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INVESTIGATION OF AERIAL POLLEN DIVERSITY IN SANTINIKETAN, WEST BENGAL AND PREDICTION OF POLLEN CONCENTRATION: A NEW STATISTICAL APPROACH FOR FORECASTING OF POLLEN SEASON

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Abstract:
The present study deals with the investigation of diversity of airborne pollen in the atmosphere of Santiniketan, West Bengal (Eastern part of India) using a Burkard personal volumetric sampler for the two-years period 2014–2015. A total of 66 pollen taxa belonging to 37 angiosperm families and one gymnosperm have been identified. Grass pollen alone dominated the airborn pollen assemblage followed by Cassia sp., Acacia sp., Solanaceae, Asteraceae and Cyperaceae. Pollen grains of Cycas sp., Lagerstroemia sp., Spathodea campanulata, Lantana camara, Eucalyptus sp., Malvaceae, Liliaceae, Parthenium hysterophorus, Carica papaya, Peltophorum pterocarpum, Areca catechu, and Catharanthus roseus were also predominant in the air of Santiniketan. The annual pollen index (API) was 77,272 (pollen/m^3 of air) in Santiniketan which reflects the rich pollen diversity of this famous sub-urban tourist spot of West Bengal. The place has the highest annual concentrations of pollen in April (13024/m^3in 2014 and 12160/m^3 in 2015) in both of the study years. The studies carried out established the association between aero pollen concentration, meteorological factors and air quality data (pollutants). Yearly variations of pollen seasons could be related to the influence of meteorological factors such as temperature, rainfall, relative humidity and wind speed which have been proven statistically by correlation analysis. PM10 and PM 2.5 were found to be statistically significant with total pollen count. We have made a statistical approach using the multivariate regression analysis and Generalized Linear Model to predict onset, duration and peak pollen season to evaluate the threat imposed by the presence of pollen allergens in the air. For this statistical approach, we have considered the influencing meteorological factors and air pollution data as predictive variables and pollen counts as response variable for 2014 and 2015. The fitted regression equation showed goodness of fit of the proposed model with such an adjusted R^2 value (0.8281) which explaining almost 82.81% of the variability for prediction of weekly pollen counts for future years. This aeropalynological survey may serve as guide for allergologiests to predict and manage the source and the incidence of allergic diseases among local inhabitants.

Key words: *Pollen, Santiniketan, annual pollen index, statistically significant, prediction, pollen season, Regression analysis, Generalized Linear Model.*

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INTRODUCTION:

In the past few years, air quality analysis in different part of country has taken on an important role in the field of environmental research and prevention. Air is a repository of an invisible biomass of particulate matter of different shape, size and origin which includes plant, animal and other inorganic origin. Of these, pollen grains constitute a significant fraction and represent an inevitable allergen source due to their abundant presence in atmosphere [1,2,3]. During the last few decades, there has been an increase in the incidence of pollen allergy worldwide [4,5]. The problem of the presence of pollen grains in air that could cause allergies in immunologically predisposed individuals of different locations of country, is very important, especially when tree and/or shrub essences of a proven allergenic role are planted or wildly grows in areas dedicated to public roads, parks and gardens [6,7,8,9,10]. Aerobiological researches are of higher significance in order to chart the behaviour of airborne allergens over the year; the data obtained are valuable both to allergologists for planning treatments and to allergy sufferers for planning their work and recreational activities [7]. The content of air borne pollen is characteristic of each bio-geographical zone depending upon the vegetation. With the advancement of civilization, due to rapid industrialization, urbanization and population explosions, various changes in environment have taken place and the air become polluted day by day. Among various particulate matters pollen grains are one of the major bio pollutants. The concentration of air borne pollen grain varies not only from place to place but also with in the same area, may due to climatic factors as well as interaction with pollutants [10,11]. The pollen count can be an important tool in the management of individuals with seasonal allergies [12]. India has divergent geoclimatic zones showing marked fluctuation in climatic conditions such as temperature, rain fall and relative humidity which influence floral spectrum. The sources and nature of pollen thus vary in different parts of the country. Some great pieces of work have been carried out at different eco-geographical regions in India with regard to pollen flora [9,10,14-22]. Meteorological conditions are used to explain the dynamics of pollen seasons as temperature, relative humidity and rainfall directly influence the phenology of a flower [23]. Furthermore, there is evidence that high levels of traffic-derived and industrial air pollutants may interact with pollen and bring about more intense respiratory allergy symptoms [24].

