

## Predicting dengue outbreak in the metropolitan city Lahore, Pakistan, using dengue vector indices and selected climatological variables as predictors

Ejaz Mahmood Ahmad Qureshi,<sup>1</sup> Amtul Bari Tabinda,<sup>2</sup> Seemal Vehra<sup>3</sup>

### Abstract

**Objective:** Dengue viruses have rapidly spread in Southeast Asia, particularly in Pakistan, during the last few years, so the present study was undertaken to formulate a model for predicting dengue outbreak.

**Methodology:** A panel data using STRATA statistical software was employed to determine the effects of entomological indices, Per Man Hour Density (PMHD), Minimum Infection Rate (MIR) and selected climatic variables on dengue patients by using Fixed Effects (FE) and Random Effects (RE) models.

**Results:** Results showed that R2 value, reflecting fitness of model was 0.3026 in FE model and 0.3028 in RE model, while the Coefficient and P [Z] values in RE model, indicating individual fitness of any variable in the model, revealed that PMHD, MIR, Air Temperature and Relative Humidity had positive impact on the number of dengue patients, while rainfall exhibited negative impact.

**Conclusion:** For every 10 unit rise in PMHD, MIR, atmospheric temperature and relative humidity, the number of patients increased by 4.01, 15.88, 3.10 and 5.73, respectively, while an increase in rainfall by 10 mm will result in decrease in the number of dengue patients by -1.01. Further analysis of socioeconomic and demographic variables of participants is suggested.

**Keywords:** Fixed Effects and Random Effects models, Per Man Hour Density, Minimum Infection Rate. (JPMA 67: 416; 2017)

### Introduction

Dengue is a human arboviral disease transmitted by the female mosquito of the genus *Aedes*, particularly *Aedes aegypti* and *Ae. Albopictus*.<sup>1</sup> It is considered to be the most frequent arthropod-borne disease, prevalent in tropical and subtropical regions of the world but recently its incidence has increased in temperate zones as well. Nearly 2.5 billion people in the world are at risk of this disease as they are living in the dengue endemic areas; 50 - 100 million people are affected from this disease annually. Human mortality rate due to this disease is also alarming with nearly 20,000 deaths each year.<sup>2</sup>

In Pakistan, dengue cases were first reported from port city Karachi in 1980s. Although Dengue virus has been endemic in all provinces but till 2011 only a few sporadic cases were reported from some cities of Pakistan like Peshawar, Haripur, and Abbotabad. The first large-scale epidemic was observed in 2011 in the Punjab Province, particularly in its capital city of Lahore where more than 21,000 dengue-positive cases and 279 deaths were reported.<sup>3-6</sup>

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<sup>1</sup>Department of Environmental Health, Institute of Public Health, <sup>2</sup>Sustainable Development Study Centre, Government College University, <sup>3</sup>Department of Botany, Government Post Graduate College for Women, Lahore, Pakistan.

**Correspondence:** Ejaz Mahmood Ahmad Qureshi.

Email: ejaz\_qureshi@hotmail.com

Although epidemiological and dengue vector surveillance systems existed in the metropolitan city of Lahore, no comprehensive effort has been made, thus far, for the prediction and forecasting of dengue disease. In view of the endemicity and ever-increasing number of dengue cases in this part of the world, it is imperative to formulate a prediction model that could warn about the eruption of disease before it reaches epidemic proportion and enables the dengue control authorities to get ready for emergency ahead of the time. This would also give the field staff ample time to focus their efforts on areas with highest probability of being affected. Moreover, hospitals serving the expected/potential epidemic area could be given high alert signal for making necessary preparation before hand to handle the emergency.<sup>7</sup>

Numerous studies undertaken in South East Asia and South America have advocated the use of meteorological data for dengue outbreak prediction.<sup>8</sup> A directly proportional relationship was found to exist between temperature and incidence of dengue cases in Thailand, Indonesia, Singapore, Mexico and Puerto Rico.<sup>9-14</sup> Similar relationship existed between relative humidity and elevated levels of dengue incidence in Taiwan,<sup>15</sup> while relationship of increased rainfall with dengue cases has been discussed in studies undertaken in Indonesia, Trinidad, Venezuela, Barbados and Thailand.<sup>9,16,17</sup>

Dengue outbreak prediction model should have the

following characteristics: it should quantify relationship of dengue patients with environmental, climatic and vector variables; it should focus on collection of essential continuous data, recorded at regular intervals i.e., weekly or monthly.<sup>18</sup> Integration of climatic variables, such as air temperature, relative humidity and rainfall with vector indices can increase the predictive power of the model.<sup>19,20</sup> These models can predict outbreak of the disease few weeks or months ahead of outbreak.<sup>21,22</sup>

The present study is an attempt to develop a model based on entomological and viral serotype surveillance data since vector surveillance cannot be declared successful unless and until viral surveillance is carried out along with climatological data. This research was an effort to collect such data from all towns of Lahore during 2011, 2012, and 2013.

