CFD ANALYSIS OF FLOW, POLLUTANT DISPERSION AND THERMAL EFFECT IN STREET CANYONS

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ABSTRACT

Aim of this study is to investigate the pollutant dispersion inside an urban street canyon so that the understanding of the characteristics of air flow subjected to the dispersion of pollutant can help achieve greater air quality urban areas, sustainably for improving the health and comfort of the people. Using numerical method through Computational Fluid Dynamic Software ANSYS Fluent, a simplified two dimensional street canyon is modeled to simulate the flow of pollutant subjected to building geometry as well as wind speed. The building height and street width were manipulated throughout the study. A series of multiphase analysis were conducted with different building height to street width ratio to examine the pollutant dispersion rate. With the volume fraction gradually decrease from Φ=1 to a certain value that indicates the pollutant has disperse. The result presented the relation between the street canyon geometry and the pollutant dispersion rate, with wider streets proves to have a better pollution dispersion rate as well as when the wind speed is higher. The significant of the study is to see effect of the street canyon geometry to the rate of pollutant dispersion.

KEYWORDS: *Urban street canyon; Building to street width ratio; Volume fraction; Pollutant dispersion; Multiphase*

1.0 INTRODUCTION

Urban street canyon is a basic form and structure that construct a whole city. The form of a street canyon is made of continuous buildings on each sides of a narrow street. Many researches have been conducted on urban canyons to understand the implications of this structure to the surrounding such as, a study of general properties of urban climate of a street canyon on microclimate, a study of orientation of the canyon

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on facing directions, the height, length and width of the canyon, and a study of temperature phenomena considering several factors. These studies are important to understand significance of these structures so people can be comfortable while being within these urban canyons. The canyon's geometry and orientation can impact various local conditions such as radio reception signals, the wind speed which the air moving is accelerated and channelled, the temperature which can cause urban heat island effect, as well as the quality of air and the concentration of pollutants of stagnant air at ground level.

Carbon Monoxide (CO) is an odourless, colourless, and tasteless gas that is slightly dense than the air. It is a toxic gas produce from incomplete combustion of carbon based fuels from motor vehicles, appliances, factories, household fires and others. It is poisonous to humans and animals when inhale in high concentrations, even though it is produce by animals with low metabolism as well as produced by human body naturally and is thought to have some normal biological functions. It is considered that carbon monoxide is a temporary atmospheric pollutant in some urban areas, mainly from the exhaust of internal combustion engine that includes vehicles, portable and back-up generators and others, but also from incomplete combustion of various other fuels including wood, coal, charcoal, oil, paraffin, propane, natural gas, and trash. There have been relatively few recent studies on pollutant dispersion inside an urban street canyon and there are none on building height as well as wind speed in the aspect of pollutant dispersion. Observing that most of the prior investigations were concerned on unstable stratifications (Li et al., 2009) and thermal heating (Chan & Liu, 2011;Wang et al., 2011), the present case is continuing the study of pollutant dispersion inside an urban street canyon in the aspect of building geometry as well as wind speed.

2.0 LITERATURE REVIEW

Li et al., (2009) conducted a study using a Large-Eddy Simulation based on a one-equation sub grid-scale model to investigate the flow field and pollutant dispersion characteristics inside urban street canyon. They conducted the study by heating the ground level of the street canyon to simulate an unstable thermal stratification condition. (Li et al., 2009), states that thermal stratification (due to solar radiation, anthropogenic heat, etc.) plays an important role in the air flow and pollutant dispersion processes. Air circulation and temperature distribution within urban street canyons are of high significance for pedestrian comfort and pollutant dispersion. Usually the traffic exhaust is hotter than ambient air and this fact will also influence the pollutant transport in urban areas. They used the bulk Richardson number R_b introduced in the study by Uehara et al., (2000), to quantify the thermal effect over the inertial force, which was defined as

$$R_b = \frac{gh}{U_h^2} X \frac{T_h - T_f}{T_a + 273} \tag{1}$$

where g is the gravitational acceleration, h is the building height, T_h is the temperature at the roof level, T_f is the temperature at the ground level, T_a is the reference (ambient) temperature, and U_h is the stream wise velocity at the roof level.

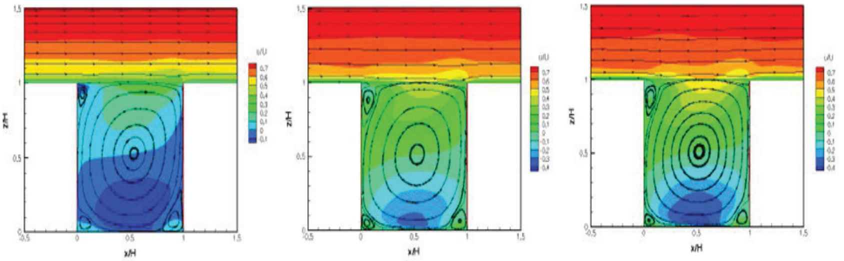


Figure 1. Flow patterns and normalized stream wise velocities under different stratification. R_b: (left) 0; (middle) -3; (right) -5. (Li et al., 2009)

They use three set of values 0, -3 and -5 for their R_b number for the thermal stratifications and Figure 1 shows that it produces different flow pattern inside the street canyon, which confirms their statement that thermal stratification plays an important role in the air flow and pollutant dispersion processes.

There are several findings from (Li et al., 2009) in unstable stratification condition where, first they found that the flow pattern varied a little. Second, with the increase of unstable stratification, the stream wise velocity at the lower half street canyon increased and the wall friction at ground level of the street increases due to higher velocity gradient. Next, at higher R_b number, the vertical velocities (both downward and upward) were greatly strengthened and the leeward updraft will bring more pollutants to the roof level but the windward downdraft will take more pollutants back to the ground level. Finally, the pollutant concentration inside the street canyon decreased with the increase of the R_b number, but the pollutant concentration outside the street canyon increased with the increase of R_b number. With further study base on (Li et al., 2009) should be considered for unstable stratifications affects the pollutant removal rate by adding disturbance to the flow of air as well as the pollutant.

Shui et al., (2009) conducted a study for two-dimensional (2D) street canyons considering varieties of building-height-to-street-width aspect ratios (h/b) to explore how significant the street canyon geometry to the flow regimes, recirculating wind, and pollutant transport. Shui et al., (2009) also concentrated on aspect ratios of $0.067 \leq h/w \leq 2.5$. Reynolds-averaged Navier-Stokes (RANS) equations were used for the CFD study with the model of Renormalization Group (RNG) k-ε turbulence used.

