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Investigations on Effect of Different Strategies for Air Pollution Treatment with Plants as Air Filter: A CFD Analysis

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Abstract

The objective of the present research work is to investigate the effect of implementing various types of plant panels on air quality characteristics, such as the removal of particulate matter (PM10) particles, using CFD simulation. This study finds the inclusion of three different types of plant filter panels, such as blocking, parallel, and zigzag forms. CFD simulation was performed using ANSYS Fluent, considering steady state conditions within a range of 0.5-2.0 m/s for air inlet velocities. It was found that the zigzag arrangement of panels has resulted in highly turbulent and mixed flow, as compared to the parallel configuration, which resulted in smooth flow, and the blocking configuration has produced low-velocity zones of recirculation. Besides this, it was also revealed through CFD simulation that PM10 mass flow was lowest for zigzag, minimum for blocking panels, and intermediate mass flow of PM10 particles for parallel. In summary, it was gathered that zigzag panels yielded superior filtration, uniform air flow as compared to the other two configurations, especially in the velocity range of 1-1.5 m/s.

Keywords

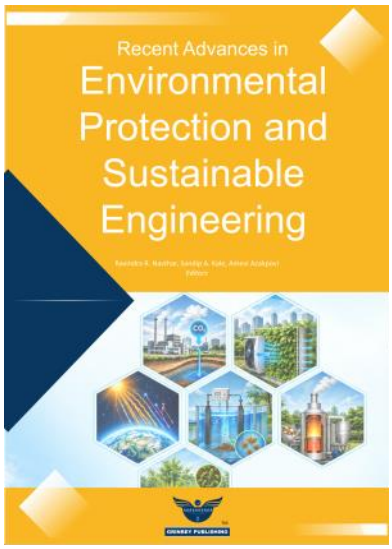
Computational Fluid Dynamics; Plant-Based Air Filtration; Particulate Matter (PM_{10}) Removal; Sustainable Air Purification; blocking; zigzag; parallel.

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1. Introduction

Environmental degradation is increasing rapidly, especially through air pollution. Air pollution occurs due to both natural sources and human activities, degrading the quality of air both within and outside buildings [1]. In this context, it was observed that major sources of air pollution include exhaust from vehicles and industries, the use of fossil fuels, and heavy construction and mining activities [2]. Again, it was gathered that major air pollutants were seen as particulate matter, carbon monoxide, carbon dioxide, and nitrogen oxides. Ozone and Volatile Organic Compounds, which degrade the quality of air [3,4,5]. It was observed that within buildings, burning of wood and coal, usage of construction materials, and dreadful human activities degrade the environment in terms of air pollution [6,7,8]. In the scenario of indoor air pollution, both Li and Hutzel [6] and Yu et al. [7] gathered that improper and a lack of ventilation is another major cause of indoor air pollution. On the other hand, it was gathered by Wang et al. [8] that the implantation of air filtration systems reduced the level of indoor air pollution.

It was gathered that the plantation of plants and trees within the ecosystem and promotion of green infrastructure for the removal of elements causing air pollution [9,10,11,12]. In this context of removal of air pollutants, Tran et al. [9] worked on the effectiveness of planting trees in the urban environment, which helps in reducing pollutants from the air. On the contrary, Cai et al. [12] utilized the technique of CFD analysis for the investigation of air purification based on vegetation. In addition to this, it was also found that plant-based biofilters can capture the particulate matter, which is dependent upon the velocity of air [13,14]. In another investigation, it was also found that optimizing the flow of air within the plant chambers can be achieved by proper placement of a fan, which in turn resulted in uniformity of air and photosynthesis [15]. Again, in this scenario, it was gathered that the Azolla-based biofilter system emerged as a sustainable solution for the removal of pollutants residing within buildings for low-carbon generation [16]. It was gathered that through all these investigations proved that by optimizing the flow of air, density of vegetation, and through proper selection of correct species of plant filters, the effectiveness of filtration and the proper reduction of pollutants.

It was also gathered that for the reduction of air pollution, vegetation in the urban environment has played a major role. Researchers in the past observed that particulate matter levels can be reduced through the implementation of large green spaces such as Tehran's Pardisan Park via dispersion [11]. Besides, it was also found that the shape of trees helps in the spreading of pollutants [10]. Some other researchers found that arrangements of vegetation in clustered manner with optimized green coverage helps in reduction of both carbon monoxide and as well as that of particulate matter [9,12]. In addition to the above investigations, additional efforts by researchers found that this system of plant filter systems has proven to be an economical and sustainable approach for the reduction of PM levels [17,18].

Besides CFD modelling and simulation approaches, artificial intelligence driven has revolutionized the prediction of air quality purification and pollutants removal rate. In this context, it was found by researchers that the employment of AI-based prediction models (CFD-CNN-GRU frameworks) proved to be highly effective in capturing the amount of PM 2.5 particles and can also help in optimizing the performance of plant-based filtration systems. Besides the integration of CFD and AI-based approaches, digital twin found to be highly effective in continuous and real monitoring of plant-based filtration systems [2,3,5,19]. Besides this, it was gathered that solar-powered cleaning systems help in reducing $PM_{2.5}$ and CO_2. It was also found that within the scenario of industrial and waste treatment for pollutants dispersion for industrial scenarios, it can be predicted effortlessly via CFD simulation [5].

It was gathered from the above literature review that there are three major factors, namely vegetation-based filtration, CFD-driven optimization, and data-driven modelling, which majorly control the quality of air in a sustainable form. Therefore, in the present study, three major configurations of plant filters, namely blocking, zigzag, and parallel, were derived to assess the effectiveness of air quality and pollutant removal using CFD simulation in ANSYS Fluent 21 [14]. The output of the CFD simulation was expressed in the form of four different field variables, such as air velocities, PM 10 particle velocity, temperature, and particle trajectories. This study aims to find the most efficient configuration for maximizing pollutant removal and promoting the development of sustainable, plant-based air purification systems for both indoor and urban environments.

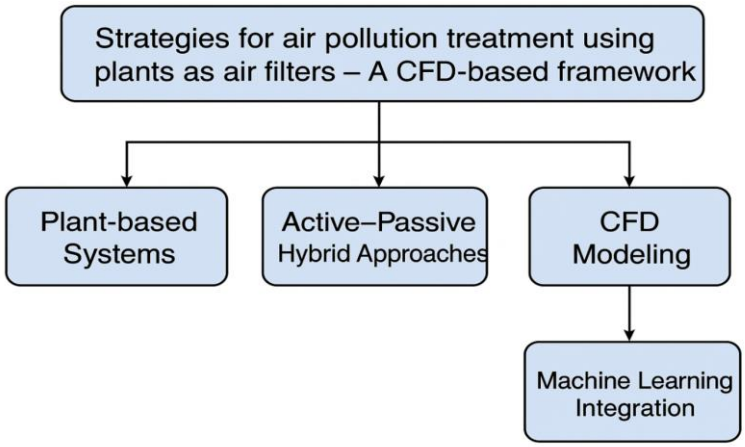


Fig. 1. Various strategies for air pollution treatment using plants as air filters based on CFD based framework

2. Materials and methods

The following section gives the materials and methods for the present work.

2.1 Geometrical modelling and Preprocessing

In the present work for the purpose of CFD analysis, the first step is to create a geometric model of the plant-based filtration which is rectangular form having dimensions of 100 × 80 × 30 cm along with two openings of 10 × 10 cm size at inlet and outlet of the rectangular chamber. Different CAD models were prepared for blocking, parallel and zigzag patterns so as to assess the effect of inlet air velocity on the average air velocity at inside and outlet and as well as on the PM_{10} particles removal due to such type of arrangements. Figures 2 to 4 show the CAD representations for each configuration. Figure 5 presents the overall methodology used for this CFD study.

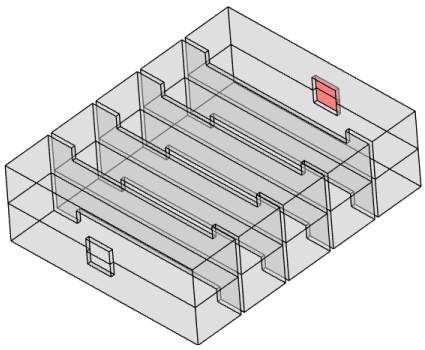


Fig. 2. Air-filtration-Plants-Blocking panels

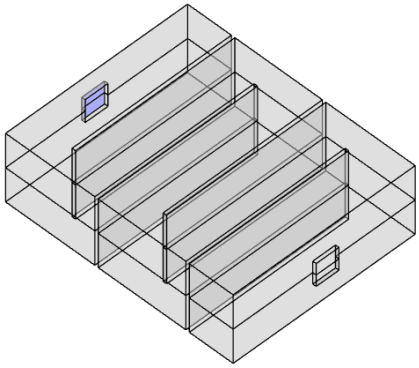


Fig. 3. Air-filtration-Plants-zigzag-panels

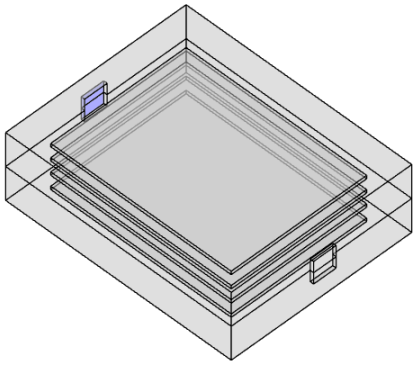


Fig. 4. Air-filtration-Plants-parallel panels

2.2. Mesh Generation

After preparation of CAD models, the next step within CFD analysis is to generate meshing of the prepared model. In the present analysis, model is mesh using unstructured tetrahedral grid of element grid size of 2.5 mm was considered, which was capable of replicating the complex behaviour of plant panels. Skewness and orthogonal quality were checked for ensuring the quality of mesh for achieving convergence condition as well as mesh independence tests was also performed to before fixing the mesh size. Meshed models of rectangular chamber are shown in Figures 6, 7, and 8 for blocking, zigzag, and parallel panel configurations, respectively.

