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INVESTIGATING COMMUNITY HEALTH EFFECTS OF BIOAEROSOL POLLUTION IN HO CHI MINH MEGACITY, VIETNAM

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Abstract

This study assessed the effects of bioaerosol pollution on community health across six urban and residential communities located in Ho Chi Minh megacity, Vietnam. A questionnaire survey was performed on 300 respondents to record health complaints from exposure to bioaerosols. The health symptoms (i.e. flu and cough) were highest in those items with means equal to 6.518 (SD=2.5068) and 6.555 (SD=2.6696), whereas the lowest item was "chest tightness" with mean equal to 3.334 (SD = 2.7001). The results showed that the questionnaire retained good internal consistency with Cronbach's alpha was 0.613. Using principle component analysis, we have identified 12 questions related to health complaints that could be grouped into five main clusters: PC_1 named "nose symptoms"; PC_2 named "throat (respiratory symptoms)"; PC_3 named "fever symptoms"; PC_4 named "flu (flu-like symptoms)"; and PC_5 named "cough symptoms", respectively. The results indicated the potential effects of bioaerosols on human health, with the PCs have accounted for 63.2 percent of the overall total variance and with eigenvalues equal to 1.502 >1. Using multiple linear regression models, this study found that latent factors (i.e. daily habit, living environment, and medical history) such as duration from last pain, residential duration, duration staying at home, home time, distance to street can explain the effect of bioaerosols on health symptoms at the 0.05 significance level. The findings are helpful and significant reference for urban planning, policy making and the community health protection in Ho Chi Minh megacity.

Key words: bioaerosol, effect, health symptoms, Ho Chi Minh megacity, Vietnam

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1. Introduction

Bioaerosols are natural or artificial particles of biological (microbial, plant, or animal) origin suspended in the air. These particles are also referred to as organic dust. Bioaerosols may consist of bacteria, fungi (and spores and cell fragments of fungi), viruses, microbial toxins, pollen, and plant fibers (Douwes et al., 2003). Size of bioaerosol particles varies from below 1 μm to 100 μm in aerodynamic diameter. Sanchez-Monedero et al. (2008) showed that viable bioaerosol particles can be suspended in air as single cells or aggregates of microorganism as small as 1–10 μm in size. Being exposed to bioaerosol, either directly or indirectly, can lead to negative effects for human health and quality of life (Jyotshna and Brandl, 2011; Shokri et al., 2010; Soleimani et al., 2020; Yildiz et al., 2017), including infectious diseases

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(Chretien et al., 2015), acute toxic effects, and allergies (Bunger et al., 2007). Although the concentration of bioaerosols in the atmosphere was thought to be about minute concentrations, there are increasing evidence showing that the portion of bioaerosols constituting ambient aerosols is substantially high, ranging from 5 % to 80 %, and could impose negative impacts on human health (Jaenicke, 2005; Peccia et al., 2008). The risk of being exposed to bioaerosol concentrations has also been reported by many investigators (Ilies et al., 2018; Lee and Liao, 2014; Lee et al., 2006; Madhwal et al., 2020; Madsen et al., 2014; Viegas et al., 2014). Bioaerosol pollution of residential air can occur in concentrations of health issues. The adverse human health effects may be due to microorganisms associated with an airborne route of exposure (Daniels et al., 2016; Herr et al., 2003; Yoo et al., 2016). In the air, microorganisms will combine and interact with particulate matter increasing healthy risk issues such as allergies and asthma (Haas et al., 2013). Air pollution is an important environmental issue and it directly effects on human health (Park, 2018; Saksena et al., 2003). Children and elderly people are particularly sensitive to air pollution, including particulate matter and bioaerosols (Cho et al., 2019; Seino et al., 2005). Bioaerosol particles (e.g. fungal spores) in indoor can be led to the potential risk on occupants of adverse health effects (Lipşa et al., 2016). The negative effects of bioaerosol particles on human health is particularly concerning over megacity, especially as Ho Chi Minh megacity, a typical case in Vietnam.

Ho Chi Minh City, a megacity in the south of Vietnam, has many conditions that favor the presence of bioaerosol, including the tropical climate as well as high level of air pollution. The temperature and humidity of Ho Chi Minh megacity are generally high throughout the year (HCMCSO, 2019; Phan et al., 2020), providing good conditions to develop bioaerosol in the ambient air (Hai et al., 2019; Hung et al., 2020). The economic development in this city has also led to various environmental issues, including high level of air pollution (Bang et al., 2011; Hung et al., 2015), identifying as one of the major issues facing the health care system (Mehta et al., 2013, 2014; Phung et al., 2016). With more than 10 million people living in Ho Chi Minh megacity, the impacts of bioaerosol on human health are potentially high, but there is no study has quantitatively assessed the impacts of bioaerosol on community health due to the relatively high cost of such investigations. To fill in this gap, this study takes an alternative approach, and uses health complaints as a proxy to evaluate bioaerosol and its effects on community health in Ho Chi Minh megacity. Specifically, we designed a questionnaire to collect health-related information from residence of six communities across Ho Chi Minh megacity. The responses were collected from participations were then analyzed using Principal Component Analysis (PCA) and multivariate regression to identify the key factors that explain bioaerosol-related health issues facing citizens of Ho Chi Minh megacity.

