Discovering Source of Residents’ Complaint on Air Quality: Preliminary Studies on Particulate Matter (PM$_{2.5}$) and Sulphur Dioxide (SO$_2$)

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Abstract. Based on previous report, air quality in Universiti Tun Hussein Onn (UTHM) main campus can be categorized as good quality. However, high numbers of complaints especially on dust and unpleasant odour received from residents which located adjacent to industrial area in Parit Raja, Batu Pahat, Johor. Thus, this preliminary study is to discover the source of complaints with focus on Particulate Matter (PM$_{2.5}$) and Sulphur Dioxide (SO$_2$) concentrations. PM$_{2.5}$ and SO$_2$ were measured by using Temtop airming 1000 and aeroqual series 500, respectively at five sampling stations in UTHM main campus. Measurement for PM$_{2.5}$ and SO$_2$ concentrations were collected for 24 hours and 1 hours, respectively from July to September 2019. The average concentration for PM$_{2.5}$ at Tun Dr Ismail Residential College (83.63 ug/m$^3$) and Faculty of Civil Engineering and Built Environment (40 ug/m$^3$) were above the allowable limit. Meanwhile, SO$_2$ concentrations for all sampling stations were not exceeded the allowable limit. However, very high concentrations were detected at short duration that did not affect the average concentration. This high concentration can be the cause of complaints on unpleasant odour. Finding from this study can be used as preliminary data for detail monitoring and finding the source of air pollution.

1. Introduction
Air pollution is one of the major environmental issues that happened in Universiti Tun Hussein Onn Malaysia (UTHM) main campus due to industrial activities located adjacent to the campus. Due to existing of the industrial activities, UTHM’s residents were highly concerned with their health especially on respiratory problem. In addition, high number of complains were received to management of university and Occupational Safety, Health, and Environment (OSHE) due to problem of air pollution. Several students and staffs also need to refer to medical facilities inside and outside university due to respiratory problem such as asthma. Furthermore, UTHM’s residents also concerned the long term effect from the air pollution, especially staffs that will be stay for 20 to 30 years in future.

Air pollution can be defined as the contamination of the indoor or outdoor air by a range of gasses and solids that modify its natural characteristics. Any particles or gasses that effect air quality is called air pollutant. Key health-harmful of air pollutants include particulate matter (PM$_{2.5}$ and PM$_{10}$), carbon monoxide (CO), ozone (O$_3$), black carbon (BC), sulfur dioxide (SO$_2$) and nitrogen oxides (NO$_x$) [1].
Some of air pollutants come from natural sources, but most of air pollutants comes from human activity. Natural sources of air pollutants include radon which is a radioactive gas, mist, ozone, volcanic and combustion gases. There are three main sources of air pollution from human activities which are mobile sources, power stations, and stationary emission from industrial activities [2]. The main sources of air pollution in UTHM campus was came from nine factories that processing on of fiber-board, electronic and electrical manufacturing, and textile manufacturing. From these nine industries, 18 stacks were continuously produce variety of air pollutants to surrounding area. Other than industrial activities, air pollution in campus ambient air also caused by vehicle emission. From the data recorded by Safety Department UTHM, the number of vehicles are increased from 10,232 in year 2012 to 11,037 in year 2014 [3]. It was believe this number will be increased two or three-fold in current situation. This two factors has result in increased of air pollution in UTHM campus.

Particulate matter 2.5 (PM$_{2.5}$) refers to fine particle that are generally 2.5 micrometers or smaller. Particulate matter which is the term for a mixture of solid particles and liquid droplets found in the air [4]. Sources of PM$_{2.5}$ primarily come from vehicle exhaust or industrial area that involve burning of fuels, heating oil or coal. New Malaysia Ambient Air Quality Standard (NMAAQS) was established to replace Malaysia Ambient Air Quality Guideline that has been used since 1989. Based on NMAAQS the average standard for PM$_{2.5}$ are 35 micrograms per cubic meter of air (µg/m$^3$) for daily standard (24 hours) and 15 µg/m$^3$ for annual standard (1 year). PM$_{2.5}$ are able to travel deeply into the respiratory system. Exposure to PM$_{2.5}$ will cause a health effect like respiratory and cardiovascular illness. Scientific study have proved that long term exposure to particles can increased the rate of bronchitis, reduced the functional of respiratory organ and increase mortality from lung cancer and heart disease [5].