Shui et al., (2009) states that based on the parameters used to estimate the ventilation and pollutant removal performance are ventilation rate (VR) and pollutant removal rate (PRR) proposed by Cheng et al., (2008), turbulent transport dominates over 80% of the total VR as well as the PRR which propose how important turbulence flow in both ventilation and pollutant dispersion in an urban street canyon.

The VR and PRR increases with respect to the decreasing aspect ratio, meaning that wider streets will acquire an entrainment that carries fresh air down to the street canyon and gradually improves the air quality. With narrow streets, it tends to accumulate the pollutant emitted at ground level of the street canyon with a high re-entrainment of pollutant that follows the free-stream air entrainment inside the street canyon which ends up prolonging the pollutant residence.

The investigation conducted by Wang et al., (2011) is to explore the impact of solar radiation on pollutant dispersion and air flow stream in an urban street canyon with an aspect ratio of one. The investigation is based on the situation created by the movement of the sun where it shines on the windward wall of the building, leeward wall of the building and towards the ground level of the street canyon. This will heat the building wall surfaces and the ground increasing the air temperature heated by the wall. Wang et al., (2011) states that, determining the air flow fields within street canyon is significantly affected by the thermally induced buoyancy that creates an unstable thermal stratifications which supports the previous statement by Li et al., (2009), thermal stratification plays an important role in the air flow and pollutant dispersion processes. Based on Figure 2, the air flows for each heating conditions differs, for each situation creates different buoyancy force and air flow vortex.

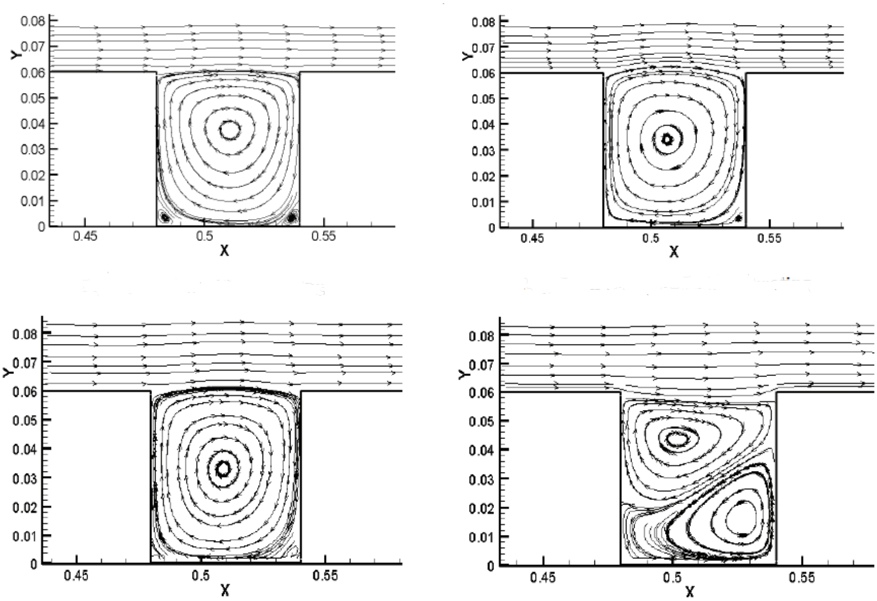


Figure 2. From top left clock wise, air flow with no heating, air flow with leeward heating, air flow with floor heating and air flow with windward heating (Wang et al., 2011)

The findings on solar heating has an important effect on the air flow field, when the windward wall was heated it creates an upward buoyancy flux that opposes the downward advection flux along the wall creating two oppose vortexes and resulting an accumulation of pollutant at the windward side of the building and increases the concentration of pollutant in the street canyon. When the leeward wall and ground level was heated, the air flow field and pollutant dispersion pattern were the same to the situation of that without solar radiation. The air near to the leeward wall and ground level is heated when the sun shines on these sides, it creates a buoyancy flux that adds to the upward advection flux along the leeward wall, and the air goes up vertically and strengthens the vertical movement and the intensity of the vortex is increased. The pollutant concentration in the street canyon decreases as this effect intensifies.

3.0 METHODOLOGY

This study is conducted using a CFD software ANSYS FLUENT. A simple two dimensional model of the street canyon was used for the CFD simulation, where several building geometry is carried out for the street canyon. The validation case is based on Wang et al., (2009), where the study conduct a model of street canyon with aspect ratio of 1:1 with the wind speed set as parallel to the street canyon model. The volume fraction, Φ in the previous study is set in an area source with Φ=1

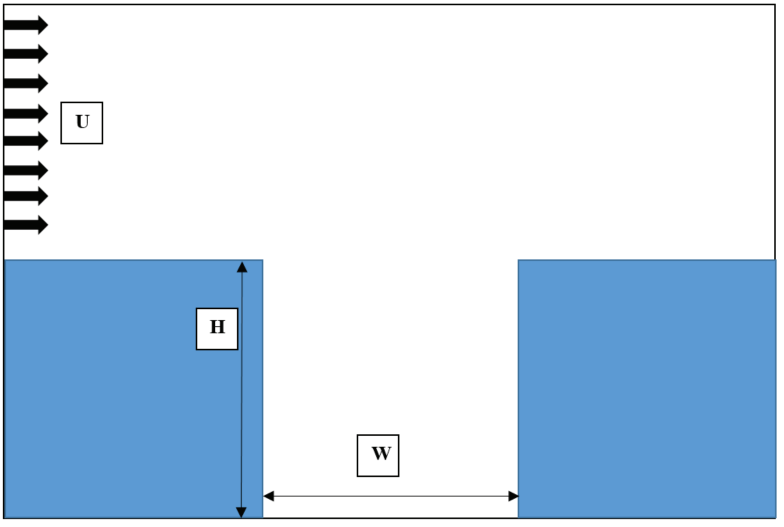


Figure 3. Model of the street canyon

Figure 3 shows the example of how the urban street canyon is being modelled for the simulation. The blue region represents the buildings between the streets, the white region represent the space of where the air will flow, *H* represent the height of the building, *W* represent the width of the street, and *U*, represent the speed of the air that will flow across the street canyon. The pollutant that is trapped inside the street canyon chosen is carbon monoxide. The modelling, meshing, and the setup and solution is all done through the software. There are several cases for this study with different variables considered.

The model is drawn in the geometry pane of the FLUENT solver, where there were five types of building geometry drawn for the street canyon. The model is a simplified two dimensional model as shown in Figure 4, where the use of simplified two dimensional building geometry is easier to capture the fluid flow of the air and the pollutant. The geometry that was manipulated for the street canyon model was the buildings height, H and the streets width, *W*. The street canyon H/W ratio ranges between $0.5 \leq H/W \leq 2$ based on the manipulated building height and street width.