2. Methods

2.1. Studied area

Ho Chi Minh megacity, one of the largest cities in Vietnam, is located at 10°45′N, 106°42′E. The city covers an area of 2.096 km^2, and it is home to roughly ~ 10 million citizens. This study is carried out on six urban and rural areas in the city (Fig. 1).

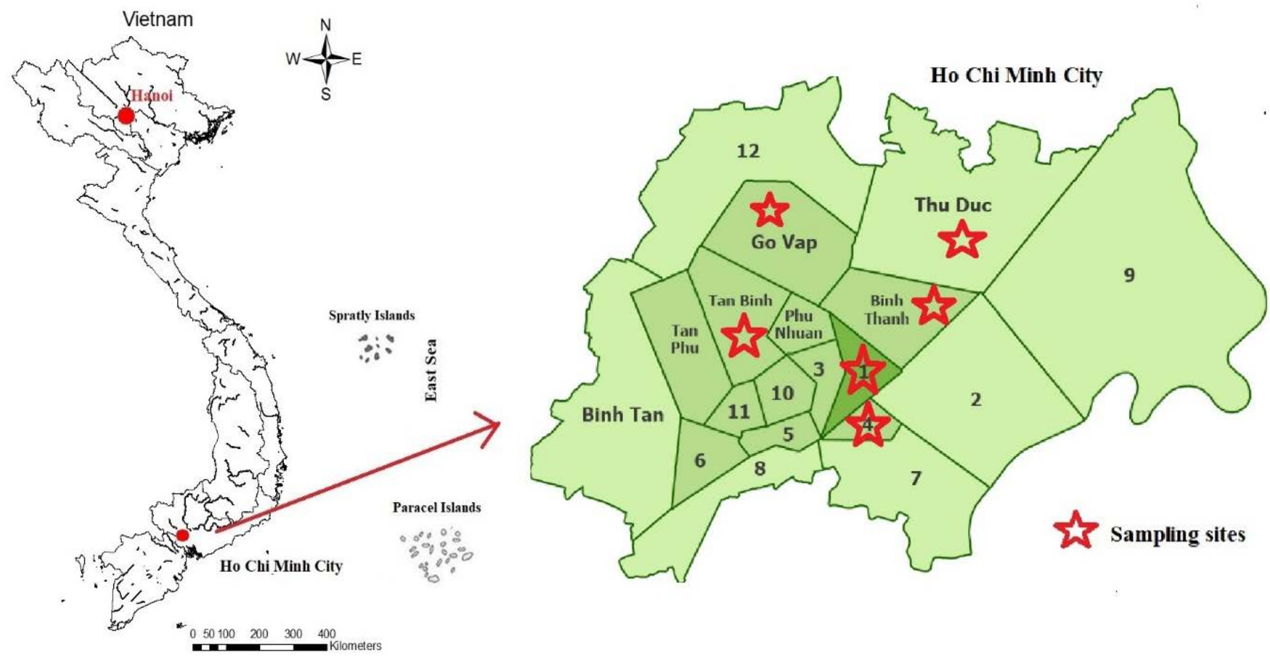

Fig. 1. Map of Ho Chi Minh megacity and studied sites

2.2. Questionnaire design and reliability analysis

During 2014–2016, Hai et al. (2019) conducted the study aimed to determine characteristics of airborne bacteria and fungi in the atmosphere in Ho Chi Minh megacity. Based on the above results, the health effect investigation is designed using a structured questionnaire. In this study, a questionnaire validated by expert, is used to collect data on community's demographics, living condition characteristics, and medical history. The face-to-face interview was then conducted by investigators to collect information about the relationships between symptoms related to bioaerosol and latent factors of habit, medical history and environment conditions (Hu et al., 2017; Jack and Clarke, 1998; Kelsey et al., 1986; Oppenheim, 1992). Based on the experience from previous studies (Basu et al., 2018; Krajewski et al., 2004; Minette, 1989), it is decided that the suitable duration of the questionnaire was within 30-45 min. The answer was recorded using Likert 11 point scale from 0 (Not extremely severity) to 10 (Extremely severity) in response to the main question: "*In the last 12 months have you had (i.e. cough, sore throat, bronchitis, snivel, head ache, flu, wheeze, dermatitis, asthma, sinus, fever, chest tightness)*? The study assessed the questionnaire's reliability using the internal consistency approach by Cronbach's alpha (Cronbach, 1951; Tavakol and Dennick, 2011). Cronbach's alpha is used in this study as an indicator of scale reliability and the internal structure of test is given as a number from 0 to 1. In which, the Cronbach's alpha varied from 0.6 to 0.7 is considered as an acceptable level of reliability (Ursachi et al., 2015).

