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Determination of Particulate Matter and Toxic Gaseous in Ambient Air Adjacent to Industrial Area

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A B S T R A C T

Air quality in the residential areas adjacent to the industrial regions is of great concern due to the association with particulate matter and toxic gaseous which has adverse effects on human health. Therefore, the present study aimed to investigate the air quality in term of PM_{10} concentrations and toxic gaseous (CO and NO) at University Hussein Onn Malaysia (UTHM) residential college which is adjacent to a wood processing, electronic and fibre board factories. Four Stations defined as Station 1 (KKM), Station 2 (KKP), Station 3 (KKTDI) and Station 4 (KKTU) were selected for this investigation. PM_{10} concentrations were measured using the E-Sampler Particulate Matter for 24 hours period within the dry season (February –May 2016) which was associated with the heavily haze phenomenon in Malaysia. The distribution of selected toxic gases in UTHM student hostels was determined using the TSI IAQ (CO) and Dragger X-am 7000 (NO). PM_{10} and toxic gaseous levels were compared to the Ambient Air Quality Standard (AAQS) and to compute the assumption of the sources of PM_{10} by using Open Air R Package Software. Data were analysed using the R Software and packages (Open-air, BRT, Akima). The highest concentration of PM_{10} was 114 µg/m^3 recorded at KKTDI followed by 58 µg/m^3 at KKP. The maximum CO concentrations noted at KKP (1.8 ppm). However, both PM_{10} and CO concentrations not exceeded the AAQS of 150 µg/m^3 and 30 ppm respectively. Moreover, concentrations of NO at KKP (0.61 ppm) and KKM (2.18 ppm) exceeded the AAQS (0.17 ppm) indicating the possibility of presence health risk for students at UTHM due to poor air quality. The air quality is directly associated to level of energy consumption which causes climate changes and accumulation of greenhouse gases.

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INTRODUCTION

The rapid urbanization and industrialization in Malaysia during the last two decades have associated with the ambient pollutants that may have negative impacts on human health [1-3]. Malaysia had initiated a strategy in 1991, so called Wawasan 2020 which is the aspiration to become a fully developed country by 2020. The urbanization population on 2011 is about 72.8% with the highest location at Kuala Lumpur followed by Klang and Johor Bahru [4]. The developments in industrial sector has increased from 38.5% in 1980 to 44.5% in 2002. This increases is associated with the decease of air quality, the results from the study in 2009, using data 1997 to 2006 showed that the average of PM_{10} concentrations recorded at different locations of Kuala Lumpur were 56.41 µg/m^3, which is under the permissible value recommended by Ambient Air Quality Standard (150µg/m^3) (AAQS) [5]. The high rate of urbanization and industrialization might also increase the concentration of sulphur dioxide (SO_2), nitrogen oxide (NO), carbon monoxide (CO), lead (Pb) and ozone (O_3) [6]. CO reduces the oxygen carrying capacity of red blood cells. The health effects depend on the duration of exposure and the concentration of CO inhaled. Higher concentration of CO can lead to impaired vision, disturbed coordination and eventually death. In contrast, NO irritates the mucosa of eyes, nose, throat and the lower respiratory tract. NO_2 also aggravates existing chronic respiratory diseases. Long-term exposure to NO_2 lead to reduction of lung function and reduces the resistance to respiratory infections [7].

The effect of particulate matter on human health depend on the particles size and their concentration in air. The fine particles (<10µm) are more harmful compare to the coarse particles, in terms of mortality, cardiovascular and respiratory effects [8, 9]. It has been revealed that the exposure to $PM_{2.5}$ is associated with lung cancer mortality

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[10]. However, the degree of risk depend also on the time exposures to the particulate matter [11]. The short term exposure usually effects on the respiratory symptoms such as cough, shortness of breath and asthma [12], while long-term exposure for many years is associated with reduced lung function and the development of chronic bronchitis and premature death [1].

On the other hand, the exposure to NO_2 might increase the bronchial reactivity. In study of CO poisoning, 37% of patients with CO poisoning have myocardial injury and 38% have died at a median follow-up of 7.6 years [13]. Many industrial areas in the world have poor air quality due to presence of industries that used coal combustion method in their industrial processes. The highest concentration of PM_{10} was 400µg/m^3 at Delhi, India [9]. In Malaysia, the maximum PM_{10} concentrations was recorded in Penang (421µg/m^3) in 2008 which exceeded the AAQS, but this case was noted only one time due to the haze event that struck the country in that year [14]. The concentration of PM_{10} in some industrial area such as Penang, Selangor and Kuala Lumpur reached more than 100 µg/m^3 as reported by several investigators [15, 16]. However, these values still less than AAQS standards limits. According to DSM [17], the total emission of PM_{10} into the atmosphere from the industry activities in Malaysia in year 2011 was 11.3 tons, while CO was 11.9 tons, the maximum concentrations was for NO_2, where 62.5 tons was generated into the atmosphere. In order to protect the public health from the adverse effects of air pollutants, several countries have adopted regulations for air quality standards based on Particulate Matter (PM_{10}). In Malaysia, the Ambient Air Quality Guidelines (AAQG) has recommended that the PM_{10}, should be less than 150 µg/m^3/ 24 hours or less than 50 µg/m^3/ 12 months. Some countries such as Australia recommended more stringent standards where, PM_{10} should be less than 50 µg/m^3/ 24 hours and 0 / 12 months. In Japan, PM_{10} should be between 100-200 µg/m^3/ 24 hours and 0 /12 months.

