), who further noted that when such situations are naturally random, such models are said to be Stochastic or Probabilistic.

Adeleke and Olagunju (2012a) had earlier observed that the estimation of level of spread of diseases will ease the process of estimating the volume of necessary medicare formula needed by a community that has been affected by a contagious disease for a period of time, since the medical officials already know the volume required by an individual, rather than embarking on door-to-door counting which could be cumbersome and economically unwise considering financial implication and time management.

In another paper, Adeleke and Olagunju (2012b) again observed that the medical officials would be more effective when they know the speed of infection and even its acceleration, which will spur them into aggressive action to avoid an out-of-control situation, which may require more hands and/or speedier action. Thus, formulae were derived for the said velocity and acceleration of spread.

Now, the need to make decision as to whether to relocate the affected community may come into focus, considering the enormity of the infection. This decision will easily be made if the proportion of the community infected is known. The knowledge of the proportion infected will also make easy, the decision concerning the needed space (shelter) and materials. Thus, the focus of this paper is obtaining a formula that will easily estimate the proportion of the community infected.

The Considered Estimating Model for the Spread, Velocity and Acceleration of Infection

From an earlier discussion, Adeleke and Olagunju (2012a), through the use of Generating Functions (*G.F*), obtained an equation of the form $P\frac{\partial \phi}{\partial x} + Q\frac{\partial \phi}{\partial y} = R$ with auxiliary equations $\frac{dx}{P} = \frac{dy}{Q} = \frac{d\phi}{R}$.

This this kind of equation was obtained by considering the probability generating function

$$Y(z,t) = \sum_{N=1}^{\infty} P_N(t) z^N$$

The solution process led to a linear probability differential equation with auxiliary equations $\frac{dt}{1} = \frac{dz}{rz(1-z)} = \frac{dY}{0}$

This finally gave the solution as

$$Y(z,t) = \left(\frac{(1-z)}{z}\ell^{rt}\right) \quad (1)$$

This could be used to estimate the number of infected persons (Y) at a given time interval (t) if the rate of infection (r) (from history) and the initial population (z) are known.

This (1) was used to derive the formula to estimate the velocity of infection by differentiating (1) with respect to *t*.

Thus, velocity $V(z,t) = \frac{(1-z)}{z} r e^{rt}$ (1a)

Equation (1a) was later differentiated with respect to time in order to obtain the acceleration of spread. This led to the Acceleration of spread as

$$A(z,t) = \frac{(1-z)}{z} r^2 e^{rt} \quad (1b)$$

These equations were applied to certain existing Cholera, Malaria and Tuberculosis data, with their attendant graphs and interpretations.

Model for Estimating Proportion of Infection

As discussed in the introduction to this paper, Now, the need to make decision as to whether to relocate the affected community may come into focus, considering the enormity of the infection. This decision will easily be made if the proportion of the community infected is known. The knowledge of the proportion infected will also make easy, the decision concerning the needed space (shelter) and materials. Thus, the focus of this paper is obtaining a formula that will easily estimate the proportion of the community infected. Apart from the importance of decision on relocating and cleansing the abode of the victims, another importance of estimating the proportion that has been infected in such a community may also be that of taking steps to forestall the spread of the disease to the outside world. We note that such proportion is the ratio of the infected population to the total population. This implies

$$Infected\ \Pr oportion = \frac{Number\ of\ people\ Infected}{Total\ Number\ in\ Community}$$

since the infected number of individuals Y can be determined using $Y(z,t) = \left(\frac{(1-z)}{z}e^{rt}\right)$ (1)

Differentiating (1) with respect to *z*, we have

$$\text{Infected Proportion} = \frac{\partial Y(z,t)}{\partial z}$$

But $\frac{\partial Y(z,t)}{\partial z} = \frac{\partial}{\partial z}\left(\frac{(1-z)}{z}e^{rt}\right)$

Then, $\frac{\partial Y(z,t)}{\partial z} = -\frac{1}{z^2}e^{rt}$ (2)

Now, for the purpose of convenience,

Let $\frac{\partial Y(z,t)}{\partial z} = Q(z,t)$

Then, $Q(z,t) = \frac{e^{rt}}{z^2}$ (3)

Applying values for the parameters *z*, *r* and *t*; (noting that $r = \frac{Infected\ Population\ 'n'}{Total\ Population\ '\rho'} = \frac{n}{\rho}$), we have the estimated proportion of the community that were infected.