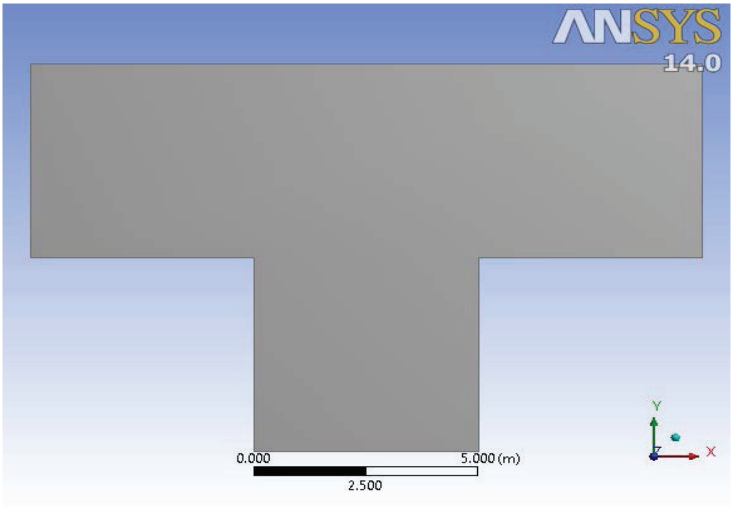


Figure 4. Example of the simplified two dimensional street canyon model

Table 1. Case A parameters

Case A	H (m)	W (m)	U (m/s)	Ratio
1	5	5	5	1:1
2	7.5	5	5	3:2
3	10	5	5	2:1

Table 2. Case B parameters

Case B	H (m)	W (m)	U (m/s)	Ratio
1	5	5	5	1:1
2	5	5	7.5	1:1
3	5	5	10	1:1

Table 3. Case C parameters

Case C	H (m)	W (m)	U (m/s)	Ratio
1	5	5	5	1:1
2	5	7.5	5	2:3
3	5	10	5	1:2

There are three cases covered in this study which are divided into Case A, Case B and Case C. Each case has a manipulated variable that ranges from building height, street width to wind speed. For Case A the manipulated variable was the building height, as shown in Table 1, there are three set of heights for the street canyon and the other two parameters remain constant. Table 2, shows the parameters for the street canyon for Case B. For this case the speed of the wind was manipulated to investigate the role of the wind in the aspect of pollutant dispersion. The aspect ratio 1:1 was chosen based on Case

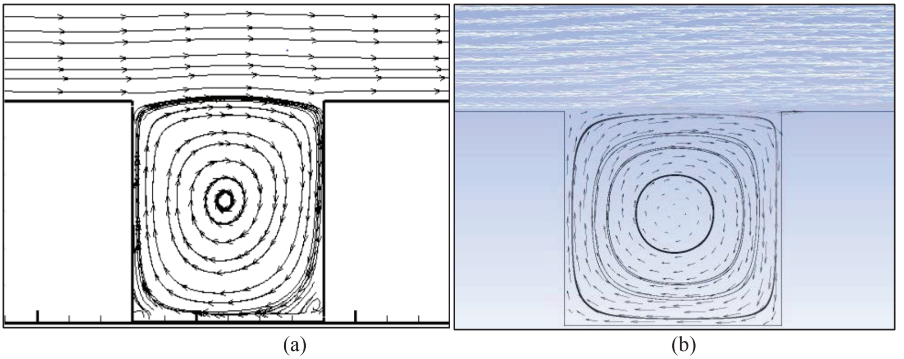
A where the model has the better pollution dispersion rate out of the three cases. The manipulated variable was the width of the street with the parameter is set as in Table 3.

All of the cases used realizable turbulence model k-ε in a multiphase flow. The pollutant was set at an area source of uniform pollutant concentration Φ=1, which is the volume fraction. Then the calculation was set with a time step size of 0.01 for 1000 Number of Time Steps. The time step setting shows the simulated analysis for 10 seconds, then it is run in an interval of 10 seconds until it reached 60 seconds. This was done to capture image of the flow of the air and the pollutant in the street canyon. Each 10 Seconds the value of volume fraction is analysed to see the rate of pollutant dispersion inside the street canyon.

Thermal heating was added to varying the result for pollutant dispersion inside the street canyon. With a constant temperature for the wind the walls of the building and the street of the street canyon was heated. This will indicate what sort of impact that thermal heating can do in terms of pollutant dispersion rate.

4.0 RESULT AND DISCUSSION

Wang et al., (2011), used the wind flow parallel to the street canyon with an area source of pollutant is set Φ=1 inside a street canyon with an aspect ratio of 1:1. The mathematical model was based on the numerical solution to the governing fluid flow and transport equations, which were derived from the basic conservation and transport principles in incompressible flows. In the present study, similar parameters was used and produce comparable streamline as shown in Figure 5.



(a) (b)

Figure 5. (a) air flow streamline from Wang et al., (2009); (b) present study air flow streamline

The air flow streamline produce in the present study is similar with the study conducted by Wang et al., (2011). The current study results agreed well with the CFD measurements inside the street canyon, with similar air profile with a steady flow of vortex inside the street canyon. With different inflow boundary velocity and turbulent intensities adopted, the current study shows positive result when being compared with Wang et al., (2011). In spite of several differences in terms of boundary conditions, both profiles of velocity are quite similar. This validation suggest that the present the CFD model may be used for simulating air flow and pollutant dispersion in an urban street canyon with current conditions.

4.1 Turbulence Model Comparison

The turbulence model used as comparison in the current study was the realizable k-ε model, SST k-ω turbulence model and Reynolds stress model. The significant difference between these models is the number of equations used to solve the CFD model. The k-ε model is a two equation model which gives a general description of turbulence with two transport equations to represent the turbulent properties of the flow. The transition SST model is based on the coupling of the SST transport equations with two other transport equations, one for the intermittency and one for the transition onset criteria, in terms of momentum-thickness Reynolds number, it uses four equations. And the Reynolds stress is the component of the total stress tensor in a fluid obtained from the averaging operation over the Navier-Stokes equations to account for turbulent fluctuations in fluid momentum which uses five equations to solve the CFD model.

Table 4. Tabulated concentration data for turbulence model comparison

Time (s)	*k-ε* (ϕ)	SST (ϕ)	Reynolds (ϕ)
0	1.000	1.000	1.000
10	0.8637	0.8644	0.8590
20	0.8546	0.8538	0.8461
30	0.8515	0.8440	0.8350
40	0.8385	0.8280	0.8156
50	0.8293	0.8210	0.8090
60	0.8094	0.8058	0.7990

The reason for conducting the simulation with different turbulence model was to see the effect of number of equations used to solve the model on the data. As tabulated is Table 4 the data shows that the Reynolds stress produce the least amount of volume fraction for carbon monoxide after 60 seconds with 0.7990 compared to SST and k-ε with 0.8058 and 0.8094 respectively. Even though Reynolds stress has the least volume fraction, when compared the value does not deviate that far from one another. This can clearly be seen on Figure 6 where the difference was small over time.It also showed that pattern between the three turbulence models was almost the same at each point. Although the boundary condition was use all the same for the three models the graph show that it has the same trend throughout 60 seconds.