In Johor, the concentrations of PM_{10}, NO and CO at University Tun Hussein Onn Malaysia (UTHM) have been reported by several investigators [5, 18]. However, the periodic assessment is needed due to the presence of many factories around the university and in order to protect student health from the sudden pollutants as that happened in 2006, where the concentration of PM_{10} recorded more than 1291µg/m^3 [18]. Moreover, the concentrations of PM_{10} and toxic gaseous might depend on the meteorological factors as recorded previously in Penang where the PM_{10} reached 400µg/m^3 during haze season. The air quality is associated with the energy consumption and climate change [19]. Ozturk [20] revealed that the increasing in energy consumption by 1% was associated with 0.12, 0.65, 0.12 and 0.11% of increasing in the greenhouse gas, carbon dioxide, methane and nitrous oxide emissions, respectively. In the present study, the concentrations of PM_{10} as well as the toxic gaseous (CO and NO) around UTHM Industrial area were measured. Moreover, the verification in PM_{10} and toxic gaseous in a response to the haze season which is a special case cause in Malaysia and Indonesia was investigated. Detection of haze season and air pollutants in this work may emphasize the novelty of present study. The relations between meteorological factors including temperature, humidity, wind direction and wind speed to the air quality were examined in order to have the best understanding their role in the level of distribution of the PM_{10} and toxic gaseous in ambient air of the residences areas adjacent to industrial regions.

The present study aimed to investigate the air quality in term of PM_{10} concentrations and toxic gaseous (CO and NO) at University Hussein Onn Malaysia (UTHM) residential college which is adjacent to a wood processing, electronic and fibre board factories.

MATERIAL AND METHODS

Study area

University Hussein Onn Malaysia (UTHM) is a public university located at Parit Raja nearby an industrial area (Figure 1). The university is adjacent to the manufacturing electrical products, packaging services and wood processing factories. These factories are operating on the fiber board manufacturing, paper mills and packaging and semiconductor. Therefore, represent a source for particulate matter during the operation processes. Among 70% of the individual emission measurement from industrial plants and domestic stoves the PM_{10} is the major part with 90% of emission [21].

Four stations were selected due to the special locations around the industrial area with different distances to determine the level of PM_{10} and toxic gaseous distribution. The stations included Melewar Residential College (about 900 m from the industrial area) hereafter referred as Station 1 (KKM); Perwira Residential College (800m) hereafter referred as Station 2 (KKP), TDI Residential College (400 m) hereafter referred as Station 3 (KKTDI) and Taman University Residential College (2400m) hereafter referred as Station 4 (KKTU) (see figure 1).

Estimation of PM_{10} and toxic gaseous concentrations

E-Sampler was used to measure the concentration of PM_{10} in ambient air of the specified stations (Figure 2a). This equipment used to provide meteorological data of humidity, temperature, wind direction and wind speed from sampling area. Figure 2 shows the E-Sampler equipment apparatus and their set-up. The distribution of CO was determined using the TSI IAQ while NO was determined using Dragger X-am 7000 (Figures 2b and 2c). Data for PM_{10}, CO and NO concentrations were

determined at the investigated stations. CO and NO was estimated only at Station 1 and Station 2 because these stations represent the student residential area. Each station was measured at the same time within 24 hours during the dry season between February and May 2016.

In order to confirm the presence or absence of polycyclic aromatic hydrocarbons (PAHs) which includes acenaphthylene, fluorine, phenanthrene,anthracene,fluoranthene,pyrene, benzo(a)anthracene andchrysene. The air samples were analysed by gas chromatography at Universiti Kebangsaan Malaysia (UKM), Bangi, Malaysia.

Data analysis

The data collected during the period of study was arranged in the Microsoft Excel using .csv format and then used to compute the relevant

RESULTS AND DISCUSSION

PM_{10} concentrations and meteorology parameters at four stations are illustrated in Table 1. It can be noted that the mean of PM_{10} concentration at station 3 (23.32µg/m^3) was more than the observed value at station 4 (5.28 µg/m^3). Mean of PM_{10} concentrations at station 1 and station 2 were similar (916.07 *vs.* 20.15 µg/m^3). The concentrations of toxic gases (CO and NO) at Station 1 and Station 2 is presented in Figure 3. It shows that that the concentrations of CO and NO at Station 1 is more than that at station 2 (0.22 *vs.* 0.2 and 0.34 *vs.* 0.18 ppm, respectively).

The time series plot for PM_{10} concentrations at the investigated stations are presented in Figure 4. The maximum PM_{10} concentrations was recorded at Station 3 (114 µg/m^3), whereas the lowest concentration was noted at station 1 and 4 (40 and 43 µg/m^3, respectively). PM_{10} at Stations 2 was 58µg/m^3. Moreover, these concentrations are within the AAQS standards. The time series plot on the concentration of CO and NO against count at both stations is presented in Figure 5. The highest concentrations of CO in Station 1 were recorded at around count 200 (1.8 ppm), and in Station 2 at count 65(0.8 ppm) (Figure 5). Moreover, the concentrations of CO at both stations has lower than the AAQS (30 ppm in one hour). For NO concentrations at Station 1, there are missing values and the highest data was recorded (0.61 ppm) at count 75, while at Station 2 the highest concentrations was 2.175 ppm at count 30. These values indicated that the NO concentration at both stations has exceeded the AAQS (0.17 ppm within one hour).

Figure 6a shows the time variation of PM_{10} in a week in which the PM10 recorded the maximum concentrations. The highest concentration at station 1 was recorded on Thursday, at 2 to 6 am o'clock. The reading was changed at the noon to the night, but still less than the highest concentration recorded in the morning. Figure 6b shows the time variation of PM_{10} at Station 2. The maximum PM_{10} concentration was recorded on Friday, at 9.00am, while, the lowest reading was recorded at 12.00pm. The highest concentration at Station 3 was recorded on Monday, at 5 to 8 am o'clock (Figure 6c), while the highest concentration of PM_{10} at station 4 was recorded on Sunday, at 2.00 to 5.00 pm (Figure 6d).