2.3. Survey campaign

According to Pallant (2010) illustrated the minimum sample should be more than 150 and at least five observations for each variable. Some authors have recommended sample size at least 5 to 10 observations or the minimum sample of 300 respondents when conducting PCA approach (CoComrey and Lee, 2013). In this study, we conducted the survey by randomly method to interview 300 respondents living in Ho Chi Minh megacity. Table 1 summarizes main activities of the survey, which was carried out in July and August, 2019. The study chose six typical urban and residential regions to assess the effects of bioaerosol pollution on community health belong to Ho Chi Minh megacity.

2.4. Statistical analysis

To facilitate the evaluation of the multidimensional maps of principal component (PCs) loadings, PCA was used as an exploratory tool to investigate patterns in the studied data. The main purpose of PCA aimed to reduce the dimension of explanatory variables (i.e. cough, sore throat, bronchitis, snivel, head ache, flu, wheeze, dermatitis, asthma, sinus, fever, chest tightness) and improve, transfer the old variables into a new one called PCs. PCA is a statistical procedure for identifying the components that best explain the variance in the data (Wold et al., 1987). In order to enhance the interpretability of the factors, a varimax rotation is applied to the significant factors with an initial eigenvalue >1.0 (Guo et al., 2004). PCA is carried out on the correlation matrix and only the components having an eigenvalue greater than one are included in the evaluation of data, based on Kaiser–Guttman criterion in which components with an eigenvalue >1 (Kaiser, 1960; van Assen et al., 2015). PCA is performed using the SPSS software (version 13.0 for Windows), and the criteria for significance in the procedure were defined at $p<0.05$ and $p<0.01$.

Table 1. Research activities in survey campaign

Site	*Site characteristics*	*Time Period*	*Content*
Tan Binh District	- Purposes: A health issue assessment in residential area. - Characteristics: Locates in the east of the city, has a high population density, a medium air pollution level.	29 July to 4 August	Survey and interview: 50 respondents
Binh Thanh District	- Purposes: A health issue assessment in residential area. - Characteristics: Locates in the northeast of the city, has a medium population density, a medium air pollution level.	29 July to 4 August	Survey and interview: 50 respondents
Go Vap District	- Purposes: A health issue assessment in rural area. - Characteristics: Locates in the northwest of the city and less impacted by human activities, a low air pollution level.	29 July to 4 August	Survey and interview: 50 respondents
District 1	- Purposes: A health issue assessment in urban area. - Characteristics: Locates in center city, has a high population density and strongly impacted by human activities, a high air pollution level.	29 July to 4 August	Survey and interview: 50 respondents
Thu Duc District	- Purposes: A health issue assessment in urban and residential area. - Characteristics: Locates in the northeast of the city, belong to suburban area and less impacted by human activities, a low air pollution level.	29 July to 4 August	Survey and interview: 50 respondents
District 4	- Purposes: A health issue assessment in urban area. - Characteristics: Locates in the southeast of the city, has a high population density and a high air pollution level.	29 July to 4 August	Survey and interview: 50 respondents

In the regression analyses of health effects, the study evaluates the effects of bioaerosol exposure with important items and demographic variables such as duration staying at home per day, residential duration, distance to street, medical history, age, gender.

3. Results and discussion

3.1. Demographic of survey respondents

Research samples are distributed randomly by interviewing 300 respondents, in which the ratio of men and women among the main respondents is 67 and 33 percent respectively. Respondents' job includes student, officer, freelancer, worker, trader, unemployment and retirement with the percentage of 8.3, 2.3, 34.0, 16.3, 13.3, 8.0 and 16.0 respectively. The results of descriptive statistics showed the respondents' age is from 13 to 87. The process deal with firstly raw database, the study removed unobtainable or blank questionnaires and the results in Table 2 illustrates the demographic of the suitable respondents.

The duration from last pain varied from 7 to 1600 days and averaged at 211.12 (SD = 278.885) days. On average number of children (< 6 years old) and elder people (> 70 years old) of all respondents in Ho Chi Minh megacity equal to 0.62 (SD = 0.886) and 0.49 (SD = 0.785) respectively. This study paid attention to children because cultivable fungi and particle levels showed high positive correlations with children's respiratory health (Liu et al., 2014). As an indoor biological pollutant, fungi are ubiquitous in indoor ambient and exposure to fungal spores recognized health issues such as atopic dermatitis or respiratory diseases (Gaitanis et al., 2012; Green et al., 2006; Kurup et al., 2000). Moreover, Table 3 illustrated that the characteristics of survey respondents related to the living period at the local (residential duration), home time (time of day) and number of hours staying at home, distance from houses to nearest street. The average residential duration was 13.6703 (SD = 14.60785) years and varied from 0.5 to 70 years. The respondents' hours staying at home was equal to 16.4330 (SD = 6.19439) hours. The distance from houses to streets was ranged 0 to 800 m and averaged 26.7956 (SD = 84.37515) m. The detail results of characteristics of survey respondents is shown in Table 3.