In aerobiological studies, the forecasting models were chiefly based on climate and the pattern of weather conditions [25] and also air pollution parameters. More specifically, regression analysis helps one understand how the typical value of the criterion variable (pollen count) changes when any one of the independent variables (meteorological and air pollution parameters) is varied, while the other independent variables are thought fixed. Most usually, regression analysis estimates the conditional expectation of the dependent variable given the independent variables – that is, the average value of the dependent variable when the independent variables are fixed. The aim of the present study was to analyse the diversity of the aerial pollen in Santiniketan, West Bengal and we have made a statistical approach using the multiple regression analysis to predict onset, duration and peak pollen season to evaluate the threat imposed by the presence of pollen allergens in the air [26]. It is therefore crucial to determine the peak pollen season of different regions for management of allergic ailments of local population.

MATERIALS AND METHODS:

Sampling site

Santiniketan is a semi-rural establishment based on Visva-Bharati, a central university established by famous Nobel Laureate poet R.N. Tagore, on the outskirts of the Bolpur town having luxuriant vegetation. It is located at 160 km north-west of Kolkata (23.68°N 87.68°E) and has an average elevation of 56 m. As it is a lateritic zone, the summer temperature is moderately high, less humid, the maximum temperature goes up to 46^{o} C in the month of May being the hottest; monsoon season starts from June and continues up to October and the daily mean temperature during this period varies between 32-38^{o} C and the winter temperature goes down as low as 7-8^{o}C. It is one of the most popular tourist place in West Bengal, welcomes about thousands of tourists per year.

Aerobiological monitoring

Burkard personal air sampler, placed at a height of 0.5m above the ground (air suction rate = 10 litre/min) was operated for 10 minutes for monitoring and assessment of airborne pollen spectra. The sampler was operated for two consecutive years (January 2014 to December 2015) at two different locations (Gurupally and Shyambati) of Santiniketan (Fig 1) to get the actual scenario of pollen spectra of this lateritic zone. The hourly counts were then averaged to obtain the mean concentration which in turn gave the monthly concentration. The exposed slides were mounted, scanned thoroughly, counted and converted into number of pollen per m^3 following the guidelines of The British Aerobiology Federation

(1995)[27]. Possible plant sources of airborne pollen were identified by conducting monthly vegetation surveys and field collections. Both entomophilous and anemophilous plants were recorded and observed their flowering times. The identification of air borne pollen was done mainly with the help of prepared reference slides by our laboratory and also by consulting published literatures [28-31].

Fig 1: Aerobiological sampling by Burkard personal volumetric sampler at different sampling locations of Santiniketan.Collection of meteorological Data and air quality data:

The detailed meteorological data such as maximum and minimum temperature (°C), rainfall (mm), wind speed (km/h), relative humidity (%) were collected weekly from the Sriniketan Meteorological station, situated about 3 km away from the sampling site, to evaluate their influence in pollen dissemination and monitoring the pollen seasons.

Weekly average air quality data such as PM10 (µg/m³), PM 2.5 (µg/m³), SO_2 (µg/m³) and NO_2 (µg/m³) were collected from official website of West Bengal Pollution Control Board (emis.wbpcb.gov.in/airquality/citizenreport.do) to evaluate their effect on pollen load in the air.

Statistical Analysis:

The association between weekly pollen load (No./m^3), different meteorological parameters (Maximum and minimum temperature, relative humidity, rain fall and wind speed) and air quality data (PM10, PM 2.5, SO_2 and NO_2) were analysed by Pearson's Product Moment method. The statistical analysis and computation was undertaken with R studio (ver. 3.2.2) and MiniTab17 where values of *p*-value < 0.05 were considered to be statistically significant. For the forecasting of pollen season, and to find the effects of different meteorological and pollution parameters on pollen count, regression analysis and a generalized linear model (GLM), was constructed with log link fit.

In statistical modelling, regression analysis is a set of statistical procedures for assessing the relationships among variables. It includes many techniques for modelling and analysing several variables, when the focus is on the relationship between a dependent variable and one or more predictors variables. Regression analysis was performed to produce forecast and prediction models, where its use has significant overlap with the field of machine learning. Before its application, the scatterplots of independent and dependent variables as well as their correlation were analysed. If Pearson correlation was high and linear relationship was observed, then a linear regression function was obtained. Regression analysis is also used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. The generalized linear model (GLM) is a flexible generalization of ordinary linear regression that allows for response variables that have error distribution models other than a normal distribution. The GLM generalizes linear regression by allowing the linear model to be related to the response variable via a link function and by allowing the magnitude of the variance of each measurement to be a function of its predicted value. Poisson regression assumes the response variable Y has a Poisson distribution, and assumes the logarithm of its expected value can be modelled by a linear combination of unknown parameters. A Poisson regression model is sometimes known as a log-linear model, especially when used to model contingency tables.

