Original Article

Assessment of the relationship between particulate matter level and respiratory diseases in dogs and cats in Bangkok, Thailand

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Abstract

Particulate matter (PM) 2.5 has become a serious pollution concern in many countries, including Thailand. Due to its small particle size, PM2.5 can penetrate deep into pulmonary tissues, posing health risks to humans. Furthermore, it is hypothesized that PM2.5 may also cause respiratory diseases in dogs and cats. This study aimed to evaluate a relationship between PM2.5 levels and the number of dogs and cats visiting due to respiratory problems in Bangkok, Thailand, and to investigate potential environmental factors that may contribute to these health outcomes. A total of 184 dogs and 73 cats were included in the study. Medical records of dogs and cats with respiratory issues from the Small Animal Teaching Hospital, Faculty of Veterinary Science, Chulalongkorn University, Thailand, were analyzed, along with data collected from questionnaires and PM2.5 values in Bangkok from October 1, 2021 to March 31, 2023. The study found no statistically significant correlation between average PM2.5 levels in Bangkok and the number of veterinary visits for dogs (p=.057) or cats (p=.126). The study also provided descriptive data on dogs and cats with respiratory disease, including animal characteristics, household environments, types of respiratory diseases, and exposure to risk factors. This study will raise awareness among pet owners about managing dogs and cats.

Keywords: cats, dogs, particulate matter, PM2.5, respiratory disease

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Introduction

The respiratory system is one of the most vital body systems, and it plays an important role in oxygen and carbon dioxide exchange to keep the cells in the body alive and functioning. Consequently, impaired respiratory function can significantly reduce the quality of life in patients with respiratory problems and may even lead to death. Respiratory problems do not only exist in humans but also occur in companion animals. Dogs and cats can experience a wide range of respiratory diseases, such as canine chronic bronchitis, feline asthma, feline upper respiratory disease complex, tracheal collapse, etc. Moreover, there are numerous pathogens, irritants, and allergens, including bacteria, viruses, and particulate matter, that can cause respiratory illness.

Particulate matter (PM) is a complex mixture with diverse chemical and physical characteristics (WHO, 2021). PM can be classified based on size, composition, origin, and solubility (Xing *et al.,* 2016). In this study, we focused on PM2.5, which refers to particles with a diameter less than or equal to 2.5 microns (Xing *et al.,* 2016).

Bangkok, the bustling capital of Thailand, is currently facing a critical air pollution problem due to high levels of PM2.5. The main sources of PM2.5 in Bangkok are thought to be vehicle emissions, construction sites, and open burning of agricultural waste. Bangkok is known for its heavy traffic congestion, which leads to high levels of vehicle emissions (Primocare, 2023).

PM2.5 can cause serious health problems because its small size allows it to penetrate deeper into pulmonary tissues than larger particles, such as PM10, can (Choi *et al.,* 2004). Health problems associated with exposure to PM2.5 include increased hospitalizations, cardiovascular and respiratory diseases, cancer, morbidity, and mortality (Atkinson *et al.,* 2014; Bell *et al.,* 2014).

According to the air pollution index provided by the Pollution Control Department, the threshold for PM2.5 levels considered harmful to human health is approximately 37.6 micrograms per cubic meter. However, the effects of PM 2.5 concentration on dogs and cats have not yet been thoroughly investigated. Nonetheless, there were some findings in the previous study that indicate that exposure to complex mixtures of pollutants can cause pulmonary structural changes in dogs and lead to respiratory disturbance or respiratory diseases in the future (Calderón-Garcidueñas *et al.,* 2001).

Although numerous studies have been conducted on the effects of PM2.5 on humans, there are few studies on companion animals. A previous study in Taiwan reported that the association between indoor air pollution and respiratory disease in dogs is complicated, whereas an unacceptable level of household PM2.5 (>35 $\mu g/m^3$) is significantly associated with respiratory problems in cats (Lin *et al.,* 2018).

The objectives of this study were to investigate the relationship between PM2.5 levels and the number of dogs and cats visiting the Small Animal Teaching Hospital, Faculty of Veterinary Science, Chulalongkorn University, Bangkok, Thailand, due to respiratory problems from October 1, 2021 to March 31, 2023, and to examine potential environmental factors that may contribute to these health outcomes.

Materials and Methods

The study was conducted as a retrospective study. Medical records of 184 dogs and 73 cats that visited the Small Animal Teaching Hospital, Faculty of Veterinary Science, Chulalongkorn University, Thailand, for respiratory problems from October 1, 2021 to March 31, 2023, along with data collected from questionnaires and PM2.5 values in Bangkok, were retrieved for analysis.

The medical history of the animals, including their names, hospital numbers (HN), species, breeds, genders, ages, body weights, and final diagnoses, were retrieved from the hospital information system.

Bangkok consists of 50 districts, which can be divided into six regions, including Central Bangkok, North Bangkok, South Bangkok, Eastern Bangkok, North Thonburi, and South Thonburi. The daily PM2.5 levels for each district in Bangkok were obtained from the Pollution Control Department's website (www.air4thai.com).

In addition, information about the lifestyle and risk of exposure to air pollutants was obtained from the owners through a telephone questionnaire (Figure 1).