TABLE 1. The Summary Data of PM_{10} and Meteorology Data at four stationswithin UTHM campus during the dry season (February to May 2016)

Stations*		PM_{10} (µg/m^3)	Temperature (˚C)	Humidity (% RH)	Wind speed (m/s)	Wind direction (˚)
Station 1	*Min.*	≤1	22	38	0.3	≤0.1
	Mean	16.07	28.18	49.81	1.748	170.9
	Max.	40	38.50	79	10	360
Station 2	*Min.*	≤0.1	22	39	0.3	≤0.1
	Mean	20.15	29.39	49.05	2.207	182.6
	Max.	58	39.70	66	10	360
Station 3	*Min.*	≤1	22	38	0.3	≤0.1
	Mean	23.32	27.64	49.51	0.9773	212.3
	Max.	114	34.80	61	10	360
Station 4	*Min.*	≤1	17.6	38	0.2	≤0.1
	Mean	5.282	28.51	49.51	1.142	213.1
	Max.	43	38.10	61	5.4	360

*Station 1 (Melewar Residential College, KKM); Station 2 (Perwira Residential College, KKP); Station 3 (TDI Residential College, KKTDI) and Station 4 (Taman University Residential College, KKTU)

Figure 1. Location of University Tun Hussain Onn Malaysia (UTHM) and the industrial area; A) UTHM; B) Industrial area

Figure 2 Sampling instrument; 1) E-sampler Particulate Matter used for PM_{10} determination and meteorological parameters, 2) Dragger X am 7000 Used for determination CO concentrations; 3) TSI IAQ Monitor Used for determination NO concentrations

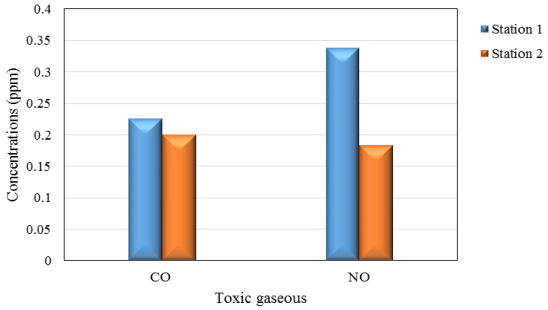


Figure 3. Mean of the toxic gaseous concentrations at Station 1 and Station 2 within University Tun Hussain Onn Malaysia (UTHM) during the dry season 2016. Station 1 (Melewar Residential College, KKM); Station 2 (Perwira Residential College, KKP);

Figure 7 shows time variation plot for the concentrations of CO, NO and meteorology data against time. The time was separated by hours. The relation between each data was shown in this variation plot with 95% of confidential ($p<0.05$). At Station 1 high level of CO recorded between 2.30 and 5.00 pm (Figure 7a).The highest level of NO concentrations noted at mid-day then fell slightly before remained constant. At Station 2 there are high level of CO and NO recorded at the mid-day might be from vehicle activities during lunch hour and same situation for NO, it was found that the high level began at 10am then fell gradually and continuously until at the end of sampling (Figure 7 b).

The polar plot for four stations on the map is depicted in Figure 8. The location of instrument is at the middle of the cross of the polar plot. The polar plot map shows that the high concentration of PM_{10} at Station 1 might be coming from the industrial area (northeast), while at Station 2, the high concentration might be due to the activities from the resident of KKP such as cooking and cleaning process (northeast) and the mean wind speed was 2.207 m/s from the south-east, which is stated the higher concentration might be came from the vehicles and road dust from the nearby road. At Station 3 the mean wind speed was dominant at 0.9773 m/s from south-east of the industrial area. Finally, at Station 4, the high concentration of PM_{10} might be come from the vehicles and road dust at distances 2500m from the nearby road. The polar plot of CO and NO at station 1 and 2 is depicted on the map (Figure 8 b). At Station 1 and station 2, the high concentration of NO might be come from vehicles activities (southeast) and night market such as frying and roasting (southeast). Meanwhile, the concentration of NO at Station 1 and Station 2 shows the wind dominantly come from southwest might be from industrial and north from vehicle activity.

In this study, Boosted Regression Tree (BRT) was used for the analysis of meteorological parameters (Figure 9). The results can be used for the prediction of concentration of PM_{10}. First step after the compilation of database; data is developed for the PM_{10} boosting algorithm. In this step, the learning rate, number of trees and interaction depth were set. The output from the BRT is analysed using graphical output, namely, partial dependent plots, which show the influence of the independent variables and the interactions between those variables. Important variables are the plot that shows how much the meteorological data affect the concentration of PM_{10}. Figure 9 shows the plot of important variable at Stations 1, 2, 3 and 4, respectively. From these four plots, the ambient temperature recorded as the most influenced variable that affect the concentration of PM_{10}, followed by wind direction, humidity and wind speed. These four figures show about the differences relative influence of temperature, humidity, wind direction and wind speed.

The results of gas chromatography analysis of the air samples are depicted in Table 2 and Figure 10, which indicate that the acenaphthylene, fluorine, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene and chrysene were detected, but the concentration of these compounds were very low in compare to the standards sample.