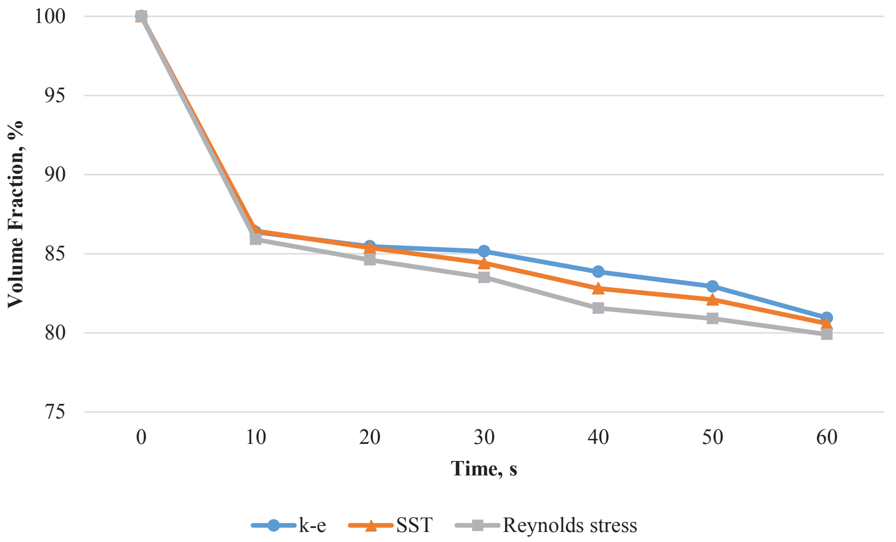


Figure 6. Volume fraction against time for different turbulence model

By combining both observation of small difference in data and the similar trend between the three models, it can be said that the data produce is more accurate as the number of equation increase for this case it was the Reynolds stress model with five equation. This hypothesis is due to the small difference of data produce between the three models.

So with the difference of data was not that significant, the study was continued using the k-ε model for the time taken to simulate the model was the least for it only uses two equation to solve. With the trend of data similar to one another the difference won't deviate far from the other two turbulence model.

4.1.1 Case A: difference in aspect ratio in terms of building height

Table 5. Tabulated concentration data for Case A

Time (s)	Ratio 1:1	Ratio 3:2	Ratio 2:1
0	1.000	1.000	1.000
10	0.863	0.881	0.892
20	0.854	0.877	0.890
30	0.851	0.872	0.887
40	0.838	0.865	0.884
50	0.829	0.856	0.880
60	0.809	0.843	0.876

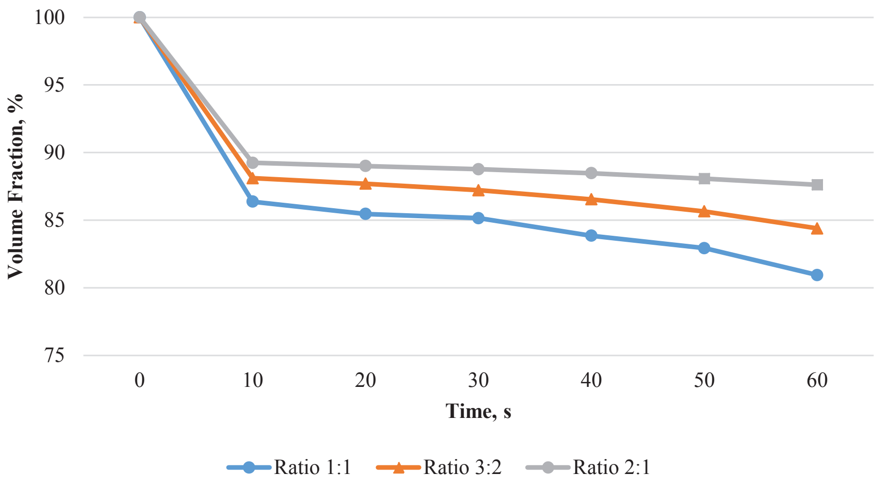


Figure 7. Volume pollutant against time for different aspect ratio height

The tabulated data in Table 5 was data recorded for Case A with different aspect ratios. The result for Case A indicates that an urban street canyon with taller buildings disperse the pollutant at a much slower rate compared to building with lesser height. The wind flow across the building and street canyon creates a vortex inside the street canyon that helps the pollutant escapes, but with the rotation of the wind inside the street canyon the vortex tend to bring back the pollutant back to ground level. With a building ratio where the height is greater in length than the width of the street, the pollutant that escaped is small in volume fraction compared to the pollutant that is brought back to the street. The pollutant is easily trapped with greater building height.

As Figure 7 shows for Case A, a building street canyon with a smaller value of building height to street width ratio have a better pollutant dispersion rate even with the wind speed is set the same for each model ratio. For this case, the ratio 1:1 pollutant dispersion rate is better than the ratio of 3:2 and ratio of 2:1. As shown in Figure 7, the initial volume fraction value at 0 seconds equals to Φ = 1, and gradually decrease overtime throughout 60 seconds. The value recorded for every 10 seconds until the 60th second differs for each ratios, for ratio 1:1 the volume fraction value was 0.863, 0.854, 0.851, 0.838, 0.829, and 0.809 respectively for every 10 seconds. The volume fraction value for ratio 3:2 is 0.881, 0.877, 0.872, 0.865, 0.856, and 0.843 for every 10 seconds. And for ratio 2:1 the volume fraction value for every 10 second was 0.892, 0.890, 0.887, 0.884, 0.880, and 0.876. The graph is plotted as volume of pollutant which is volume fraction in percentage against time in seconds.

The volume fraction value at the 60th second for 1:1 is smaller compared to 3:2 and 2:1 with 0.809, 0.843, and 0.876 respectively. With the wind speed across the street canyon is the same for all three ratios, the building with lesser in height has the greater pollutant dispersion rate. This shows that greater building height traps more pollutant inside its street canyon. For illustrative purpose, Figure 7 until Figure 9 shows the contour of the case A.