The main objective of this study was to formulate a prediction model, based on entomological vector indices and climatic variables which could be used to predict the occurrence of dengue epidemics. As dengue can be predicted by entomological and viral surveillance along with climatic data of a particular area, vector indices like Ovitrap Index (OI) and Per Man Hour Density (PMHD) used for entomological surveillance were included in the study. Similarly, Minimum Infection Rate (MIR), used for viral surveillance, was also included. A panel data was employed to find out the effect of independent variables (OI, PMHD, MIR and climatic variables like temperature, relative humidity and total rainfall) on depended variable (Dengue patients) by using Fixed Effects (FE) and Random Effects (RE) Models.

## Material and Methods

### Study Site

The study was conducted in 10 towns of the metropolitan city of Lahore, laying between 31°15'-31°45' N and 74°01'-74°39' E and supporting a population of more than 11 million within a land surface area of 1,172 km<sup>2</sup>. Lahore is one of the most densely populated cities in the world. It is marked by a number of localities with minimal or no civic amenities, resulting in heaps of garbage, open drains, vacant land plots with collection of debris and stagnant water in almost all ten studied towns. Lahore has a semi-arid climate, the hottest month being June, when average air temperature can exceed 40°C (104.0°F). The monsoon rains start in late June, and the wettest month is July, with heavy rainfall, while the coolest month is January with dense fog.<sup>23</sup>

### Duration of Study

This study was carried out from July to December each year during 2011, 2012, and 2013.

## Data Collection

Data of dengue suspected patients (those suffering from fever with at least two symptoms, such as headache, backache, pain in bones and joints, retro-orbital pain, rash, haemorrhage) was recorded. These patients were followed for Blood Complete Examination and those with reduced White Blood Cells and Platelets were subjected to Dengue Test (IgM and IgG Antibodies ELISA) by a commercially available device, the SD BIOLINE Dengue combo (Standard Diagnostic Inc., Korea). Patients with positive dengue test (either IgM, IgG or both) were declared dengue confirmed patients and were included in the study. All serological positive patients irrespective of IgM, IgG or both were also included in this study.

In addition to this, adult mosquito density was recorded from houses of dengue patients and nearby places where mosquito ovitraps were placed. These houses [10 in each of 5 Union Councils (UC), in every town] were selected for placing ovitraps by adopting the following method: After arriving at a UC site, first house was selected randomly and was labelled as House 1, thereafter the second house was selected by walking 50 meter in the direction of tip of a pencil thrown overhead. In this manner, 10 houses were selected in all sampled UCs. The house which was not available (locked or where the dwellers were not cooperative or did not allow the surveillance team to enter) was rejected and the very next house to it was selected. Adult *Ae. aegypti* were captured from these houses and from the immediate vicinity of these houses by using mechanical backpack aspirator. Blood of suspected dengue patients and adult mosquitoes pools (7 - 8 mosquitoes/pool) were sent to the Entomology Laboratory at the Institute of Public Health, Lahore, for confirmation by NS1 Antibody (IgM and IgG) ELISA for dengue patients and NS1 Antigen ELISA in mosquitoes (Bio-Rad Laboratories) to determine their infectivity.<sup>24</sup>

Data of ecological and environmental variables were collected at each site while climatological data (cumulative rainfall in mm, relative humidity in percentage and mean temperature in °C) in the study area during the entire study period were collected from the local meteorological office.

## Data Analysis

Descriptive Analysis was carried out to determine Mean ± SD by using software SPSS, version 19. A multiple regression analysis was performed using a panel data set by STATA statistical software analysis package, version 13 to formulate prediction model. In this model, effect of independent variables (PMHD, MIR, and climatological variables of adult mosquitoes) on the depended variable

(dengue patients) was elucidated by using FE and RE models with the help of following equation:

$$\text{Dengue patients} = a + \beta_1\text{PMHD} + \beta_2\text{MIR} + \beta_3\text{Temperature} + \beta_4\text{Humidity} + \beta_5\text{rainfall}$$

### Ethical Consideration

Formal permission from the Ethical Committee of the Sustainable Development Study Centre, Government College University, Lahore, was sought before conducting the study. Verbal consent of the residents was taken from the households where immature and mature forms of mosquitoes were collected. Confidentiality of the data was assured.

