GEOGRAPHICALINFLUENCE ON CONTROLLED RATE OFINFLUENZA AH1N1 (SWINE FLU) IN INDIA

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Abstract : Influenza AH1N1 is a highly infectious pathogen. It is threatening to people's life because it spreadseasily, and its impact is more dangerous, especially in India. In this paper, an initial mathematical epidemic model for the evolution of swine flu (H1N1) infected people of different size population has been established. This represents the involvement of different rates based on varied assumptions. Governing and authorized bodies take necessary actions to control the spread of disease; they implement the prevention policies to secure and aware people. These statistical data are used to estimate some parameters of the model in different states of India and in different time-periods for better understanding of the situation and possible solutions.

Keywords
Influenza A (H1N1), Mathematical epidemic modelling, SIR epidemic model, Basic reproduction number, Controlled rate.

1.INTRODUCTION

As per the records of history and present situations, the increase in spread of infectious diseases as pandemics has become a huge concern and of great threat to human health. An epidemic is any sudden outburst of a disease within a given population and a pandemic is an epidemic that spreads across regions, which could be countries, continents or the whole world.

Of the various epidemics that have occurred throughout the history, one such epidemic is the Influenza. There are mainly three types of influenza, namely, Influenza A, Influenza B and Influenza C. Influenza of type A and type B are more prevalent in human population and are of particular public health concern. Influenza A has many subtype strains, e.g. H1N1, H2N2, H3N2, etc.

In this paper we focus on H1N1 subtype which is currently circulating in human population and is known as Swine Flu. In the 21st century, Swine flu has emerged as a deadly infectious disease. Influenza is a contagious disease spreading from person to person by means of large respiratory droplets, either directly by droplets that are expelled as a result of sneezing or coughing or indirectly by getting in contact with the droplets which could result from touching the nose or mouth of the victim. This disease is transmitted to susceptible individuals by inhalation or ingestion of these infected droplets containing virus.

2.HISTORIC OUTBREAK

In 16^{th} century in Europe, several outbreaks of influenza were found but the most destructive outbreak of influenza happened in 1918-1919 regarded as 'Spanish flu'. The H1N1 A virus was responsible for this. The epidemic is believed to have resulted in 50 millions to 100 million deaths worldwide. Then there were Asian flu of 1957-1959 and Hong flu in 1968- 1970 both claimingover one million and 700,000 lives, respectively.

The recent outbreak of the influenza happened in the year 2009. This was also caused by the subtype H1N1 A virus. It emerged in March 2009 in Mexico. The H1N1 virus spread rapidly throughout the world. The WHO(World Health Organization) on June 11, 2009 announced the first ever influenza pandemic of the 21st century.

The disease started in India in May 2009 and the first laboratory confirmed case was reported from Hyderabad on 16^{th} May 2009. Soon the disease spread to other parts of the country. The WHO declared H1N1 post- pandemic on 10^{th} August 2010. The pandemic influenza A H1N1 virus is now circulating as seasonal influenza A H1N1 virus.

Recently in 2015 an outbreak of swine flu (H1N1 Virus) was reported in India, which was similar to 2009 influenza pandemic. This outbreak was reported in late 2014 and early 2015. In March 2015, health ministry realised a data and according to this data 31,974 people had been reported infected and 1895 persons had died.

At present, an increase in seasonal influenza has been observed in many states of India. To bring these pandemic in control mathematical epidemic modelling plays an important role. Sowe have carried out a retrospective descriptive study in order to study the epidemiology and establish the magnitude and severity of recent influenza A H1N1 outbreak in India with the help of mathematical modelling.

3.MATHEMATICAL EPIDEMIC MODELLING

Role of mathematical modelling in epidemics is to providea solution which will help in understanding the complexities of infectious diseases and also in controlling them. Mathematical epidemiology refers to modelling for the transmission of pandemic and its spread.

'W.O. Kermack' and 'A.G.McKendrick' published the first paper on mathematical epidemic theory in 1927. In thisparticular paper, they used a very simple deterministic SIR (Susceptible-Infected-Recovered) model .