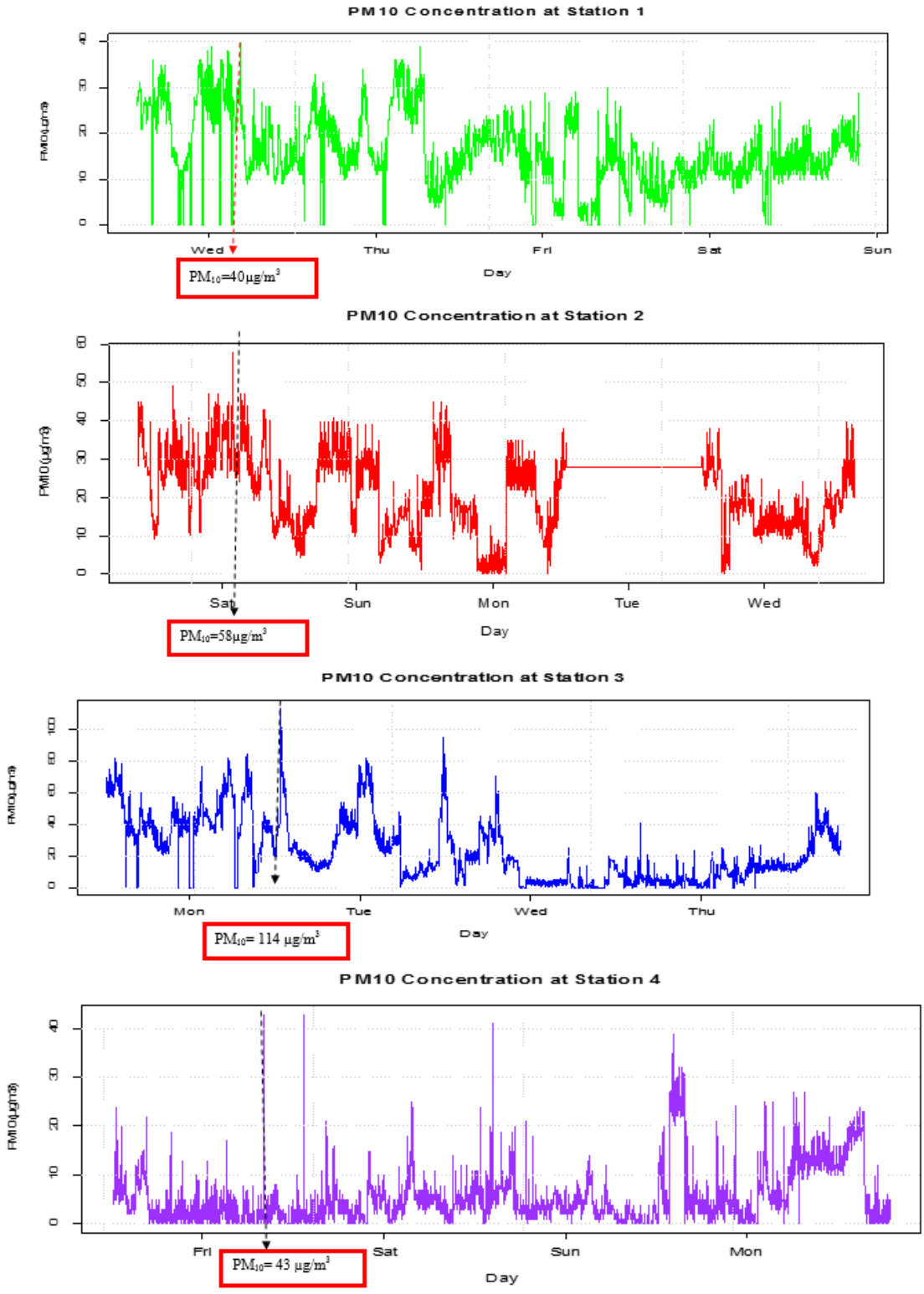


Figure 4 The Time series concentration of PM_{10} at four stations within UTHM; Station 1 (Melewar Residential College); Station 2 (Perwira Residential College); Station 3 (TDI Residential College) and Station 4 (Taman University Residential College)