The selection criteria focused on dogs and cats in Bangkok that had visited the Small Animal Teaching Hospital, Faculty of Veterinary Science, Chulalongkorn University, Thailand, with respiratory tract diseases, including canine chronic bronchitis, feline inflammatory bronchial disease (chronic bronchitis or feline asthma), brachycephalic obstructive airway syndrome, tracheal collapse, lung collapse, and other respiratory diseases. Patients with respiratory infections, cardiovascular diseases, and pulmonary hypertension were excluded.

Statistical analysis was conducted using SPSS software version 28.0. The study variables included the number of visits for dogs and cats, PM2.5 levels, age, body weight (kg), gender distribution, living environment, air purifier usage, clinical signs, household type, risk factors, and the prevalence of various respiratory and other diseases. The PM2.5 values used for analysis were the monthly average PM2.5 levels over the 18-month study period. The correlation between the number of visits of dogs and cats and the PM2.5 value was analyzed using Spearman's rank correlation. The correlation coefficient ranges from -1 to 1. The normality test for the age and weight of dogs and cats was conducted using the Kolmogorov-Smirnov test; therefore, the data are reported as the median and interquartile range (25^{th}-75^{th} interquartile range). The other variables are reported as descriptive statistics. Statistical significance was considered at $p<0.05$.

Patient history and symptoms questionnaire

Owner/client's name_____ Species_____

Pet's name_____ HN_____ Breed_____

Sex_____ Date of birth ____/____/____ Age____years_____months

Body weight_____kg

Please complete the pages below as accurately as possible.

1. How many dogs or cats are kept in the household?
   ☐ ____ dogs ☐ ____ cats ☐ Others; _____
2. The type of animal's living environment.
   (The animals that are partially outdoors or indoors are categorized in the outdoor group.)
   ☐ 100% Indoor ☐ Outdoor
3. If kept 100% indoors, is there an air purifier? If so, how often is it used in the area where the animal stays?
   ☐ Yes, _____
   ☐ No
4. If kept outdoors, how often is the animal allowed outside?
   _____
5. What are the potential risks of pollution in the area around the house?
   ☐ Being near a main road
   ☐ Exposure to smoke from nearby factories
   ☐ Secondhand smoke
   ☐ Incense smoke/perfumes/sprays/candles
   ☐ Cooking smoke
   ☐ Construction dust
   ☐ Mosquito repellents
   ☐ No risk as mentioned above
   ☐ Others; _____
6. What symptoms prompted the owner to bring the animal to the veterinarian?
   ☐ Coughing or sneezing more than 5 times per day
   ☐ Coughing or sneezing for more than 5 minutes
   ☐ Having signs of depression
   ☐ Others; _____
7. Did other animals in the household (if any) have similar symptoms?
   ☐ Yes
   ☐ No
8. Did the animal's symptoms worsen during any particular time of year?
   ☐ Yes, when_____
   ☐ No
9. Is the animal currently receiving any treatment?
   ☐ Yes, _____
   ☐ No

Figure 1 The questionnaire for interviewing the patients' owners.

Result

The average monthly PM2.5 levels in Bangkok and the number of visits to Chulalongkorn University Small Animal Teaching Hospital of 184 dogs and 73 cats were collected throughout the study period, as shown in Table 1 and Figure 2.

Spearman's correlation was conducted to evaluate the relationship between the average PM2.5 levels in Bangkok and the number of visits by dogs and cats with respiratory problems. The correlation between the average PM2.5 levels in Bangkok and the number of visits of dogs (p=0.057) and cats (p=0.126) was not significant (Table 2).

Our data on monthly average PM2.5 concentrations, when compared to the AQI criteria in Table 3, revealed that only February 2023 (PM2.5 = 39.1 µg/m^3) and March 2023 (PM2.5 = 39.3 µg/m^3) had PM2.5 concentrations within the "Unhealthy" category (PM2.5 = 37.6-75.0 µg/m^3) (Figure 3).

Additionally, we calculated the seasonal average PM2.5 levels for each district in Bangkok and visualized them on maps. The number of dogs and cats visiting Chulalongkorn University Small Animal Teaching Hospital during the corresponding seasons was calculated as the average number of visits for six regions of Bangkok. Categorizing seasons based on the announcement provided by the Thai Meteorological Department. The results are presented in Figure 4.

Data from 184 dogs and 73 cats were collected. The age, weight, gender, living environment, air purifier usage, clinical signs, and household type of dogs and cats in this study are shown in Table 4. The risk factors affecting the respiratory system and the current respiratory diseases in the retrieved dogs and cats were revealed in Table 5 and Table 6, respectively. The clinical signs of the recruited dogs and cats included respiratory signs such as nasal discharge, sneezing, coughing, and respiratory distress. All clinical signs were recorded through telephone questionnaires with the owners. The absence of clinical indicated that the pets did not show any abnormal respiratory signs noticed by the owner.

