PASSIVE AIR SAMPLING OF NITROGEN DIOXIDE WITHIN SERDANG AREA

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ABSTRACT

Nitrogen dioxide, (NO_2) is one of the major air pollutants arise from human activities. It is toxic and prolonged inhalation of high concentration NO_2 will bring severe effect to the respiratory system and can eventually cause death. It is also one of the precursor for the formation of tropospheric ozone and particulate matter that result in serious air pollution. Air sampling is the most common surveillance and monitoring system for the determination of the amount of air pollutants present in the air. By air sampling, the source of the air pollutants can be found and the problem can be tackled from its roots effectively. Active air sampling method is the common air sampling method being used but it suffers from complicated structured and high cost of operation. Recently, the passive air sampling method is getting more attention due to its simple structure, low cost and less attention for operation. It has been widely used in cold and dry countries such as Canada and Italy to determine particular types of air pollutants such as NO_2 and SO_2 concentrations. This method however has not been tested in rainy and humid countries like Malaysia. In this study, the passive air samplers have been located at 3 different locations around Universiti Putra Malaysia (UPM). The sampling period is 1 week followed by lab test. Throughout the air sampling process, the average NO_2 concentration at location with extensive road system and construction sites was around 36.8 ppb which is much higher than in the UPM Engineering Faculty of 14.0 ppb. The average NO_2 concentration of the roadside without any nearby construction site was 23.4 ppb. Consequently, both the transportation and construction sites contributed to the increase of the amount of NO_2 in the air. Therefore, passive sampler is a reliable technique and highly potential to be used as an alternative method to monitor NO_2 concentration in other parts of Malaysia.

Keywords: Nitrogen dioxide, Passive method, Air sampling, Air monitoring, Air pollution

1. INTRODUCTION

Air pollution has been widely known as one of the major threats to human survivor and the situation is worsen by the rapid industrialisation and advance in transportation. Nitrogen dioxide (NO_2) is one of the most common air pollutants in the atmosphere. The anthropogenic sources of NO_2 emission into the atmosphere includes transportation, power plants, industrial emission, lightning, soil emissions and biomass burning. However, more than half of its emission is from the transportation system. Studies in Pakistan and India showed that the NO_2 concentration is higher at the cities located near the highways (Shaiganfar, Beirle et al. 2011, Shabbir, Khokhar et al. 2015). The uncontrolled emission of NO_2 to the air had led serious problems affecting both living organisms and the environment. NO_2 had been proven to cause lung problems, lead to the formation of smog and tropospheric ozone (Żak, Melaniuk-Wolny et al. , Tunnicliffe, Burge et al. 1994, Europe and Organization 2006). after undergoes photochemical reaction with others pollutants in the air. All of them are harmful so it is important that its amount in the atmosphere to be known and some effective measures should be taken to prevent the further increase of its amount in the air. Due to this, it is important that its amount in the atmosphere to be monitored effectively.

Systematic surveillance for monitoring the air quality with air sampling is one of the most common method being applied for obtaining environmental analysis data to ensure that the concentration of NO_2 in the air is always within safe limits. By air sampling, we can know the source of the air pollutants and able to tackle the problem effectively. A good planning for air sampling can optimise the number of sample collected and reduce the operating cost (Stranger, Krata et al. 2008). Generally, the air sampling strategies can be categorised into active and passive method (Cerutti, Gil et al. 2016). In active sampling, air is forced to diffuse by a pump and large volume of air sample can be taken in short period of time. However, it is large and needs external power sources to operate and hard to determine the time-weighted average concentration (Marć, Namieśnik et al. 2016). On the other hand, passive sampling does not require power source for operation whereby the air pollutants are trapped onto sorbent material by diffusion mechanism.

Passive sampling method gives some significant advantages such as simple structure, low operating cost and electric free. It is suitable to determine the time-weighted average concentration of NO_2 in air. Recently, passive sampler had been used for various purpose and sampling different type of pollutants such as NO_2, sulphur dioxide (SO_2), ozone and volatile organic chemical (VOC) (Marć, Zabiegała et al. 2014, Pienaar, Beukes et al. 2015, Esteve-Turrillas and Pastor 2016, Rosario, Pietro et al. 2016). Passive samplers have been used to determine the NO_2 concentration at the airport in Italy (Gaeta, Cattani et al. 2016) and, room indoor and outdoor (Gilbert, Gauvin et al. 2006, Oiamo, Johnson et al. 2015). Another research team from Canada had monitored the concentration of NO_2 at a natural gas production facility and concluded that passive sampling was a reliable approach for air monitoring (Islam, Jackson et al. 2016). Recently, in Turkey, an integrative approach to determine the various types of air pollutants by using passive sampler had been conducted near the coal power plant (Küçükaçıl Artun, Polat et al. 2017). Its main drawback, however, the result is reported to be easily altered by the change in environmental condition (Król, Zabiegała et al. 2010, Zabiegała, Sărbu et al. 2011, Pienaar, Beukes et al. 2015)

