A Study of Indoor Air Quality of Public Toilet in University's Building

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***Abstract*—This paper presents a study of IAQ in toilets located in the Faculty of Civil and Environmental Engineering building, Universiti Tun Hussein Onn Malaysia (UTHM). This study was conducted to determine the level of gas pollutants exist in the male and female toilets. The important IAQ parameters considered in this study are SO_2, NO, and CO_2. The measurements were conducted during break hour and taken using air quality monitoring. The result indicated that SO_2 exceeded the threshold value and this could have adverse effect on inhalation such as asthmatic. Finally, the existing SO_2 was affected by mechanical ventilation mode, while the existing CO_2 was more generated in female toilet.**

Keywords: SO_2, NO, CO_2, Asthmatic, IAQ

I. INTRODUCTION

Indoor Air Quality (IAQ) is a term referring to the air quality within and around buildings and structures, its significance especially being its relation to the health and comfort of building occupants [1]. In recent years, scientist and public have put much concern about indoor air quality since people mostly spent their time more than 70 – 90% indoors [2–4]. Additionally, several studies have found that indoor air pollution levels to be greater than outdoor levels [5], [6]. Thus, it is risky to health posed by indoor air pollution than those posed by outdoor air pollution. Clearly, the quality of indoor air should be better for most of the time.

Toilet is one of public facilities, which is frequently used by people and located indoor. Therefore, maintaining good air quality in toilet is essential in order to keep it hygienic and sanitary. This is aligned with the statement mentioned by Wilke [7], "In order to create a healthier and safer environment, the first step is in the washroom."

Numerous studies have been previously conducted regarding to indoor air in toilets are as follows, Nakajima et al [8], studied on evaluation of odour from portable toilets in a four-bed hospital ward. A portable toilet is used for patients who cannot use a toilet by themselves. In his study, all the patients in the ward used a conventional portable toilet for four consecutive days, and then an odourless portable toilet for six consecutive days. The results show that in comparison with the conventional portable toilet, the odourless portable toilet could reduce pollutants level of existing gases such as 14% of hydrogen sulphide (H_2S), 30% of ammonia (NH_3), 58% in chemicals of light molecular weight and 44% in chemicals of heavy molecular weight. From these results, it can be concluded that the ambient odour in the hospital ward was significantly improved by using the odourless portable toilet. Furthermore, Jung et al [9], studied flush toilet cleanliness in Raffles Girl's School (RGS). The results found that the wetness of the toilets, the lack of litter bins and refuse lids, and the lack of ownership in toilets are the most contributors to the problem of hygiene and dirtiness of the school toilets. These automatically impacted the IAQ of the RGS toilets.

Tsang [10], researched on gas emissions generated from dry toilets. Dry toilet is a type of toilet which uses no water or uses only small amount of water. The results of this study indicated that the average concentrations of gasses emission of O_2 was close to ambient at 20.8%, H_2S was 0.395

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ppm, NH_4 was 345 ppm, and the last was NH_3 at 7.9 ppm.

Based on the findings of previous studies which had been described above, it can be concluded that odour gasses are the main problem within toilet and could have affect on user healthy. Thus, it motivates to study the level of IAQ in toilets of the university buildings.

II. IAQ PARAMETERS

Indoor environment of building is a complex system that involves many parameters which has impact on health and comfort [11]. According to Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places [12], air contaminant is one of factors that could have affected on indoor air quality. Gas is one of air contaminant categories [13]. Carbon Dioxide (CO_2), Nitric Oxide (NO), and Sulfur Dioxide (SO_2) are gases which considered to this study.

In order to assess the indoor air quality that could have affect to the human health, it is necessary to compare the measurement results of indoor air quality with the threshold value in table 1.