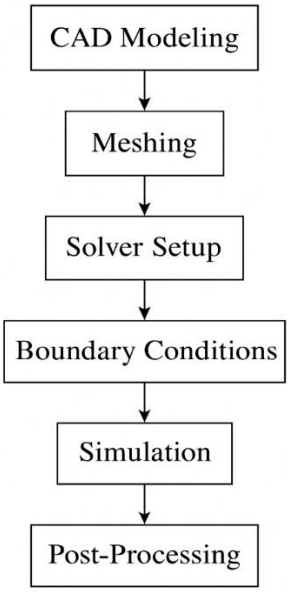


Fig. 5. Methodology adopted during the CFD analysis of air filtration with plants as filter

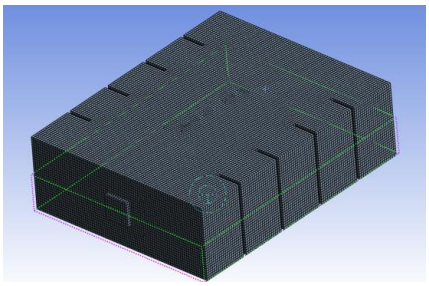


Fig. 6. Mesh model of air-filtration-plants-blocking panels

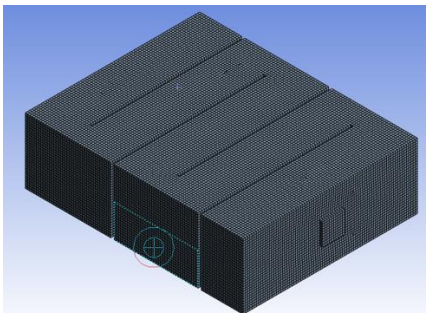


Fig. 7. Meshed model of air-filtration-plants-zigzag-panels

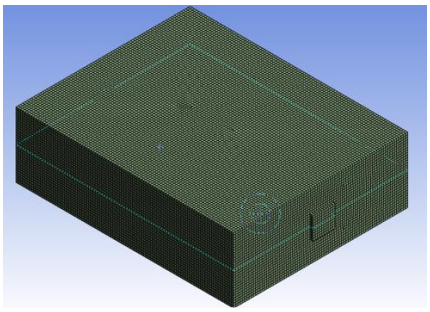


Fig. 8. Meshed model of Air-filtration-Plants-parallel panels-mesh

2.3. Physical and Numerical Modelling

After preparing the numerical model for CFD analysis, The CFD simulation was conducted in ANSYS FLUENT 21 by assuming incompressible flow and by considering pressure-based solver for steady state flow. In addition to this, the process of filtration via plant-based filter panel of PM_{10} particles was enabled through modelling of air as major continuous phase within the multiphase Eulerian framework. During the CFD simulation k–ε model was utilized for simulation of airflow in turbulent mode. Table 2 shows the pretties of air used in modelling of air for CFD analysis. In order to consider the effect of temperature, energy equations were also included.

Table 1. Properties of air for CFD simulation

Sr.	Properties of air	Magnitude/value
1.	Density	1.225 kg/m³
2.	Dynamic Viscosity	1.7894×10^{-5} kg/m·s,
3.	Thermal Conductivity	0.0242 W/m·K
4.	AQI	90
5.	Initial PM_{10} concentration	80 µg/m³

2.4. Boundary Conditions

In the present analysis through CFD simulation of different configuration of plant(panel) based filtration system four different initial velocities of 0.5,.01,.5, and 2.0 m/s were employed to study its effect upon on output field variables. During the all cases of CFD simulation, atmospheric conditions i.e. 298.15 K (25°C) pressure at 101325 Pa were considered at outlet as inlet temperature and initial pressure respectively. Besides this, diameter of hydraulic opening was taken as 0.1m at both inlet and outlet with an intensity of turbulence of 5% was applied. Besides this a gauge pressure of 0 Pa was imposed at outlet for ensuring discharge of air in smooth form. Table 2 gives the different boundary conditions used in all cases of CFD analysis, which shows that AQI, inlet conditions, initial velocity of air, PM_{10} particles concentrations for all three different configurations.

Table 2. Boundary conditions used in CFD analysis

Sr	Plant Configuration	AQI	PM_{10} ($\mu g/m^3$)	PM_{10} (kg/m^3)	Inlet Velocity (m/s)	Inlet Temperature (K)
1.	Blocking Panels	90	80	8×10^{-8}	0.5, 1.0, 1.5, 2.0	298.15
2.	Zigzag Panels	90	80	8×10^{-8}	0.5, 1.0, 1.5, 2.0	298.15
3.	Parallel Panels	90	80	8×10^{-8}	0.5, 1.0, 1.5, 2.0	298.15

2.5. Numerical Solution and Post-Processing Analysis

In the present analysis the governing partial differential equations for mass, momentum, energy, and turbulence were based on Finite element Volume scheme in conjunction with pressure-velocity coupling based on SIMPLE algorithm. The discretization schemes utilized are as follows: body-force weighted for pressure, second-order upwind for momentum and energy, and first-order upwind for turbulent kinetic energy (k) and dissipation rate (ε). Hybrid initialization was implemented, and simulations were conducted for up to 1000 iterations or until residuals decreased below 10^{-6}, thereby confirming convergence. After CFD simulation the ANSYS Fluent gives the field variables in terms of the contour plots of air velocity, velocity of PM_{10} particles and velocity vector trajectories with the domain of filtration plant for all three configurations.

3. RESULTS & DISCUSSION

3.1 Air velocity distribution for different strategies/models for air pollution treatment

Figure 9-20 shows the effect of inlet air velocity upon the velocity of air as field output variable for different configurations of plant-based filtration systems such as blocking, parallel and zigzag. It was gathered that the output field variable i.e., dependent upon input variables such as inlet velocity of air, types of panels and geometry of the air plantation chamber. All these parameters assess the strength of recirculation of air, dispersion of air across the chamber for uniformity and contact of air and surface for filtration purpose.

Contour plots of velocity of the blocking panels configuration were depicted in figures 9-12, which shows the variation of intensities across the chamber for four different inlet velocities of air. It was clear from the contour plots (figures 9-12) that greatest velocity of air appeared near inlet and outlet of the chamber, which was attributed to pressure difference. In addition to this, it was also gathered that minimum velocity of air was seen in the central zones of chamber which in turn produced recirculation of air before the blocking panels and further this has yielded in increment in greater residence time and better air to surface interaction for filtration purpose. Besides it was also realized that increment in inlet velocity of air from 0.68 m/s to 2.77 m/s resulted in more pronounced uniform distribution of air due to intensified air flow, but it still there is some zones of stagnations that were situated behind the blocking panels having low velocities. It was clear that blocking panels significantly resisted the air flow and lowered the filtration effect due to non-uniformity of air flow.

On the contrary, figures 13-16 shows the contour plots of velocity throughout the rectangular chamber for parallel configurations of plant-based filtration systems. It was clear from these figures that for parallel arrangement the air flow majorly through the central route and replicating a streamlined patterns and offers resistance in moderate manner. It was also gathered for parallel configurations, that at lower inlet velocities in the range from 0.5m/s -1.0 m/s distribution of velocity remains nearly smooth but the interaction of air to surface is minimum near the sidewalls. It was cited that as the velocity of air increases beyond 1.0 m/s, it results in a significant filtration effect. Besides these, zones of stagnation with low velocities were also observed, which can be overcome by improvement in designs and, in turn, resulted in better filtration efficiency. In another case, the air filtration plant's zigzag configuration resulted in the highest dispersion of air, as shown in figures 17-20. In all cases, the zigzag configuration resulted in better filtration as compared to the other two cases, which can be attributed to higher air-to-surface interaction.

It was seen that at lower intensities of inlet air velocity (0.5-1.0 m/s), the air moved smoothly across the channel, but upon increment in inlet air velocity in the range of 1.5-2.0 m/s has resulted in zones of accelerated airflow near the bending zones and resulted in moderate recirculation of air behind these panels. Figure 20 shows the maximum speed of 2.79 m/s, demonstrating better mixing and momentum transmission, but it also displays a small amount of unevenness close to the panel boundaries. Based on these observations, it was found that zigzag configuration brought better redistribution and higher time of residence in comparison to blocking and parallel panels arrangement. Hence zigzag panels arrangement found to be most effective in uniformity of flow, enhanced mixing, and filtration effect as compared to parallel and blocking configurations.