Although many countries have been measuring NO_2 using passive sampling method, it is interesting to note that most are dry and cold climate countries. Until now, there is no study using passive sampler to measure NO_2 in hot and humid country such as Malaysia. Therefore, it is crucial to determine whether the passive sampler is suitable to be used in hot and humid climate environment. In this study, the reliability of passive samplers was checked by studying the effect of surrounding temperature to the NO_2 concentration. In addition, the effect of transportation load with NO_2 concentration was investigated.

2. EXPERIMENTAL METHODS

2.1. Solution preparation

NO_2 absorbing liquid was prepared prior the field testing. Its purpose is to absorb the NO_2 from the atmosphere in which it will only selectively absorb NO_2 and leave out other types of air components. The NO_2 absorbing liquid was prepared by dissolving 0.44 g of sodium hydroxide (*R&M Chemicals, United Kingdom*) into distilled water. 3.69 g of sodium iodide (*Wako, Japan*) was then added into the mixture after noticed that all the sodium hydroxide had been dissolved. It was followed by the addition of methanol (*Merck, Germany*) to the mixture until it reached 50 mL. The mixture was shacked carefully to ensure even mixing and the NO_2 absorbing liquid was produced. Saltzman reagent is a colouring solution which was prepared for aiding in the determination of the absorption values of the NO_2 containing solution. Saltzman reagent was prepared by mixing of 0.8 g of sulfanilic acid (*Wako, Japan*), 0.02 g of N-1-napthylethylenediamine-2-hydrochloride (*Wako, Japan*), 0.8 mL of phosphoric acid (*Merck, Germany*) and distilled water. The solution was then shacked for few minutes for ensuring even mixing.

Prior to the determination of the amount of NO_2 being absorbed by the air sampler, a standard curve for different concentration of NO_2 ions against its absorption values was calibrated. Both sodium iodide standard solution and sodium nitrite standard solution were prepared. Mixing different amount of each solution will yield different NO_2 oncentration in the solution. Saltzman reagent was then added to the mixed solution to give a purplish colour for the measuring of respective absorption values by using UV-spectrometer (*Shimadzu, Japan*) with the wavelength of 540 nm. The standard curve produced was then used as indicator in determination of the concentration of NO_2 in the air.

2.2. Sample preparation

The passive air sampler used consists of 3 layers as shown in Figure 1. The purpose of 1st layer is to prevent the influx of dust and wind into passive air sampler. The 2nd layer is to act as support while the 3rd layer consists of filter paper (*Whatman, United Kingdom*) that will be soaked with 50 µL of NO_2 absorbing liquid. At the sampling location, the passive air sampler was placed a certain distance from the ground to prevent dust and other particulate matter that present on ground into the passive air sampler. The particulate matter will block the absorbing surface of filter paper and hence reduce the amount of NO_2 being absorbed and thus the result will be underestimated. The main location for the setup of passive air sampler was located at Faculty of Engineering Universiti Putra Malaysia (UPM), Serdang area. There are total 3 different locations had been chosen for the air sampling of NO_2 as shown in Figure 2 and its description in Table 1.The duration for each sampling cycle was 1 week. Table 2 tabulated the details about the sampling period.