TABLE 1. THRESHOLD LIMIT VALUE (TLV)

Parameters	TLV	Exposure via inhalation	Symptoms	*Ref
SO_2 (PPM)	0.3	10 Minutes	Asthmatic	ERPG [14]
CO_2 (PPM)	80,000 – 100,000	5 – 10 Minutes	Severe headache, sweating, dimness of vision, tremor and loss of consciousness	Hazard Manage-ment [15]
NO (PPM)	50	10 – 30 Minutes		OEL-CLV [16]

*Ref : References

a. *Carbon Dioxide*

CO_2 is colorless, odorless gas. In addition, CO_2 is one of asphyxiant gases that could be interfere the availability of oxygen for tissues [13]. The unavailability of oxygen for 3 to 5 minutes could lead to brain damage or death. The existing CO_2 gas on indoor is affected due to the presence of occupants and impacted to human health [17]. Thus, it indicated that CO_2 gas can be used as an indicator of IAQ [18].

b. *Nitric Oxide*

Nitric Oxide (NO) is a colorless, odorless, and tasteless gas that is only slightly soluble in water. [13]. Its affinity with hemoglobin is 1500 times greater than CO_2 [19], nitrosylhemoglobin is formed between NO and hemoglobin which is rapidly oxidized to methemoglobin [20-22].

C. *Sulfur Dioxide*

Sulfur Dioxide (SO_2) is a colorless gas with a strong pungent odor [13] and the odor can be detected at 0.5 ppm [2]. However, most people could smell SO_2 from 0.3 ppm to 1 ppm [23]. According to ERPG [14], SO_2 at 0.3 ppm for 10 minutes could increase airway resistance of asthmatic experience. Thus, the existence of SO_2 gas on indoor became more concern in this paper due to its adverse effect on human health with short term exposure in certain concentrations.

Many studies concerning the relationship between SO_2 exposure in polluted air and human health had been conducted. Balmes et al [24] exposed two females and six males non smoking asthmatics to humidified air with 0.5 ppm or 1.0 ppm of SO_2 for 1 minute, 3 minutes, and 5 minutes respectively. The subjects inhaled SO_2 from a mouthpiece attached, a pulsed fluorescent SO_2 analyzer is used to continuously measured the SO_2 concentrations. After 1 minute exposures, 2 subjects are developed chest tightness. After 3 and 5 minute exposure, 7 of 8 subjects indicate that specific airway resistance (SRaw) was increased, accompanied by wheezing, chest tightness, or dyspnea. Bethel et al [25], studied on effect of 0.25 ppm SO_2 on airway resistance. As many as 28 subjects are exposed with SO_2 gas at 0.25 ppm for 5 minutes, and all exposed subjects indicated the increment of SRaw. However, Linn et al [26] also studied on SO_2 with 23 subjects exposed with 0.4 ppm during 5 minutes, and it could have increased SRaw of subjects exposed according to his study.

III. METHODOLOGY

Sampling Sites

This study was conducted on four selected toilets at Faculty of Civil and Environmental Engineering of Universiti Tun Hussein Onn Malaysia. The four selected toilets where two toilets are used for gents, and two more are for women. The selected toilets were ventilated by natural ventilation through open windows or mechanical ventilation using fan. Table 2 below describes the characteristic of toilets according to this study.

TABLE 2. CHARACTERISTIC OF TOILETS

Toilet	Toilet types	Vent. Systems	Number of People Within the Toilet	Area (m^2)	*H (m)
1	Male	Mechanic-al	3	13.8074	2.8
2	Male	Natural	6	9.976	2.8
3	Female	Mechanic-al	5	15.12	2.8
4	Female	Natural	2	11.52	2.8

*H: Height

Sample Collection and Analysis

Investigating was conducted during break hours in one day. Temperature, relative humidity, CO_2, NO, and SO_2 were measured for 10 minutes using Air Quality Monitoring. The instrument was placed vertically at a height of 1.2 m. During the investigating periods, each of the investigated toilets was occupied.

All the data obtained were subjected to descriptive statistical analysis including mean, standard deviation, maximum value, and minimum value using statistical analysis functions in Microsoft Excel. Finally, one sample T-test and independent samples T-test were conducted using Statistical Package for The Social Science (SPSS) version 17.