Table 1 Monthly average PM2.5 levels in Bangkok and Number of visits of dogs and cats throughout the study period

Month, year	Average PM2.5 level (µg/m^3)	Number of visits of dogs	Number of visits of cats
October, 2021	17.8	17	10
November, 2021	23.3	17	11
December, 2021	35.1	26	8
January, 2022	29.8	7	12
February, 2022	30.3	18	19
March, 2022	23.2	15	10
April, 2022	20.5	29	11
May, 2022	18.1	32	16
June, 2022	15.6	15	21
July, 2022	14.4	28	14
August, 2022	15.3	21	14
September, 2022	16.8	29	10
October, 2022	24.9	19	18
November, 2022	26.2	13	20
December, 2022	28.9	21	16
January, 2023	32.8	15	5
February, 2023	39.1	6	10
March, 2023	39.3	16	6

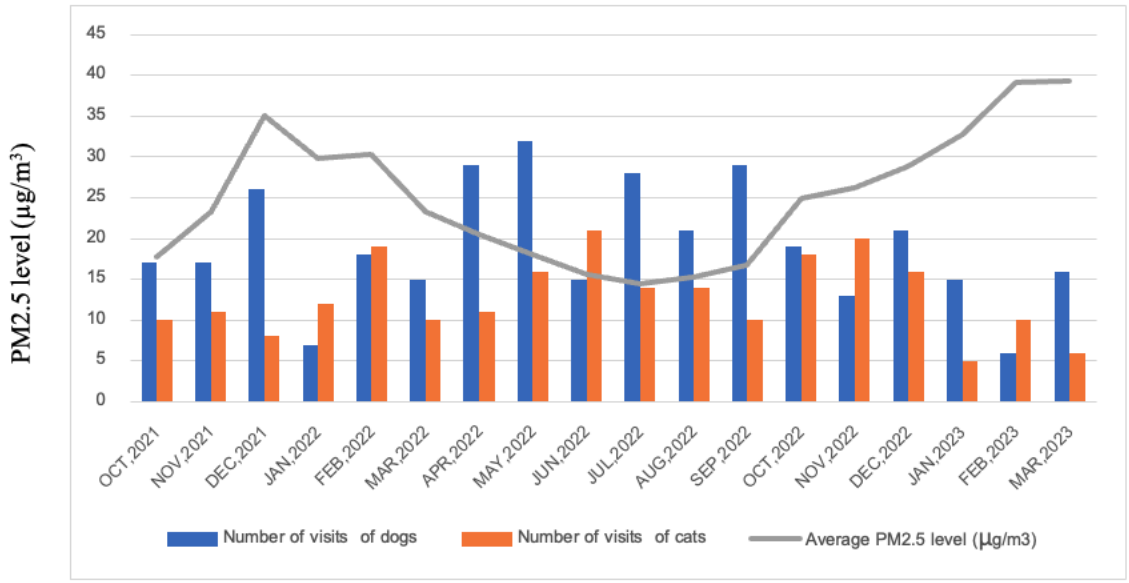

Figure 2 Monthly average PM2.5 levels in Bangkok and number of visits of dogs and cats throughout the study period.

Table 2 Spearman's correlation between the average PM2.5 levels in Bangkok and the number of visits of dogs and cats.

Species	Correlation coefficient	*p*-value
Dogs	-0.456	0.057
Cats	-0.374	0.126

Table 3 Criteria of Thailand Air Quality Index (AQI) (Pollution Control Department).

Air Quality Index (AQI)	Color	Meaning	PM2.5* (ug/m³)	Note
0-25		Excellent	0-15.0	Everyone can live their life normally.
26-50		Satisfactory	15.1-25.0	**General public:** able to do outdoor activities normally **People who need special health care:** abnormal symptoms should be observed, such as frequent coughing, difficulty breathing, shortness of breath, wheezing, chest tightness, chest pain, palpitations, nausea, unusual fatigue, or dizziness.
51-100		Moderate	25.1-37.5	**General public:** reduce the amount of time spent doing strenuous outdoor activities or exercises. **People who need special health care:** - Use personal protective equipment such as $PM_{2.5}$ protective masks every time you go out. - Reduce the duration of activities or outdoor exercise that requires a lot of energy. - If there are abnormal symptoms, consult a doctor immediately.
101-200		Unhealthy	37.6-75.0	**General public:** - Use personal protective equipment such as $PM_{2.5}$ protective masks every time you go out. - Limiting the amount of time spent doing strenuous outdoor activities or exercises. - Abnormal symptoms should be observed, such as coughing, difficulty breathing, or eye irritation. **People who need special health care:** - Use personal protective equipment such as $PM_{2.5}$ protective masks every time you go out. - Avoid activities or outdoor exercise that require a lot of energy. - Follow your doctor's advice. If there are any abnormal symptoms, seek medical attention.
201 Above		Very unhealthy	75.1 Above	**Everyone:** Should avoid outdoor activities. - Use personal protective equipment such as $PM_{2.5}$ protective masks every time you go out. - If you have any health symptoms, you should consult your doctor. - People with congenital disease should be in a safe area from air pollution. Have the necessary medicines and equipment ready and strictly follow the doctor's advice.

* PM2.5 24 hours continuous average: (µg/m3)