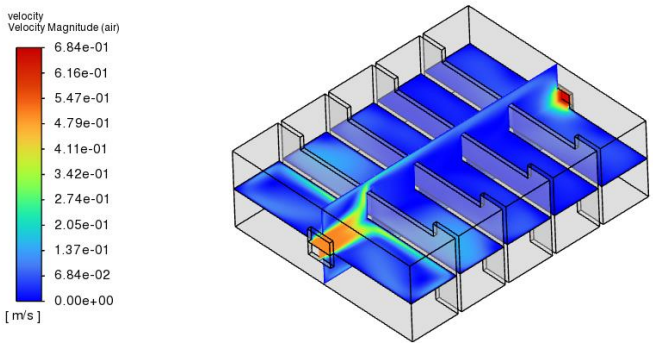


Fig. 9. Air-filtration-Plants-Blocking panels-v-0.5-velocity contour

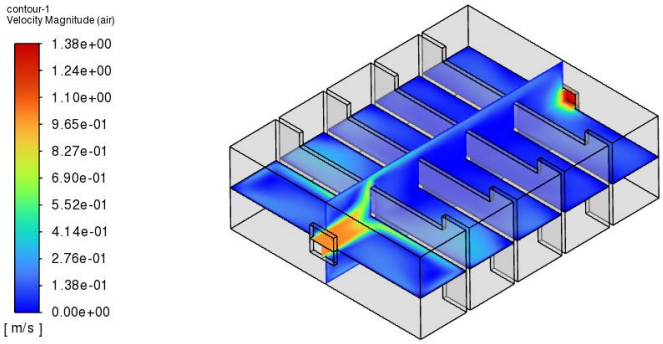


Fig. 10. Air-filtration-Plants-Blocking panels-v-1-velocity contour

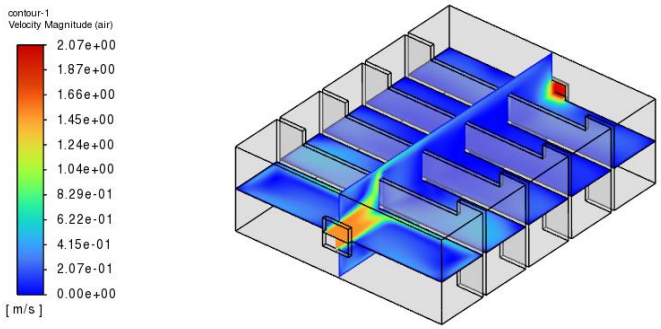


Fig. 11. Air-filtration-Plants-Blocking panels-v-1.5-velocity contour

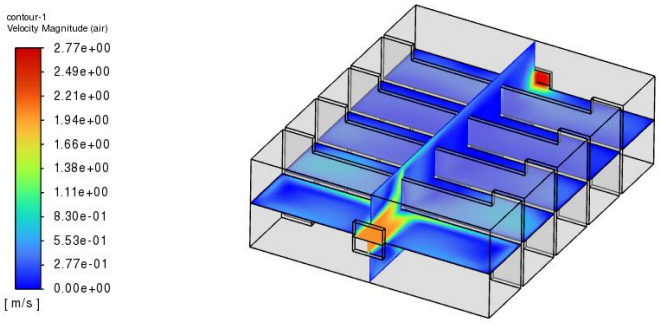


Fig. 12. Air-filtration-Plants-Blocking panels-v-2-velocity contour

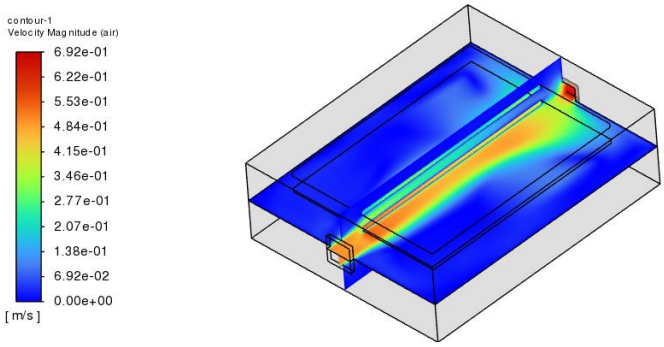


Fig. 13. Air-filtration-Plants-parallel panels-v-0.5-velocity contour

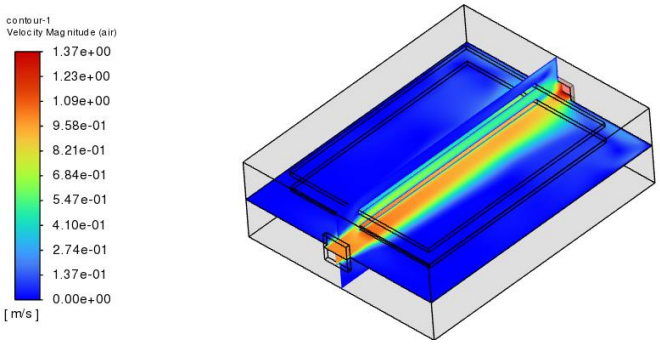


Fig. 14. Air-filtration-Plants-parallel panels-v-1-velocity contour

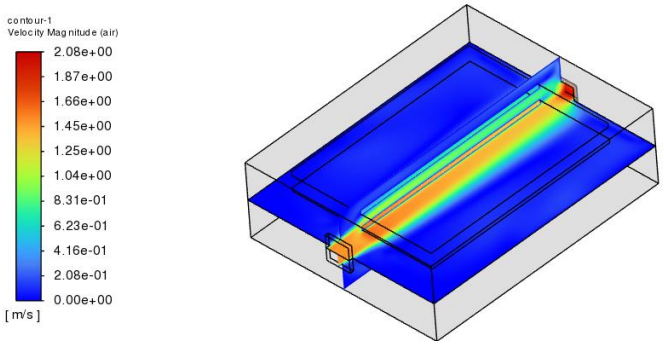


Fig. 15. Air-filtration-Plants-parallel panels-v-1.5-velocity contour

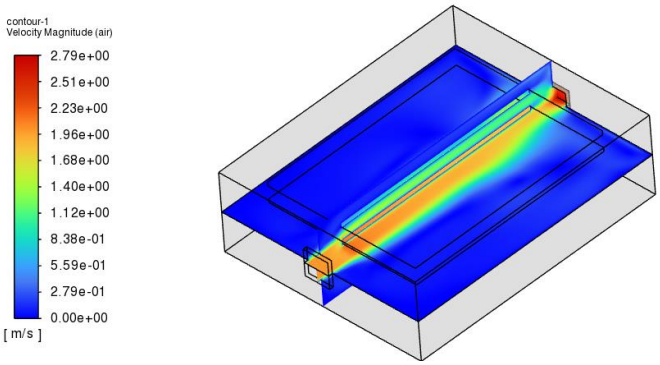


Fig. 16. Air-filtration-Plants-parallel panels-v-2.0-velocity contour

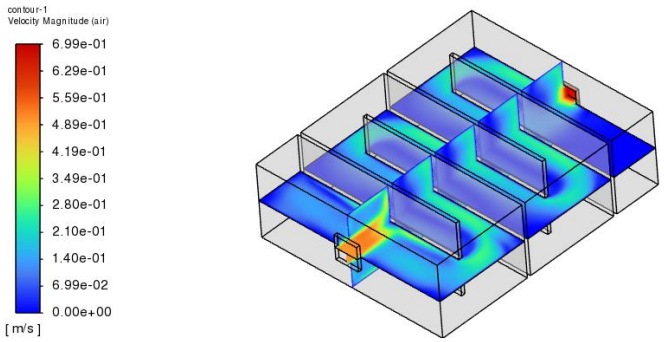


Fig. 17. Air-filteration-Plants-zigzag-panels-v-.5-velocity contour

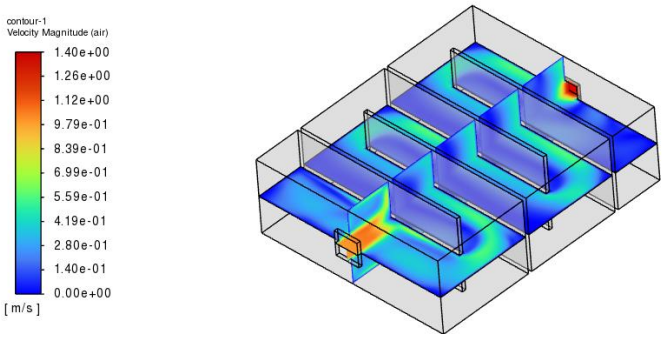


Fig. 18. Air-filteration-Plants-zigzag-panels-v-1-velocity contour

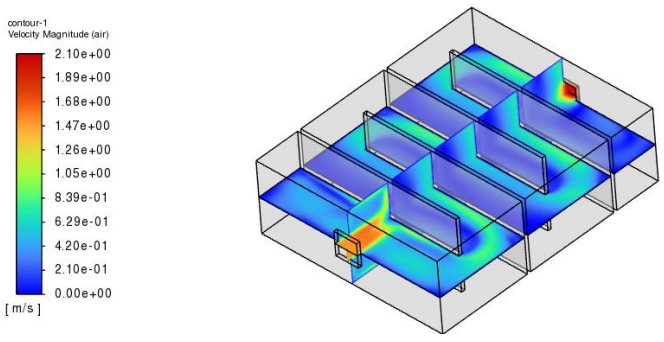


Fig. 19. Air-filteration-Plants-zigzag-panels-v-1.5-velocity contour

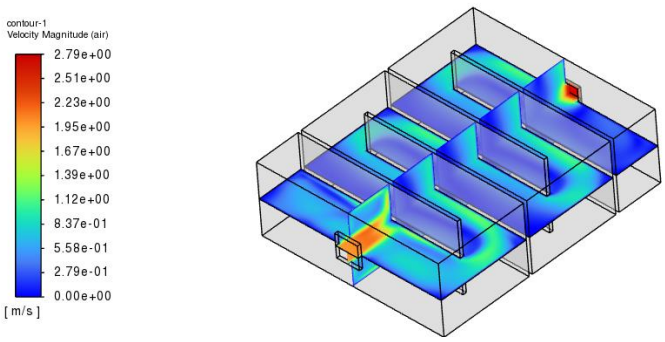


Fig. 20. Air-filteration-Plants-zigzag-panels-v-2-velocity contour

3.2 PM_{10} velocity distribution of different models for air pollution treatment

Figures 21 to 32 depicted the effect of inlet velocity (0.5 m/s to 2.0 m/s) on PM_{10} velocity distribution for all three configurations of air-filtration panels namely blocking, parallel and zigzag. Figure 21 to 24 shown the distribution of velocity for blocking panel configuration which ranges from 0-2.89 m/s. Figure 21 shows the contour plot of velocity distribution at inlet velocity of 0.5 m/s for blocking configuration which indicated that there is generation of stagnation behind the panels due to complete blockage of air which resulted in longer residence time with reduced overall uniformity of flow. It is also clear from figure 22 and 23 that upon increment of inlet velocity of air from 1.0 m/s to 1.5 m/s there is increment in turbulence and flow becomes continuous as compared to lower inlet velocities, but it still includes localized recirculation behind blocking configurations. In addition to this, figure 24 illustrated a strong jet-like flow and turbulence which resulted in more mixing during air flow and transportation of pollutants.