IV. Results and Discussion

Indoor Climate

Indoor air temperatures recorded in the toilets was between 23.8 to 28.7 degree Celsius and the recorded relative humidity was in the range of 67% to 93%. Based on descriptive statistical tool analysis as in table 3, the mean values of temperature for four toilets are 25.4 °C, 27.657 °C, 26.709 °C and 28.41 °C respectively, while the range of mean values of relative humidity was 68.476 to 83.809 %. These results could be affected from the climate of Malaysia in the tropical region with hot and humid condition [27].

TABLE 3. Descriptive Statistical of Indoor Climate Parameters During Measurement Periods

Parameters	Mean±SD	Min	Max
Temperature (°C)			
Toilet 1	25.4±0.552	23.8	25.8
Toilet 2	27.657±0.244	26.8	27.9
Toilet 3	26.709±0.03	26.7	26.8
Toilet 4	28.41±0.241	27.7	28.7
Relative Humidity (%)			
Toilet 1	83.809±3.355	81	93
Toilet 2	70.714±1.23	70	75
Toilet 3	82.476±2.315	75	84
Toilet 4	68.476±1.631	67	73

Indoor Air Quality

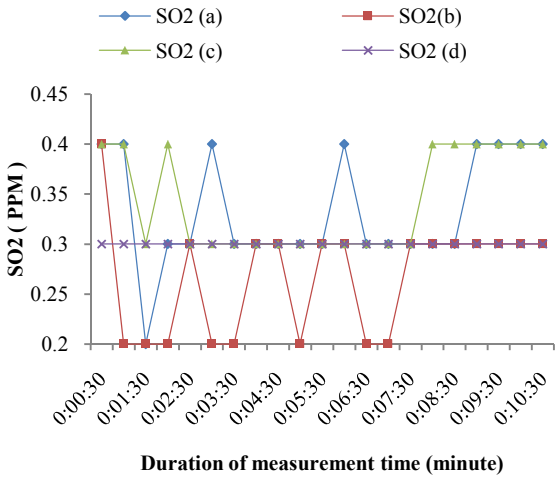
The descriptive statistical data of SO_2, NO, and CO_2 that were obtained from four selected toilets in Faculty of Civil and Environmental Engineering of University Tun Hussein Onn Malaysia are given in Table 4. SO_2 measured was between 0.2 ppm to 0.4 ppm, while NO was between 0.1 ppm to 10.4 ppm. Finally, the existing CO_2 measured was between 366 ppm to 588 ppm.

TABLE 4. Descriptive Statistical Analysis of IAQ Parameters During Measurment Periods

Parameters	Mean±SD	Min	Max
Sulfur Dioxide (SO_2) - PPM			
Toilet 1	0.333±0.057	0.2	0.4
Toilet 2	0.266±0.057	0.2	0.4
Toilet 3	0.342±0.05	0.3	0.4
Toilet 4	0.3±5.68x10^{-}	0.3	0.3
Nitrogen Monoxide (NO) – PPM			
Toilet 1	1.538±1.523	0.1	6.7
Toilet 2	2.1±2.57	0.3	10.4
Toilet 3	1.962±1.512	0.4	6.02
Toilet 4	0.68±0.116	0.6	1.1
Carbon Dioxide (CO_2) - PPM			
Toilet 1	369.428±1.075	368	371
Toilet 2	418.047±11.57	373	423
Toilet 3	520.428±36.301	440	573
Toilet 4	414.381±73.465	366	588

a. Sulfur Dioxide (SO_2)

Sulfur Dioxide measured in selected toilets such as toilet 1, toilet 2, and toilet 3 has the maximum concentration at 0.4 ppm during the measurement periods. This is indicate that a possibility of asthmatic symptoms could have affects on human health who used these toilets frequently. Figure 1 below depicts the number of existing SO_2 during the measurement period in the selected toilets.