4.EPIDEMIOLOGY AND EPIDEMIC MODELS

Epidemiological mathematical modelling helps in understanding of mechanisms which influence the spread of the disease as an epidemic. It suggests strategies that could beadopted to control the spread, to construct mathematical models reflectingthe dynamic properties of infection disease, to analyze the dynamic behaviour and todo some simulations.

Basic SIR model is used, which relies on three epidemiological classes S(t), I(t), and R(t).The simplest SIR model of Kermack and Mckendrick computes the theoretical number of people infected with contagious illness in a closed population over time. Transmission of a disease is a dynamical process driven by the interaction between susceptible and infective. The behaviour of the SIR models are greatly affected by the way in which transmission between infected and susceptible individuals are modelled.

Susceptible **S (t)**: the persons in population who are not infected but may become infected
Infected **I(t)**: the persons in population infected by the Swine flu(H1N1)
Recovered **R (t)**: the persons in population who was infected but now they are free from Swine flu(H1N1).
Population of Susceptible S (t) transits in infected population I (t) with rate **α**.
Population of infected person I (t) transits in recovered population R (t) with rate **β**.
Total population is N (t) = S(t) + I(t) +R(t)
and we assumed Υ is birth rate which is independent from time as well as natural death rate d. Transmission rate α is dependent on susceptible population S(t) as well as infected population I(t).Here we assume that newborn has probability to be healthy is 1. Death rate caused by Swine flu (H1N1) with rate δ. All persons in susceptible population S (t) have probability to be infected are equally likely.

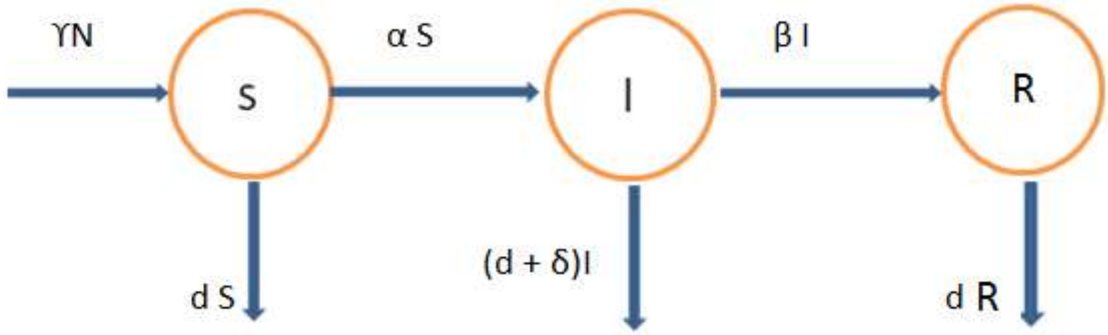


Fig.4.1. Compartmental model of the Swine flu (H1N1) disease on population

With above assumptions, an epidemiological Mathematical model for Swine flu (H1N1) is following linear system of ordinary differential equations.

N (t) = S (t) + I (t) + R (t), (1)

S' (t) = ϒ N (t) – d S (t) – α S (t), (2)

I' (t) = α S (t) – (d +δ) I (t) – β I (t), (3)

R' (t) = β I (t) – d R (t), (4)

here I (t), S(t) and R(t) denotes the three subpopulations at time t. This mathematical model is used for estimate parameters related to Swine flu (H1N1). This mathematical model is used for estimating parameters related to Swine flu (H1N1).

Scaling the model

Now after differentiating equation (1)w.r.t. t

we have, N' (t) = S' (t) + I' (t) + R' (t),

=>N' (t) = ϒ N (t) – d S (t) – (d + δ) I (t) – d R (t)

=>N' (t) = ϒ N (t) – d S (t) – d I (t) – δ I (t) – d R (t)

=>N' (t) = ϒ N (t) – d N (t) – δ I (t)

Therefore N' (t) = (ϒ – d) N (t) – δ I (t) (5)

Dividing both sides of (5) by N,

We have N'/N = (ϒ – d) – δ I (t)/N (t). (6)

Now we define the following. s = S / N, i = I/ N, r = R / N, (7)

By equation (6) we get, N'/ N = ϒ – d – δi. (8)

We have s = S / N

=> s' = (S'N –SN')/N^2 = S'/N – SN'/NN = S'/N – s(ϒ – d – δi) (9)