Although in this situation could raise pressure drop and stress on plant surfaces. Overall, the blocking structure offered a high potential for particle capture due to greater retention time, but i t sacrificed flow homogeneity and energy efficiency.

Figures 25 to 28 shows the velocity of PM_{10} particles for the parallel configurations which shown that airflow followed majorly central zone of the chamber in linear fashion. It was noticed that as the inlet velocity of air from 0.5 m/s to 2.0 m/s, maximum velocity increased from 0.67 to 2.59 m/s. It was gathered from figure 25 and figure 26 that at lower velocities, minimum turbulence with little interaction with plant surfaces was observed, which indicated flow was smooth and laminar. On the other hand, it can be seen from figure 27 and figure 28 which corresponds to inlet velocity of 1.5 m/s and 2. 0 m/s, upon increment of velocity has increased the turbulence and gradient of velocity which eventually resulted in more improved transport of particles and better interaction with the plants, but it includes zones of low velocities near the walls as well. In summary, the parallel structure produced the most uniform and energy-efficient airflow, but with lesser mixing and particle capture due to the shorter residence period.

Figures 29 to 32 shows the contour plots of air velocity which shows the flow in zigzag manner created turbulence and better particle dispersion due to change in direction in readily form. Figure 29 shows the distribution of air velocity; flow remains slow and in recirculated manner which created improved time of residence and deposition of particulate. Figure 30 and 31 shows the contour plots for 1 m/s and 1.5 m/s the air flow becomes distributed in uniform form with balanced turbulence. Figure 31 shows more pronounced mixing with ample amount of PM_{10} capture. It was found from figure 32 that for velocity of 2.0 m/s, resulted in greatest velocity of 3.27 m/s which in turn resulted in enhanced dispersion with decreased time of residence with some higher loss of pressure.

In nutshell panels in blocking configuration increased deposition of particles via stagnation with low homogeneity of air flow. The parallel arrangement provides smoother and more energy-efficient flow with little contact. The zigzag shape achieves the optimal balance of mixing, turbulence, and residence time. As a result, for vegetation-based air-filter systems, a zigzag design with moderate inflow velocities of 1.0 to 1.5 m/s provides the optimal mix of filtration efficiency, air distribution, and energy performance.