Illustration

Considering the Angola Cholera Data as obtained from the World Health Statistics (2011),

The population then = 18,498,000

The Infected Population = 2019

And Total Population = 18,498, 000;

Hence, historical rate of infection $r = \frac{2019}{18498000} \approx 0.00011$

So, given that exponential, $\ell = 2.7183$

> Q:=abs((e^(r*t))/(z^2));

$$Q := \left|\frac{e^{(r\,t)}}{z^2}\right|$$

> Q:=abs((e^((n/P)*t))/(z^2));

$$Q := \left|\frac{e^{\left(\frac{n\,t}{P}\right)}}{z^2}\right|$$

> Q:=abs((2.7183^((2019/18498000)*t))/(z^2));

$$Q := \left|\frac{2.7183^{\left(\frac{673}{6166000}\,t\right)}}{z^2}\right|$$

>

Q:=abs((2.7183^((2019/18498000)*60))/(z^2));[within 1hour]

$$Q := \frac{1.006570351}{|z|^2}$$

> eval(Q,z=18498000); $2.941674282\ 10^{-15}$

>
Q:=abs((2.7183^((2019/18498000)*1440))/(z^2));[within 1day]

$$Q := \frac{1.170197616}{|z|^2}$$

> eval(Q,z=18498000); $3.419870483\ 10^{-15}$

>
Q:=abs((2.7183^((2019/18498000)*43200))/(z^2));[1 month]

$$Q := \frac{111.6288025}{|z|^2}$$

> eval(Q,z=18498000); $3.262321180\ 10^{-13}$

>
Q:=abs((2.7183^((2019/18498000)*518400))/(z^2));[1 year]

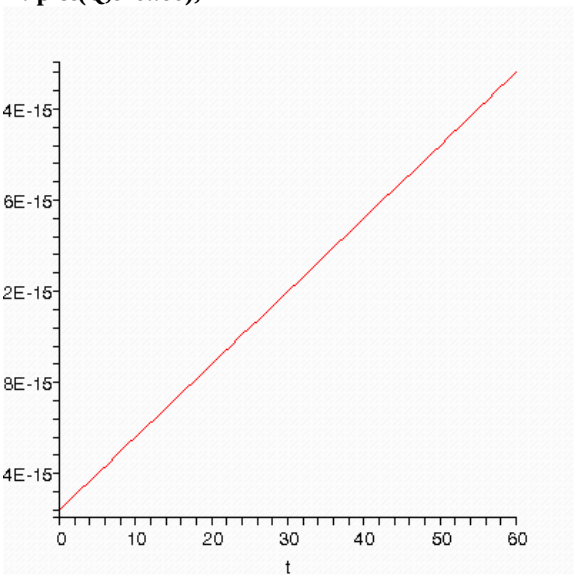
$$Q := \frac{3.743822000\ 10^{24}}{|z|^2}$$

> eval(Q,z=18498000); $1.094121726\ 10^{10}$

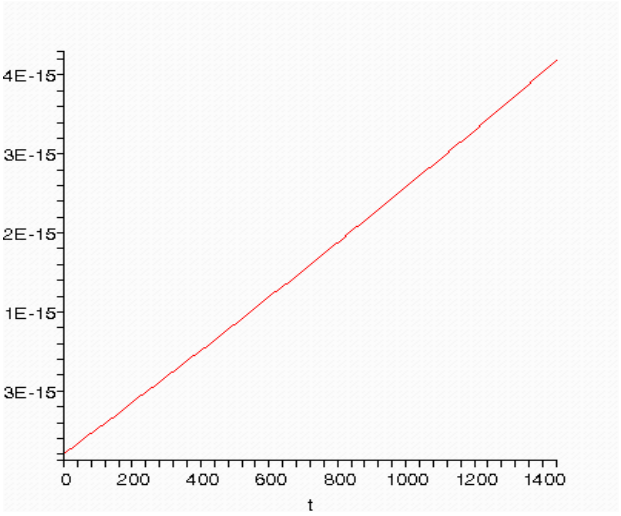
Implication: Considering the fact that the proportion of people catching the infection within 1 year is 1.0941 X 10^{10}, which is greater than the population of the considered community (i.e. 1.8498 X 10^{7}), it implies that the whole community would be ravaged within 1 year unless drastic actions are taken by the authorities.