And similarly,

i' = (I'N –IN')/N^2= I'/N – IN'/NN = I'/N – i (ϒ – d – δi) (10)

and

r' =(R'N –RN')/N^2= R'/N – RN'/NN = R'/N – r (ϒ – d – δi). (11)

Now consider equation (2) and divide both the sides by N,

=> S'/N = ϒ – d S/N – α S/N, (12)

By (9) we s' = S'/N – s(ϒ – d – δi)

=>s'= ϒ – d S/N – α S/N-s(ϒ – d – δi)

=>s'= ϒ – s(t) (ϒ + α – δi(t)). (13)

Similarly, using (3)

I' (t) = α S (t) – (d +δ) I (t) – β I (t), Dividing both sides by N we get,

I' /N = α S (t)/N – (d +δ) I (t)/N – β I (t)/N, and by (10)

i' (t)= I'/N – i (ϒ – d – δi)

We have

- ⇨ i' (t) = α S (t)/N – (d +δ) I (t)/N – β I (t)/N -i (ϒ – d) +δ i^2
- ⇨ i' (t) =α s(t) – i(t)(β + ϒ + δ – δ i(t)), (14)

Now considering equation (4)

R' (t) = β I (t) – d R (t),Dividing both sides by N we get,

R'/N= β I (t)/N – d R (t) /N and by using (11)

r' = R'/N – r (ϒ – d – δi).

$r' = \beta I(t)/N - d R(t)/N - r(\Upsilon - d - \delta i)$.

⇨ $r'(t) = \beta i(t) - (\Upsilon - \delta i(t)) c(t)$, (15)

As we considered in the beginning

N (t) = S (t) + I (t) + R (t),dividing this by N on both the sides

1 = S (t)/N + I (t)/N + R (t)/N,

⇨ 1 = s(t) + i(t) + r(t) by (7) (16)

This show that after scaling the model has been transformed into a nonlinear we have

s (t) + i (t) + r (t) = 1,

⇨ r (t) = 1- s (t) + i (t) if we consider there is no infective initially i. e. i(0) = 0

⇨ r(t) = 1-s(t) = 0

So we can eliminate r(t) and consider the system.

$s' = \Upsilon - s(t)(\Upsilon + \alpha - \delta i(t))$

$i'(t) = \alpha s(t) - i(t)(\beta + \Upsilon + \delta - \delta i(t))$.

The severity of the epidemic, the initial rate of increase and the feasibility of controlling an epidemic critically depends upon the value of the Basic Reproduction Number (R_0). R_0 is defined as the average number of new infections that one case generates, in an entirely susceptible population; during the time they are infectious. If $R_0 > 1$,an epidemic will occur and if $R_0 < 1$, the outbreak will die out.

The value of R_0 for any specific epidemic can be estimated by fitting the SIR model to incidence data collected during the initial exponential growth phase. The value of R_0 may also be calculated retroactively from the final size of the epidemic. If the SIR model is used, R_0 for influenza is equal to the infectivity/transmissibility of the strain (β) multiplied by the duration of the infectious period. Therefore, once the value of R_0 has been obtained, the value of β can be determined.This means the feasibility of controlling an epidemic will critically depend on the value of the R_0.

The parameters of the model α and β are unknown and to calculate them we need to check about the stability and simulation of the model .As our objective of the paper is to know about the control rate in different states of the India over a 2012 to 2019.

So variables and parameters of model:

Variable	**Description (at time 't')**
S(t)	Susceptible
I(t)	Infected
R(t)	Recovered
Parameter	**Description (per day)**
ϒ	birth rate or input rate
A	Transmission rate
D	natural death rate
Δ	Death rate caused by Swine flu (H1N1)
B	Recovery rate coefficient

5.DISCUSSION

Let us look into the data about different states of India in which number of reported cases of Swine flu (H1N1) are high over the time period of year2012- 2019. Based on the released data by the Health Ministry (6), wecan calculate percentage of controlled rate from the reported cases.