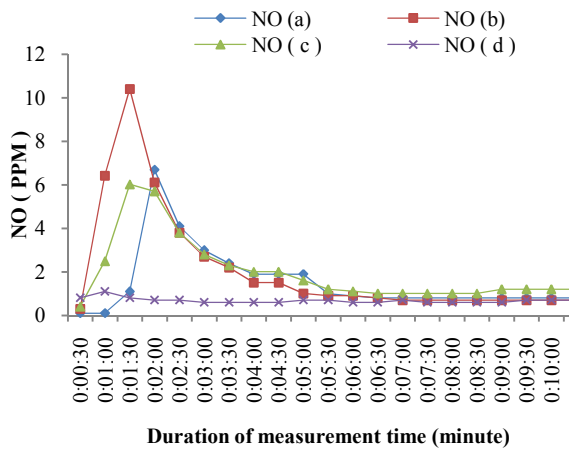
*(a) : Toilet 1, (b) : Toilet 2, (c) : Toilet 3, (d) :Toilet 4

Figure 1. SO_2 measured in four selected toilets

b. Nitric Oxide (NO)

The recommended threshold value for NO is 50 ppm for 10 to 30 minutes according to OEL-CLV [16]. Based on table 4, all of the mean values of NO gas measured in selected toilets were not exceeded the threshold value during the measurement period. The maximum concentration of NO was measured in toilet 2 with 10.4 ppm, while the minimum was in toilet 1 with 0.1 ppm.

Figure 2 shows the Nitric Oxide value in four selected toilets during measurement period.



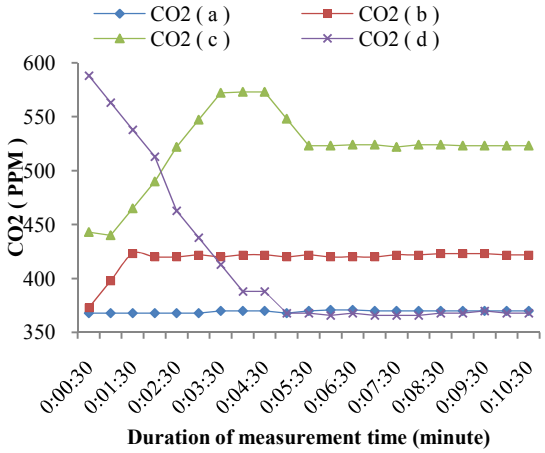
*(a) : Toilet 1, (b) : Toilet 2, (c): Toilet 3, (d) : Toilet 4

Figure 2. NO measured in four selected toilets

c. Carbon Dioxide (CO_2)

During the measurement periods, the maximum of CO_2 concentration was recorded in toilet 4 about 588 ppm. However, the threshold value for CO_2 exposure that could have adverse effect to human health was in the range of 80,000 to 100,000 ppm for 5 to 10 minutes based on Hazard Management [15]. Thus, it indicates that the existing CO_2 in selected toilets are in acceptable range.

According to Muhammad-Darus et al [1], the existing CO_2 on indoor is affected by the presence of people. Comparing to this study it can be seen from table 4 that, the highest of mean values concentration of CO_2 was toilet 3 with 5 peoples totally during the measurement, while the lowest concentration of CO_2 was measured in toilet 1 with 3 peoples totally during measurement periods. Figure 3 below shows the number of existing CO_2 during measurement periods.



*(a) : Toilet 1, (b) : Toilet 2, (c) : Toilet 3, (d) : Toilet 4

Figure 3. CO_2 measured in four selected toilets

One Sample T-test

A one sample T-test is used to test whether a population mean is significantly different from some hypothesized value [28]. Thus, mean values of existing gases measured were compared to the recommended threshold value on table 1 using One Sample T-test

TABLE 5. ONE-SAMPLE STATISTICS

Parameters	*N	Mean	Std. Deviation	Std. Error Mean
SO_2	84	0.3107	0.05601	0.00611
CO_2	84	430.5714	68.87448	7.51482
NO	84	1.5705	1.73674	0.18949

*The number of valid data

TABLE 6. ONE SAMPLE TEST

Parameters	t	df	Sig (2-tailed)	Mean Difference
SO_2	1.753	83	0.083	0.01071
CO_2	-10588.332	83	0.000	-79569.43
NO	-255.572	83	0.000	-48.42952

Based on table 6, there is a possibility of occurrence asthmatic symptoms due to the number of existing SO_2 in toilets ($p>0.025$). While the other gases, CO_2 ($p<0.025$) and NO ($p<0.025$) are in acceptable threshold value. This means that, CO_2 and NO in the selected toilets could not have adverse effect to health in 10 minutes of exposure.