3.2. Reported community health symptom related to of exposure to bioaerosol

Most previous studies have used data from limited monitoring stations to estimate the bioaerosol levels and examine the health effects (Adams et al., 2014; Docampo et al., 2011). Regarding to the relationship between health effects and diseases, exposure to biological agents (bacteria and fungi) may be associated with infectious diseases and allergies (Robertson et al., 2019). Exposure to spores released by fungal groups is known to cause, and worsen, allergies (Flores et al., 2014). Here we used bioaerosol exposure levels derived from a previously collected database (Hai et al., 2019), which shows the major bacterial taxa identified in the ambient air in Ho Chi Minh megacity were *Bacillus siamensis, Micrococcus varians, Staphylococcus aureus,* and *Enterobacteriaceae*. In addition, some airborne fungi (*Aspergillus sp., Fusarium solani, and Penicillium janthinellum*) were also found during both wet and dry seasons (Figs. 2-3; Hai et al., 2019).

Table 2. Descriptive statistics of surveyed respondents

	N	***Minimum***	***Maximum***	***Mean***	***Std. Deviation***
Gender	300	0	1	0.67	0.471
Age (years old)	300	13	87	38.21	14.163
Job[a]	295	1	7	4.14	1.766
Number of baby/children (person)	296	0	6	0.62	0.886
Number of older people (person)	291	0	4	0.49	0.785
Last pain (days)	198	7.00	1600.00	211.12	278.885

[a]*Note: Respondents' job including 1-Student; 2-Officer; 3-Freelancer; 4-Worker; 5-Trader; 6-Unemployment; 7-Retirement*

Table 3. The characteristics of survey respondents

		Residential duration (years)	***Time staying at home (hours)***	***Home Time[b] (time of day)***	***Distance to street (m)***	***Number of windows***
N	Valid	300	291	299	296	292
	Missing	0	9	1	4	8
Mean		13.6703	16.4330	3.3311	26.7956	2.6062
Std. Deviation		14.60785	6.19439	0.71471	84.37515	2.18689
Variance		213.389	38.370	0.511	7119.166	4.783
Range		69.50	19.00	3.00	800.00	14.00
Minimum		0.50	5.00	1.00	0.00	0.00
Maximum		70.00	24.00	4.00	800.00	14.00

[b]*Note: 1-Morning; 2-Afternoon; 3-Night; 4-All day*

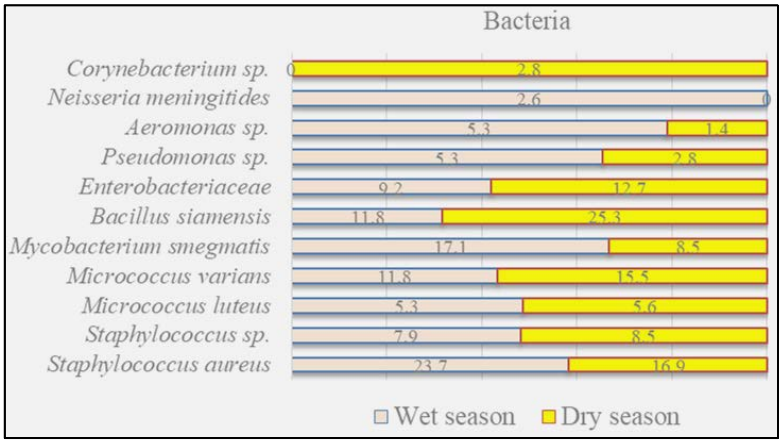

Fig. 2. Bacterial identification results (Hai et al., 2019)

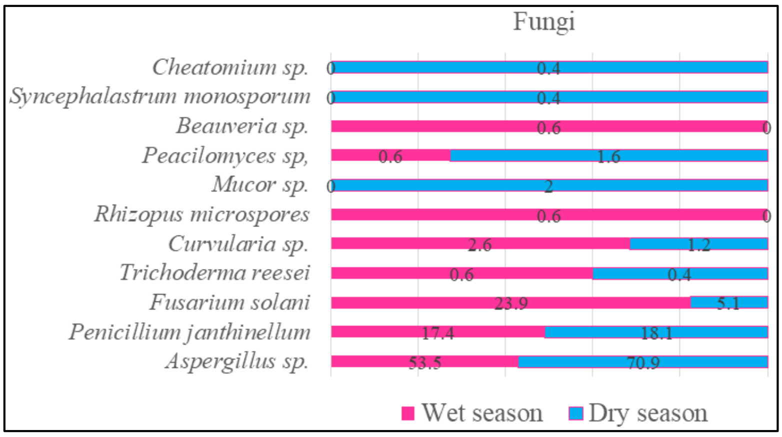

Fig. 3. Fungal identification results (Hai et al., 2019)

Exposure to bioaerosols associated with allergens, microbes, and particulate matter can cause serious illness with higher concentrations leading to respiratory problems, lung infections, and cancer (Humbal et al., 2018). The fungal spores affect community health and increase chest problems (Taia et al., 2019). For example, *Penicillium* is illustrated to produce mycotoxins that could be affected human health (Pitt et al., 2000). Table 4 shows the integrating results of the health issues related to bioaerosol components in the air ambient.