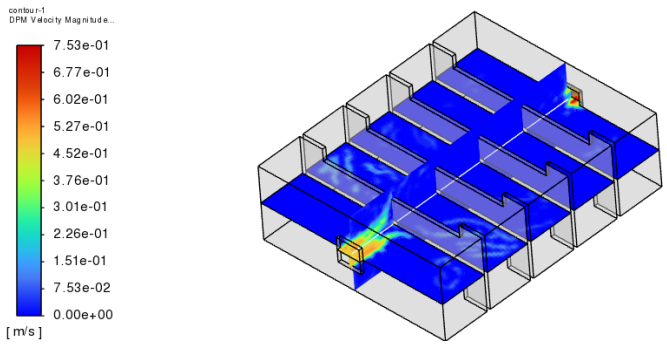


Fig. 21. Air-filtration-Plants-Blocking panels-v-0.5-pm10-velocity contour

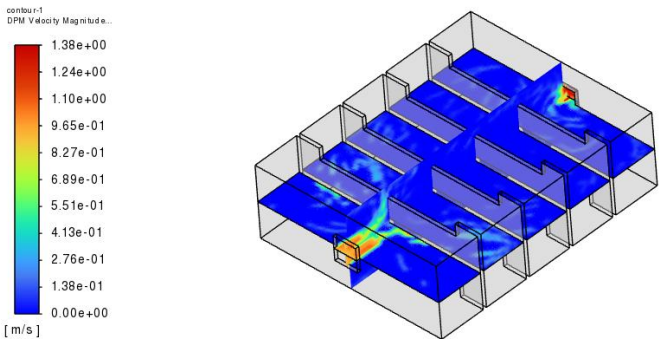


Fig. 22. Air-filtration-Plants-Blocking panels-v-1-pm10-velocity contour

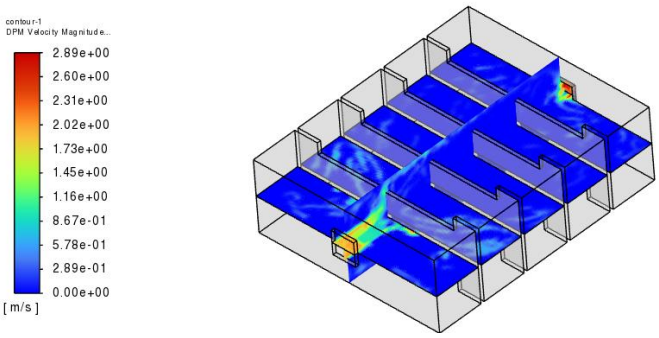


Fig. 23. Air-filtration-Plants-Blocking panels-v-1.5-pm10-velocity contour

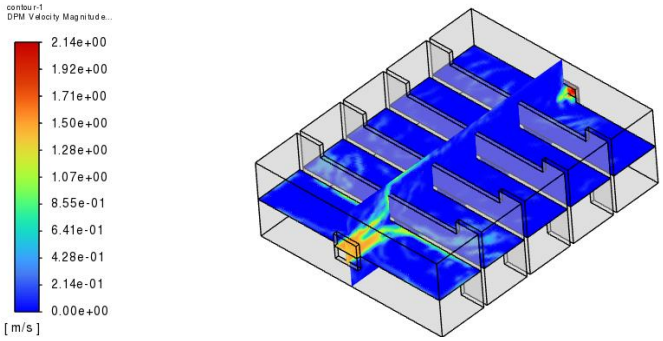


Fig. 24. Air-filtration-Plants-Blocking panels-v-2-pm10-velocity contour

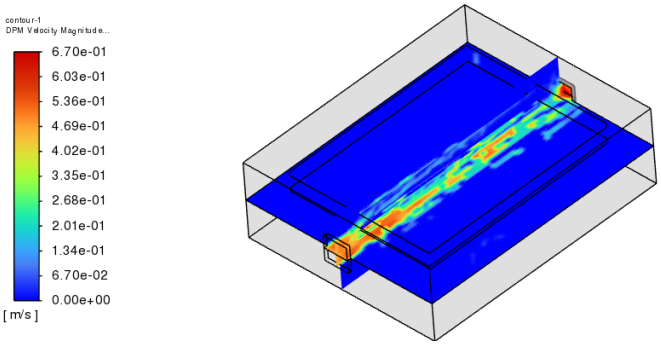


Fig. 25. Air-filtration-Plants-parallel panels-v-0.5-pm10-velocity contour

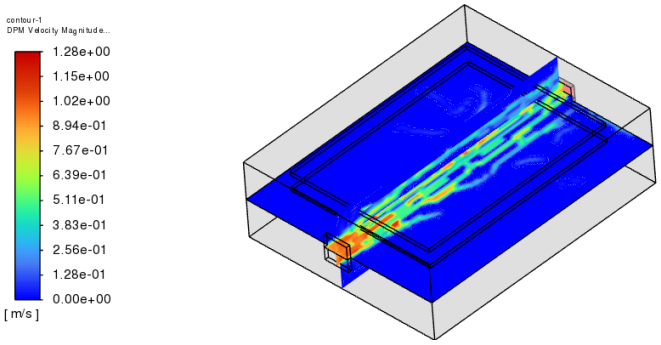


Fig. 26. Air-filtration-Plants-parallel panels-v-1-pm10-velocity contour

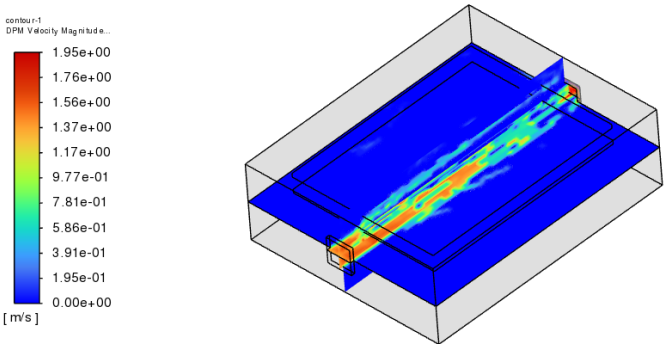


Fig. 27. Air-filtration-Plants-parallel panels-v-1.5-pm10-velocity contour

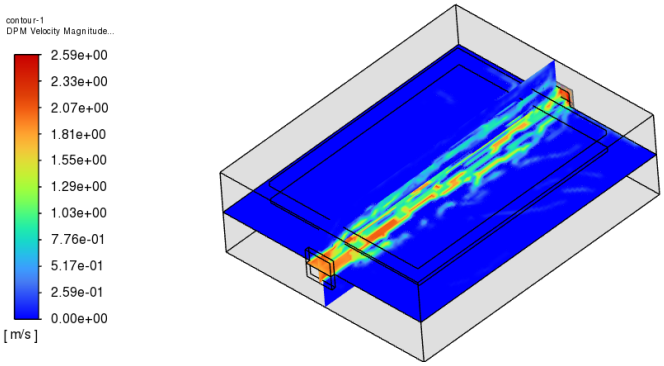


Fig. 28. Air-filtration-Plants-parallel panels-v-2-pm10-velocity contour

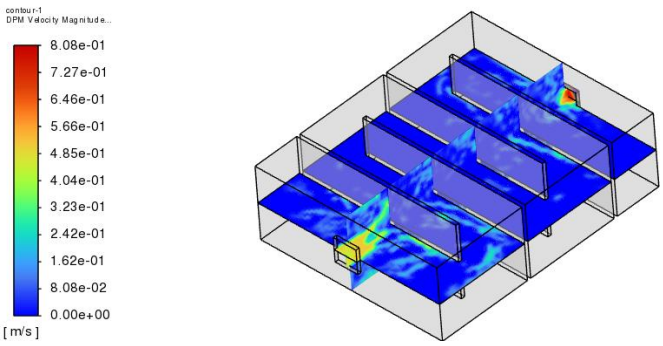


Fig. 29. Air-filteration-Plants-zigzag-panels-v-.5-pm10-velocity contour

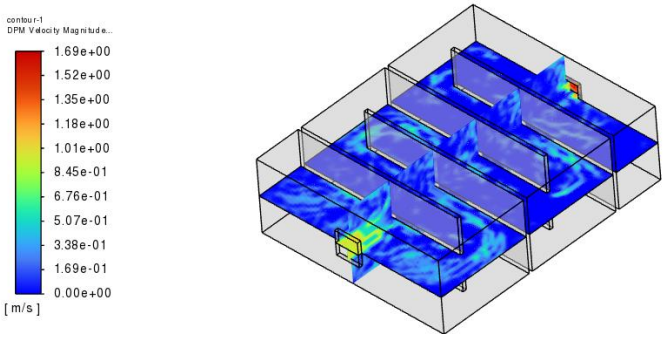


Fig. 30. Air-filteration-Plants-zigzag-panels-v-1-pm10-velocity contour

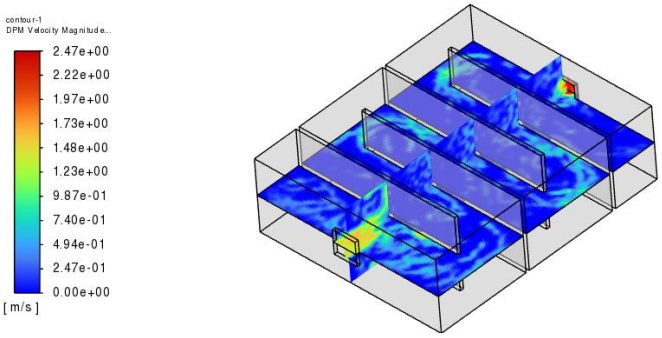


Fig. 31. Air-filteration-Plants-zigzag-panels-v-1.5-pm10-velocity contour

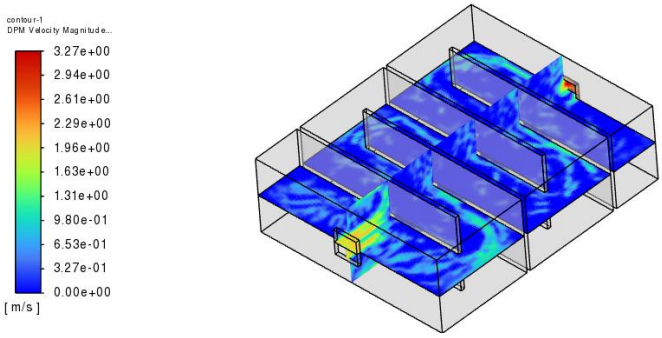


Fig. 32. Air-filteration-Plants-zigzag-panels-v-2-pm10-velocity contour

3.3 Effect of air velocity on field variables for different models

Figures 33 to 41 show the airflow and particle behavior in plant-based filtration systems with different plant arrangements, including blocking, zigzag, and parallel to airflow, at varying inlet velocities (0.5–2.0 m/s). An increment in average air velocity with inlet velocity, which was seen from Figures 33-37, ensured stability in aerodynamic response. It was observed that for the zigzag case, peak velocities are obtained at all planes, which resulted in the best mixing and lowest stagnation zones, which can be attributed to zigzag paths. On the other hand, moderate configuration and moderate velocity with less turbulence and a blocking configuration experienced the greatest resistance and the lowest velocity of air. In a summarized manner, it was gathered that the zigzag configuration is the best out of all three cases due to the best air circulation velocity and maximum filtration.

Figures 38-39 show the PM_{10} mass flow rate for all three configurations. It was gathered that the PM10 mass flow rate at the outlet is lowest for zigzag due to the highest turbulence, intermediate for parallel, and maximum for the blocking configuration. On the other hand, figures 40-41 show that the inside air temperature increases with increments in air inlet velocity. Slightly higher air temperature was recorded for the zigzag configuration as compared to the other two cases, which can be attributed to better mixing of air via convection, higher turbulence, and superior filtration effect.

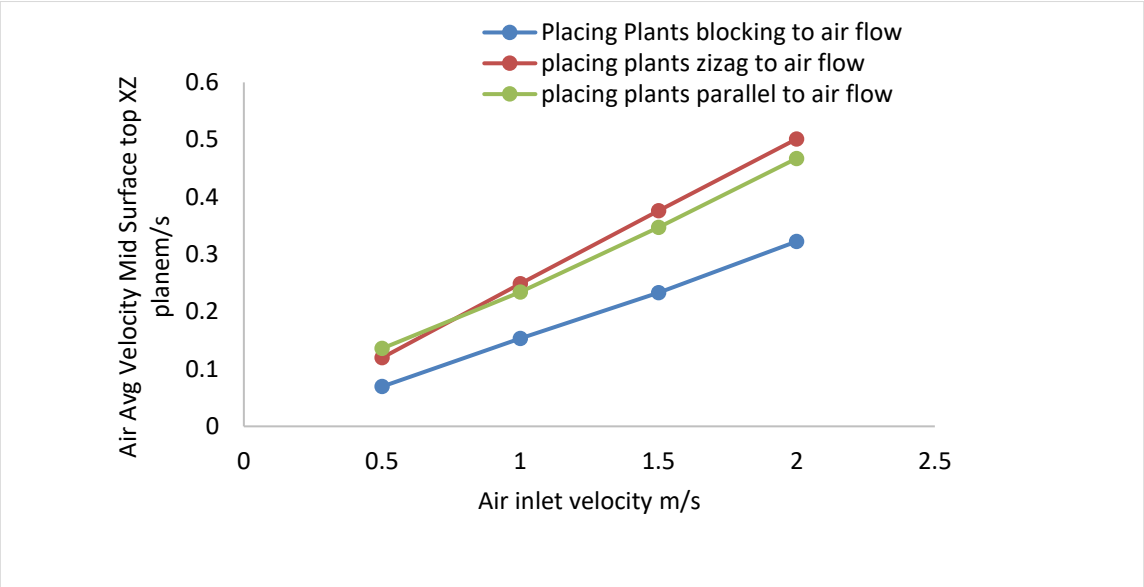


Fig. 33. Air Average velocity at Mid Surface Top (XZ plane) Vs Air Inlet Velocity

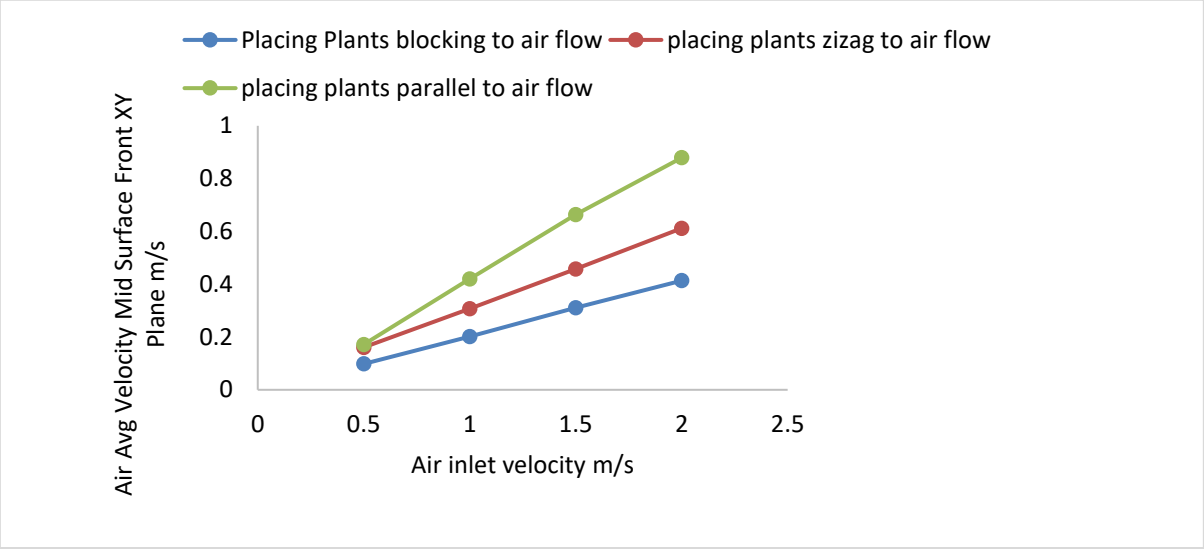


Fig. 34. Air Average velocity at Mid Surface flow Front (XY Plane) Vs Air Inlet Velocity