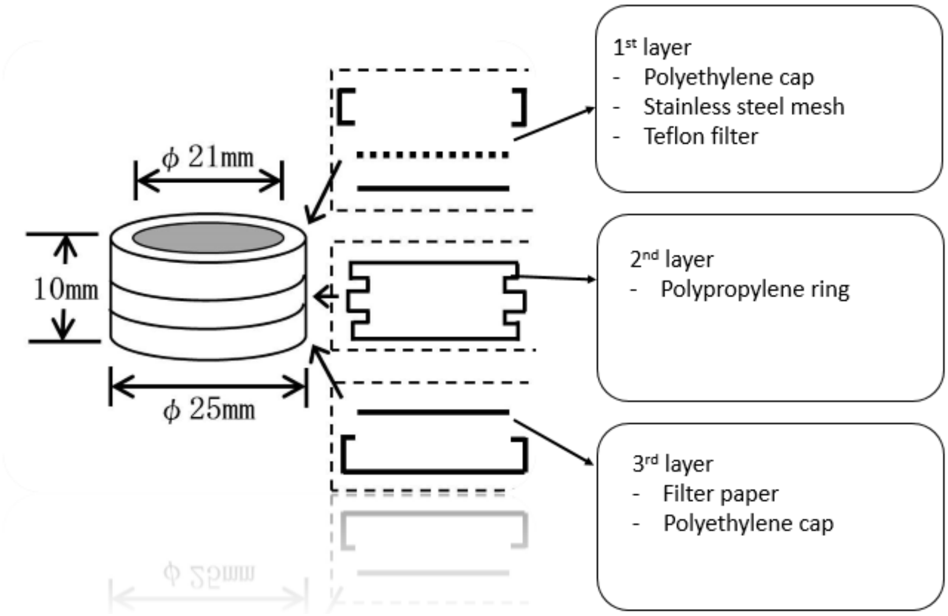

Figure 1 Passive air sampler

Table 1 Sample location description

Sample	Symbol	Location	Description	Estimation of vehicle pass (average per day)
A		UPM Engineering Faculty	Lakeside	
B		Petrol station beside UPM	Roadside	
C		Petrol station Besraya Highway	Roadside and construction side	

Figure 2 Location of air sampling (Serdang area)
(Obtain from Google Maps)

Table 2 Sampling period details

Sampling period notation	Month/Year	Week of the month
1	July 2016	5
2	August 2016	1
3	August 2016	2
4	August 2016	3
5	August 2016	4
6	September 2016	1
7	September 2016	2
8	September 2016	3
9	September 2016	4
10	September 2016	5
11	October 2016	1
12	October 2016	2
13	October 2016	3
14	October 2016	4
15	November 2016	1
16	November 2016	2
17	November 2016	3
18	November 2016	4
19	December 2016	1
20	December 2016	2
21	December 2016	3
22	December 2016	4
23	December 2016	5
24	January 2017	1
25	January 2017	2
26	January 2017	3
27	February 2017	2
28	February 2017	3
29	February 2017	4
30	March 2017	1

2.3. Determination of NO_2 concentration

The filter paper was removed from the passive air sampler after 1 week sampling period. It was soaked in distilled water and placed overnight to allow the NO_2 absorbed diffuse to the distilled water. The solution was then mixed with Saltzman reagent for the determination of its absorption values by using UV-spectrometer with the wavelength of 540 nm. The NO_2^- concentration of the solution with absorbed atmospheric NO_2 was determined from the standard curve calibrated previously. The concentration of NO_2 in the atmosphere of various tested location were then calculated and determined by using equation derived from Fick's Law:

$$Concentration\ of\ NO_2 in\ atmoshere\ (ppb) = \frac{C_{NO_2}\text{-}\ VLRT}{PDt} x\ 10^9$$

Whereby P is the total air pressure (Pa), R is the gas constant (J/mol.K),T is the average temperature during the air sampling period (K), V is the volume occupied by NO_2 absorbed on the filter paper, L is device constant (m^{-1}) and $C_{NO_2^-}$ is obtained from the chemical absorption test by using UV-spectrometer.

3. RESULTS AND DISCUSSION

3.1. Surrounding temperature of sampling location

According to the equation for determination of the concentration of NO_2, the surrounding temperature of the sampling location was needed. The temperature taken was based on the average temperature throughout the sampling week and the data was obtained from a nearby weather station and the results were as shown in Figure 3. It can be seen that the average temperature was almost similar with some fluctuation throughout the sampling period from July 2016 to March 2017 as Malaysia is a hot and humid country that does not have distinct extreme hot and cold season. At the time of sampling period, the lowest average temperature recorded was of 27℃ while the highest average temperature recorded was of 30℃, with only 3℃ different.