The bioaerosols have been popularly reported as risk factors for many diseases such as asthma, allergic rhinitis, infections and skin allergies (Atkinson et al., 2006; Burge and Rogers, 2000; Harley et al., 2009). Bornehag et al. (2005) showed that indoor ambient moisture increased the risk of respiratory symptoms (e.g. cough, asthma or wheezing) for children aged from one to six. Regarding to health symptoms Table 5 showed item “chest tightness” was lowest in those items with mean equal to 3.334 (SD = 2.7001), indicating a lightly health symptom. Flu and cough items were highest in those items with means equal to 6.518 (SD = 2.5068) and 6.555 (SD = 2.6696). Many indoor air quality complaints include blocked sinuses or runny nose, eye irritation, headache, sore throat, dizziness, and fatigue. Human exposure pathways to air pollution mainly such as inhalation, dermal absorption and increasing potentially adverse health effects (Hu et al., 2017). Some symptoms such as wheeze, chest, dyspnea were strongest associated with grain dust, indicating that components of the dust in air ambient. This suggests that each component of the dust may be given different effects on inhalation.

In addition, the health questions asked in the study are shown in Table 6. Cronbach’s α for the complete 12-item questionnaire was 0.613. The results showed that the questionnaire retained good internal consistency because even with the deletion of any individual item (Basu et al., 2018; Ursachi et al., 2015).

PCA initially extracts five components and using eigenvalues (>1.0) as a measure of the variance of each component. The results of the varimax rotated factor loadings showed the health issues at sampling sites in Ho Chi Minh megacity. Possible symptoms of community illness related to bioaerosols. The five PCs have been identified and explained for 63.2 percent of the overall total variance and with eigenvalues was equal to 1.502 >1 (Table 7). It means that the important hypothetical variables explained the majority of total variance with 36.8 percent loss of information. To promote clarity component identification, a component loading criterion of more than 0.3 was set. The component loading patterns based on this criterion are summarized in Table 8 with loadings greater than 0.3 shown in bold font. Though the PCs can still provide information on the most meaningful items and describes a whole data set relevant data reduction with minimum loss of original information. The first three PCs contribute about 44.4 percent of the total variation in the dataset and have eigenvalues equal to 1.258 >1 (Fig. 4).

Table 4. A health issues related to bioaerosol components

Health issues	*Reason and effect*	*References*
Cough	Cough-generated aerosols Infectious aerosols Exposure to fungal spores	Acuña-Villaorduña et al. (2018), Heldal and Eduard (2004), Roy and Milton (2004), Sattar and Ijaz (2002), Straumfors et al. (2016)
Sorethroat	Aerosol exposure Microbial components	Straumfors et al. (2016), Williamson et al. (1995)
Bronchitis	Exposure to bioaerosols (endotoxin and bacteria)	Eduard et al. (2009), Michel et al. (1989), Zejda et al. (1994)
Snivel	Bioaerosol emissions Bioaerosol exposure	Heldal and Eduard (2004), Pearson et al. (2015)
Headache	Microbial components	Burger (1990), Douwes et al. (2003), Heldal and Eduard (2004), Straumfors et al. (2016)
Flu or influenza	Bioaerosol	Rule et al. (2018)
Wheeze	Infectious aerosols Fungi and pollen exposure Microbial components	Harley et al. (2009), Roy and Milton (2004), Sattar and Ijaz (2002), Straumfors et al. (2016)
Dermatitis	Allergic skin diseases Exposure to bioaerosols	Kallawicha et al. (2016)
Asthma	Exposure to bioaerosols	Atkinson et al. (2006), Badirdast et al. (2017), Eduard et al. (2004), Williamson et al. (1995)
Sinus	Potential health effects of bioaerosols	Douwes et al. (2003), Pearson et al. (2015)
Fever	Airborne endotoxins	Rylander et al. (1978), Rylander and Haglind (1984)
Chest tightness	Microbial components Exposure to fungal spores	Rylander (1996), Rylander and Haglind (1984), Rylander et al. (1978), Straumfors et al. (2016)