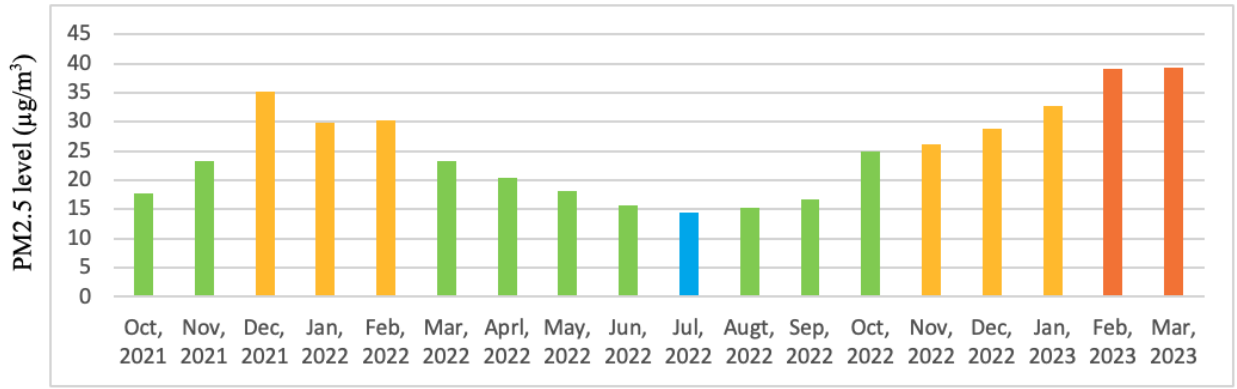

Figure 3 Monthly average PM2.5 levels in Bangkok categorized by AQI.

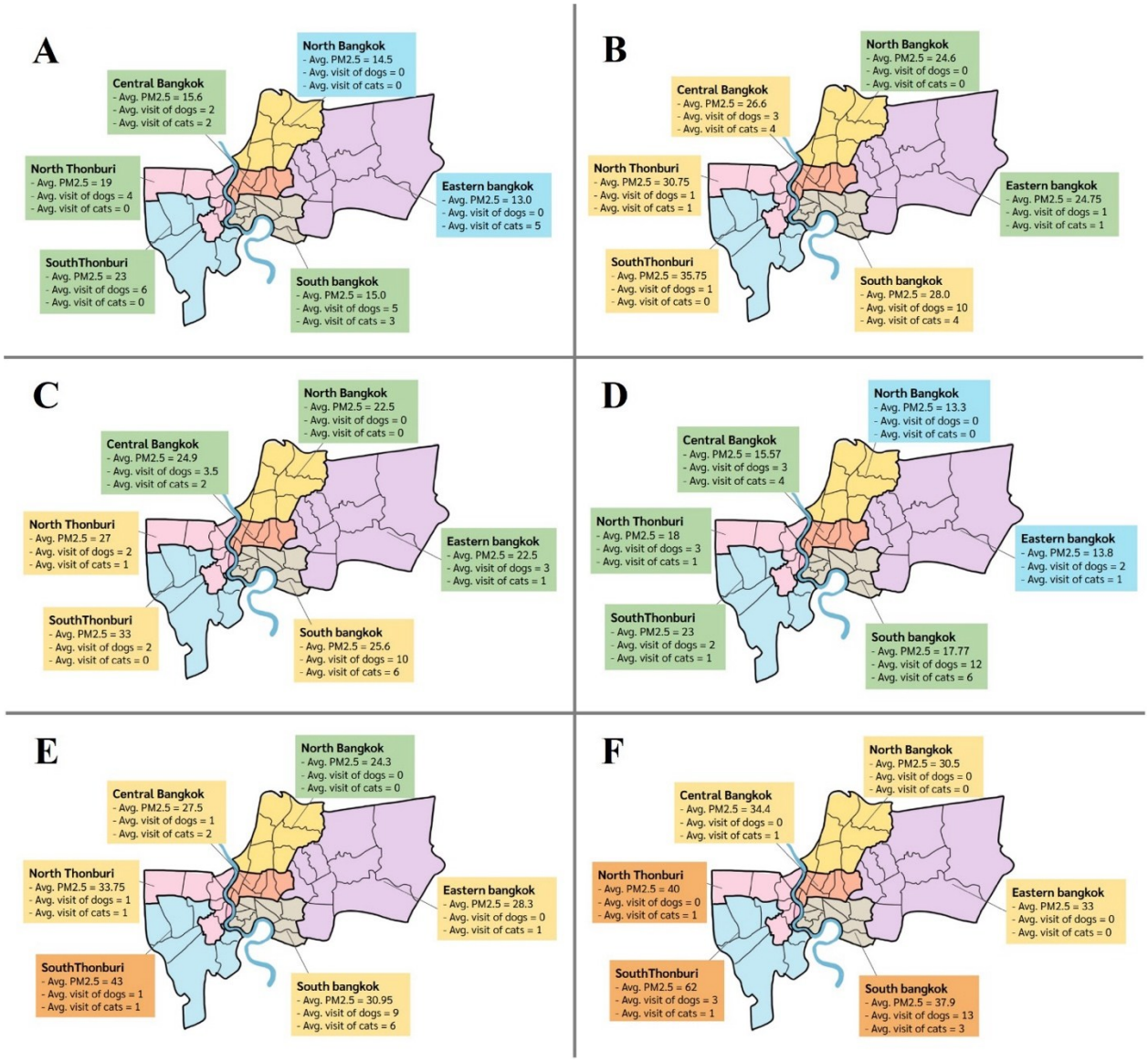

Figure 4 Average PM2.5 levels of each season classified according to the AQI color scale, along with the average visit of dogs and cats categorized by season and district in Bangkok: (A) A map showing data during the rainy season (October 2021); (B) A map showing data during the winter season (November 2021 – February 2022); (C) A map showing data during summer season (March 2022 – April 2022); (D) A map showing data during the rainy season (May 2022 – October 2022); (E) A map showing data during the winter season (November 2022 – February 2023); (F) A map showing data during summer season (March 2023).