If $x \in R\ n$ is a vector of independent variables, then the model takes the form

$$\mathbf{Log\ (E\ (Y \mid x)) = \alpha + \beta' x,\ where\ \alpha \in R\ and\ \beta \in Rn}$$

Sometimes this is written more compactly as

$$\mathbf{log\ (E\ (Y \mid x)) = \theta' x,}$$

Where x is now an (n + 1)-dimensional vector consisting of n independent variables concatenated to a vector of ones. Here θ is simply α concatenated to β.

Thus, when given a Poisson regression model θ and an input vector x, the predicted mean of the associated Poisson distribution is given by

$$\mathbf{E(Y \mid x) = e^{\theta' x}.}$$

In the more general multiple regression model, there are p independent variables:

$$y_i = \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_p x_{ip} + \varepsilon_i ,$$

Where x_{ij} is the i-th observation on the *j*-th independent variable. If the first independent variable takes the value 1 for all i, $x_{i1} = 1$, then β_1 is called the regression intercept.

RESULTS AND DISCUSSION:

From the aerobiological investigation, a total of 66 pollen types were identified which belonging to 37 families of angiosperms and 1 Gymnosperm from the atmosphere of Santiniketan during the entire study period though a few pollen types remained unidentified. Among them pollen grains of 33 trees, 14 herbs, 19 shrubs and one climber were recorded. For both of the year, the average pollen contribution of trees was maximum (47.72%), followed in the degree of prevalence by herbs (28.99%), shrubs (16.85%), grasses (5.83%) and climbers (<1%) (Table 1).

Table 1: Average percentage contribution of airborne pollen by five types of plants based on their habitat, in Santiniketan (2014-2015).

Habitat	% of pollen contribution
Tree	47.72 %
Herbs	28.99%
Shrubs	16.85%
Greasses	5.83%
Climber	<1%

A total of 1,57,400/m^3 pollen grains were trapped during the 2 years of sampling period. Of these, 1,55,608/m^3 pollen grains constituting 97.74% of the total pollen trapped were identified and assigned to 66 different pollen types. The remaining 2.26% of pollen grains were included under unidentified category. During our investigation, the maximum monthly concentration was observed in April (13024/m^3) in 2014 followed by May (10656/m^3), March (10560/m^3) and February (7840/m^3) while the highest pollen peak season was recorded in April (12160/m^3) in 2015 followed by March (11680/m^3), May (10304/m^3) and February (8416/m^3) (Fig 2).

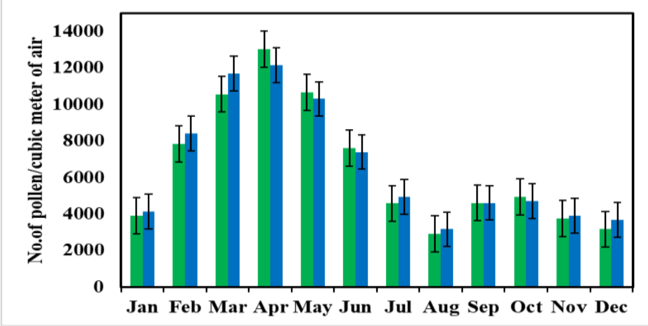

Fig 2: Seasonal variation of the monthly mean pollen concentration (pollen grains/m^3) recorded in the air of Santiniketan (2014-2015): the 1st study year (2014) is showing in green bar diagram and the 2nd study year (2015) is showing in blue bar diagram.

Pollen of Poaceae were most dominant and accounted for 8.64 and 7.16 % of the total pollen load followed by *Solanum* sp. (5.41 and 5.34%) in 2014 and 2015 respectively (Table 2). The next in the order of abundance were *Cassia* sp. (4.55%), *Acacia* sp. (4.06%), Asteraceae (3.82%), the only gymnosperm *Cycas* sp. (3.05%), Cyperaceae (3.01%), *Lagerstroemia* sp. (2.64%), *Spathodea campanulata* (2.44%), *Eucalyptus* sp. (2.07%). The remaining types contributed less than 2.0% each (Table 2) in the 1st year of study (2014) (Table 2).