Table 5. Descriptive statistics of health symptoms

Item	*N*	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
Cough	299	0.0	10.0	6.555	2.6696
Flu	299	0.0	10.0	6.518	2.5068
Bronchitis	299	0.0	10.0	5.448	2.3487
Wheeze	298	0.0	10.0	5.376	2.3598
Headache	299	0.0	10.0	5.355	2.3477
Asthma	299	0.0	10.0	5.294	2.0432
Sorethroat	299	0.0	10.0	5.191	2.6229
Dermatitis	299	0.0	10.0	5.100	2.2960
Snivel	299	0.0	10.0	5.097	2.3027
Sinus	298	0.0	10.0	4.896	2.1956
Fever	299	0.0	10.0	4.171	2.4415
Chest tightness	299	0.0	10.0	3.334	2.7001

Note: Using Likert 11 point scale: 0 (Not extremely severity) to 10 (Extremely severity)

Table 6. Health questionnaire items and corresponding reliability values (Cronbach's α)

Question	*Corrected Item-Total Correlation*	*Cronbach's Alpha if Item Deleted*
In the last 12 months have you had cough?	0.326	0.601
In the last 12 months have you had sore throat?	0.293	0.608
In the last 12 months have you had bronchitis?	0.335	0.600
In the last 12 months have you had snivel?	0.320	0.603
In the last 12 months have you had head ache?	0.320	0.603
In the last 12 months have you had flu?	0.209	0.624
In the last 12 months have you had wheeze?	0.334	0.600
In the last 12 months have you had dermatitis?	0.208	0.623
In the last 12 months have you had asthma?	0.378	0.595
In the last 12 months have you had sinus?	0.354	0.598
In the last 12 months have you had fever?	0.285	0.609
In the last 12 months have you had chest tightness?	0.301	0.606

Table 7. Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.566	21.387	21.387	2.566	21.387	21.387	1.744	14.533	14.533
2	1.509	12.573	33.959	1.509	12.573	33.959	1.737	14.474	29.007
3	1.258	10.480	44.439	1.258	10.480	44.439	1.438	11.982	40.989
4	1.202	10.013	54.452	1.202	10.013	54.452	1.435	11.954	52.944
5	1.052	8.768	63.220	1.052	8.768	63.220	1.233	10.277	63.220

Extraction Method: Principal Component Analysis.

Table 8. Categorical PCA pattern matrix with item loadings of ≥0.3 for a five-component

	Component				
	1	2	3	4	5
Sinus	**0.820**	0.164	0.118	-0.044	-0.090
Asthma	**0.811**	0.011	0.092	0.135	0.155
Wheeze	**0.335**	0.241	0.016	0.326	0.318
Bronchitis	0.059	**0.814**	0.054	0.031	0.152
Snivel	0.279	**0.678**	-0.097	0.015	0.003
Sore throat	-0.141	**0.656**	0.264	0.198	-0.262
Chest tightness	-0.041	0.131	**0.818**	0.125	0.058
Fever	0.310	-0.044	**0.808**	-0.058	0.002
Flu	0.043	-0.094	0.032	**0.808**	-0.112
Headache	0.033	0.260	0.047	**0.677**	0.075
Cough	0.140	-0.022	0.011	0.246	**-0.750**
Dermatitis	0.285	-0.052	0.093	0.279	**0.651**

Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization.

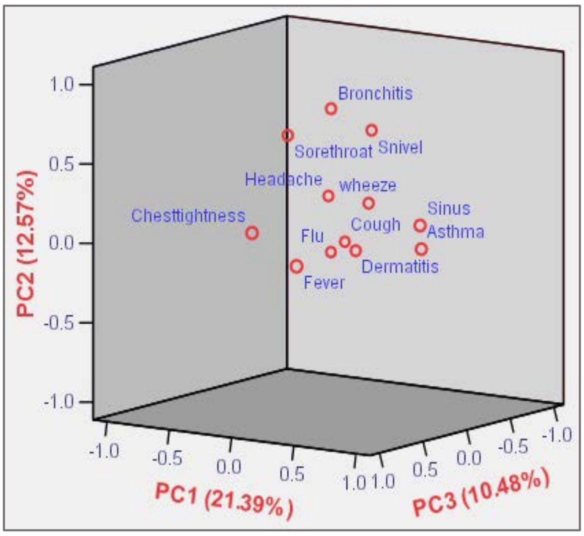

Fig. 4. PCA loadings plot by major PCs

In the PCA loadings plot by major PCs (Fig. 4) showed that PC_1 accounts for 21.387 percent of the total variance and is characterized by high loading for sinus, asthma, wheeze (positive loadings). PC_2 consists of bronchitis, snivel, sore throat (positive loadings) which accounts for 12.573 percent of the total variance. PC_3 has shown disease sources which are related to fever problems. The last two PCs has identified two major clusters involving flu and cough symptoms. The detail of five PCs is as follow: PC_1 (sinus, asthma, wheeze) named "nose symptoms"; PC_2 (bronchitis, snivel, sore throat) named "throat or respiratory symptoms"; PC_3 (chest tightness, fever) named "fever symptoms"; PC_4 (flu, headache) named "flu or flu-like symptoms"; and last but not least PC_5 (cough, dermatitis) named "cough issues".