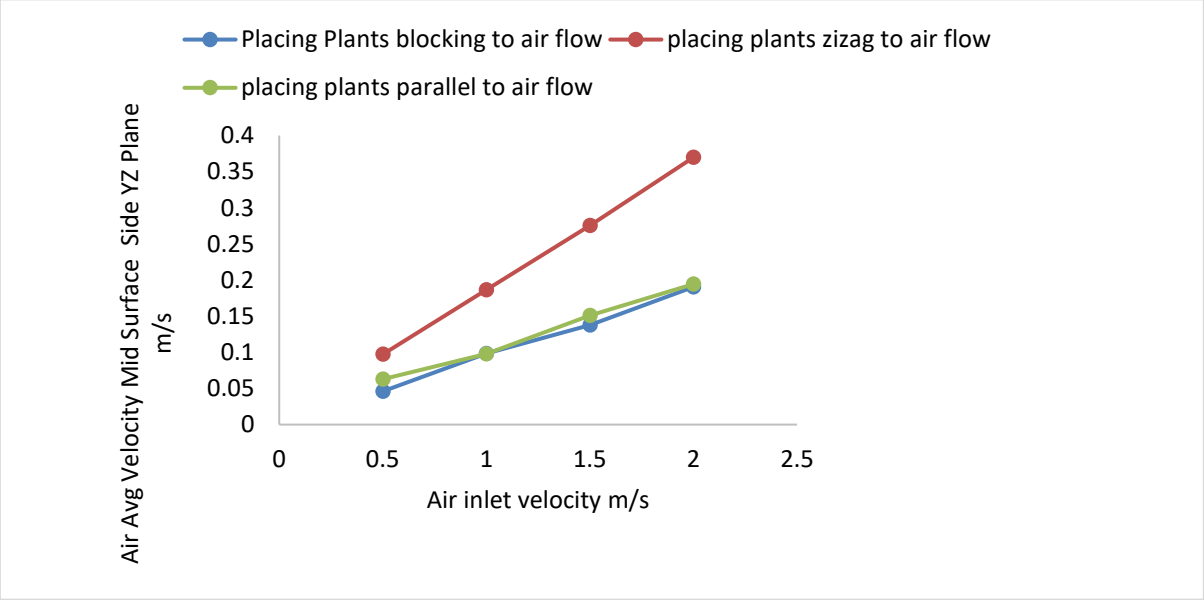


Fig. 35. Air Average velocity at Mid Surface Side (YZ plane) Vs Air Inlet Velocity