Breed: The breeds of dogs in the study included Pomeranian (n=53), Mixed breed (n=29), Chihuahua (n=24), Shih Tzu (n=23), Poodle (n=11), Yorkshire Terrier (n=10), Pug (n=7), Bangkaew (n=4), French Bulldog (n=3), Golden Retriever (n=2), Maltese (n=2), Jack Russell Terrier (n=2), Alaskan Malamute (n=1), American bulldog (n=1), American Bully (n=1), Beagle (n=1), Bulldog (n=1), Finnish Spitz (n=1), Japanese Spitz (n=1), Labrador Retriever (n=1), Miniature Pinscher (n=1), Shiba Inu (n=1), Spitz (n=1), Terrier (n=1), Welsh Corgi (n=1) and unknown (n=1). The three most predominant breeds encountered in this research were Pomeranian, followed by mixed breeds, and Chihuahuas.

Meanwhile, the breeds of cats included Domestic Shorthair (n=53), Scottish Fold (n=7), Persian (n=5), Mixed breed (n=3), Munchkin (n=2), American shorthair (n=1), Korat (n=1) and unknown (n=1). The three most predominant breeds encountered in this research were Domestic Shorthairs, followed by Scottish Folds, and Persians.

Age: The median age for dogs was 11.0 years (range: 8.0 - 13.0), whereas the median age for cats was 6.0 years (range: 4.0 - 10.0). Our study categorized dogs into three age groups: young adults, mature adults, and seniors (Creevy *et al*., 2019). The senior group, comprising dogs over 9 years old represented the largest population. The mature adult group, comprising dogs aged 6-9 years was the second largest. Young adults were the smallest population.

In contrast to dogs, most cats in our study were classified as young adults, aged between 1 and 6 years (Quimby *et al*.,2021). The next largest groups were mature adults and seniors, which were of similar sizes.

Body Weight: The median body weight for dogs was 5.00 kg (range: 3.6 - 8.00 kg) due to the predominance of small breeds in our study population. While for cats, it was 4.40 kg (range: 3.87 - 5.20 kg).

Gender Distribution: Among the dogs, 99 were male (53.8%) and 85 were female (46.2%). In the cat population, 30 were male (41.1%) and 43 were female (58.9%).

Living Environment: A large proportion of dogs (91.8%) lived indoors, and a similar trend was seen in cats (75.3%). Our survey respondents indicated that the majority of dogs and cats are housed indoors.

Air Purifier Usage: Among the dogs, 47.3% (87/184) had access to an air purifier, similar to 45.2% (33/73) of cats.

Clinical Signs: As part of our research, we use questionnaires with pet owners to gather information regarding their pets' symptoms during periods of heightened PM2.5 concentrations. Examples of symptoms include coughing, sneezing, reverse sneezing, nasal discharge, difficulty breathing, cyanosis, and syncope. The prevalence of clinical signs in indoor pets was similar between those living in households with air purifiers and those without.

Household Type: A higher percentage of dogs (67.4%) lived in multiple-dog households, while 32.6% of dogs lived in single-dog households. In comparison, 86.3% of cats lived in multiple-cat households, and 13.7% lived in single-cat households. Our study revealed that the majority of dogs and cats were kept in multiple household environments. The multiple-dog households (85/124; 68.54%) and multiple-cat households (41/63; 65.1%) had other animals that were free from clinical signs. Households with other animals showing similar symptoms were observed in 31.46% (39/124) of dogs and 34.9% (22/63) of cats.

The most prevalent risk factors among dogs were cooking behavior, followed by exposure to sprays/perfumes and construction dust. A total of 85 dogs were identified with multiple risk factors, while 29 dogs did not demonstrate any of the defined risk factors. Similarly, the most prevalent risk factors among cats were exposure to sprays/perfumes, followed by second-hand smoke and construction dust. In total, 43 cats were identified with multiple risk factors, whereas 12 cats did not demonstrate any of the defined risk factors.

Table 6 shows the prevalence of various respiratory and other diseases in the animals selected for the study. In the dog population, chronic bronchitis was the most prevalent disease. In the cat population, feline inflammatory bronchial disease was the most prevalent disease. Due to the lack of bronchoalveolar lavage (BAL) samples in this study, we were unable to distinguish between chronic bronchitis and asthma. Consequently, we have grouped these conditions under the term "feline inflammatory bronchial disease". Other respiratory diseases included chronic obstructive pulmonary disease, acute respiratory distress syndrome, and nasopharyngeal narrowing. Other conditions encompassed obesity, myxomatous mitral valve disease in dogs (without clinical signs of congestive heart failure), and chronic kidney disease in cats.

Table 4 The characteristics of dogs and cats enrolled in the study.

Variable	Dogs (n=184)	Cats (n=73)
Age (year)	11.0 (8.0 - 13.0)	6.0 (4.0 - 10.0)
Body weight (kg)	5.00 (3.6 - 8.00)	4.40 (3.87 - 5.20)
Male	98	30
Female	86	43
Outdoor living (%)	8.2 (15/184)	24.7 (18/73)
Indoor living (%)	91.8 (169/184)	75.3 (55/73)
Air purifier (%)	47.3 (87/184)	45.2 (33/73)
No air purifier (%)	52.7 (97/184)	54.8 (40/73)
Single household (%)	32.6 (60/184)	13.7 (10/73)
Multiple households (%)	67.4 (124/184)	86.3 (63/73)

Age and body weight of dogs and cats are reported as median (25^{th}-75^{th} interquartile range).