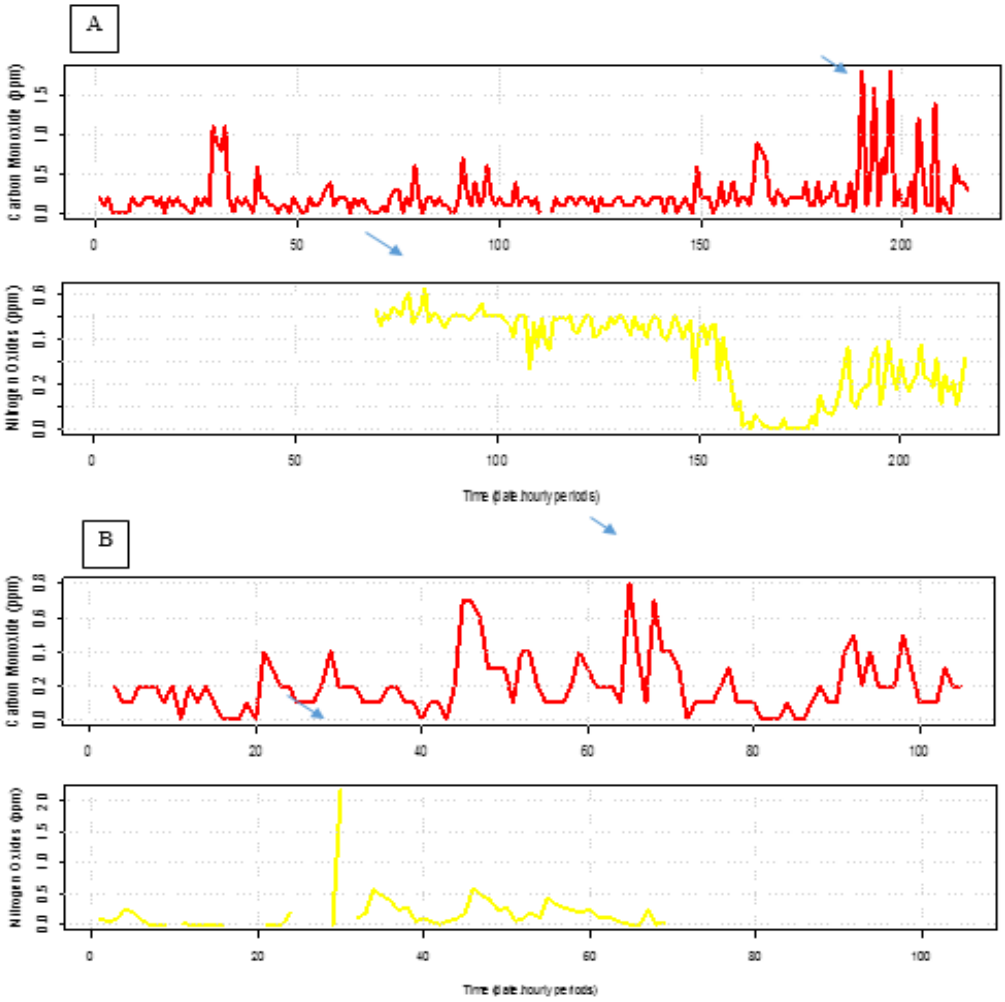
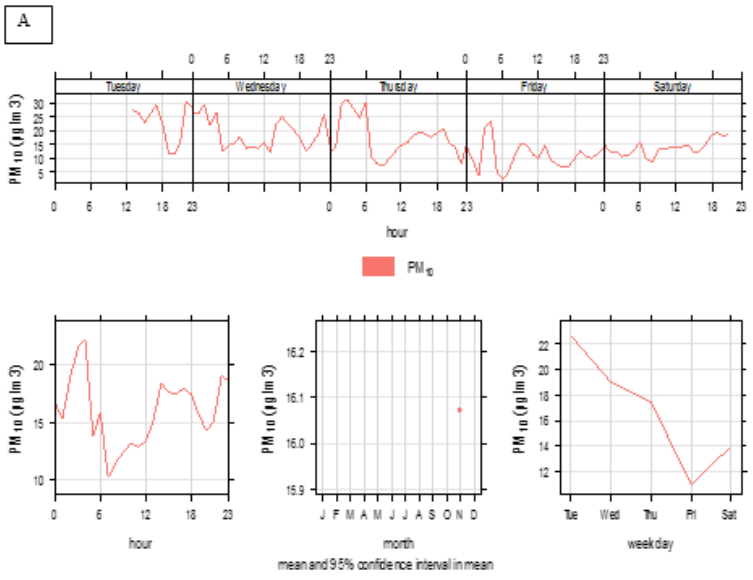
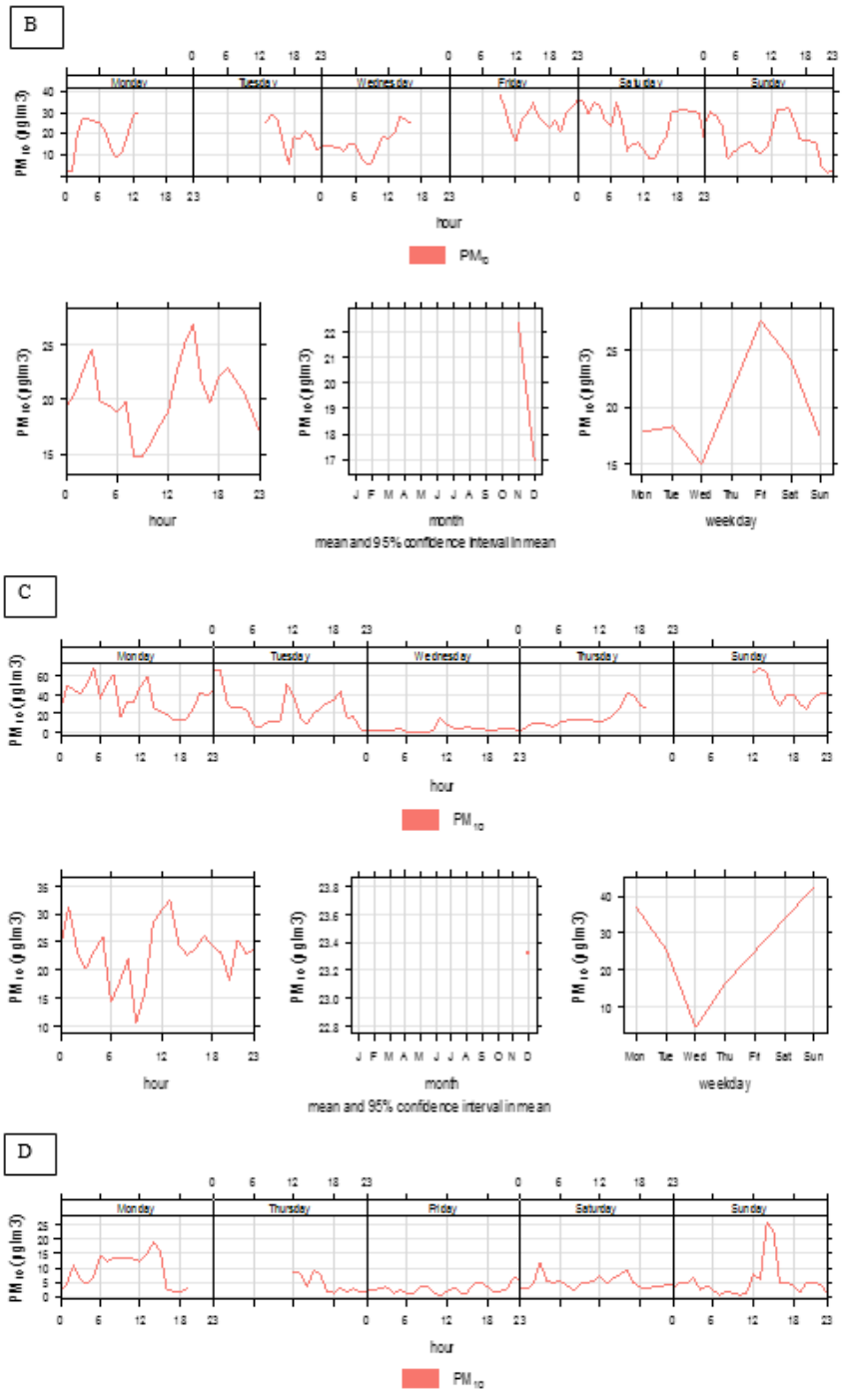