Sulfur dioxide (SO$_2$) is a gas that has a strong smell. This gas react easily with other chemical compound to form a harmful compound, such as sulfuric acid and sulfate particles. The main sources of SO$_2$ in air comes from human sources. For example, the generation of electricity from coal, oil and gas that contain sulfur, and SO$_2$ is released when they are process. The average standard that have been established in NMAAQS for SO$_2$ is 25 parts per billion (ppb) for one hour standard. Based on US National Library of Medicine, sulfur dioxide are very toxic by inhalation and may irritate the eyes and mucous membrane [6].

In 2008, PM$_{2.5}$ and PM$_{10}$ was measured in UTHM campus and the highest average concentration of PM$_{10}$ and PM$_{2.5}$ obtained was 33.08 µg/m$^3$ and 0.72 µg/m$^3$, respectively. During that year, both concentrations were less than the allowable limit [7]. [8] conduct a simple modelling with focus on parameter PM$_{10}$. In 2015, a study conducted by [9], measured on PM$_{10}$ in UTHM campus and the highest concentration was detected at 55.56 µg/m$^3$ which below the allowable limit. The study not measured on PM$_{2.5}$ due to this parameter was introduce in Malaysian standard in a year later. In 2016, [8] continuously measure on PM$_{10}$ with addition gas parameters namely carbon monoxide (CO) and nitrogen oxide (NO) and highest concentrations of 114 µg/m$^3$, 1.8 ppm and 0.61 ppm for PM$_{10}$, CO and NO were detected, respectively. Based on previous studies, very limited conducted on PM$_{2.5}$ measurement. Limited data during 2008 until present study and thus, this study will contribute to safety level of particulate matter in UTHM campus. SO$_2$ gas was reported once in 2016 by [2] and high concentrations was detected at certain duration. Due to limitation of data, this study was conducted to discover the source of air pollution problem in UTHM main campus.

2. Materials and Methods
This section is divided into two sub-sections, namely, details of sampling stations and measurement of PM$_{2.5}$ and SO$_2$ concentrations.

2.1. Details of sampling stations
Five stations were selected as sampling stations based on mostly exposure of UTHM staffs and students to air pollution from the industrial area in Parit Raja, Batu Pahat, Johor. These locations also were selected based on high number of complains was received to management of university and Occupational Safety, Health, and Environment (OSHE) on air pollution. In addition, the selection was based on distance which was estimated previously from ratio in Google Map from the industrial area. Table 1 shows the detail of sampling stations.
### Table 1. Detail of sampling stations

| Sampling station | Locations                          | Distance (km) | Direction from industrial area |
|------------------|------------------------------------|---------------|-------------------------------|
| TSN              | Tun Syed Nasir College             | 2             | West (W)                      |
| E14              | Block E14                          | 0.5           | West (W)                      |
| RMC              | Research Management Centre         | 1             | North West (NW)               |
| KTDI             | Tun Dr Ismail College              | 1.5           | North West (NW)               |
| FKAAB            | Faculty of Civil and Environmental Engineering | 2             | West-Northwest (WNW)         |

### 2.2. Measurement of PM$_{2.5}$ and SO$_2$ concentration

In this study, all sampling stations were conducted simultaneously for measurement of PM$_{2.5}$ and SO$_2$. Temtop Airing 1000 Detector Device was used to collect the PM$_{2.5}$ concentration. The air sampling for PM$_{2.5}$ was conducted in 24 hours. For SO2 gas, the Aeroqual series 500 portable air quality sensor was used. The sensor enables accurate real time measurement of SO$_2$ in the air. SO$_2$ data was stored in data logger and can be downloaded and view in monitor base (Microsoft Excel). The air sampling was conducted for an hour at each station at afternoon. The air sampling was performed once a week during working day at each station from July to September 2019. Samplings of meteorological data such as temperature, humidity, wind speed and wind direction were collected at each sampling stations. Sampling meteorological data was collected by using 100M Professional Weather Station Thermometer Humidity Rain Pressure Data Recorder with PC Solar Power Wireless Weather Center apparatus.

### 3. Results and Discussions

This section is divide into two sub-sections namely average PM$_{2.5}$ concentration and average SO$_2$ concentration.