Unlike 1st year, in the 2nd year (2015) of study the degree of prevalence was *Cassia* sp. (5.10%), Cyperaceae (3.49%), *Acacia* (3.13%), *Cycas* sp. (3.01%), Asteracear (2.77%), *Lagerstroemia* sp. (2.59%), Malvaceae (2.27%), Liliaceae (2.14%), *Spathodea campanulata* (2.02%) and so on. A closer analysis of Table 2 shows that some of the pollen types like *Gelonium multiflorum*, Liliaceae and *Typha* sp. were found to be absent in 1st year of study (2014). Among them only Liliaceae pollen types contributed a considerable prevalence (2.14%) in 2015. For this reason, we presume that the pollen grains which found in the 2nd year could have reached the city's' bio aerosol from some neighbouring places transported by the turbulent wind. Pollen grains released in the air are not always deposited immediately near the source of emission or in a radius of a few tens of metres from it. In fact, a small percentage is transported by strong currents of air over very large distances [32]. A further confirmation of long distance pollen diffusion is supplied by the studies by Dyakowska (1948) [33] and Polunin (1955) [34] who captured specific pollen grains at hundreds of kilometres from the nearest source of emission.

Table 2: Frequency (No. of pollen/m^3 of air) and percentage contribution of different pollen types observed during study period in the air of Santiniketan.

Types of pollen	Pollen loads (no./m^3) in 1st year	Yearly % of contribution	Pollen loads (no./m^3) in 2nd year	Yearly % of contribution
Acacia sp.	3200	4.06	2496	3.13
Acanthaceae	1216	1.54	1152	1.45
Ailanthus sp.	736	0.93	832	1.04
Albizia lebbeck	960	1.22	576	0.72
Alstonia scholaris	800	1.02	864	1.08
Apiaceae	1152	1.46	1152	1.45
Areca catechu	1184	1.50	896	1.12
Argemone mexicana	800	1.02	704	0.88
Asteraceae	3008	3.82	2208	2.77
Azadirachta indica	768	0.98	768	0.96
Barringtonia	608	0.77	576	0.72
Bauhinia sp.	736	0.93	800	1.00
Bombax ceiba	736	0.93	960	1.20
Borassus flabellifer	992	1.26	736	0.92
Brassica sp.	928	1.18	736	0.92
Brownea coccinea	544	0.69	672	0.84
Caesalpinia	1088	1.38	1088	1.37
Callistemon sp.	960	1.22	704	0.88
Carica papaya	1088	1.63	832	1.04
Cassia sp.	3584	4.55	4032	5.10
Catharanthus roseus	1152	1.46	1440	1.81
Casuarina	832	1.06	896	1.12
Cheno-	1280	1.63	1344	1.69
Clerodendrum sp.	384	0.49	640	0.80
Cocos nucifera	1280	1.63	1184	1.49
Convolvulaceae	704	0.89	864	1.08
Croton	1312	1.32	1280	1.61
Cycas sp.	2400	3.05	2400	3.01
Cyperaceae	2368	3.01	2784	3.49
Dalbergia sisoo	704	0.89	608	0.76
Delonix regia	832	1.06	832	1.04
Eucalyptus sp.	1632	2.07	1184	1.49
Euphorbia sp.	608	0.77	576	0.72
Fabaceae	1024	1.68	1344	1.69
Gelonium	-	-	448	0.56
Lantana camara	1664	2.11	1472	2.86
Lagerstroemia sp.	2080	2.64	2048	2.59
Lamiaceae	1184	1.50	832	1.05
Leucas sp.	416	0.53	-	-
Liliaceae	-	-	1696	2.14
Madhuca indica	832	1.06	768	0.97
Malvaceae	1472	1.87	1792	2.27
Mangifera indica	704	0.89	1088	1.38
Mimosa pudica	1056	1.34	1152	1.46
Murraya paniculata	832	1.06	1024	1.30
Nyctanthes arbor-	704	0.81	640	0.81
Parthenium	1568	1.99	1696	2.14
Peltophorum	1248	1.59	1184	1.50
Phoenix sylvestris	1344	1.71	1184	1.50