Table 5 The exposure to various risk factors for dogs and cats.

Risk Factor	Dogs (n=184)	Cats (n=73)
Cooking behavior (%)	32.6 (60/184)	19.2 (14/73)
Spray/perfume (%)	30.4 (56/184)	39.7 (29/73)
Dust from construction (%)	24.5 (45/184)	30.1 (22/73)
Car exhaust (%)	22.3 (41/184)	24.7 (18/73)
No risk exposed (%)	15.8 (29/184)	16.4 (12/73)
Second-hand smoke (%)	12.5 (23/184)	32.9 (24/73)
Incense smoke (%)	12.0 (22/184)	16.4 (12/73)
Mosquito repellent smoke (%)	6.5 (12/184)	8.2 (6/73)
Nearby factories smoke (%)	3.3 (6/184)	1.4 (1/73)

Table 6 The prevalence of various respiratory and other diseases in the animals selected for the study.

Diseases	Dogs (n=184)	Cats (n=73)
Chronic bronchitis (%)	95.7 (176/184)	0
Brachycephalic airway syndrome (%)	4.3 (8/184)	0
Tracheal/lung collapse (%)	12.0 (22/184)	0
Feline inflammatory bronchial disease (chronic bronchitis or Feline asthma) (%)	0	97.3 (71/73)
Other respiratory diseases (%)	15.2 (28/184)	11 (8/73)
Other diseases (%)	42.4 (78/184)	17.8 (13/73)

Discussion

The purpose of this study is to investigate the relationship between PM2.5 levels and the prevalence of respiratory diseases in dogs and cats in Bangkok, Thailand. Specifically, the study aims to assess how varying levels of air pollution, particularly PM2.5, correlate with the incidence of respiratory conditions in dogs and cats and to explore potential environmental factors that may contribute to these health outcomes. During our study period of 1 year and 6 months, we found that the number of visits of dogs and cats with respiratory problems was not correlated with the average levels of PM2.5. Senior dogs and young adult cats were the most affected life stage groups, with chronic bronchitis being the most common condition in dogs and inflammatory bronchial disease in cats.

Previous studies in humans showed that the more PM2.5 concentration level was increased, the more hospital visit number would become (Tsai *et al.,* 2014; Peng *et al.,* 2016; Zhao *et al.,* 2017; Zhang *et al.,* 2019; Wang *et al.,* 2021). When comparing our monthly average PM2.5 data to Thailand's Air Quality Index, we found that only February and March 2023 exhibited PM2.5 levels within the "Unhealthy" range, which can lead to abnormal symptoms like coughing, difficulty breathing, or eye irritation (Pollution Control Department). Compared to a previous study in Taiwan, an unacceptable level of household PM2.5 (>35 μg/m^3) was significantly associated with respiratory disease in cats. In contrast, PM2.5 levels were not different between dogs with respiratory diseases and the control group (Lin *et al.,* 2018). In addition, another study explained that hypercellular response in canine lower airways was relevant to unacceptable indoor PM2.5 levels (Lin *et al.,* 2020). However, we did not find an association between PM2.5 levels and visits of dogs and cats with respiratory diseases at the Small Animal Teaching Hospital in this study. Upon examining the monthly visit details, we found that the South Bangkok area had the highest number of hospital visits. This is likely because the Chulalongkorn University Small Animal Teaching Hospital is also located in this area.

However, PM2.5 concentration levels in Thailand vary across seasons. A previous study in Thailand showed that PM2.5 levels are highest in the summer, followed by winter, with the lowest levels in the rainy season (Hassan Bran *et al.,* 2024). However, in our study, the relationship between PM2.5 concentration levels, the prevalence of respiratory diseases in dogs and cats, and season was not found. This lack of correlation may be attributed to the relatively short study period of 1 year and 6 months.

Moreover, the average PM2.5 concentration used in the present study was calculated from 12 air quality measuring stations around Bangkok, which were approved by the Pollution Control Department, Ministry of Natural Resources and Environment. However, the locations of these stations may not accurately reflect the actual PM2.5 concentration in all household areas of the dogs and cats in this study, as there are no stations in some areas. Providing air quality monitoring in the areas where pets live in individual households could provide the actual PM2.5 concentration (Lin *et al.,* 2018; Lin *et al.,* 2020).

Regarding the characteristics of dogs and cats in this study, out of the 184 dogs, we found that the most common breeds were Pomeranian and Chihuahua. The median age of the dogs was 11 years, categorizing them as seniors. Additionally, the average body weight was 5 kg, which aligns with the observation that the majority of the dog population in this study consisted of aging small-breed dogs. Brachycephalic breeds have abnormal airway conformation, which may increase the risk of other respiratory disorders (Mitze *et al*, 2022). However, older small-breed dogs had a higher risk of respiratory diseases when exposed to PM2.5 (Lin *et al.,* 2018).

Meanwhile, among the 73 cats in the study, the most common breeds were Domestic Shorthairs, followed by Scottish Folds and Persians. The median age was 6 years, categorizing them as young adults, and the mean body weight was 4.4 kg. Possible explanations for the higher prevalence of respiratory diseases in older, small-breed dogs include age-related declines in respiratory function, which may be exacerbated by poor air quality. In younger cats, factors such as developing immune systems may contribute to their heightened susceptibility to respiratory diseases.

