REVIEW OF THE EFFECT OF OCCUPIED DENSITY WITH MIXING VENTILATION ON THERMAL HUMAN COMFORT AND INDOOR AIR QUALITY

Atheer Hamza Saber[1]   **Alaa Abbas Mahdi[2]**   **Mohammed Wahhab Aljibory[3]**

atheerhamza17@gmail.com   alaa.mahdi1959@ gmail.com   Dr.mohammad.wahab@ uokerbala.edu.iq

[1, 3] University of Kerbala / College of Engineering-Iraq

[2] University of Babylon / College of Engineering -Iraq

ABSTRACT

In this study many researches related to mixing and displacement ventilations in indoor and office rooms were addressed. Good ventilation is one of the most important requirements for space occupants to maintain appropriate environmental conditions, as ventilation increases thermal comfort and improves indoor air quality. However, the studies on mixing ventilation systems based on occupied density have been highlighted in the present work. Improvement of the indoor environment is economically efficient when health and productivity are taken into account. The parts of a room that a person occupies must be characterized by speed and air temperatures suitable for the occupants of the space. In the occupied zone, fresh, clean supply air must reach all its parts, and no stagnation areas can be found there. A group of field studies conducted showed, significant levels of dissatisfaction with the indoor environment in many buildings despite satisfying the typical ventilation requirements, where there are still many complaints regarding poor indoor air quality and diseases related to poor ventilation of buildings. In enclosed spaces, ventilation is one of the essential methods used to control indoor air quality (IAQ). In buildings, ventilation has an impact on the structure and, as a result, on the people who utilize it. A deteriorated indoor environment increases sick building syndrome (SBS), respiratory illnesses, and reduces comfort and productivity.

Keywords: Thermal comfort , Indoor air quality(IAQ), Mixing ventilation (MV), Displacement ventilation (DV), occupied density.

INTRODUCTION

Heat generation from multiple devices results in an increase in indoor heat in an office environment, as well as solar conditions, resulting in increased heat load. This found challenges for office room ventilation, (Chen ,2014). More than 90% of people's time is spent in a closed climate, so maintaining health in the indoor environment is an important

factor, (Awbi ,2003) and (Turiel ,1985). Respiratory disease was Abnormally observed in many countries of the world. Several recent studies have proven that most diseases are due to poor indoor air quality, (Chen ,2014) and (Turiel ,1985). Building ventilation has been systematically studied as a dynamic system for more than (100) years, (Viley and Halsted; 1858),(Roberts,1892). Ventilation system operators and designers must be aware of the requirements for human comfort and air quality, which is essential to obtain acceptable indoor conditions, (Abduljabbar et. et.al, 2010). The nature of human physical activity and indoor pollution concentrations are important factors influencing thermal comfort and discomfort, (Haghighat,2009) and (Awbi ,2008). Most researchers discussed (The locations, geometric forms for reflectors, quantity of reflectors, compared (DV) and (MV) devices, the placement of the air input and output, and the impact of an hourly air change on thermal comfort are all factors to consider) in their works, whether experimental or theoretical. This paper aims to review the scientific literature on (mixing and displacement ventilation) under different occupants density and their impact on human thermal comfort and indoor air quality (IAQ) by analyzing indoor air temperature distribution, air flow, heat removal efficacy, and effectiveness of removing pollutants and evaluating the air exchange efficiency in rooms with mixing ventilation systems for improving indoor air quality at conditions of different time due to occupants stay at indoor different regions, under Iraqi climate. Therefore, some parts of the room play a more important role than others. A revised air-exchange efficiency concept called "occupant air exchange efficiency "that takes both the airflow pattern and occupant's distribution into account for ventilation evaluation is proposed.

VENTILATION SYSTEMS

This section focuses on two types of ventilation systems (displacement and mixing ventilation). These types are the most popular systems used nowadays in many countries.

Displacement ventilation system

Displacement Ventilation system (DV), Figure. (1), can be defined as (room ventilation caused by indoor air displacement, by delivering air at low velocity and level in a room at a low temperature), (Loomans,1998). Simply, it may be defined as "an airflow pattern where old air is replaced by new air". In this system, supplied-air (outdoor air or a mixture of outdoor and indoor air) at low velocity and near the floor of the room and low cooling capacity (typically <0.5m/s, and <40W/ m^2 of floor area, (Cho et.al, 2008)) which rises with high of the room due to effect of momentum and buoyancy forces. This phenomenon is caused by the heating sources as occupants and warm surfaces. Pollution concentration and temperature stratification then were developed due to clean and cool air at a low level. The contaminated air up to a higher level in a zone above the occupants, (Haghighat,2009).