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Phyllanthus emblica	1056	1.34	768	0.97
Poaceae	5448	8.64	5664	7.16
Psidium guajava	1024	1.30	1152	1.46
Ricinus communis	1120	1.42	608	0.69
Shorea robusta	480	0.61	544	0.77
Solanum sp.	4256	5.41	4224	5.34
Spathodea	1920	2.44	1600	3.02
Syzygium sp.	800	1.02	608	0.77
Tabebuia sp.	256	0.33	288	0.36
Tectona grandis	512	0.65	512	0.65
Tinospora cordifolia	512	0.65	544	0.69
Trema orientalis	1056	1.34	896	1.13
Typha sp.	-	-	692	0.85
Verbenaceae	288	0.81	256	0.32
Xanthium	896	1.13	832	1.05
Zizyphus sp.	384	0.49	416	0.53
Unidentified	864	1.10	928	1.17

For Poaceae, two major seasons were obtained, first one during February – June and the second in between September – October, thus coincided with the flowering period of most of the grasses which corroborate with the observation of Ghosal et al. 2015 [9]. Based on the aeropalynological data collected during different months of two consecutive years, two pollen seasons were recognized in Santiniketan: one from mid-February to May and other from mid-September to November (Figure 2). The first pollen season was loaded with tree and shrubs pollen, while grasses and weeds showed fairly good concentration in air in the second pollen season. The predominant pollen types in the first season belongs to *Solanum* sp., *Acacia* sp., *Cassia* sp., Asteraceae, *Areca catechu*, *Spathodea campanulata*, Apiaceae, *Parthenium hysterophorus*, Fabaceae, *Borassus flabellifer*, *Carica papaya*, *Casuarina equiseitifolia*, *Cocos nucifera*, *Catharanthus roseus*, etc. The second season was loaded with pollen of Cheno-Amaranthaceae, Cyperaceae and grasses (Poaceae) (Table 2). Among the recorded pollen types in the atmosphere of Santiniketan, Pollen grains was reported to be highly allergic in nature and pollen of *Acacia* sp., *Albizia lebbeck*, *Alstonia scholaris*, *Areca catechu*, *Azadirachta indica*, Asteraceae, *Borassus flabellifer*, *Cassia* sp., *Carica papaya*, *Cocos nucifera*, *Cycas* sp., *Delonix regia*, *Lantana camara*, Chenopodiaceae-Amaranthaceae, *Eucalyptus* sp., *Madhuca indica*, *Mangifera indica*, *Parthenium hysterophorus*, *Phoenix sylvestris*, *Peltophorum pterocarpum*, *Ricinus communis*, *Trema orientalis*, *Xanthium strumarium* etc. were also described as potent pollen allergens in different literatures [17-21,34]. So it would be necessary to establish a pollen prediction model to avoid the allergic episodes of sensitized local population.

Statistical analysis

Meteorological factors like temperature, rainfall, relative humidity and wind speed are responsible for fluctuations in pollen concentration [36-38]. The effect of four such most influencing meteorological factors on prevalance of pollen counts (PC) in the atmosphere of Santiniketan has been taken into consideration to analysis their influence on pollen dispersal. To get the correlation between total weekly pollen count and the meteorological parameters, Pearson product-moment correlation was computed where *p*-values were considered to judge their significance. The synchronism recorded in the variations of weekly pollen concentration with maximum temperature, minimum temperature, wind and rainfall is found to be important (Fig 2).

In the present study, flowering seasons and pollen distribution are influenced by meteorological factors where weekly total pollen count was positively skewed and kurtotic indicating a non-normal distribution. The feasibility of using weekly pollen count (PC) and weekly meteorological data from 2014-2015 as dependent and predictive variables was tested by Pearson multivariate nonparametric correlation analysis. The weekly total pollen count was correlated positively and significantly with maximum temperature and wind speed and negatively correlated with relative humidity and rainfall (Table 3 and Figure 3).

Table 3: Results of correlation of meteorological factors as independent variables, with pollen counts as dependent variables for 2014 and 2015 using Pearson nonparametric correlation coefficient.

Meteorological	Correlation	p value
Maximum	**0.21****	**<0.001**
Minimum	0.06	0.69
Relative Humidity	**-0.58****	**<0.001**
Rain fall	**-0.37***	**<0.001**
Wind speed	**0.24***	**<0.001**