Table 5.1

Percentage of controlled rate in different states with high reported cases during 2012-2019

State	Reported cases	Number of deaths	Percentage of controlled rate
Delhi	12,301	62	99.4959759
Gujarat	22,119	1,488	93.2727519
Karnataka	10,650	295	97.2300469
Kerala	4147	241	94.18857
Maharashtra	20,258	2524	87.5407246
Madhya Pradesh	3949	683	82.7044821
Rajasthan	18,638	1421	92.3757913
Tamilnadu	8228	146	98.2255712
Uttar Pradesh	7074	229	96.7627933

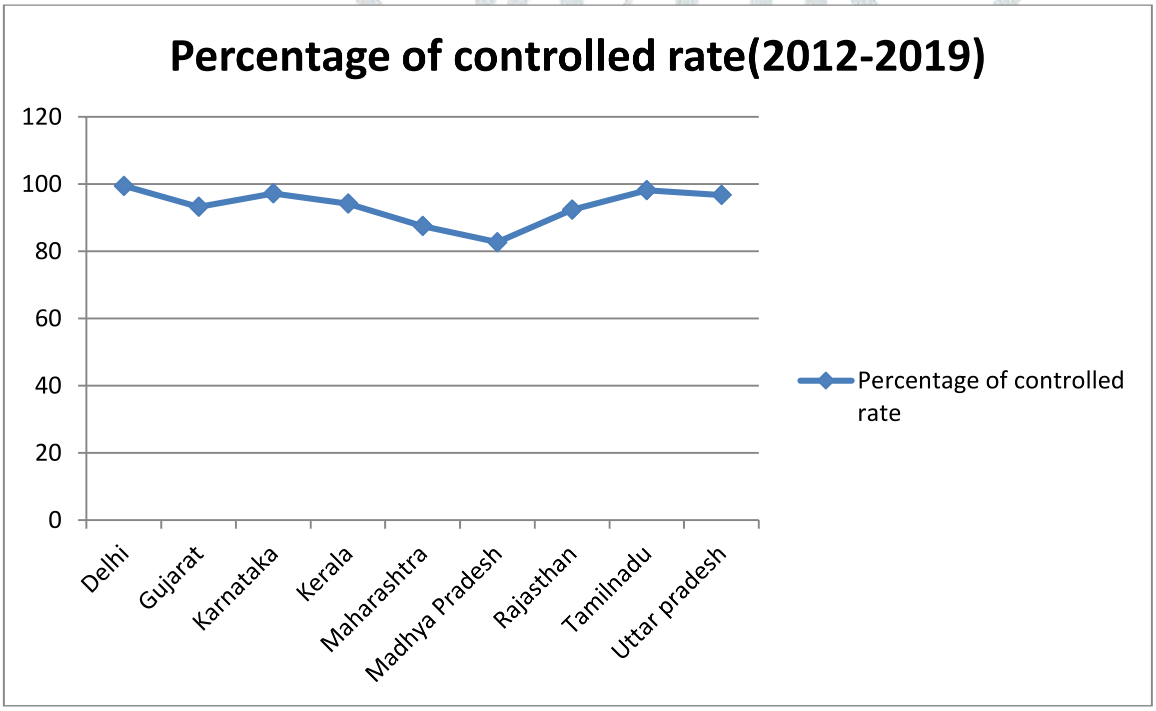


Fig. 5.1: Percentage of controlled rate from reported case in few states of India. It is more than 83% over a period of 7 years.