Figure 5: The Time series concentration of CO and NO; A) Station 1 (Melewar Residential College, KKM); B) Station 2 (Perwira Residential College, KKP)

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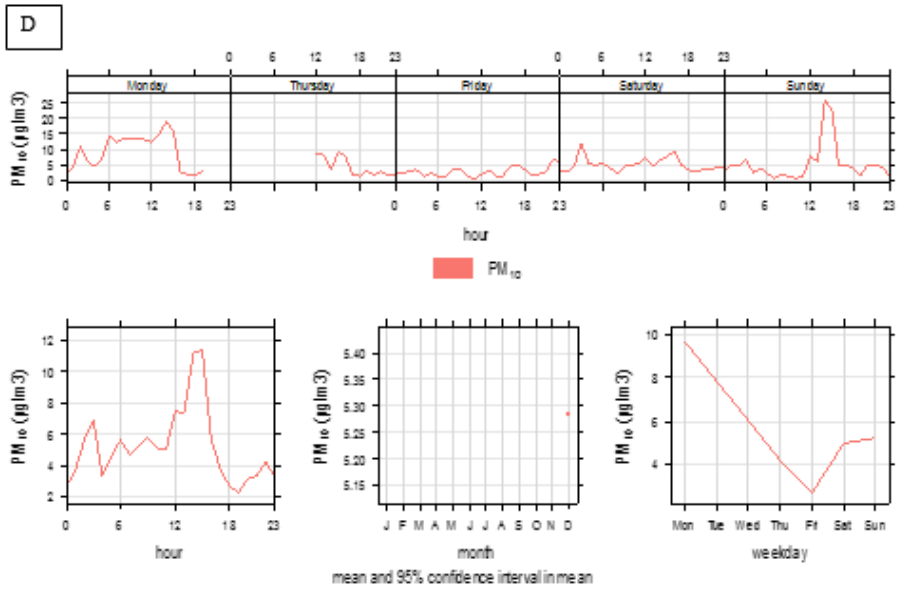

Figure 6 Time variationof PM_{10} concentrations; a) Station 1 (Melewar Residential College); b) Station 2 (Perwira Residential College); c) Station 3 (TDI Residential College); d) Station 4 (Taman University Residential College)

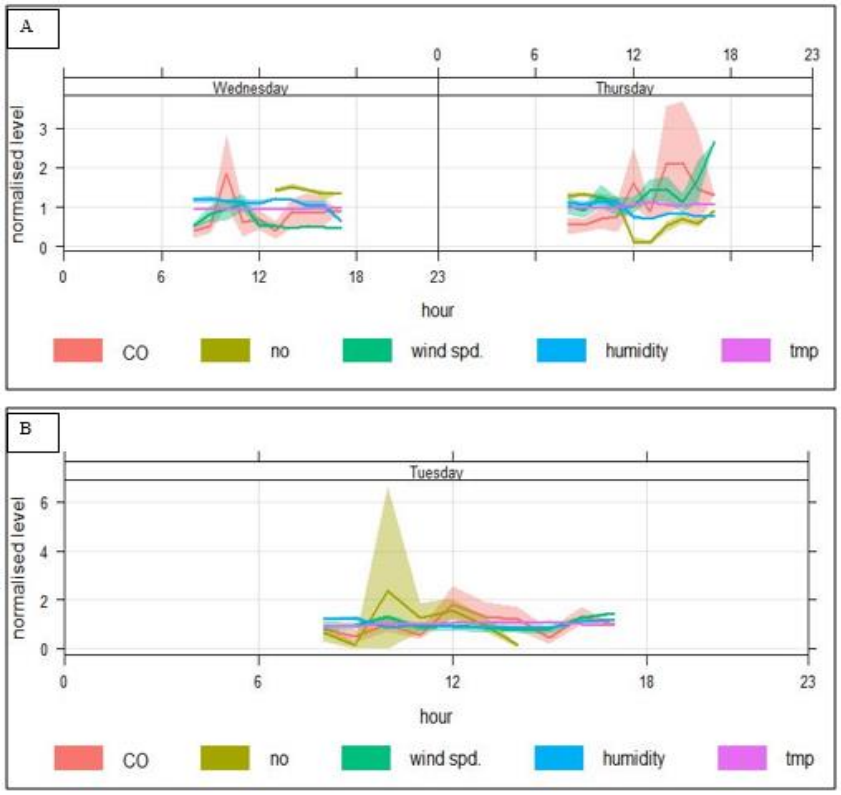

Figure 7: Time Variation of CO, NO and Meteorology Data at Station 1 and Station 2 (CO, Carbon monoxide; NO nitrogen Oxide; tem, temperature). A) Station 1 (Melewar Residential College, KKM); B) Station 2 (Perwira Residential College, KKP).

In this study, R Software was used for analysis of collected data. R is 'GNU S', a freely available language and environment for statistical computation and graphics which provides a wide variety of statistical and graphical techniques: linear and nonlinear modelling, statistical tests, time series analysis, classification, clustering and others [22]. R software is free and open sources software. The open source of R and related analysis packages are

used in this study. For concentrations of $PM_{10,}$ CO and NO, the packages used was an open air packages. Open air is an R package primarily developed for the analysis of air pollution measurement data but which is also of more general used in the atmospheric science. Boosting is a common method that attempts to 'boost' and improve the model accuracy for the given algorithm. The Boosted Regression Tree (BRT) of particle number was applied in this study as described by Yahaya et al. [23].