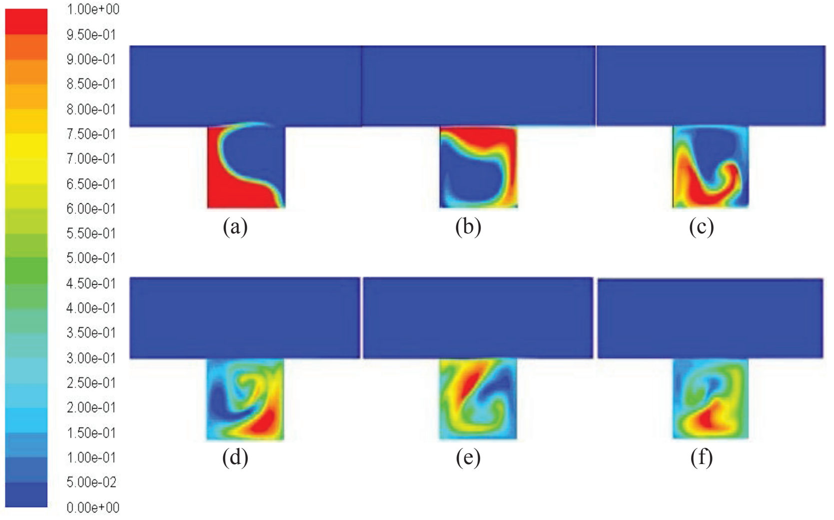


Figure 8. Carbon Monoxide Volume Fraction contour: Case A for ratio 1:1 with wind speed 5 m/s with different time interval; (a) 10s, (b) 20s, (c) 30s, (d) 40s, (e) 50s, (f) 60 s

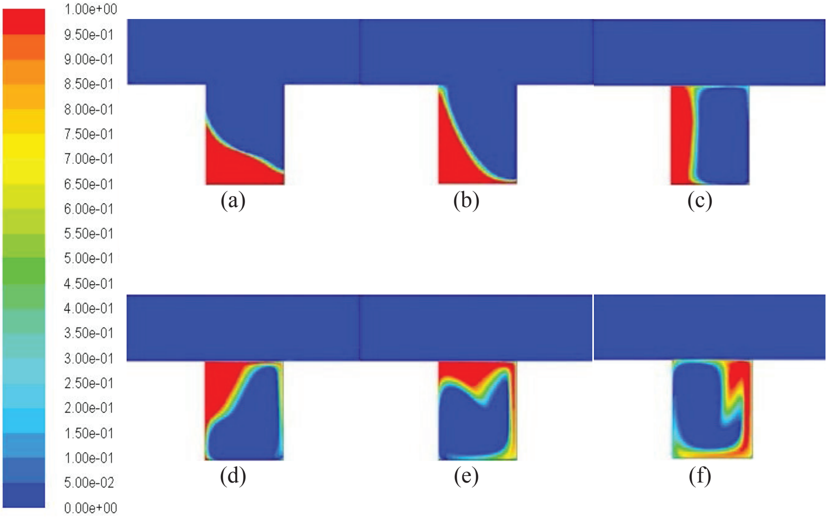


Figure 9. Carbon Monoxide Volume Fraction contour: Case A for ratio 3:2 with wind speed 5 m/s with different time interval; (a) 10s, (b) 20s, (c) 30s, (d) 40s, (e) 50s, (f) 60 s

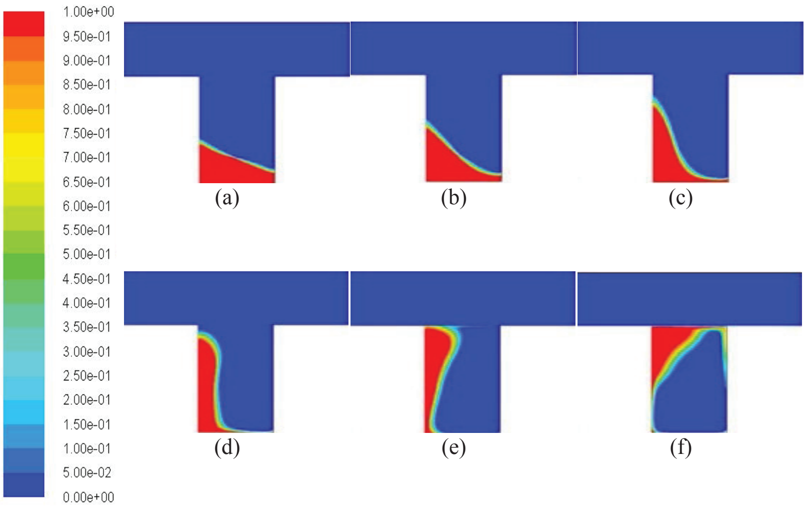


Figure 10. Carbon Monoxide Volume Fraction contour: Case A for ratio 2:1 with wind speed 5 m/s with different time interval; (a) 10s, (b) 20s, (c) 30s, (d) 40s, (e) 50s, (f) 60 s

4.1.2 *Case B: difference in wind speed*

Table 6. Tabulated concentration data for Case B

Time (s)	5m/s (ϕ)	7.5m/s (ϕ)	10m/s (ϕ)
0	1.000	1.000	1.000
10	0.863	0.854	0.853
20	0.854	0.841	0.816
30	0.851	0.820	0.795
40	0.838	0.806	0.780
50	0.829	0.796	0.765
60	0.809	0.784	0.750

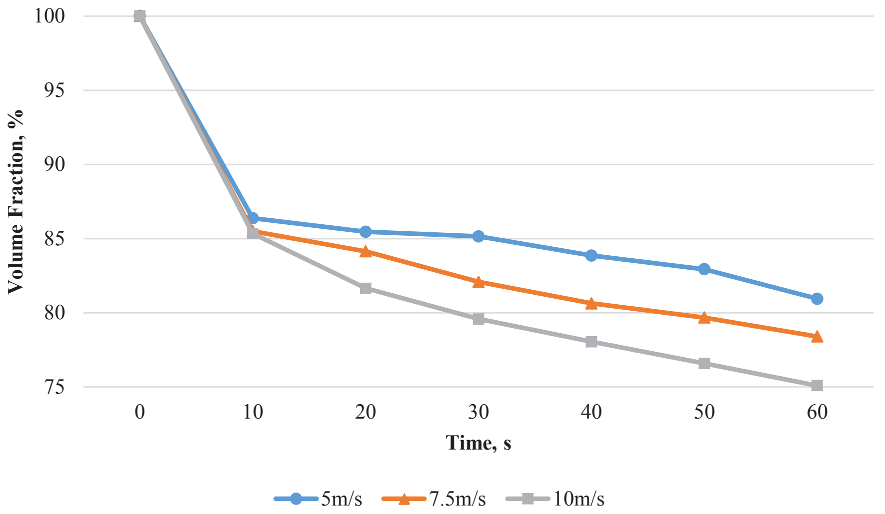


Figure 11. Volume pollutant against time for different wind speed

For Case B, the model building height to street width ratio used was 1:1, this is because it has a better pollutant dispersion rate compared to the other two ratio 3:2 and 2:1 based on the result gathered in Case A. The wind speed across the urban street canyon was set with three different values, 5 m/s, 7.5 m/s, and 10 m/s, as tabulated in Table 6. This case was conducted to see the effect of different wind speed on the pollutant dispersion inside an urban street canyon.