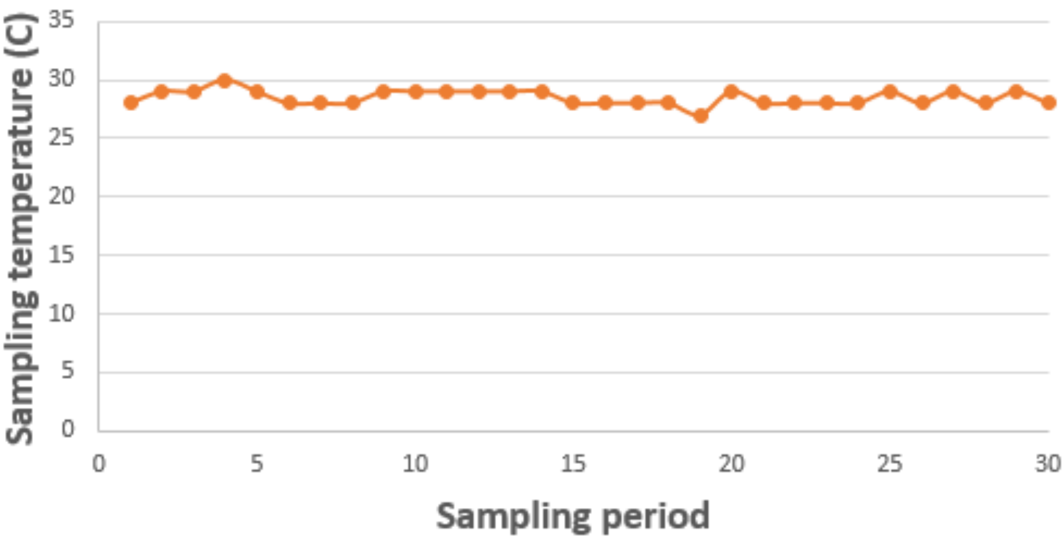

Figure 3 Average temperature in Serdang area (July 2016 to March 2017)

3.2. NO_2 concentration of sampling location

The main findings in this research paper is the NO_2 concentration in the air in Serdang area and the detailed results are tabulated in Figure 4. Throughout the air sampling period, the average NO_2 concentration at the location A was 36.8 ppb which was much higher than location B of 23.4 ppb and location C of 14.0 ppb respectively as shown in Figure 4.

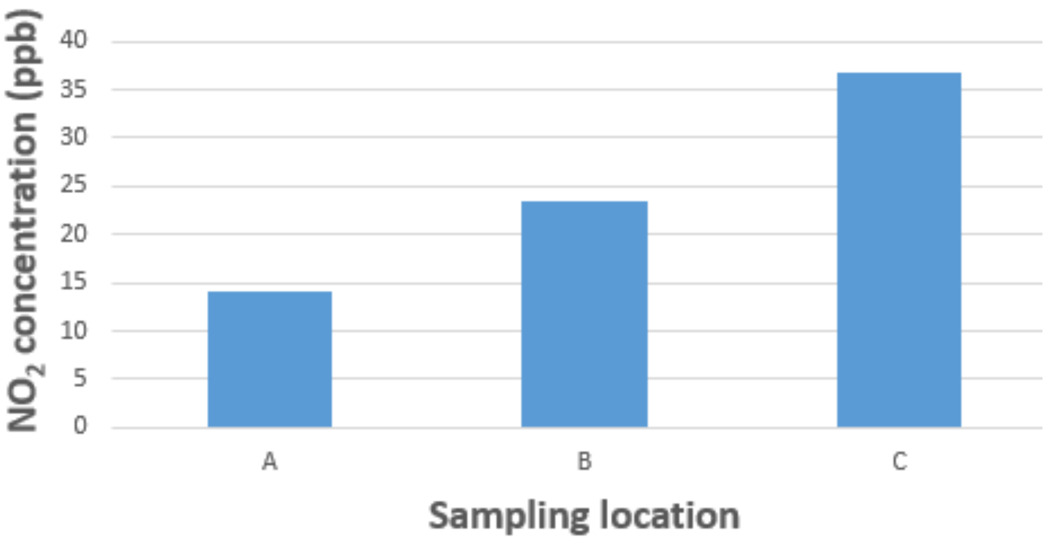

Figure 4 Average NO2 concentration at different sampling location

From Figure 5, it can be seen that the location C recorded the highest amount of NO_2 present may due to the combination factor contribute from the huge amount of automobile pass by that sampling location and a construction site located right beside location C. The location C was placed between the 2 major highways in Serdang area, namely Besraya Highway and Plus Expressway. The Plus Expressway or commonly known as North-South Expressway is currently the longest highway in Malaysia with the total length of 772 km, spanning between 2 international borders from Malaysia-Thailand border to Malaysia-Singapore border. Since it is a major highway, there were lots of vehicles using it every day especially the section of highways where the passive sampler was placed as it was the starting point for the south-bound traffic. The highest concentration of NO_2 recorded at that location may indicate that any mode of transportation such as buses and cars were the major contributor to the release of excessive NO_2 to the air. This can be related with the studies done by Oiamo et. al. and Shabbir et. al. who further validate that automobiles were one of the major contributors to the emission of NO_2 to the atmosphere (Oiamo, Johnson et al. 2015, Shabbir, Khokhar et al. 2015). Furthermore, the nearby construction site could also be one of the contributors to the emission of NO_2. The maximum concentration of NO_2 recorded at location C was 44.2 ppb in September 2016 week 4 followed by February 2017 week 2 of 43.1 ppb. This may related to the end of holiday seasons in which many people came back to the Kuala Lumpur city centre from the Southern part of Peninsular Malaysia and this part of the highways was a must to pass by if using the expressway. The increase number of cars in this period was the reason for the NO_2 level in location C to increase.