Many of these diseases are thought to be spread by sick individuals through coughing, sneezing, speaking, and breathing (Roy and Milton, 2004; Sattar and Ijaz, 2002) because these activities can release aerosol particles containing potentially infectious microorganisms (Fennelly et al., 2012; Lindsley et al., 2010; Morawska et al., 2009). In this study, PCA was performed on the 12 remaining items and the eigenvalues for the resulting components are shown in the scree plot (Fig. 5).

Furthermore, some studies have illustrated the use of the Kaiser–Guttman criterion in which components with an eigenvalue >1 are retained (Cattell, 1966; Hung et al., 2020; van Assen et al., 2015; Yeomans and Golder, 1982). Therefore, results in Fig. 5 shows the existing five subgroups related to different symptoms. Thus, this is also reported by the similarly illness and health issues such as fevers, chills or cough (Basu et al., 2018; Radon, 2006).

The five PCA components appear to fit the main themes the questionnaire intended to ask, which namely the presence of related symptoms as a potential indicator of negative effect from bioaerosol exposure. Bioaerosol exposure is linked to health issues including chronic bronchitis, asthma, dermatitis, flu.

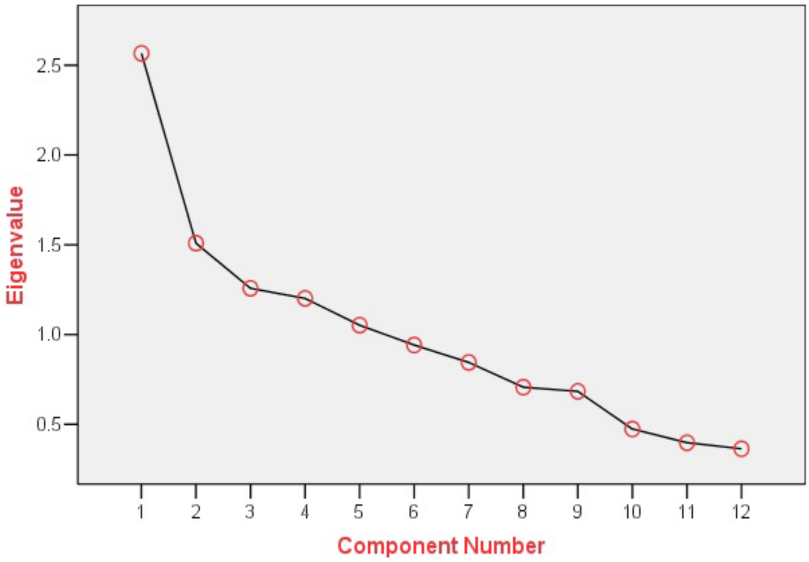

Fig. 5. Scree plot of eigenvalues after PCA

Our findings indicate that residents living in the urban areas in Ho Chi Minh megacity have reported health response and complaints, indicating health problems related to environmental bioaerosols are a substantial concern of the community.

3.3. Influence of latent factors on health symptom

Human exposure to bioaerosols (mostly due to occupational exposure or air pollution) is associated with a wide variety of acute and chronic diseases ranging from allergies, asthma, rhinitis, sinusitis and bronchitis (Brown and Hovmøller, 2002; Douwes et al., 2003; Eduard et al., 2012; Heederik and Von, 2012). In this study, the influence of latent factors (i.e. habit, environment and medical history) on health symptoms related to bioaerosols were also examined. Specifically, we identified the major latent factors, including last pain, residential duration, time staying at home, home time, distance to street, and age, assessed their relationships with health symptom levels through multiple linear regression.

Overall, the latent factors could be used to explain the variation in eight out of 12 health symptoms related to bioaerosols across the study area (Table 9). Specifically, the regression models using six latent factors have p-value of less than 0.01 for cough, sore throat, bronchitis and respectively explain 23.6, 22.8, 24.9 percent of the health symptom variation. Table 9 also shows that the six latent variables can explain 20.3, 15.8, 16.5, 18.9 and 21.6 percent of the variation in headache, flu, wheeze, asthma, and fever respectively (p-value of less than 0.05). However, the p-value of snivel, dermatitis, sinus, chest tightness was >0.05, indicating no statistical significance. It is informative to note that, living near highly dense traffic areas perhaps increases the serious risk of health issues, indicating that traffic air pollution can potentially exacerbate health symptoms.