Same as Case A, the result for Case B is recorded every 10 seconds throughout 60 seconds with the initial volume fraction value $\Phi = 1$. With the wind speed set at 5 m/s the volume fraction value for every 10 seconds was 0.863, 0.854, 0.851, 0.838, 0.829, and 0.809. When the wind speed is set at 7.5 m/s the volume fraction value for every 10 seconds was 0.854, 0.841, 0.820, 0.806, 0.796, and 0.784. For the wind speed that is set at 10m/s the volume fraction value is 0.853, 0.816, 0.795, 0.780, 0.765, and 0.750. The graph was also plotted as volume of pollutant, volume fraction in percentage against time in seconds.

Case B highlights that, greater wind speed will improve the pollutant dispersion rate inside the urban street canyon. Figure 11 indicates that when the wind speed is at set at the maximum for this case when it is set at 10 m/s the pollution inside the street canyon disperse at a faster rate compared to lower wind speeds. This could be seen at the 60th second where the volume fraction value is 0.750, 0.784, and 0.809 for 5 m/s, 7.5 m/s, and 10 m/s respectively. Addition on that, Figure 11 until Figure 13 show the contour of the Case B. The finding provides evidence that the wind speed affects the pollutant dispersion inside the street canyon as it improves the pollutant dispersion rate with greater wind speed value.

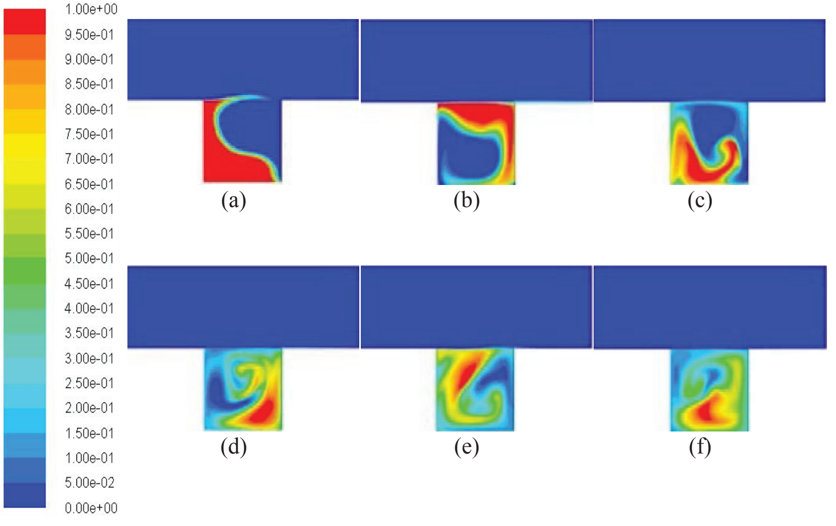


Figure 12. Carbon Monoxide contour: Case B for wind speed 5 m/s with ratio 1:1 with different time interval; (a) 10s, (b) 20s, (c) 30s, (d) 40s, (e) 50s, (f) 60 s

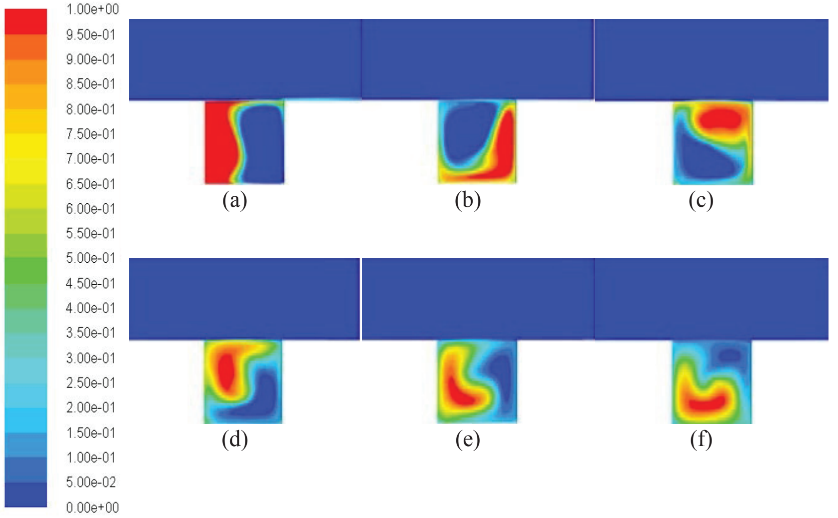


Figure 13. Carbon Monoxide contour: Case B for wind speed 7.5 m/s with ratio 1:1 with different time interval; (a) 10s, (b) 20s, (c) 30s, (d) 40s, (e) 50s, (f) 60 s

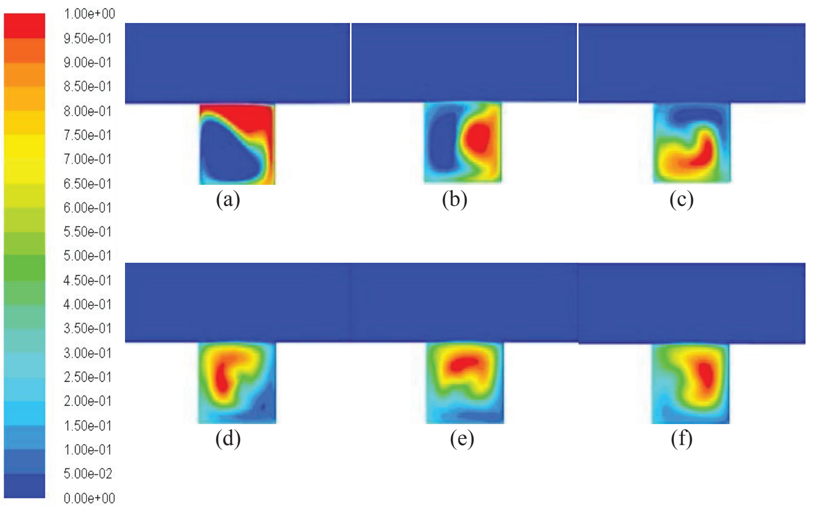


Figure 14. Carbon Monoxide contour: Case B for wind speed 10 m/s with ratio 1:1 with different time interval; (a) 10s, (b) 20s, (c) 30s, (d) 40s, (e) 50s, (f) 60 s