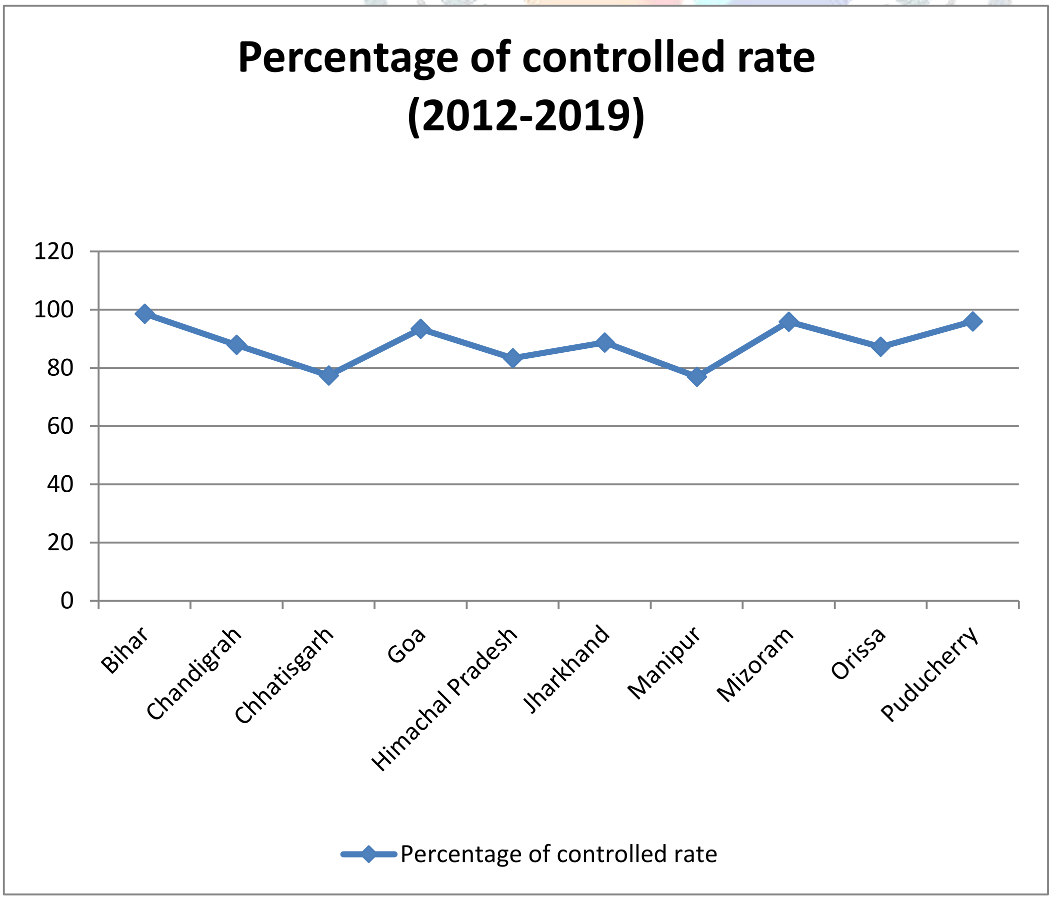
Let us discuss about states in which number of reported case are low of Swine flu (H1N1). As per the released data by the Health Ministry, we can calculate percentage of controlled rate out of reported.

Table 5.2

Percentage of controlled rate in different states with low reported cases during 2012-2019

State	Reported cases	Number of deaths	Percentage of controlled rate
Bihar	414	6	98.55072464
Chandigarh	181	22	87.8453038
Chhattisgarh	636	144	77.3584905
Goa	555	37	93.33333333
Himachal Pradesh	496	83	83.266129
Jharkhand	97	11	88.6597938
Manipur	13	3	76.9230769
Mizoram	24	1	95.8333333
Orissa	602	77	87.2093023
Pondicherry	614	25	95.9283387
Assam	257	10	96.10894942
Meghalaya	3	1	66.66666666

Fig. 5.2:Percentage of controlled rate from reported cases across different Indian states. The minimum controlled rate is approximately



80%.

Let us look at the controlled rate of Swine flu Cases report (2012-2019) of India .In this report, year wise number of reported case (positive case) and the number of death caused by Swine flu (H1N1) is presented.

Table 5.3

Percentage of controlled rate during 2012-2019

Year	Reported cases	Number of deaths	Percentage of Controlled rate
2012	5044	405	91.9706582
2013	5253	699	86.6933181
2014	937	218	76.7342582
2015	42592	2990	92.9799023
2016	1786	265	85.162374
2017	38811	2270	94.1511427
2018	14992	1103	92.26427428
2019	17366	530	96.9480594