### Results

During 2011, a total of 5288 dengue patients were reported in 5 UCs each of all 10 towns of Lahore city, while average PMHD and MIR was 88.39 and 1.83, respectively during this period. In 2012, no dengue patient was reported while average PMHD and MIR were 60.92 and 1.34, respectively. In 2013, 256 dengue patients were reported and average PMHD and MIR were 84.10 and 1.65, respectively.

Descriptive analysis of dengue vector indices, infectivity rate and total dengue patients in different seasons during 2011, 2012 and 2013 is shown in Table-2.

### Prediction Model

A panel data using STATA statistical software was employed to elucidate the effect of entomological indices (PMHD, MIR) and climatological variables on dengue patients by using FE and RE models.

**Table-1:** Total number of dengue patients, PMHD and MIR in all studied towns of Lahore.

Variables	Years		
	2011	2012	2013
Dengue patients	5288	25	256
PMHD	88.39	60.92	84.10
MIR	1.83	1.34	1.65

PMHD: Per Man Hour Density. MIR: Minimum Infection Rate.

**Table-2:** Descriptive analysis of dengue vector indices, infectivity rate and total dengue patients in different seasons during 2011, 2012 and 2013.

Season	Mean $\pm$ SD			
	Ovitrap Index (OI)	Per Man Hour Density (PMHD)	Minimum Infection Rate (MIR)	Total Dengue Patients
Early rainy	0.44 $\pm$ 1.26	33.19 $\pm$ 37.68	0.65 $\pm$ 1.38	1.83 $\pm$ 6.25
Late rainy	4.76 $\pm$ 5.40	131.10 $\pm$ 61.59	2.74 $\pm$ 1.48	49.47 $\pm$ 86.09
Early post rainy	4.18 $\pm$ 4.79	130.41 $\pm$ 65.31	2.36 $\pm$ 1.62	32.84 $\pm$ 63.17
Late post rainy	0.72 $\pm$ 1.75	27.11 $\pm$ 38.62	0.32 $\pm$ .97	1.62 $\pm$ 2.98

**Table-3:** Impact (Regression analysis) of PMHD, MIR, air temperature, relative humidity, and rainfall on number of dengue patients by using FE model. Overall  $r^2$  Value = 0.3026.

Pts	Coefficient	z- value	P> [z]
PMHD	0.4229049	11.49	0
MIR	0.926407	0.64	0.522
Air temp.	0.2798934	0.96	0.339
Rel. humidity	0.5804953	2.92	0.004
Rainfall	-0.0997246	-2.57	0.01

Number of observations = 780. Number of groups = 10

F (5, 765) = 68.17

Probability > = 0.0000.

PMHD: Per Man Hour Density. MIR: Minimum Infection Rate.

**Table-4:** Impact of PMHD, MIR, air temperature, relative humidity and rainfall on number of dengue patients by using RE model. Overall  $r^2$  Value 0.3028.

Pts	Coefficient	z- value	P> [z]
PMHD	0.4013516	11.52	0
MIR	1.58831	1.17	0
Air temp	0.309617	1.06	0.289
Rel. humidity	0.5726182	2.89	0.004
Rainfall	-0.1010979	-2.61	0.009

Number of observations = 780. Number of groups = 10

Wald chi2 (5) = 336.28

Probability > = 0.0000.

PMHD: Per Man Hour Density. MIR: Minimum Infection Rate.

Impact of entomological indices (PMHD, MIR) and climatological variables on dengue patients by using FE and RE models were shown in Tables-3 and 4.

Hausman Test value (Prob > chi2) was 0.39. As this value was >0.1, decision of using RE Model was made.

### Discussion

This study revealed that the occurrence of the dengue disease like other infectious diseases is not symmetrical. The reasons could be an epidemic like situation with increased number of cases in 2011 (after a massive and widespread flooding in 2010 with formation of potential mosquito breeding places) in comparison to very low in 2012 and in 2013 (Table-1). Another reason was good

surveillance, improvement of sanitation and an effective anti-dengue awareness campaign along with insecticide spray in all towns in 2012 and 2013. Findings of this study are supported by the studies conducted by different researchers who reported that breeding habitats associated with dengue cases were strongly related with hygienic conditions of the area including inadequate drinking water supply and lack of drainage system, discarded bottles and used tyres where rain water was collected or stored.<sup>7,12,25,26</sup>