4.1.3 Case C: difference in aspect ratio in terms of street width

Table 7. Tabulated concentration data for Case C

Time (s)	Ratio 1:1	Ratio 2:3	Ratio 1:2
0	1.000	1.000	1.000
10	0.863	0.836	0.840
20	0.854	0.830	0.820
30	0.851	0.827	0.815
40	0.838	0.822	0.805
50	0.829	0.815	0.788
60	0.809	0.802	0.765

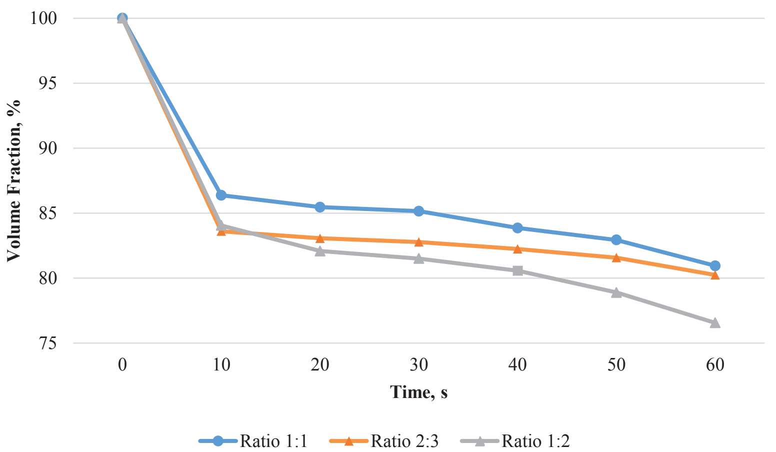


Figure 15. Volume pollutant against time for different aspect ratio street

Case C is almost similar with Case A where the building height to street ratio width was manipulated but for this case the street width was varied. For the three situation the wind speed remain the same for all three models. The width of the street is 5 m, 7.5 m, and 10 m, creating an aspect ratio of 1:1, 2:3, and 1:2 respectively as in Table 7.

With the data was recorded for every 10 seconds throughout 60 seconds similar with the other two cases Case A and case B, the volume fraction value is set Φ = 1 as the initial value. The volume fraction value for every 10 seconds for ratio 1:1 is the same as Case A as well as Case B. But when the building height to street width ratio is 2:3 it differs for the value was 0.836, 0.830, 0.827, 0.822, 0.815, and 0.802 for each 10 second interval. For ratio of 1:2, the volume fraction value for every 10 seconds for 60 seconds was 0.840, 0.820, 0.815, 0.805, 0.788, and 0.765. As in Case A and Case B, the graph in Case C is plotted as volume of pollutant which volume fraction in percentage against time in seconds.

Figure 15 indicates that with wider streets the pollutant can disperse at a better rate compared to narrow streets. This is shown at the 60th

second, where building height to street width ratio of 1:2 has a volume fraction value of 0.765 which is the least compared to ratio 1:1 and ratio 2:3 with volume fraction value of 0.809 and 0.802 respectively. Pollutant phase distribution can be ilustrated in Figure 15 until Figure 17.

This case is somewhat similar to a previous study by Shui et al., (2009) where they stated that wider streets enhance the pollutant removal rate inside the street canyon, for this study case it is 1:2 which equals to 0.5.

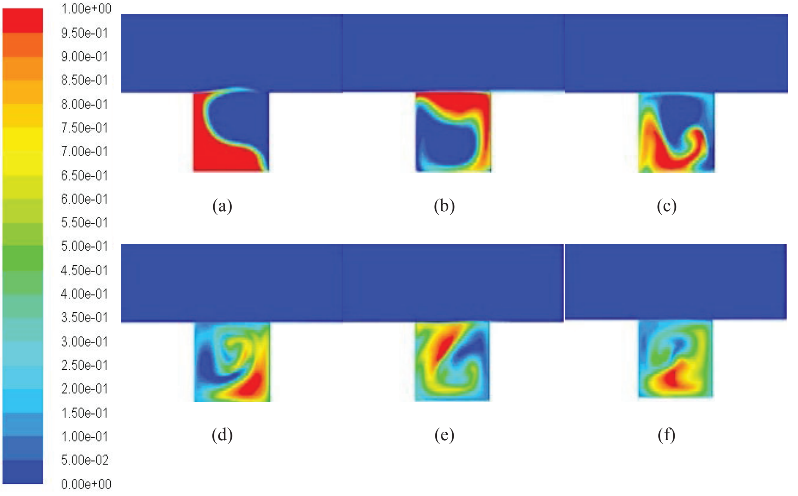


Figure 16. Carbon monoxide contour: Case C for ratio 1:1 with wind speed 5 m/s with different time interval; (a) 10s, (b) 20s, (c) 30s, (d) 40s, (e) 50s, (f) 60 s

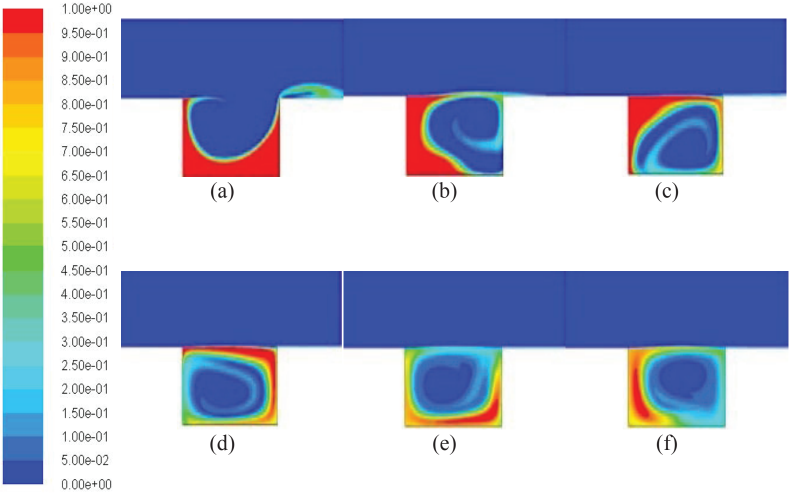


Figure 17. Carbon monoxide contour: Case C for ratio 2:3 with wind speed 5 m/s with different time interval; (a) 10s, (b) 20s, (c) 30s, (d) 40s, (e) 50s, (f) 60 s