Significant values in bold; Level of significance *0.05, **0.01

The statistically significant r values, for PC and maximum temperature was 0.21 and PC and wind speed was 0.24 with the given probability values p <0.001 for all the mentioned variables (Table 3) while r value for PC and minimum temperature was 0.06, which was not found to be statistically significant. However, our results showed that relative humidity (RH) and rainfall is negatively correlated with the pollen count (r value= -0.37 and -0.58 respectively) with the p value <0.001; thus less pollen grains were trapped during heavy rainfall. Thus pollen catch was low to due to wash out of pollen grains from atmosphere by rainy shower. It is evidenced that temperature is the factor that exerts the greatest influence on the release of pollen grains in the atmosphere [37,39]. The pollen grains were found to be correlated positively with temperature, thus our finding supports the view that moderately high temperature with low relative humidity accelerates the pollen dispersal (Ghosal et al., 2015). High temperature promote an increase in pollen concentration, while a rise in relative air humidity and rainfall cause a decrease in pollen concentration. Their effects on pollen suspension in air are shown in Figure 3. A larger data set combined with a parallel phenological study provides more insight into the effect of meteorological parameters on anthesis and the daily and seasonal pollen prevalence. Anemophilous pollen outnumbered and dominated over the entomophilous pollen type [40]. This could be attributed to the wind currents which are the carrier of pollen from one plant to another for pollination thus wind speed was found to be significantly and positively correlated with total pollen load in atmosphere.

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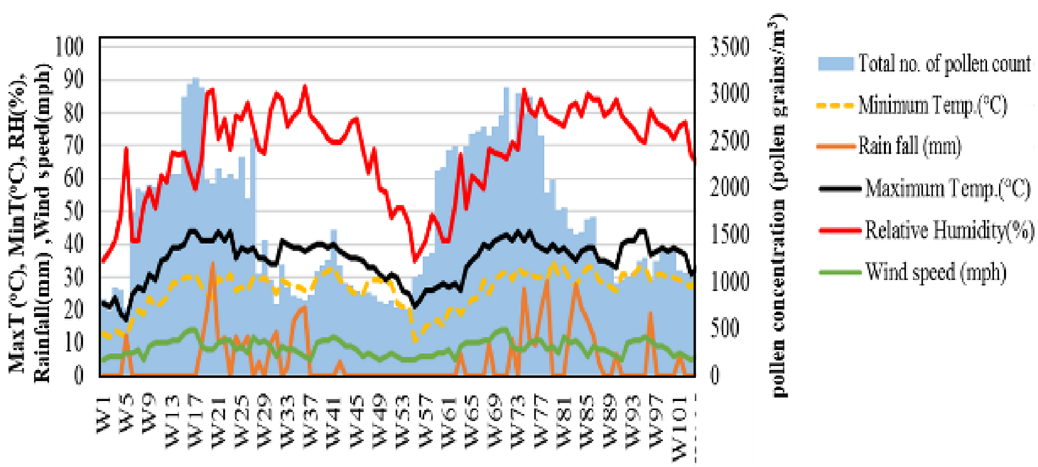


Fig 3: Average weekly (January'14 to December'15) distribution of total pollen load in the air of Santiniketan during two years of study, plotted against weekly maximum and minimum temperature (◦C), wind speed(m/hr), relative humidity (%) and rainfall (mm). [X axis: Time scale in weeks; 1st Y axis: Meteorological parameters and 2nd Y axis: (Area diagram) weekly pollen count (No./m^3 of air)]

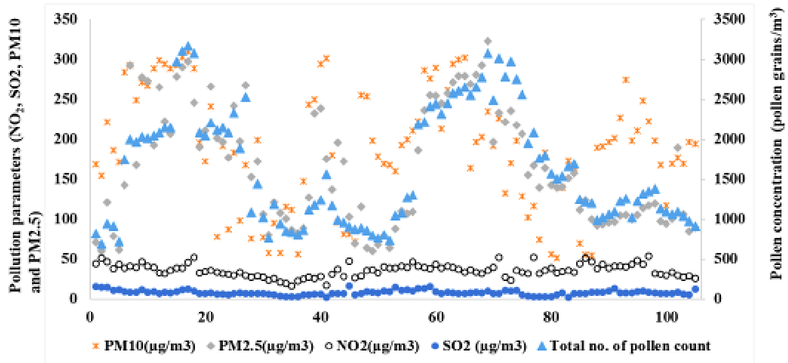


Figure 4: Scatter plot showing the correlation between total weekly pollen count with air quality data (NO_2, SO_2, $PM_{2.5}$ and PM_{10}). [X axis: Time scale in weeks; 1st Y axis: air pollution parameters and 2nd Y axis: weekly pollen count (No./m^3 of air)]

Table 4: Correlation matrix for total pollen count and three major pollutants using Pearson nonparametric correlation coefficient (corresponding *p*-values mentioned in brackets).