Graphs

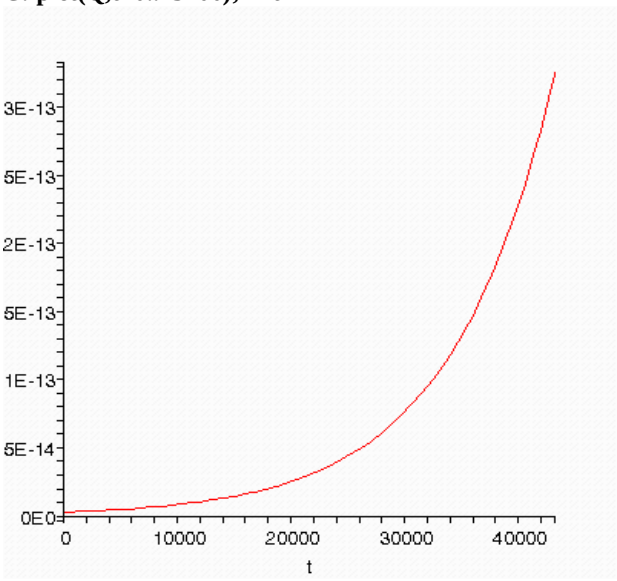
A: plot(Q,t=0..60);1hr



B: plot(Q,t=0..1440);1day



C: plot(Q,t=0..43200);1mth



Interpretation of Graphs

In graphs A and B, the Proportion of Infection rose steadily because the disease has not spread round the whole community. But we observe in graph C that given more time, the infection has gone round the community. Hence, the proportion infected rises sharply to a very high level. It is advisable that people should stay away from that community, and evacuation should be considered. Whoever will be treating them needs extra caution.

RECOMMENDATION

While very serious effort should be made towards providing remedy, using everything at their disposal, the authorities should relocate the yet-to-be-infected citizens in order to avoid economic paralysis and possible societal extinction.

REFERENCES

Adeleke, R. A. and Olagunju, S. O. (2012a) Determining Level of Spread of an Infectious Disease in a Given Community. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS), University of Newcastle, United Kingdom. 3(1). 98-102. (ISSN2141-7016)

Adeleke, R. A. and Olagunju, S. O. (2012b): Estimating Velocity and Acceleration of Spread of an Infectious Disease in an affected Community. Research Journal in Engineering and Applied Sciences (RJEAS), U.S.A. 1(6), 419-422. (ISSN2276-8467)

Anderson, Roy (1992) 'The Transmission Dynamics of Sexually Transmitted Diseases'. The Behaviour Components in Sexual Behaviour and Networking: Anthropological and Socio-Cultural Studies on the Transmission of HIV.23-48.

Barlett, M.S. (1960) Stochastic Population Models in Ecology and Epidemiology.Methuen, London. Elizabeth M. Bodner (2007) Microsoft ® Encarta Microsoft Corporation.

Kannan, D. (1979) 'An Introduction to Stochastic Processes.' North Holland Series in Probability and Applied Mathematics. Elsevier North Holland Inc, New Holland.

Mapple 9 Mathematical Package (as adapted)

Olagunju S. O., Bashiru, K. A. and Olowofeso O. E. (2007) Statistical Model for Estimating the Rate of Spread of Human Immune-Defeciency: A case study of Ondo Kingdom. Research Journal of Applied Sciences 2 (10):1025-1030. Medwell Journals, Pakistan. 1025-1030.

Olowofeso, O.E; Olabode, O and Fasoranbaku, A.O. (1997) 'Mathematical Modeling of Sexually Transmitted Diseases' Bulleting of the Science Association of Nigeria 21, 117-119.

Sikorski, R. and Peters, R. (2008). Human Diseaes. Microsoft Encarta.

UNESCO Institute for Statistics (2010) UNESCO Institute for Statistics Data Centre. Montreal. (http://stats.uis.unesco.org)

World Health Statistics (2011). Demograhic and Socioeconomic Statistics. Global Health Indicators II. 79-90, 151-161

APPENDIX: Some Available 2011 CountriesPopulationVsDiseases

Country	Cholera	Leprosy	Malaria	Measles	Mumps	Pertussis (Whooping Cough)	Rubella (German Measles)	Tuberclosis	Population ('000)
Afg'stan	**662**	**52**	**386929**	**2861**	**-**	**0**	**501**	**25417**	**28150**
Angola	**2019**	**937**	**2221076**	**2807**	**0**	**1127**	**10**	**41221**	**18498**
Benin	**74**	**248**	**1256708**	**1461**	**-**	**-**	**15**	**3878**	**8935**
Burundi	**355**	**280**	**1757387**	**305**	**0**	**0**	**305**	**7277**	**8303**
Chad	**67**	**484**	**182415**	**165**	**-**	**-**	**3**	**8411**	**11206**
China	**85**	**1597**	**14491**	**52461**	**299329**	**1612**	**69860**	**965257**	**1353311**
Congo	**93**	**145**	**92855**	**1**	**0**	**0**	**11**	**9765**	**3683**
DrofCong	**22899**	**5062**	**6749112**	**57**	**-**	**830**	**110**	**112222**	**66020**
Ethiopia	**31509**	**4417**	**3043203**	**1176**	**-**	**-**	**-**	**148936**	**82825**
Ghana	**1294**	**623**	**1899544**	**101**	**-**	**-**	**133**	**14892**	**23837**

Sources:
WHO/World Health Statistics (2011).
www.who.int/entity/glo/publications/world_health_statistics/en/index.html
CIA World Factbook(2012). www.worldatlas.com/aatlas/populations/ctypopa.htm
List of Contagious Diseases (2011). www.unp.me/f150/list-of-contagious-diseases-107199