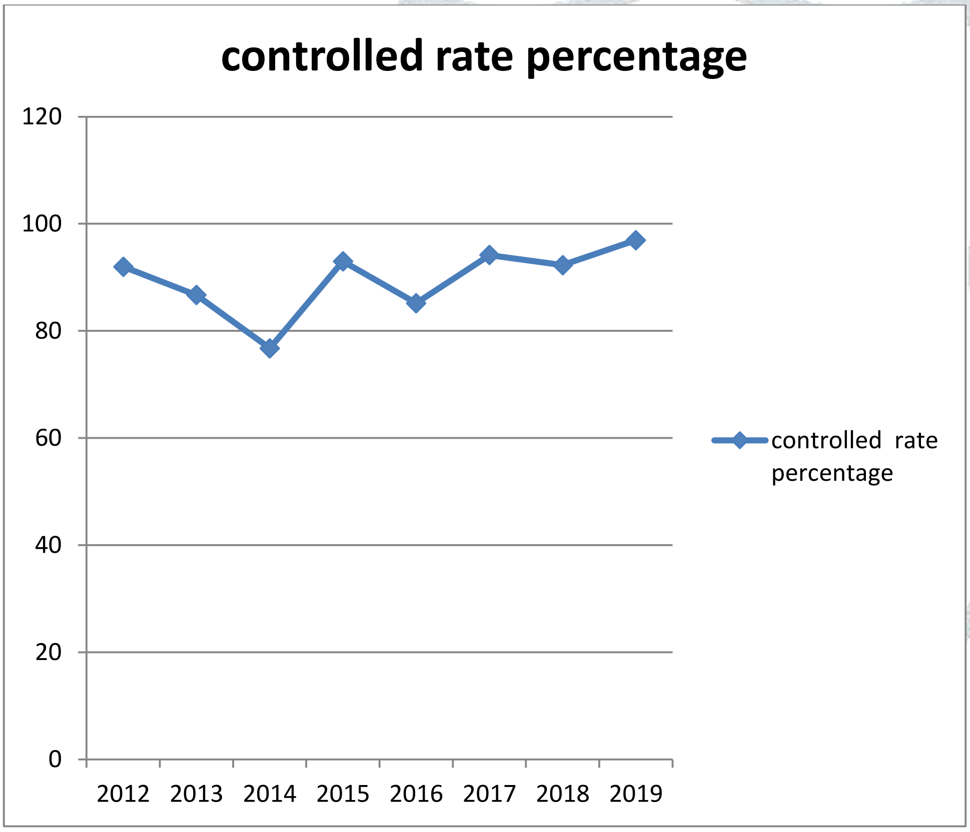


Fig. 5.3: Controlled rate percentage from 2012-2019. 2014-15 has low values of controlled rate but with the corrective and vigilant actions with the time that has grown up and it is more than 90 % in 2018 and 2019.

Now let us look at the recent data of 2018-2019 for different states of India in which number of reported casesof Swine flu (H1N1)is high. After calculating the percentage of controlled rate on the reported cases we reached to the following findings.

Table 5.4

Percentage of controlled rate in different states with high reported cases during 2018-2019

State	Reported cases	Number of deaths	Percentage of controlled rate
Delhi	3339	9	99.7304582
Gujarat	5572	204	96.338837
Karnataka	2412	86	96.4344942
Kerala	1087	58	94.6642134
Maharashtra	3140	488	84.4585987
Rajasthan	6692	368	94.5008965
Tamilnadu	3048	44	98.5564304
Telangana	1748	40	97.7116704
Uttar Pradesh	1292	23	98.2198142