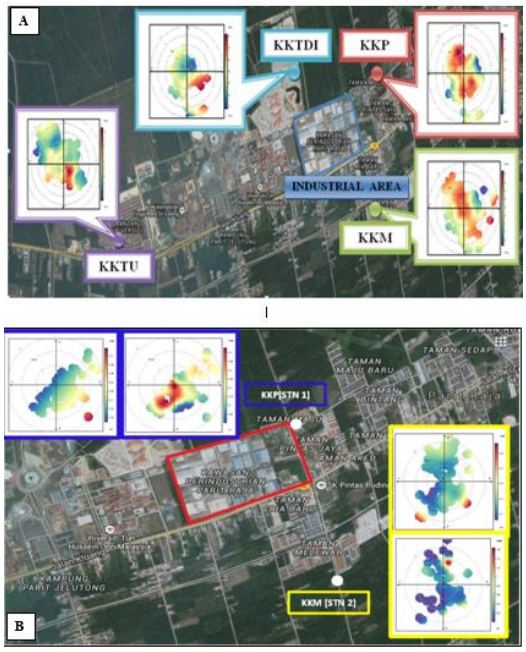

Figure 8: Polar Plot at Station 1, Station 2, Station 3 and Station 4 on the Google Map, A) PM10; B) toxic gaseous (NO and CO).Station 1 (Melewar Residential College, KKM); Station 2 (Perwira Residential College, KKP); Station 3 (TDI Residential College, KKTDI) and Station 4 (Taman University Residential College, KKTU)

Station 3 recorded the maximum PM_{10} concentrations (114 µg/m^3) followed by station 2 (58µg/m^3), while station 1 and 4 recorded the lowest concentration (40 and 43 µg/m^3, respectively). The maximum PM_{10} concentration at UTHM campus area was recorded in 2006 (1819µg/m³) [18]. However, the followed studies noted that the PM_{10}concentration are less than AAQS [5]. The PM_{10} concentration depend on the location of the station from the industrial area. In comparison to other studies, Junaidah [16] recorded 64.92 µg/m^3 in industrial area of Selangor and Kuala Lumpur. Norazian et al. [24] noted that the concentration of PM_{10} was 55.7 µg/m^3 at Shah Alam. In Terengganu, PM_{10} ranged from 69.64 to 83.58 µg/m^3 [25]. Globally, Chen et al. [26] found that the concentration of PM_{10} in China was 87 µg/m^3. Diapouli et al. [27] showed 75 55.7 µg/m^3 pf PM_{10} concentration at Athens, Greece, Massey et al.[28] found that PM_{10} at Roadside houses ranged from 247 to 255 µg/m^3, while was between 181 and 195 µg/m^3 at Urban houses in Agra India. In Delhi, India the PM_{10} concentrations ranged from 112 to 400 µg/m^3 [9]. The PM_{10} concentrations at station 3 was more than that recoded in Malaysia. However, it was less than that recoded in India. These differences would be related to the level of industrial activities.

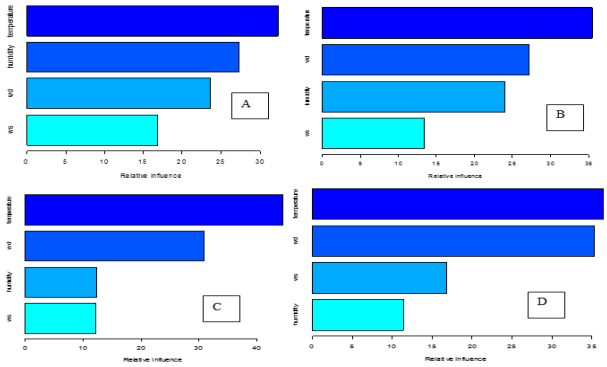

Figure 9. Boosted Regression Tree (BRT) of Metrological parameters at four stations, A) Station 1 (Melewar Residential College, KKM); B) Station 2 (Perwira Residential College, KKP); C) Station 3 (TDI Residential College, KKTDI); D) Station 4 (Taman University Residential College, KKTU)

In this study, station 3 is very close to the industrial area (400 m), while station 4 is far (2400 m). However, in previous study conducted on 2007, the PM_{10} at this station was only 6.422µg/m³. Therefore, the explanations for increasing of PM_{10} in the current work might be due to maximum emission rates from the nearby wood processing factory [18]. Besides, this study carried out during the season of haze which lead to increase PM_{10} concentrations.

The concentrations of CO in stations 1 and 2 were less than the AAQS (30 ppm in one hour), while NO concentrations at both stations have exceeded the AAQS (0.17 ppm within one hour). Similar results were reported previously by Shuhairi [29] who indicated that the concentrations of NO inside UTHM were between 1.04 and 3.2 ppm. These gaseous are coming from industrial activities which included the large combustion installations burning fuel oil or coal; cement factories; waste incinerators and road traffic, wood industries and others are correlated with the increasing of air pollution [30].