In this study, the sex distribution of the animals was balanced, with 53.3% of dogs and 41.1 % of cats being male. No sex differences were observed, which was consistent with their living environments. The majority of dogs and cats were kept indoors rather than outdoors, with 91.8% of dogs and 75.3% of cats living indoors. Nearly half of the households reported using an air purifier. This study found that most dogs and cats were kept in multiple-household environments, consistent with a previous study indicating that living in multiple-household environments is associated with a higher risk of developing respiratory diseases due to increased exposure to allergens and pathogens (Lin *et al.,* 2018). Competition for resources and social interactions within multi-pet households can lead to increased stress, potentially suppressing the immune system and increasing susceptibility to respiratory problems (Lin *et al.,* 2018).

The enrolled dogs and cats were selected based on disease history and diagnoses in medical records. All dogs and cats showed respiratory signs upon visiting the hospital. However, we found that two-thirds of multiple-dog households (68.54%) and multiple-cat households (65.1%) had animals that were free from clinical signs during periods of elevated PM2.5 levels. The absence of apparent clinical signs in other animals within the same households as the one showing symptoms may reflect individual variability in sensitivity to PM2.5 in dogs and cats.

Our study revealed that chronic bronchitis is the most prevalent respiratory disease in dogs and feline inflammatory bronchial disease in cats. Canine chronic bronchitis and feline inflammatory bronchial disease are among the most common chronic respiratory diseases in dogs and cats. PM2.5 exposure can exacerbate both diseases through various mechanisms, including direct airway irritation, exacerbation of pre-existing respiratory sensitivities, immune system

suppression, and oxidative stress-induced lung tissue damage (Lin *et al.*, 2018; Lin *et al.*, 2020; Witkop *et al.*, 2021).

In addition to general information, we collected data on specific risk factors present in each household. Cooking behavior was identified as the most significant contributor to pollution levels in dogs, while sprays and perfumes were the primary factors for cats. This information will alert owners, helping them reduce their pets' exposure to these factors and thereby lowering the risk of developing respiratory problems. Furthermore, the results showed that 85 dogs and 43 cats were exposed to more than one risk factor within their homes. In addition, 29 dogs and 12 cats had no identifiable risk factors. These findings suggest that some owners may struggle to recognize significant risk factors. This means they may not take adequate measures to prevent animal exposure to these risk factors, which could increase the risk of the animal developing respiratory problems or accelerate the disease progression.

The limitations of this study include the small sample size and the short duration of the study period. In addition, we focused only on patients visiting the Small Animal Teaching Hospital, Faculty of Veterinary Science, Chulalongkorn University, Bangkok, Thailand. Therefore, the data may not represent the overall patient population in Bangkok. Further studies should enroll more dogs and cats over a longer study period. Moreover, data from dogs and cats with respiratory problems should be collected from other hospitals in Bangkok to provide more accurate results, represent the patient population, and minimize missing data. Furthermore, various risk factors affected the patients in the present study. Therefore, selecting participants with similar characteristics may help to control these confounding factors.

This study revealed that there is no statistically significant association between the average PM2.5 levels and the number of hospital visits of dogs and cats with respiratory disease. The PM2.5 levels varied across different times of the year and districts in Bangkok. Most dogs presenting with respiratory issues were aging small-breed dogs, whereas younger domestic shorthair cats were more commonly affected by respiratory problems. Based on the result of this study, chronic bronchitis, and feline inflammatory bronchial disease were the most common respiratory diseases in dogs and cats, respectively. Factors associated with respiratory problems were also evaluated. Further research with a longer study duration and a larger sample size is recommended to better understand the relationship between PM 2.5 and respiratory problems in dogs and cats.

Supplementary Table 1 Average PM2.5 levels classified according to the AQI color scale, along with the average visit of dogs and cats categorized by season and district in Bangkok.

Season	District in Bangkok	Average PM2.5 levels (µg/m³)	Average number of dogs	Average number of cats
Rainy (October 2021)	Central Bangkok	15.60	2	2
	North Bangkok	14.50	0	0
	Eastern Bangkok	13.00	0	5
	South Bangkok	15.00	5	3
	North Thonburi	19.00	4	0
	South Thonburi	23.00	6	0
Winter (November 2021 – February 2022)	Central Bangkok	26.60	3	4
	North Bangkok	24.60	0	0
	Eastern Bangkok	24.75	1	1
	South Bangkok	28.00	10	4
	North Thonburi	30.75	1	1
	South Thonburi	35.75	1	0
Summer (March 2022 – April 2022)	Central Bangkok	24.90	3.5	2
	North Bangkok	22.50	0	0
	Eastern Bangkok	22.50	3	1
	South Bangkok	25.60	10	6
	North Thonburi	27.00	2	1
	South Thonburi	33.00	2	0
Rainy (May 2022 – October 2022)	Central Bangkok	15.57	3	4
	North Bangkok	13.30	0	0
	Eastern Bangkok	13.80	2	1
	South Bangkok	17.77	12	6
	North Thonburi	18.00	3	1
	South Thonburi	23.00	2	1
Winter (November 2022 – February 2023)	Central Bangkok	27.50	1	2
	North Bangkok	24.30	0	0
	Eastern Bangkok	28.30	0	1
	South Bangkok	30.95	9	6
	North Thonburi	33.75	1	1
	South Thonburi	43.00	1	1
March 2023	Central Bangkok	34.40	0	1
	North Bangkok	30.50	0	0
	Eastern Bangkok	33.00	0	0
	South Bangkok	37.90	13	3
	North Thonburi	40.00	0	1
	South Thonburi	62.00	3	1

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References

Atkinson RW, Kang S, Anderson HR, Mills IC and Walton HA 2014. Epidemiological time series studies of PM2.5 and daily mortality and hospital admissions: a systematic review and meta-analysis. Thorax. 69(7): 660-665.