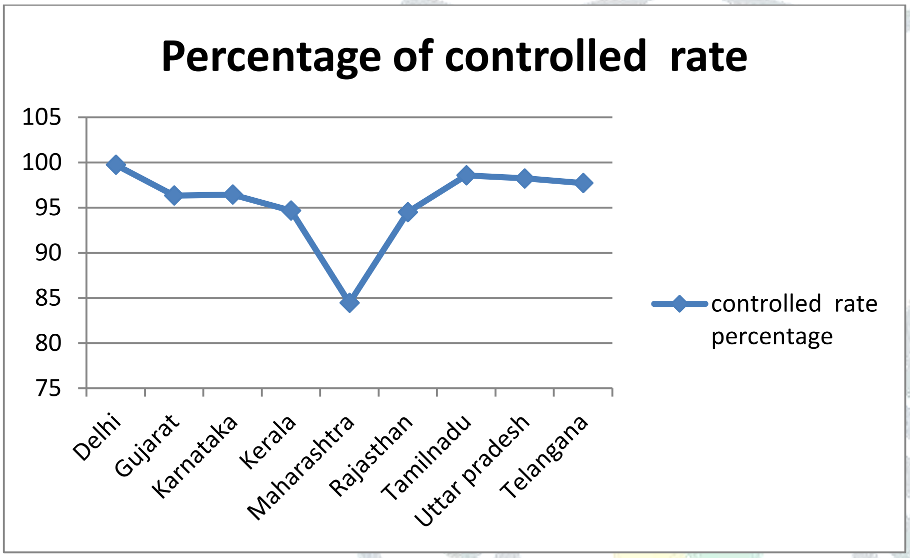


Fig.5.4: Percentage of controlled rate from reported case in few Indian states. It is more than 84%.But Maharashtra and Rajasthan states need more precautionary measures.

Similarly, now let us discuss about states in which number of reported case are low of Swine flu (H1N1) over the time period of year 2018- 2019.

Table 5. 5

Percentage of controlled rate in different states with low reported cases during 2018-2019

State	Reported cases	Number of deaths	Percentage of controlled rate
Assam	27	1	96.2962963
Chandigarh	51	4	92.1568627
Chhattisgarh	75	19	74.6666666
Goa	86	5	94.1860465
Jharkhand	45	2	95.555555
Orissa	109	10	90.825688
Uttarakhand	135	7	94.8148148

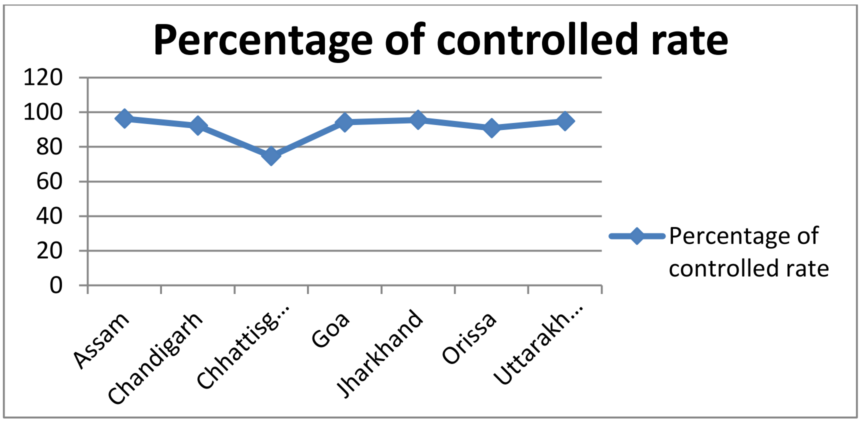


Fig. 5..5 Percentage of controlled rate from reported case in few Indian states, which is approximately 75%.

6.CONCLUSION

This study emphasizes an understanding of Mathematical modelling as a valuable tool to observe the dynamics of an epidemic, planning and evaluating treatments and included the researches done across multiple geographical locations of India. Here we calculated the percentage of controlled rates based on the data of reported cases in various categories,according to the data released by the Health Ministry.

For all the reported cases between 2012-2019 in different states, where the number of reported cases was high, we observed that the percentage of controlled rate is more than 83%. States in which number of reported case are low of Swine flu (H1N1), if we calculate percentage of controlled rate out of reported case that is near to 80.

Fig. 3 represents controlled rate percentage in different years from 2012 to 2019.comparatively the controlled value percentage is low during 2014-2015 then gradual increase has been observed which indicates sufficient corrective actions were taken. It looks almost hundred percent during 2018-2019.

Therefore further detailed investigation is represented for year 2018- 2019 for different states of India.For all the cases between 2018-2019 in different states where the number of reported cases were high, the percentage of controlled rate is more than 84 percentages and is near 75 percentages when cases of low swine flu reported states are considered.

So, based on the above results, we can conclude that the controlled rate of H1N1 is different in some states as compared to other states. This can be due to difference in geographical conditions, fluctuating weather, population density, climate, different lifestyle of people at different places etc. It is understood that more precautionsand focused medical attention are required where the percentage of controlled rate is lower.

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