Independent Samples T-test

This test is commonly used to test the effect of one independent variable to one or more dependent variables [28].

Ventilation types

TABLE 7. GROUP STATISTICS OF VENTILATION TYPES

Parameters	Vent. types	N	Mean	Std. Dev.	Std. Mean Error
CO_2	Mech.	42	444.9286	80.493	12.42
	Natural	42	416.2143	51.977	8.02
SO_2	Mech.	42	0.3381	0.0538	0.008
	Natural	42	0.02833	0.0437	0.006
NO	Mech.	42	1.7502	1.5146	0.233
	Natural	42	1.3907	1.9354	0.298

TABLE 8. INDEPENDENT SAMPLES TEST OF VENTILATION TYPES

Parameters		F	Sig	Sig. (2-tailed)
CO_2	Equal variances asumed	35.086	0.000	0.056
	Equal variances not asumed			0.056
SO_2	Equal variances asumed	11.718	0.001	0.000
	Equal variances not asumed			0.000
NO	Equal variances asumed	0.014	0.905	0.346
	Equal variances not asumed			0.346

Based on table 8, Nitric Oxide was assumed has equal variances ($p>0.05$). Additionally, ventilation types found as a factor which affecting the number of existing SO_2 in selected toilets ($p<0.025$). Referring to table 7, mechanical ventilation mode was more impacted to the number of existing SO_2 than natural mode based on comparison of its mean values.

Toilet Types

TABLE 9. GROUP STATISTICS OF TOILET TYPES

Parameters	Toilet types	N	Mean	Std. Dev.	Std. Error Mean
CO_2	Male	42	393.73	25.909	3.99798
	Female	42	467.40	78.435	12.1029
SO_2	Male	42	0.3	0.0662	0.01022
	Female	42	0.3214	0.0415	0.00641
NO	Male	42	1.8193	2.1061	0.32499
	Female	42	1.3217	1.2422	0.19169

TABLE 10. INDEPENDENT SAMPLES TEST OF TOILET TYPES

Parameters		F	Sig	Sig.(2-tailed)
CO_2	Equal Variances Assumed	95.021	0.000	0.000
	Equal Variances Not Assumed			0.000
SO_2	Equal Variances Assumed	1.153	0.286	0.079
	Equal Variances Not Assumed			0.080
NO	Equal Variances Assumed	4.984	0.028	0.191
	Equal Variances Not Assumed			0.192

According to table 10, CO_2 in this study was influenced by toilet types ($p<0.025$) , and known that female toilets gave the highest influence to the existing CO_2 in this study than male toilets refer to table 9, by comparing its mean values ($467.40>393.73$).

V. CONCLUSIONS

In this paper, indoor air quality parameters such as Sulfur Dioxide (SO_2), Nitric Oxide (NO), and also Carbon Dioxide (CO_2) were measured to determine the level of gas pollutants exist in the selected toilets at Faculty of Civil and Environmental Engineering of UTHM. Based on the measurement results, it can be drawn a few conclusions as follows:

1. The existing SO_2 concentrations on selected toilets found as a factor which could have adverse health effect such as asthmatic.
2. Mechanical ventilation in this study was found as a factor that most contributes to the number of existing SO_2, while the number of existing CO_2 was mostly affected by female toilets based on independent samples T-test analysis.
3. Mechanical ventilation in selected toilets is one of the sources that could have lead to asthmatic symptoms due to the number of existing SO_2 that was affected by mechanical ventilation mode .
4. Ultimately, the behaviour of toilet users also affected the level of indoor air quality within toilet. For example, not flushing properly, smoking, and throw cigarettes in toilet.

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