#### 3.1. Average PM$_{2.5}$ concentration

Table 2 shows the average PM$_{2.5}$ concentrations for all sampling stations. The highest concentration was detected at KTDI with the value of 83.6 µg/m$^3$. While the lowest concentration was detected at E14 with the value of 25.8 µg/m$^3$. Other stations, PM$_{2.5}$ average concentration were detected at 25.96 µg/m$^3$, 33.5 µg/m$^3$ and 47.5 µg/m$^3$ for TSN, RMC and FKAAB, respectively. By referring to west direction from industrial, TSN and E14, both locations shows almost similar concentrations, even though the difference distance was 1.5 km. In North West direction, high difference (2.5 times) between RMC and KTDI, even though the difference distance was 0.5 km. The longest distance, FKAAB shows the second highest average concentration. Based on this result, the distance do not affect the PM$_{2.5}$ concentrations. NW and WNW direction shows high average PM$_{2.5}$ concentrations due to mostly wind direction in that day came from in this direction (154° - 184°). In New Malaysia Ambient Air Quality Standard (NMAAQS), the allowable limit for average PM$_{2.5}$ concentration in 24 hours is 35 µg/m$^3$. Among all stations, KTDI and FKAAB were above the allowable limit was due to wind direction from industrial area.
Table 2. Average PM$_{2.5}$ concentration for all stations

| Sampling station | Locations                          | Distance (km) | Direction from industrial area | Average concentration PM$_{2.5}$ ($\mu g/m^3$) |
|------------------|------------------------------------|---------------|--------------------------------|-----------------------------------------------|
| TSN              | Tun Syed Nasir College             | 2             | West (W)                       | 25.96                                         |
| E14              | Block E14                          | 0.5           | West (W)                       | 25.8                                          |
| RMC              | Research Management Centre         | 1             | North West (NW)                | 33.5                                          |
| KTDI             | Tun Dr Ismail College              | 1.5           | North West (NW)                | 83.6                                          |
| FKAAB            | Faculty of Civil Engineering and Built Environmental | 2             | West-Northwest (WNW)          | 47.5                                          |

By comparing result this study with [6], PM$_{2.5}$ concentration was increased 348 times, which from 0.24 $\mu g/m^3$ to 83.6 $\mu g/m^3$ after a decade as shown in Table 3. No measurement for TSN, RMC and FKAAB in 2008 and thus no comparison can be made. Based on very high difference, PM$_{2.5}$ concentrations will be increased in future if no action taken to reduce the emission from industrial activities. The industrial area was developed in 1980 and number of factories developed in the area were increased year by year. Besides emission from stack, PM$_{2.5}$ may be release from lorries and truck commute from that area.

Table 3. Comparison PM$_{2.5}$ concentration in 2008 and 2019

| Location | [6] ($\mu g/m^3$) | This study (2019) ($\mu g/m^3$) | Increase (times) |
|----------|-------------------|---------------------------------|------------------|
| KTDI     | 0.24              | 83.6                            | 348.3            |
| E14      | 0.54              | 25.8                            | 48               |

Figure 1 shows the average PM$_{2.5}$ concentrations based on different time for five sampling stations. Based on the figure, the PM$_{2.5}$ concentration was increased after 5pm (28.24 $\mu g/m^3$) and head to the top at 10pm (69.86 $\mu g/m^3$) with increase rate of 8.32 $\mu g/m^3$/hour. Then, the PM$_{2.5}$ concentrations was decreased gradually with rate of 3.31 $\mu g/m^3$/hour until 1pm (20.22 $\mu g/m^3$). Based on industrial production, the release of emission was constant for all times. There are no different between day and night. However, this study found that very high concentration at night maybe due to meteorological factor, which temperature at night is relatively lower compare to day. When the temperature is low, the humidity is high, which is the disadvantages for the air flow and diffusion [10]. Findings from this study on high concentration at night was constants with complaints from one of UTHM resident which state that “Bau asap di sekitar kawasan kedua-dua kolej ini makin teruk lebih-lebih lagi waktu malam sampai subuh”. This statement means the unpleasant odor always occurred during night.