For location B, the NO_2 concentration was in the range at between 15.8 ppb and 28.3 ppb. Its concentration is much lower than in location C. This may due to the lack of nearby highways system and major contrition site. However, there was a small road in front of the sampling location B with the number of vehicles passed by per day were much lesser than the location A. Since there were still some automobile passed by it from time to time, so it can be explained why NO_2 concentration was higher than location C. The lowest concentration of NO_2 throughout the sampling period 9.8 ppb which as recorded by passive sampler located at location A. The low concentration NO_2 recorded may due to lack of road network at this location. The purpose of this sample was to know roughly what was the ambient NO_2 concentration around Serdang area without the affect by any source of anthropogenic emission. With the data taken by this sample, comparison can be made which showed that automobile and construction will surely contribute to the emission of NO_2 to the air.

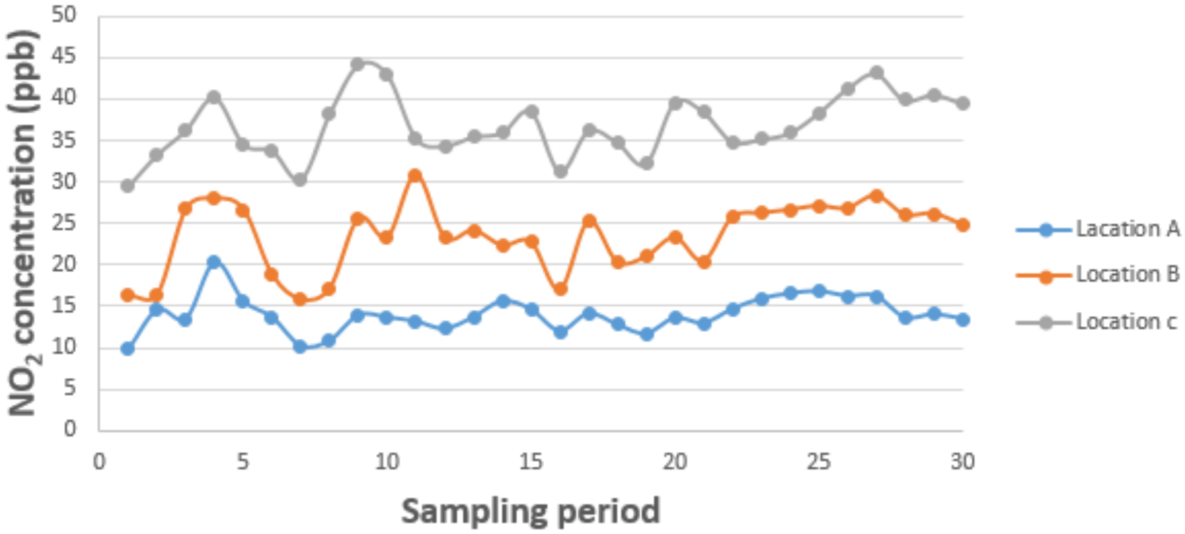

Figure 5 NO_2 sampling data

Although it can be quite clear to notice that the NO_2 concentration was higher or lower at particular locations, the results fluctuated along the sampling period. This may due to some external factors which affected the air sampling results such as relative humidity and rapid changing in weather conditions. These factors are beyond the study scope of this journal paper and may be a high interest to focus in the future.

4. CONCLUSION

In conclusion, the results of the passive sampler were quite consistent although with only minor fluctuation due to some uncontrollable external factors such as humidity and frequent changing in weather condition. The passive sampling method was suitable to be used in Malaysia but detail study is still needed to be done by future researchers to fully understand how the external factors give some minor effects to the air quality results. The average NO_2 concentration at the with extensive highways network and nearby construction site was the highest of 36.8 ppb while the location with only small road excess recorded 23.4 ppb and the location away from the road recorded the lowest concentration of 14.0 ppb. Therefore, it can be concluded that the automobiles and construction site had major roles into the contribution of the emission of NO_2 to the air. This proves that this research can improve the air sampling method and promote passive air sampling method in Malaysia, thus, encourage more researchers in Malaysia to involve in this area. With more extensive research about passive air sampling method in future, passive method can surely be an alternative to active air sampling in Malaysia.

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