On the other hand, meteorological factors such as high humidity and prevailing wind directions during sampling might cause a spike in PM_{10} concentration measurement [18]. Most of the researchers identified that meteorological factors stimulates the level PM_{10} concentration [31]. From study conducted by UTHM researchers during the last years, air quality at UTHM around industrial area can be proved that the level of

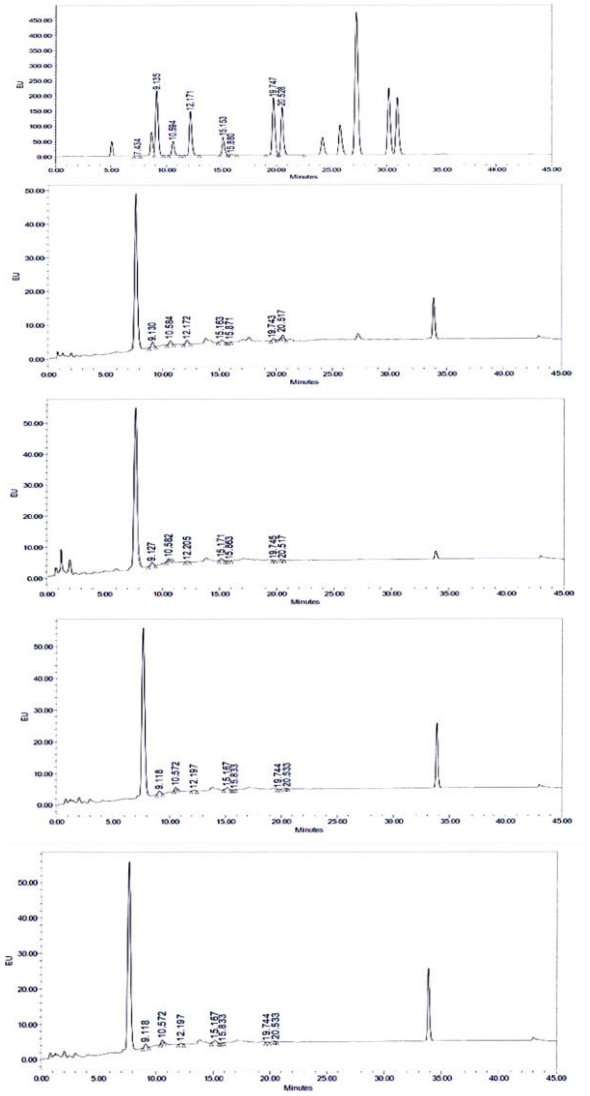

Figure 10. Polycyclic aromatic hydrocarbons (PAHs) in Air samples as determined by Gas chromatography

contaminants of air show that it can be higher and lower than AAQS [5, 18].

The time variation plot for the concentrations of CO, NO and meteorology data against time was useful for possible explanations for increasing of CO and NO, where the high level of CO recorded between 2.30 and 5.00 pm might due to traffic congestion increase at that time including heavy vehicle such as buses, while the assumption source of NO might be from industrial area based on the wind speed and wind direction. It has been demonstrated that the PM_{10} concentrations which exceeded the AAQS were caused by coal consumption from industry and vehicle transportation, road dust, dust from city construction projects, fireworks during celebrations, and dust storm (26, 32-35].

CONCLUSION

The current study has revealed that the concentrations of PM_{10} and CO was less than the standards limits recommended by AAQS, whereas, NO concentrations exceeded the AAQS, indicating the possibility of presence health risk for the residential area. However, these concentrations have increased during the haze season in comparison with the wet season which indicate that their effect might increase depending on the climate change in the future. Further, more studies for determination of SOx as well as the Gas Chromatography analysis of PM_{10} and $PM_{2.5}$is required during the haze season to qualify the air quality.

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Persian Abstract

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چکیده

کیفیت هوا در مناطق مسکونی مجاور نواحی صنعتی به علت ارتباط با ذرات جامد و گازهای سمی که اثرات نامطلوب بر سلامت انسان دارند، از اهمیت زیادی برخوردار می‌باشد. لذا مطالعه حاضر با هدف بررسی کیفیت هوا با توجه به غلظت PM_{10} و گازهای سمی (NO و CO) در کالج مسکونی دانشگاه حسین اون مالزی (UTHM) که در مجاورت کارخانه‌های پردازش چوب، الکترونیک و تخته فیبر قرار دارد، انجام پذیرفته است. چهار ایستگاه تعریف شده به عنوان ایستگاه ۱ (KKM)، ایستگاه ۲ (KKP)، ایستگاه ۳ (KKTDI) و ایستگاه ۴ (KKTU) برای این تحقیق انتخاب شدند. غلظت PM_{10} با استفاده از ذرات جامد E-Sampler برای یک دوره ۲۴ ساعته در فصل خشک (فوریه تا می ۲۰۱۶) که با پدیده غبار شدید در مالزی همراه بود، اندازه‌گیری شد. توزیع گازهای سمی انتخابی در خوابگاه دانشجویان UTHM با استفاده از TSI IAQ (CO) و Dragger X-am 7000 (NO) تعیین شد. PM10 و سطوح گازهای سمی با استاندارد کیفیت هوای محیط (AAQS) مقایسه شد و فرضیه منابع PM_{10} با استفاده از نرم‌افزار Open Air R Package محاسبه شد. داده‌ها با استفاده از نرم‌افزار R و بسته‌ها (Open-air, BRT, Akima) مورد تجزیه و تحلیل قرار گرفتند. بیش‌ترین غلظت PM_{10}، 114 µg/m3 در KKTDI و به دنبال آن 58 µg/m3 در KKP ثبت شد. حداکثر غلظت CO در KKP (8/1 ppm) گزارش شد. با این حال، غلظت هر دو PM_{10} و CO بیش از استاندارد کیفیت هوای محیط (AAQS) به ترتیب µg/m3150 و 30 ppm نبوده است. علاوه بر این، عبور غلظت NO در KKP (61/0 ppm) و در KKM (18/2 ppm) از AAQS (17/0 ppm) نشان دهنده احتمال وجود خطر برای دانشجویان در UTHM به دلیل کیفیت نامطلوب هوا می‌باشد. کیفیت هوا به‌طور مستقیم با سطح مصرف انرژی همراه است که باعث تغییرات اقلیمی و انباشت گازهای گلخانه‌ای می‌شود.