In 2018, PM$_{2.5}$ was introduced in new air quality standard in Malaysia. Thus, this parameter was not measured before 2018 and the report that sent to Department of Environment shows the air quality in UTHM main campus is in good condition. Nevertheless, high number of complaints on tiny dust was received especially from staffs and students that stay at KTDI. Due to this problem, effort on PM$_{2.5}$ measurement was initiated and the source of complaints can be obtained.
3.2. Average SO2 concentration

Other than complaints on dust, high number of complaints were also received on unpleasant odour. Thus, SO2 gas was measured. This gas was selected due to one of raw material, namely, Ammonium Sulphate. SO2 gas may be released due to high temperature and pressure in Fibreboard processing. Table 4 shows the average SO2 concentrations for all sampling stations. The highest concentration of SO2 was detected at RMC with concentration of 140 $\mu$g/m$^3$. In same direction, KTDI, with difference distance 0.5 km, SO2 concentration was reduced to 90 $\mu$g/m$^3$. Other station near to industrial area, E14, shows the average SO2 concentration was 100 $\mu$g/m$^3$. There is no detection of SO2 gas at TSN and FKAAB.

Based on the table, the distance was highly influence on SO2 concentration. Distance more than 2 km, no detection of SO2 gas. Based on New Malaysia Ambient Air Quality Standard (NMAAQS) the safe limit for one hour reading for SO2 concentration is 250 $\mu$g/m$^3$ and all sampling stations were below the allowable limit. Thus, this condition indicates that the release of SO2 gas from the industrial area was not cause adverse impact to human health and environment.

Table 4. Average SO2 concentration for all stations

| Sampling station | Locations                        | Distance (km) | Direction from industrial area | Average SO2 concentration ($\mu$g/m$^3$) |
|------------------|----------------------------------|---------------|---------------------------------|----------------------------------------|
| TSN              | Tun Syed Nasir College           | 2             | West (W)                        | ND                                     |
| E14              | Block E14                        | 0.5           | West (W)                        | 100                                    |
| RMC              | Research Management Centre       | 1             | North West (NW)                 | 140                                    |
| KTDI             | Tun Dr Ismail College            | 1.5           | North West (NW)                 | 90                                     |
| FKAAB            | Faculty of Civil and Environmental Engineering | 2 | West-Northwest (WNW) | ND                                     |

*ND: Not Detected

Figure 2 shows SO2 concentration at different time between 8.35am to 5.45pm at RMC. Based on the figure, SO2 concentration mostly constant except between 10.30am to 10.50 am, which very high concentrations were detected and above the allowable limit. The highest concentration was detected at 10.35am, 0.53 $\mu$g/m$^3$. Then decrease to 0.29 $\mu$g/m$^3$ (10:40 am), 0.25 $\mu$g/m$^3$ (10.45am) and 0.26 $\mu$g/m$^3$
(10.50am). Even though average SO₂ concentration was below the allowable limit based on Table 4, at certain time, very high SO₂ concentration was released from industrial activities emision. This gas release may cause the high complaints from residents that stay at KTDI. Thus, the conflict between standard compliance and complaints on air quality were take place. The factory is responsible on air quality based on compliance of air quality standard. If the gas release is below the allowable limit, there is no legal action on the factory. In previous study, high concentration of SO₂ (0.66 µg/m³) gas was also detected between 8am to 10am [9]. However, the study did not measured SO₂ gas at other time thus no comparison can be made as shown in Table 5.

![SO₂ concentration at different time between 8.35am to 5.45pm at RMC](image)

**Figure 2.** SO₂ concentration at different time between 8.35am to 5.45pm at RMC

**Table 5.** Comparison of average SO₂ concentration between [9] and this study

| Time Period          | Average SO₂ concentration (µg/m³) |
|----------------------|-----------------------------------|
| [7]                  | This study                        |
| 8-10am               | 660                                |
| 8am-9am              | 50                                 |
| 9.30-10.30am         | 30                                 |
| 10.30-11.30am        | 100                                |

4. Conclusion

Among all stations, two stations (KTDI and FKAAB), PM₂.₅ concentrations were above the allowable limit. By comparing with previous studies, PM₂.₅ concentration was increased 348 times, which from 0.24 µg/m³ (2008) to 83.6 µg/m³ (2019). This increment was constant with increase number of complaints from UTHM residents on tiny dust. Average for SO₂ concentrations for all stations were below the allowable limit. However, these concentrations were not consistent with number of complaints on unpleasant odour, which very high number of complaints. This is due to high concentration of SO₂ was detected in short duration that did not affect the average concentration. Thus, the result shows the air quality is in good condition, but the number of complaints were very high. Data from this study can be used as preliminary data for detail monitoring of air quality in UTHM campus. In addition, it is highly recommended to measure for other gasses such as formaldehyde gas in future due to contain in one of the raw materials that use.
5. References

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