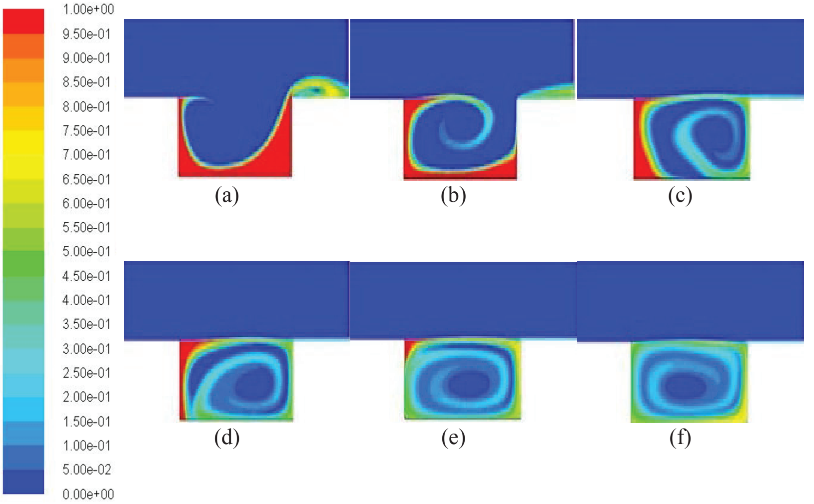


Figure 18. Carbon monoxide contour: Case C for ratio 1:2 with wind speed 5 m/s

4.1.4 Thermal heating

The objective of this boundary condition was to investigate the impact of heating of building facades and ground surfaces on the flow of air and the pollutant dispersion assumed at different time of the day. To examine the effect of thermal heating towards air flow and pollutant dispersion, four simulation was done with different parts that was heated that is the street, the windward of the building, the leeward of the building and no heating. The temperature of the street, the windward wall or the leeward wall was set to 37°C, while the ambient air temperature was not changed at 27 °C.

Table 8. Tabulated data for thermal heating

Time (s)	No Heating (ϕ)	Street Heating (ϕ)	Windward Heating (ϕ)	Leeward Heating (ϕ)
0	1.000	1.000	1.000	1.000
10	0.8637	0.8518	0.8623	0.8620
20	0.8546	0.8406	0.8510	0.8510
30	0.8515	0.8298	0.8410	0.8333
40	0.8385	0.8110	0.8250	0.8192
50	0.8293	0.7989	0.8190	0.8020
60	0.8094	0.7820	0.8120	0.7960

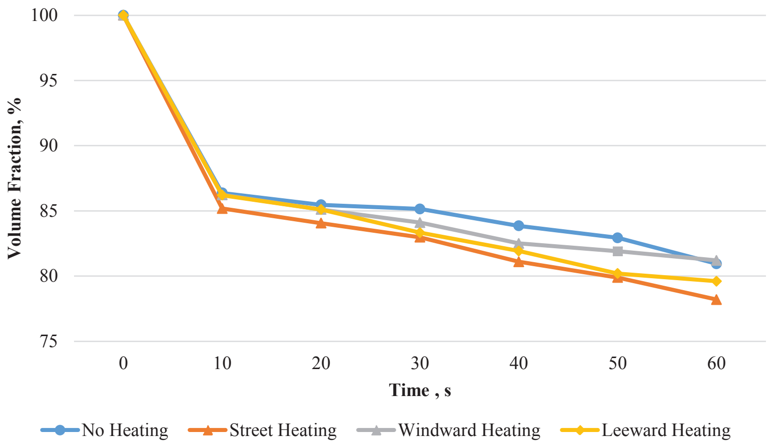


Figure 19. Volume fraction against time for thermal heating

The heated conditions creates a main vortex inside the street canyon with two small vortices in the corner while the non-heating condition only creates the main vortex in the middle of the street canyon. There was on particular difference for the windward heating, for base of a study done by Wang et al., (2011) the study produce two major vortices countering each other inside the street canyon. The present study only produce one major vortex inside the street canyon for the windward wall heating. This was due to several different boundary conditions, for example the wind speed and buoyancy forces setting and others that was not mentioned.

As the data in Table 8 shows, pollutant dispersion was at best when the street was heated with the volume fraction at 0.7820 followed by leeward wall heating with 0.7960, than no heating with 0.8094 and lastly the windward wall heating with 0.8120. The heating creates an unstable condition for the flow of air inside the street canyon causing the pollutant dispersion rate being less consistent which can be seen in Figure 19 where for the heating conditions the volume fraction of pollutant decreases non-uniformly compared to the non-heating condition that has a steady trend of pollutant dispersion rate.

The heating creates a disturbance in the street canyon causing the flow of air to be distorted that could be better or worse for pollutant dispersion rate depending on the heated façade from the position of the sun.

5.0 CONCLUSION

Pollutant inside an urban street canyon can be uncomfortable and harmful to the people within that area. One of the main pollutant inside a populated urban area is Carbon Monoxide produce by exhaust of internal combustion engine of vehicles, generators and many others. Pollutant dispersion inside an urban street canyon is important for the health and comfort of the people of that area. This present study shows that building geometry affects the pollutant dispersion rate of the street canyon that it forms.

By using numerical study through ANSYS Fluent, the study could simulate the flow of air within the street canyon that helps the pollutant disperse. The findings of this study indicates that a street canyon with a building with a height length greater than the street length tend to disperse the pollutant that is trapped at a much slower rate. Where from Case A the pollutant at the 60^{th} second for ratio 2:1 has more volume fraction that is 0.876 compared to the street canyon with lesser height that has volume fraction of 0.809 and 0.843 for 1:1 and 3:2 respectively. The entrainment of the pollutant with the wind is greater with street canyon that has taller buildings, it escapes the street canyon gradually at a slower rate.

From this study it can also be concluded that a street canyon with wider street have better enhancement in pollutant removal rate. With the volume fraction of the pollutant being 0.765 for the model that has the widest street, it was verified that it has better pollutant removal rate compared to the other two models with 0.809 and 0.802. The result are inline to the statement by (Shui et al., 2009), the wider street enhances both ventilation rate and pollutant removal rate. The small aspect ratio improves the free-stream air entrainment down to ground level together with mild pollutant re-entrainment on the windward side of the street canyon.

In summary, the current study unveils that wind speed plays a role is pollutant dispersion rate but due to its nature we can’t control the wind to help enhance the dispersion of pollutant inside the street canyon. Heating of different parts of the street canyon can help improve the dispersion rate of pollutant depending on the position of the sun. With different wind speeds and various concentration of pollutant, it may take some time for the pollutant to be completely disperse from the street canyon. But with proper city planning, building cities with wider street can help improve significantly the pollutant dispersion rate that can ensure the health and comfort of the people within the street canyon.

6.0 RECOMMENDATION FOR FUTURE WORKS

There are several recommendations that have been identified throughout this study, which may direct future studies. The parameter of the building height to street width ratio should increase with more various geometry to get a better grasp on the pollutant dispersion inside an urban street canyon. The building could be in different heights for the windward and the leeward of the building. The building model of the simulation should be more complex instead of simplify two dimensional model. Another recommendation is to add more parameters such as varying the temperature for a hot day or a cool day and other boundary conditions around the street canyon to produce a more detail analysis.

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