Seasonal variation in OI and PMHD in residences in all towns during 2011, 2012 and 2013 are shown in Table-2. Results indicate that OI value were the highest in the late and early post rainy seasons during all three sampling years, the reason being that during this period (33rd to 45th week of the year), ranges of climatic conditions such as air temperature (26.5-29.5°C), relative humidity (58.7-77%) and total rainfall (27.5-497.29 mm) were conducive for mosquito breeding. Moreover, water was abundant, vegetation/shade cover were extensive, outdoor places (parks) were not very clean and human activities near ovitrap placement sites was extensive. Consequently, ovitrap positivity was higher in such sites; As far as the adult density of the vector in early rain season, measured by PMHD is concerned, its incidence was also high in the same season in all sampling years. In late post rainy season (46th to 52nd week of the year), climatic conditions no longer remained favourable for the proliferation of mosquitoes and as a result both OI and PMHD values were relatively much lower in this season for all three years. Minimum Infection Rate (MIR), used for estimating infectivity of adult mosquitoes during 2011, 2012 and 2013 also shows similar pattern. MIR in mosquitoes, collected from field fluctuate a lot from 8.52 - 69 in different countries.<sup>27</sup> However, making a comparison of infection rates is very complex as number of different factors should be considered. For example pool sizes of sample, number of samples processed and collection period during epidemic or inter epidemic<sup>28-30</sup> have also reported that a large sample of mosquitoes should be taken because infection is an uncommon event and a large sample raises the likelihood of collecting an infected mosquito can improve the accuracy of the estimated infection rate.

Multiple Regression analysis (done by using panel data using a panel dataset by STATA statistical software analysis package, version 13) was used to formulate prediction model.

For interpretation of results of this study, the following values of FE and RE models were taken into consideration:

1. R2 and its overall value: It showed the correctness or fitness of the model.

2. Coefficient and its associated sign.

The R2 value (Table-3 and 4) correctly explain 30% of the variation in number of dengue patients. Our random effects (RE) model has provided a good explanation for the rate of change of number of dengue patients (Table-3). According to our model, PMHD and MIR are statistically significant at 95% confidence level. They have highly positive effects on increasing the number of dengue patients. Moreover, a change in relative humidity and rainfall also has significant effects on the number of dengue patients. The coefficient of rainfall shows that high amounts of rainfall have a decreasing effect on dengue patients. The reason for this being that water in ovitraps was sufficient for the development and proliferation of immature forms of *Aedes* mosquitoes and excessive water in the form of rain could not increase the proliferation of immature forms of mosquitoes; secondly, adult mosquitoes did not require water as flower nectar and human blood were available in sufficient quantity. This finding is also supported by Samways (1995) who reported that insects, particularly mosquitoes are quite sensitive to air temperature and rainfall, while according to Akram and Lee (2004),<sup>32</sup> proliferation of mosquitoes can be disturbed by changing temperature and precipitation. Similarly, Teng and Apperson (2000)<sup>33</sup> reported that higher temperature can expedite larval development resulting in increased population of mosquitoes and ultimately increasing the number of dengue patients. Vezzani et al. (2004) have supported the same observation in their studies.<sup>31,34</sup>

The results of FE model (Table-3) show that a 10 unit's increase in PMHD will result in an increase in number of dengue patients by 4.22; whereas an increase in 10 MIR units will result in an increase in the number of dengue patients by 9.26. Similarly, if temperature is increased by 10°C, number of dengue patients will be increased by 2.80, and if humidity is increased by 10%, the number of dengue patients will increase by 5.80, while if rainfall rises by 10 mm, the number of dengue patients will decrease by 1.

Results of the RE model (Table-3) show that if PMHD is increased by 10 units, number of dengue patients will be increased by 4.01 and an increase in 10 MIR units will result in an increase in number of dengue patients by 15.88. Similarly, if temperature is increased by 10°C, number of dengue patients will be increased by 3.10 and if humidity becomes 10% more, the number of dengue patients will increase by 5.73, while if rainfall is increased by 10 mm, number of dengue patients will decrease by -1.01. The F-

test on overall significance of model shows that our model provides a better fit than the intercept only version of this model. This provides us with evidence that choice of variables in our model have strong and significant effects on our dependent variable.

### Conclusion

Dengue can be predicted by entomological and viral surveillance along with climatic data of a particular area. Both the FE and RE models were statistically appropriate and can be used but the RE model was chosen over FE model by using Hausmann Test to predict the number of dengue patients. With the inclusion of the individuals' socio-demographic characteristics in the models, the findings of this research can be applied on the general population.

### Output of the Study

The present study predicts the incidence of dengue epidemic by using FE and RE Models, using the dengue vector surveillance and infectivity indices, namely, OI, PMHD, MIR along with climatic variables, namely ambient air temperature, relative humidity and rainfall.

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