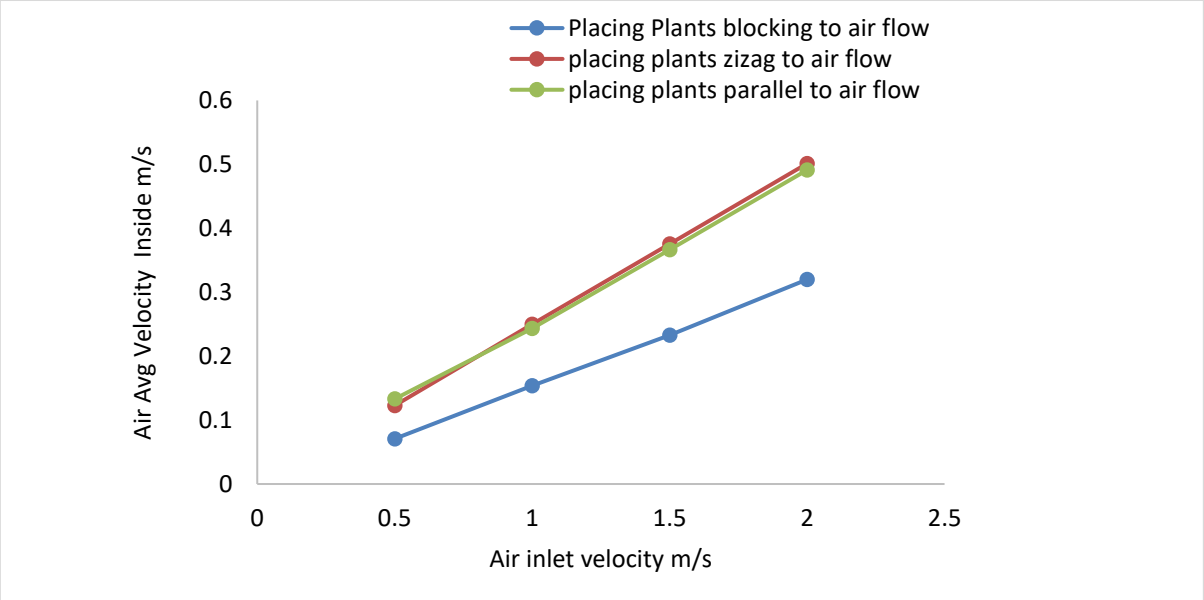


Fig. 36. Air Average velocity inside Vs Air Inlet Velocity

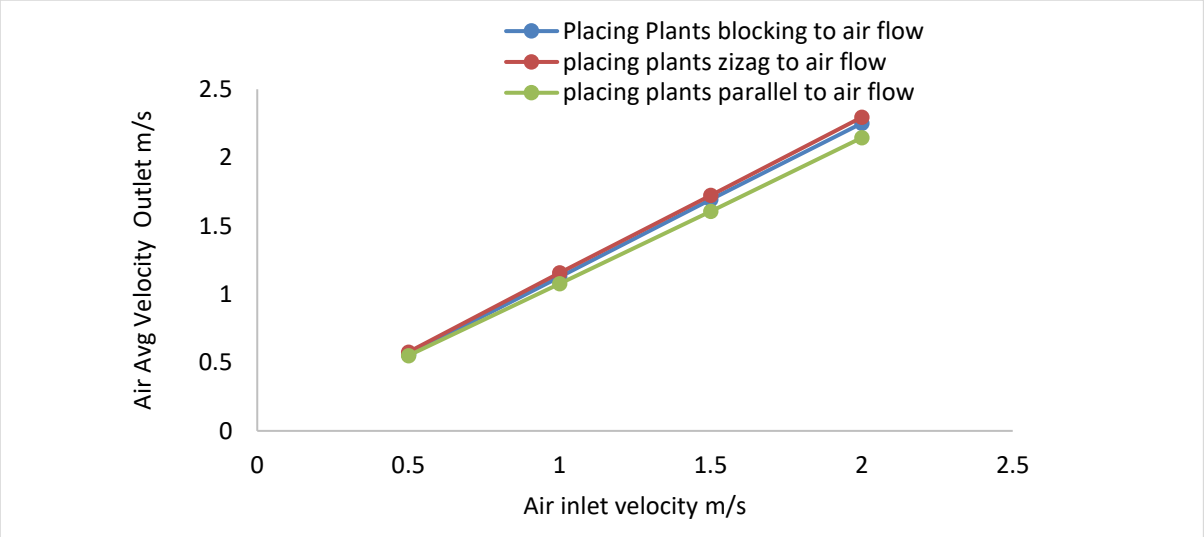


Fig. 37. Air Average velocity outlet Vs Air Inlet Velocity

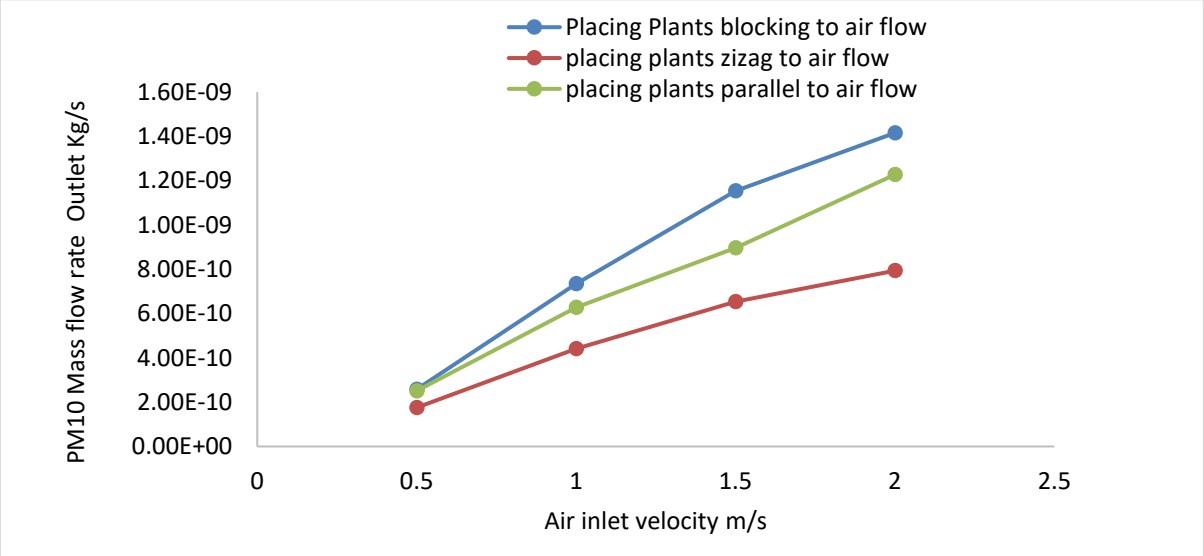


Fig. 38. PM 10 Mass flow Rate kg/s at outlet Vs Air Inlet Velocity

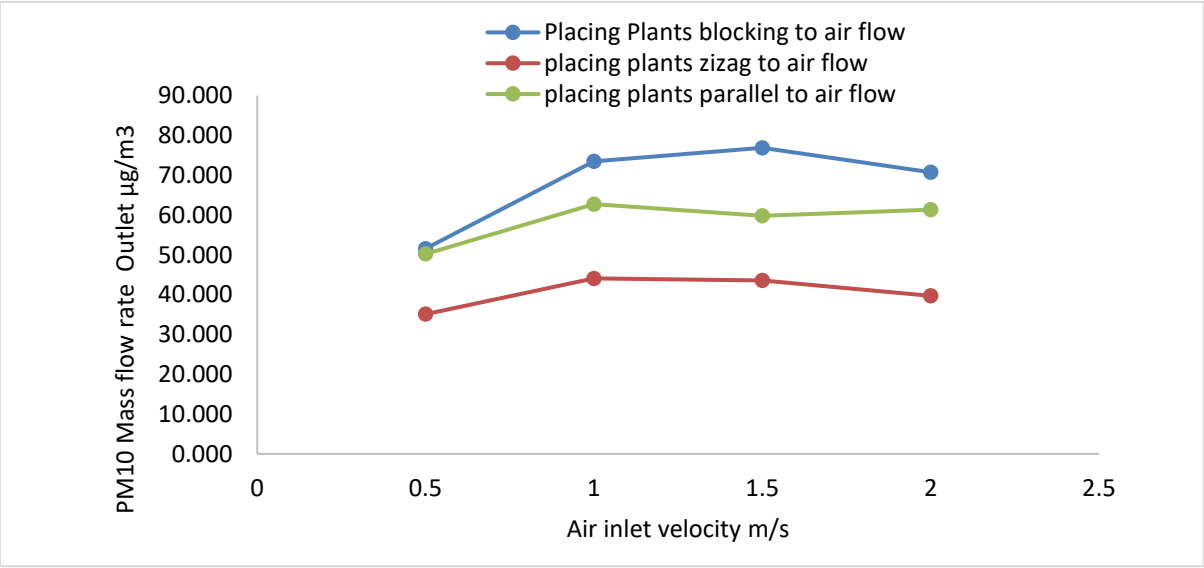


Fig. 39. PM 10 Mass flow Rate µg/m3 at outlet Vs Air Inlet Velocity

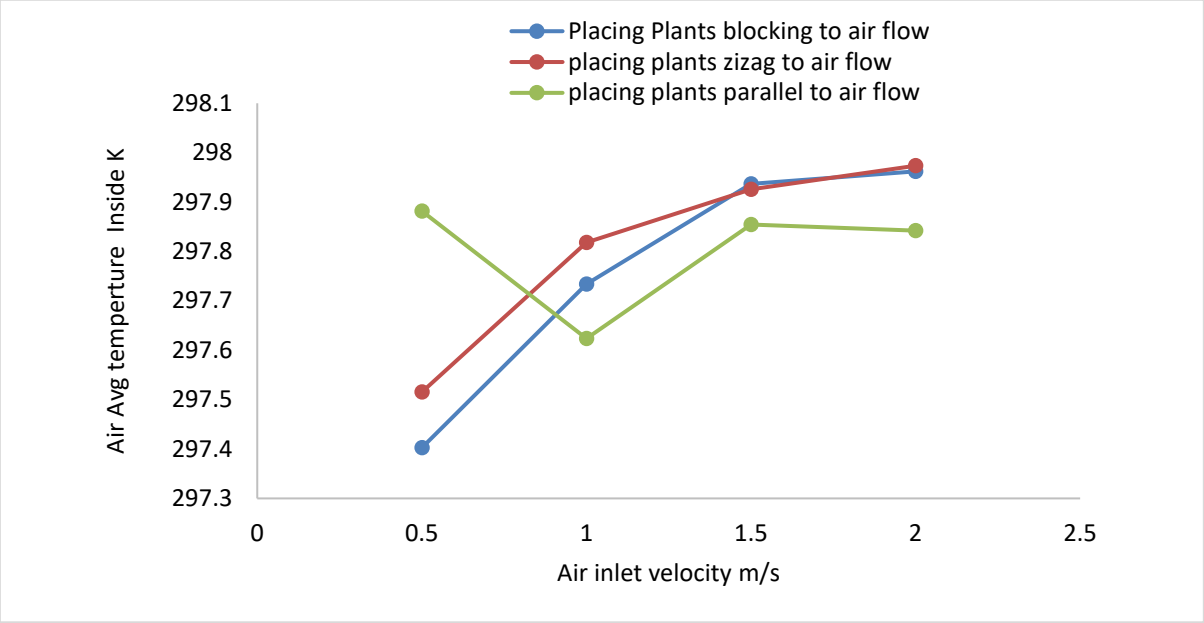


Fig. 40. Air Average Temperature inside Vs Air Inlet Velocity

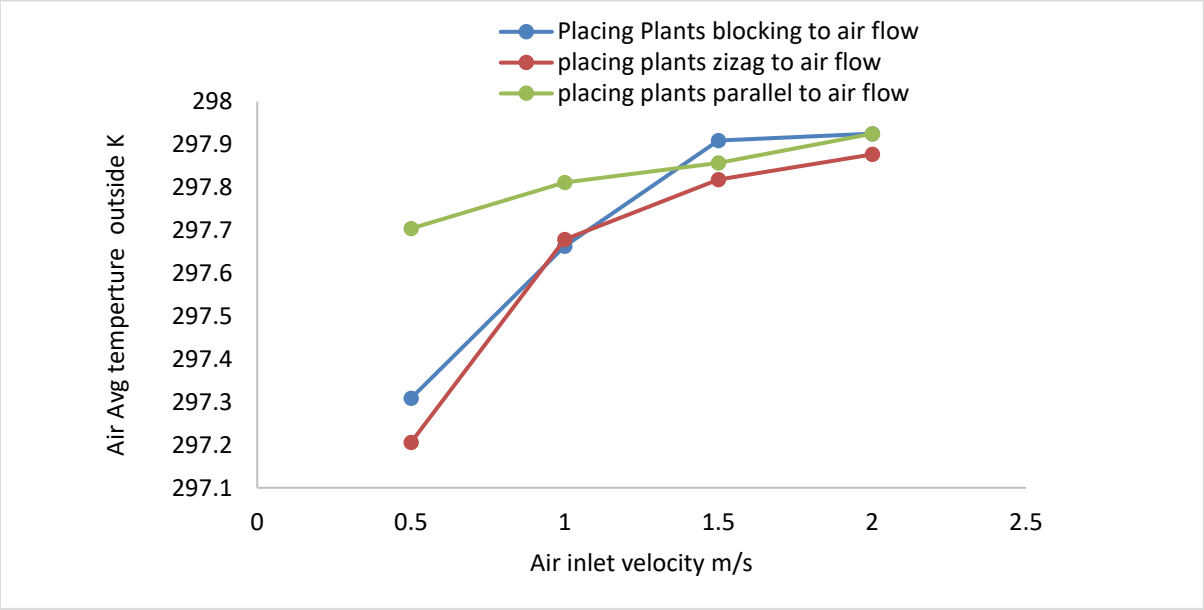


Fig. 41. Air Average Temperature Outlet Vs Air Inlet Velocity

3.4 Distribution of Velocity vectors of different models

Figures 42 ,43 and 44 show the velocity vector contours for three types of plant-based air filtration setups: blocking, parallel, and zigzag panels. In the blocking panel setup (Figure 42), the airflow faces strong resistance when it hits the front plant surfaces. In case of blocking configuration, due to arrangement of panels air gets blocked and zones of stagnation were visualized along with recirculation and resulted in poor air filtration least of all cases. It was seen from figure 43 that for parallel configuration, better air flow was obtained with high velocity in the center and lower velocity at zones near plant surfaces which resulted in better filtration effect than blocking. On the contrary figure 44 shows the zigzag configuration in which most filtration effect is obtained as compared to all cases which can be attributed to presence of alternate zones of high and low velocities with better turbulence for achievement of air filtration.