Many studies suggest that environmental characteristics, air pollution, lifestyles or behavior contribute to the increase of disease related issues (Brauer et al., 2007). The characteristics and behavior of residents (i.e. last pain, residential duration, time staying at home, home time, distance to street and age) lead to individual exposure to bioaerosols from differently urban areas in Ho Chi Minh megacity were determined (Table 9). Regression models of health issues for each symptom in these areas showed the levels of independent variables such as last pain and distance to street had a negative correlation coefficient (β <0). It means that residents were living next to streets and had nearest health symptom which indicated a higher exposure related to bioaerosol pollution. For example, living environment conditions such as sites near high traffic density streets and limited space can be contributed to health symptoms as allergic (Hu et al., 2017). In this study, statistical results showed the distance from houses to streets and the duration from last pain were averaged 26.7956 (SD = 84.37515) m and 211.12 (SD = 278.885) days, respectively.

The exposed group living nearest areas from the site at a street showed higher rates of health complaints (Herr et al., 2003). In contrast, regression models of effects of latent factors on health symptom for each symptom related to residential duration, time staying at home and age illustrated that it had a positive correlation coefficient (β >0). The residential duration, time staying at home and age are as important factors affecting exposure levels in Ho Chi Minh megacity. It means that these variables may increase together with the increase of health symptom's item. in the residential environment, the health-related problems of bioaerosol levels were assessed by microbiological pollution. Furthermore, the indoor environment plays important roles to human health because people is used to spend a lot of their time (Le et al., 2011; Nasir et al., 2012).

Table 9. Regression model of effects of latent factors on health symptom

Symptom	*Regression Model - Standardized Coefficients (β)*						*R value*	*R^2 value*	*F value*
	Last pain	*Residential duration*	*Time staying at home*	*Home time*	*Distance to street*	*Age*			
Bronchitis	-0.301	-0.246	0.303	0.261	-0.321	-0.338	0.499	0.249	3.342^{*}
Cough	0.311	0.291	-0.414	0.288	-0.318	0.001	0.486	0.236	4.806^{**}
Sorethroat	-0.253	-0.325	0.255	0.250	-0.261	-0.318	0.478	0.228	2.624^{**}
Fever	0.226	0.227	-0.363	0.383	0.312	-0.301	0.465	0.216	2.601^{**}
Headache	-0.261	0.210	-0.408	0.415	-0.216	0.230	0.450	0.203	2.240^{*}
Asthma	-0.256	0.230	0.207	-0.334	0.286	0.288	0.435	0.189	2.017^{*}
Wheeze	-0.297	0.206	0.227	0.001	-0.283	-0.213	0.406	0.165	2.557^{*}
Flu	-0.228	0.244	0.212	0.237	-0.225	-0.354	0.398	0.158	3.816^{**}
Sinus	-0.377	0.316	-0.213	0.204	-0.221	-0.228	0.464	0.215	1.768^{ns}
Chesttightness	-0.295	0.283	0.209	0.277	-0.267	0.206	0.450	0.203	0.681^{ns}
Dermatitis	0.245	0.240	-0.306	0.001	-0.209	0.224	0.370	0.137	0.948^{ns}
Snivel	-0.471	0.217	0.293	-0.220	-0.232	-0.232	0.099	0.010	1.027^{ns}

*Note: **Significant at α=0.01, *Significant at α=0.05, ns = no significant.*

Based on the survey results illustrated the respondents' hours staying at home in Ho Chi Minh megacity was equal to 16.4330 (SD = 6.19439) hours. Thus, the exposure of human population to bioaerosol pollution is a major concern in urban and residential areas in Ho Chi Minh megacity. The findings are useful to evaluate influence of related factors on health symptom for community and use to reference for future studies.

4. Conclusions

This empirical study examines the impact of bioaerosol on community health in Ho Chi Minh megacity using a questionnaire with the participated of 300 local residents. Using principle component analysis, this study identified five subgroups of bioaerosol-related health symptoms: PC_1 named "nose symptoms"; PC_2 named "respiratory symptoms)"; PC_3 named "fever symptoms"; PC_4 named "flu (flu-like symptoms)"; and PC_5 named "cough symptoms".

The study also found that complaints related to disease symptoms, i.e. flu and cough, are generally higher rates relative to other symptoms, indicating the potential effect of bioaerosol accumulation by air pollution and residential air with regard to disease symptoms. Using linear regression models, eight out of the 12 common symptoms related to bioaerosol (including headache, flu, wheeze, asthma, fever) can be linked to latent factors (statistically significant at 0.05 level), indicating that the living habit and environment can substantially affect health symptoms. This study provides the first evidence of community health effects by bioaerosol pollution in a megacity of Vietnam, demonstrating the urgent demand for further studies in evaluating the impact of environmental conditions, especially air pollution, on community health. Specifically, microorganism risk assessment can propose relevant solutions for community in Ho Chi Minh megacity.

Thus, the epidemiological questionnaire survey and the health complaints to bioaerosols exposure in indoor environment were performed in six urban and residential communities in Ho Chi Minh megacity. Research is helpful to better understand the potential risk factors related to bioaerosol effect of indoor air. In this study we only assessed complaints of the bioaerosols pollutions, therefore, the potential limitation can be led to the recall bias of health problems. It is important to more detailed investigate the roles of the air quality in future.

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