Bell ML, Ebisu K, Leaderer BP, Gent JF, Lee HJ, Koutrakis P, Wang Y, Dominici F and Peng RD 2014. Associations of PM2.5 constituents and sources with hospital admissions: analysis of four counties in Connecticut and Massachusetts (USA) for persons ≥ 65 years of age. Environ Health Perspect. 122(2): 138-144.

Calderón-Garcidueñas L, Mora-Tiscareño A, Fordham LA, Chung CJ, García R, Osnaya N, Hernández J, Acuña H, Gambling TM, Villarreal-Calderón A, Carson J, Koren HS and Devlin RB 2001. Canines as sentinel species for assessing chronic exposures to air pollutants: part 1. Respiratory pathology. Toxicol Sci. 61(2): 342-355.

Choi JH, Kim JS, Kim YC, Kim YS, Chung NH and Cho MH 2004. Comparative study of PM2.5 - and PM10 - induced oxidative stress in rat lung epithelial cells. J Vet Sci. 5(1): 11-18.

Creevy KE, Grady J, Little SE, Moore GE, Strickler BG, Thompson S and Webb JA 2019. AAHA canine life stage guidelines. J Am Anim Hosp Assoc. 55(6): 267-290.

Hassan Bran S, Macatangay R, Chotamonsak C, Chantara S and Surapipith V 2024. Understanding the seasonal dynamics of surface PM2.5 mass distribution and source contributions over Thailand. Atmos Environ. 331: 120613.

Lin CH, Lo PY and Wu HD 2020. An observational study of the role of indoor air pollution in pets with naturally acquired bronchial/lung disease. Vet Med Sci. 6(3): 314-320.

Lin CH, Lo PY, Wu HD, Chang C and Wang LC 2018. Association between indoor air pollution and respiratory disease in companion dogs and cats. J Vet Intern Med. 32(3): 1259-1267.

Mitze S, Barrs VR, Beatty JA, Hobi S and Bęczkowski PM 2022. Brachycephalic obstructive airway syndrome: much more than a surgical problem. Vet Q. 42(1):213-223.

Peng CQ, Cai JF, Yu SY, Cao ZJ, Liao YX, Liu N, He L, Zhang L, Zheng J, Shi XM and Cheng JQ 2016. Impact of PM(2.5) on daily outpatient numbers for respiratory diseases in Shenzhen, China. Zhonghua Yu Fang Yi Xue Za Zhi. 50(10): 874-879.

Pollution Control Department. "Subject: Air quality index data" [Online]. Available: http://www.air4thai.com/webV3/#/AQIInfo. Accessed January 3, 2025.

Pollution Control Department. "Subject: Archived Data" [Online]. Available: http://air4thai.pcd.go.th/webV3/#/Home. Accessed March 24, 2023.

Primocare 2023. "Subject: Understanding PM 2.5 Air Pollution and the Impacts" [Online]. Available: https://primocare.com/en/pm-2-5-air-pollution-and-the-impacts. Accessed July 1, 2023.

Quimby J, Gowland S, Carney HC, DePorter T, Plummer P and Westropp J 2021. AAHA/AAFP feline life stage guidelines. J Feline Med Surg. 23(3): 211-233.

Tsai SS, Chiu HF, Liou SH and Yang CY 2014. Short-term effects of fine particulate air pollution on hospital admissions for respiratory diseases: a case-crossover study in a tropical city. J Toxicol Environ Health A. 77(18): 1091-1101.

Wang F, Chen T, Chang Q, Kao YW, Li J, Chen M, Li Y and Shia BC 2021. Respiratory diseases are positively associated with PM2.5 concentrations in different areas of Taiwan. PLoS One. 16(4): e0249694.

Witkop JJ, Vertigan T, Reynolds A, Duffy L, Barati B, Jerome S and Dunlap K 2021. Sled dogs as a model for PM2.5 exposure from wildfires in Alaska. Environ Int. 156:106767.

WHO 2021. Recommendations on classical air pollutants. In: WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. 73-74.

Xing YF, Xu YH, Shi MH and Lian YX 2016. The impact of PM2.5 on the human respiratory system. J Thorac Dis. 8(1): E69-74.

Zhang L, Feng W, Lu BB, Li N, Li H, Gu SH, Ge T and Xu GZ 2019. The impact of ambient PM(2.5) on daily outpatient visits due to chronic obstructive pulmonary disease, among the urban residents of Ningbo city. Zhonghua Liu Xing Bing Xue Za Zhi. 40(6): 686-691.

Zhao MJ, Geng XY, Cui LL, Zhou JW and Zhang J 2017. Association between ambient PM(l0)/PM(2.5) concentration and outpatient department visits due to respiratory disease in a hospital in Jinan, 2013-2015: a time series analysis. Zhonghua Liu Xing Bing Xue Za Zhi. 38(3): 374-377.