	Pollen count	PM10(µg/m^3)	PM2.5(µg/m^3)	NO_2(µg/m^3)
PM10(µg/m^3)	**0.426** (<0.001)**			
PM2.5(µg/m^3)	**0.887** (<0.001)**	0.490** **(<0.001)**		
NO_2(µg/m^3)	0.160 (0.104)	0.249 (0.010)	0.052 (0.598)	
SO_2 (µg/m^3)	0.051 (0.602)	**0.336** (<0.001)**	0.024 (0.811)	**0.525** (<0.001)**

Significant values in bold; Level of significance *0.05, **0.01

On the basis of the pollutants and PC data set, the scatter plot was executed to associate the relationship of PM10, PM2.5, NO_2, SO_2 and weekly rate of increase or decrease of the pollen load in response to different pollutant parameters and it was evidenced that as the Particulate matters (PM) changed the pollen counts also varied considerably (Fig 4). As we have tried to elucidate the correlation between the weekly total pollen count against the four major air pollutants like PM10, PM2.5, NO_2 and SO_2, PM10 and PM2.5 was found to be positively correlated and significant with total pollen count with the given probability values p <0.001, while both NO_2 and SO_2 were found to be insignificant (Table 4). This may be attributed to the reason that particulate matter like PM10 and PM2.5 may adhere to the sticky surface of pollen easily and pollen-PM complex considered as a PM unit, thus they are directly related with each other.

As we found from the correlation analysis that atmospheric pollen load was strongly influenced by both meteorological factors and pollutants, we have analysed the air quality data and meteorological parameters as independent variables, with pollen counts as dependent variables for 104 weeks employing a Multiple Regression Analysis (MRA) model using R studio (ver. 3.2.2) for formulation of a prediction equation to predict and forecast the pollen count. The regression models were constructed by means of linear function.

On the basis of the multiple linear regression model, a useful forecast for pollen season can be made. The onset, duration and peak pollen season can easily be forecasted from this statistical model. The observation for each of these variables consisted of time-order sequences of measurements referred to as time series by statistician. An essential features of time series is the dependence between consecutive observations which makes the usual methods of analysis such as linear regression and analysis of variance inappropriate. Two-time series such as pollen count and temperature may be associated. For example, the temperature two days ago, might affect the pollen count today. For weekly data such relationship would determine the association between pollen count and temperature with a lag of two days. Such effects can be identified by taking the differences between successive observations in each series. The cross correlation between the two resulting series of differences can then be found at various lags. The cross correlation results were used to develop regression time series models incorporating those variables identified as being associated with pollen count [38].

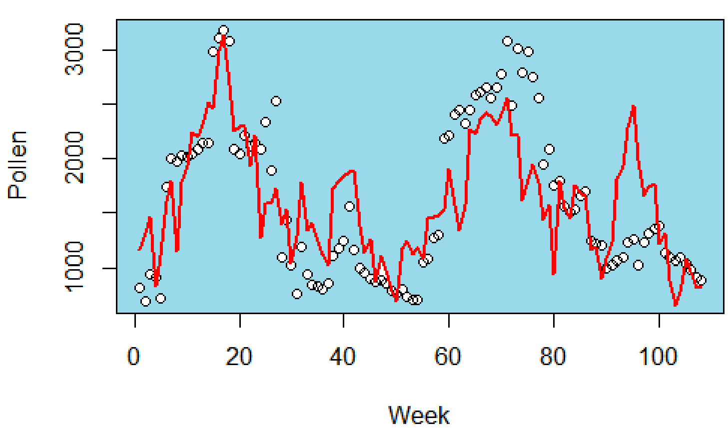
We formulated the regression equation for the forecasting of pollen count were statistically significant with an adjusted R^2 value of 0.8281, with a given probability value p<0.001 which mean the above regression model can explain almost 82.81% of the variability. For construction of regression equation, we considered only those predictable variables whose probability value was found to be $p<0.05$ in the multiple regression analysis. The performance of the model was evaluated by examining the agreement between actual and predicted weekly pollen counts. The fitted regression line using GLM for weekly pollen counts in the air of Chandernagore as predictive variable with meteorological parameters and pollutants data as response variable were plotted in Fig 5. In this figure the points indicate the observe data and line indicates the fitted values showing good fit of the model. In this figure the points indicate the observed data very close to the line indicating the fitted values showing goodness fit of the model.

Table 5: Result of multiple regression analysis for Santiniketan site.