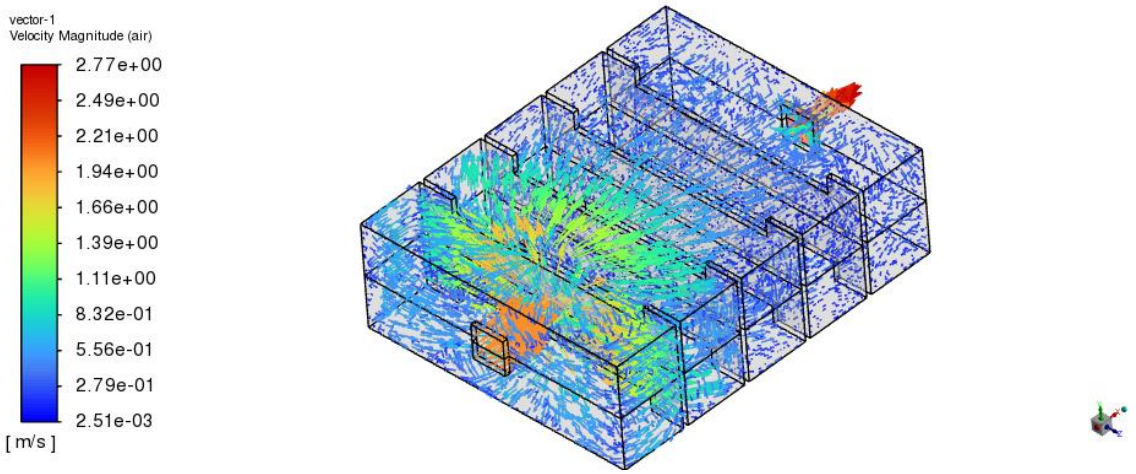


Fig. 42. Air-filtration-Plants-Blocking panels-v-2-vel-vector-velocity contour

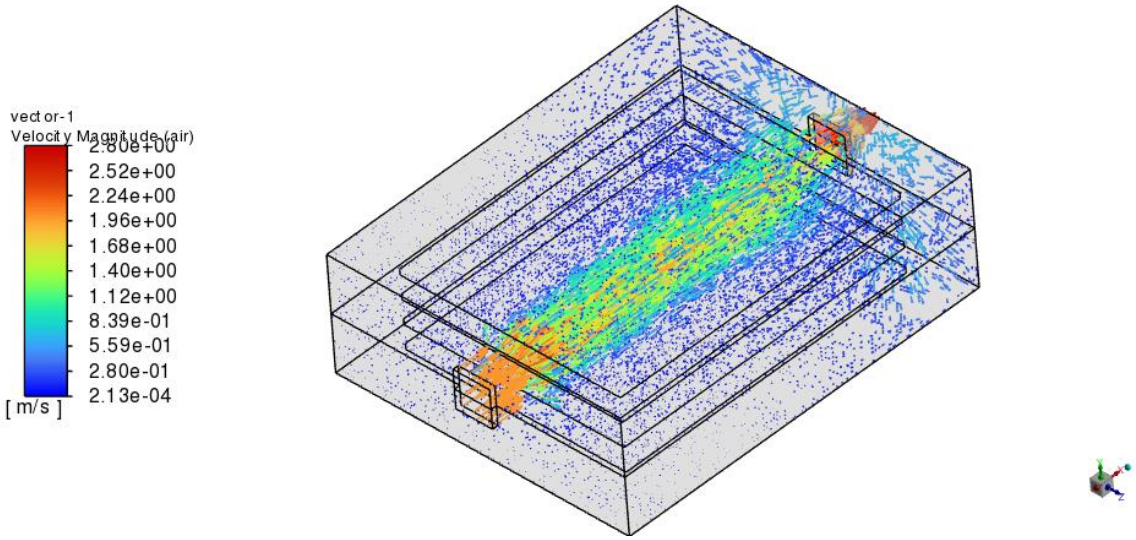


Fig. 43. Air-filtration-Plants-parallel panels-v-2-vel-vector-velocity contour

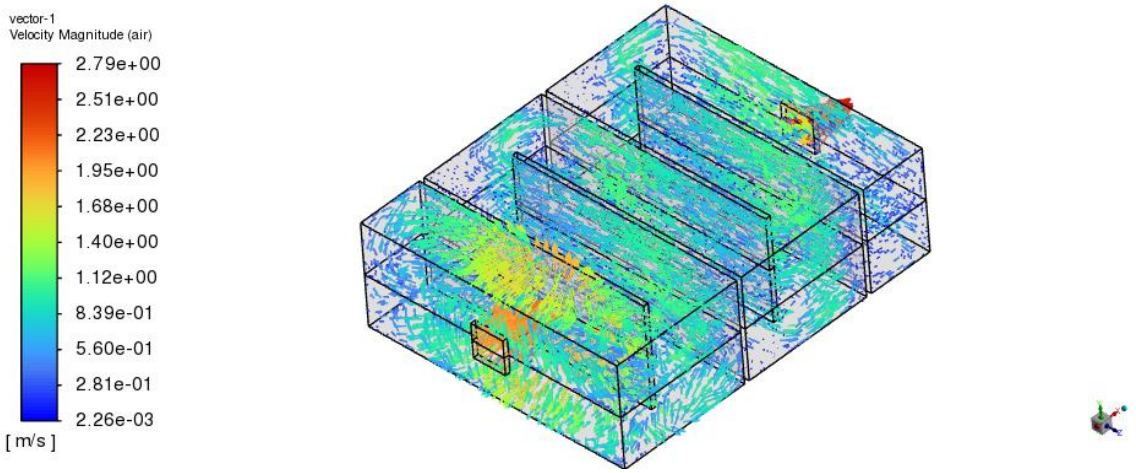


Fig. 44. Air-filteration-Plants-zigzag-panels-v-2-vel-vector-velocity contour

4. Conclusions

The present research work focuses on the three-dimensional CFD simulation of plant-based panels for air purification and pollutant removal. Three different types of plant-based panels, namely blocking, parallel, and zigzag layouts, have been utilized within the velocity ranges of 0.5-2 m/s for the investigation of airflow patterns and filtration effect. It was found through CFD simulation that both airflow characteristics and maximum removal of PM10 particles were recorded as compared to the other two configurations due to alternative geometrical paths of air-flow and maximum turbulence. On the other hand, intermediate better flow, and removal of PM10 particles were found in the case of parallel layouts. The least turbulence in air flow and minimum removal of PM10 particles were observed for the blocking configuration due to its geometry. Besides this, the optimal performance of the zigzag configuration for efficient air-flow and maximum pollutant removal occurred in a range of 1-1.5 m/s. Hence, out of all three types of plant panels zigzag configuration was found to be the most applicable design for plant air filtration systems due to the application of plant-based filters. The following are the major concluding remarks that emerged from this CFD analysis:

i. The zigzag panel configuration produced the best-mixed airflow, with alternating high and low velocity regions, and the lowest outlet PM_{10}, showing effective particulate capture.
ii. Blocking panels led to a strong slowing of airflow and large recirculation areas behind the plants, increasing residence time but creating dead zones and resulting in poor filtration effect of PM10 particles.
iii. Uniform and minimum resistance flow and minimum turbulence were obtained in the case of the parallel configuration due to flow in a straight line, and only a moderate filtration rate was obtained.
iv. An optimal velocity range of inlet air velocity from 1-1.5 m/s was obtained for all cases since it increases better mixing and increased flow rates.
v. Zigzag panels emerged as the best plant panel for air filtration work out of all cases since it has secured the best filtration performance and as well as managed pollutant removal rate.

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References

[1] Ahirwar M, Bartaria VN. A recent review on mitigation strategies for control of air pollution. *International Journal of Energy, Environment and Economics*. 2023; 31(2):219–229.

[2] Nie W, Zhu Z, Liu Q, Hua Y, Liu C, Jiang C, Cheng C, Zhang H. Numerical simulation of the dust pollution characteristics and the optimal dustproof air volume in coal washing plant screening workshop. *Journal of Building Engineering*. 2024; 87:109025.

[3] Boppana VB, Wise DJ, Ooi CC, Zhmayev E, Poh HJ. CFD assessment on particulate matter filters performance in urban areas. *Sustainable Cities and Society*. 2019; 46:101376.

[4] Pui DY, Cao Q, Kuehn T, Lo C, Chen SC. Large-scale PM2.5 removal and CO2 DAC to mitigate ambient air pollution and combat global climate change. *Journal of Environmental Sciences*. 2025.

[5] Wójtowicz-Wróbel A, Kania O, Kocewiak K, Wójtowicz R, Dzierwa P, Trojan M. Thermal-flow calculations for a thermal waste treatment plant and CFD modelling of the spread of gases in the context of urban structures. *Energy*. 2023; 263:125952.

[6] Li Z, Hutzel W. Optimization and Evaluation of a Botanical Air Filtration System in a Residence. *Journal Name Not Available*. 2018.

[7] Yu KC, Yu JM, Lai SM. Numerical simulation and construction of using indoor plants to improve indoor air quality. *International Journal of Physical Sciences*. 2011; 6(33):7604–7613.

[8] Wang Z, Pei J, Zhang JS. Modeling and simulation of an activated carbon-based botanical air filtration system for improving indoor air quality. *Building and Environment*. 2012; 54:109–115.

[9] Tran TT, Nguyen DK, Do MT, Vu TQ. Evaluation of the role of trees in removing air pollutants at selected universities in Ho Chi Minh City using i-Tree Eco model. *TNU Journal of Science and Technology*. 2022; 227(15):117–129.

[10] San Jose R, Perez-Camanyo JL. Modelling effects of type of trees on urban air pollution with a computational fluid dynamics model. *Euro-Mediterranean Journal for Environmental Integration*. 2022; 7(3):381–389.

[11] Moradpour M, Hosseini V. An investigation into the effects of green space on air quality of an urban area using CFD modeling. *Urban Climate*. 2020; 34:100686.

[12] Cai B, Cheng H, Xiang F, Wang H, Kang T. Modeling the Effects of Vegetation on Air Purification Through Computational Fluid Dynamics in Different Neighborhoods of Beijing. *Buildings*. 2025; 15(7):995.

[13] Meesang W, Baothong E, Srichat A, Mattapha S, Kaensa W, Juthakanok P, Kitisriworaphan W, Saosoong K. Effectiveness of the genus Riccia (Marchantiophyta: Ricciaceae) as a biofilter for particulate matter adsorption from air pollution. *AIMS Environmental Science*. 2023; 10(1):157–177.

[14] Meesang W, Baothong E, Poojeera S, Kaenka W, Mathapha S, Srichat A, Junsiri C. Model feasibility of air pollution treatment using plants as filter by computational fluid dynamic (CFD) analysis: A case study in laboratory. *EnvironmentAsia*. 2022; 15(1).

[15] Nurmalisa M, Tokairin T, Takayama K, Inoue T. Numerical simulation of detailed airflow distribution in newly developed photosynthesis chamber. *IOP Conference Series: Earth and Environmental Science*, Not Specified City, Not Specified Country, Year Not Specified. Proceedings of IOP Conference Series; 623(1):012095.

[16] Vivekanandan N, Rajeswari K, Kanna NV. A CFD-based assessment of Azolla biofilters for sustainable indoor air purification in low-carbon buildings. *International Journal on Interactive Design and Manufacturing*. 2025; Pages 1–14.

[17] Trinh TH, Pham C, Reiminger N, Nhut JM, Pham-Huu C. Filtration systems for particulate matter reduction in outdoor air: a review. *Journal of Environmental Management*. 2025; 390:126263.

[18] James A, Rene ER, Bilyaminu AM, Chellam PV. Advances in amelioration of air pollution using plants and associated microbes: An outlook on phytoremediation and other plant-based technologies. *Chemosphere*. 2024; 358:142182.

[19] Solari F, Lysova N, Montanari R. Monitoring and control of air filtration systems: Digital twin based on 1D computational fluid dynamics simulation and experimental data. *Computers & Industrial Engineering*. 2024; 197:110607.