Term	Coef	SE Coef	T-Value	p-value
Constant	**-686**	**328**	**-2.09**	**<0.001***
MaxT(°C)	**38.5**	**12.3**	**3.12**	**0.002***
MinT(°C)	**-11.1**	**13.0**	**-0.85**	**0.396**
RH(%)	**-6.74**	**5.14**	**-1.31**	**0.193**
Rain fall (mm)	**10.47**	**5.02**	**2.08**	**0.040***
Wind speed (mph)	**-21.7**	**19.2**	**-1.13**	**0.263**
PM10(μg/m^3)	**-0.203**	**0.566**	**-0.36**	**0.721**
PM2.5(μg/m^3)	**8.039**	**0.604**	**13.32**	**<0.001*****
NO_2(μg/m^3)	**15.37**	**4.29**	**3.58**	**0.001*****
SO_2 (μg/m^3)	**0.1**	**14.2**	**0.01**	**0.995**

Significant values in bold and red; Level of significance *0.05

Regression Equation:
Total No. of pollen count = -686 +38.5 Maximum Temp.(°C) + 10.47 Rain fall (mm) - 21.7 Wind speed (mph)+ 8.039 PM2.5(μg/m^3) + 15.37 NO_2(μg/m^3)



Red line (—) diagram indicates the expected values and Black (○) scatter plot indicates the observed values

Fig 5: Generalised linear model for fitted values against observed pollen count/m³ of air (weekly) for two consecutive years in Chandernagore sampling site.

Forecasting atmospheric pollen load in the future years is a topic of major importance in aerobiology. Forecasting models proposed in the literature are numerous and increasingly complex, but they fail in at least 25 % of cases and are not available for all botanical species [41,42]. There are several models for predicting aerobiological phenomena, such as thermal summations, regressions, autocorrelations or neural networks [26, 43,44]. A literature review carried out under the auspices of a recent EU-funded COST Action ES0603 found that airborne pollen was one of the most studied subjects in aerobiology, particularly in relation to atmospheric forecast models, as reported in chapter 4 Monitoring, modelling and forecasting of the pollen season [38].

Taking these facts into consideration, simple forecasting models based on the weekly pollen count, meteorological factors and pollution data, were developed. We were employing the multivariate regression analysis and GLM to formulate a prediction equation which will forecast the pollen season and pollen count in future years. The performance of this realistic model was satisfactory, in particular regarding the prediction of the starting date of the pollen season. We demonstrated that the relationships between pollen concentrations and meteorological situations are independent from site. This means that such models can understand the differences in area through meteorological and air pollution information.

CONCLUSION:

Many human diseases are caused by bio-aerosols suspended in the air. Inhalation allergy, caused by airborne pollen, is well known and produces many respiratory disorders of varying severity. Allergy due to pollen is growing so fast among Indian populations which become one of the most widespread diseases of the next century [19,35]. Rising sensitivity of the population to airborne pollen allergies seems to correlated the air quality, mainly influenced by air pollution. The forecast of pollen season doesn't work when considering the increasing mobility for work and leisure. The diffusion of pollen data and pollen forecasts should improve the prevention of allergic episodes, and the reduction of human and economic costs due to acute allergic symptoms [45].

To reduce the pollen allergy episodes, the information of aerial pollen diversity of a particular place and forecasting of pollen load should be more effective. The first and more elementary level of forecast is based on the location of the place, trend of the flowering or pollen concentrations, calculated on a multi-year series of observations which can explained graphically by means of pollen calendars or phenological behaviour [10]. In this connection, our documentation of airborne pollen in this eco-geographical zone of West Bengal revealed a total of 64 pollen types were recorded from Santiniketan. Pollen grains of well-known allergen species, such as Poaceae , were the in highest number, followed by many species like *Acacia* sp., *Albizia lebbeck*, *Alstonia scholaris*, *Areca catechu* , *Azadirachta indica*, Asteraceae, *Borassus flabellifer*, *Cassia* sp., *Carica papaya*, *Cocos nucifera*, *Cycas* sp., *Delonix regia*, *Lantana camara*, Chenopodiaceae-Amaranthaceae, *Eucalyptus* sp., *Madhuca indica*, *Mangifera indica*, *Parthenium hysterophorus*, *Phoenix sylvestris*, *Peltophorum pterocarpum*, *Ricinus communis*, *Trema orientalis*, *Xanthium strumarium* etc.[7,8,9,15-22]. This information demands to establish a pollen forecasting model to predict the onset and peak pollen season, so that the local population who are sensitized to pollen allergy would be benefited.

However, in order to obtain a good level of accuracy in the forecasts, the probability of modulating them in relation to the meteorological and air pollution changes must be introduced through the application of forecasting models as we have done in our regression model [46].

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