Mixing ventilation system

A mixing ventilation system (MV) was previously studied in 1899 by Robert and Son.,1899. This system has been used in different spaces such as classrooms, shopping malls, offices, cinemas, etc. which provide thermal comfort to the occupants, (Müller , et.al., 2013). In a mixing ventilation system, the air supply and air in a room are mixed by the force of the supply momentum and the effect of buoyancy force. It can be used for cooling and heating space as ventilation. The air supply is used to decrease the pollution concentration inside the occupied zone (hence there is another name for mixing ventilation is dilution ventilation, which is also used), (Awbi ,2008). Figure (2) shows the mixing system. The mixing ventilation system (MV) delivers air to the room at a high speed from the diffuser, A high-speed jet of air is delivered to the top of the room (roof or wall at a high height) to ensure air circulation in the room, which is commonly located at or near the roof over the occupied zone, the temperature and pollutant concentration distribution in the occupied zone must be uniform as a result (Awbi,2007).

REVIEWING THE PREVIOUS WORKS

Experimental works

Nielsen, (1996)**,** examined different aspects of personal exposure at different stratification heights in a displacement ventilated room. For the experiments, a thermal manikin was used to measure personal exposure. A personal exposure takes the concentration gradients as well as the influence of the human thermal boundary layer into account. The objective of the study was to determine the indoor air quality in a displacement-ventilated room directly by asking humans about how they perceived the air quality. The perceived air quality in the displacement ventilated room is then compared with conventional mixing ventilation to see if the indoor air quality is improved. The results showed that the flow in the boundary layer around a person is able to entrain and transport air from below the breathing zone to a great extent, thus improving the quality of the inhaled air. The experiments also showed that the perceived air quality in the displacement ventilated chamber is substantially better than in the case of mixing ventilation. A personal exposure model for the displacement ventilated room is also proposed. Fong, et al., (2011), evaluated thermal comfort conditions in a classroom with three ventilation methods. In an environmental chamber, the thermal feeling is investigated using mixing ventilation, displacement ventilation, and stratum ventilation. Forty-eight subjects took part in all of the tests, which were conducted in a classroom with the same boundary conditions but different ventilation systems. Experimental measurements were carried out in a classroom with dimensions (8.8m×5.1m×2.4m) , as shown in Figure(3), located at the University of Hong Kong. The three ventilation methods were subjected to a thermal comfort analysis based on the prescribed supply airflow rate, room temperature, and relative humidity. The thermal neutral temperature is generally (2.5 °C) higher under stratum ventilation than under mixing ventilation and (2.0 °C) higher than under displacement ventilation. This finding suggests that stratum ventilation could provide enough thermal comfort in rooms

with temperatures as high as (27°C). The energy saving attributable to less ventilation load alone is around (12%) compared with mixing ventilation and (9%) compared with displacement ventilation. Michal, et al.,(2012), studied experimentally in a simulated room in a low-energy building heated and ventilated by warm air and equipped with a mixing ventilation system, air distribution, ventilation efficiency, and thermal environment were measured. The case study is an office room with dimensions (of 4.2m×4.0m ×2.4m) , during the winter in Denmark. The room was equipped with two models and a light bulb representing the internal heat source. The pollutant removal efficiency and air change efficiency were used to estimate the ventilation effectiveness. The effect of an increased air change on the effectiveness of ventilation depends on the air conduction terminals. Depending on the location of the air tips, the aeration efficacy changed between (0.4 and 1.2) where (1) is the complete mixing. The ventilation air supplied into the room when the radiant floor heating system was simulated was effectively mixed and generated uniform conditions with a ventilation efficacy of approximately (1). Tomasi, et. al., (2013), investigated in a simulated home room with radiant floor ventilation/cooling and mixing systems, the effect of modest ventilation rates (1 or 0.5 air changes per hour) on thermal comfort and ventilation effectiveness was explored. The experiments were carried out in a full-scale chamber measuring (4.2m×4.0m×2.4m), as shown in Figure (4), at the Technical University of Denmark's International Centre for Indoor Environment and Energy. A pollutant source located (1.3 m) from the occupant was considered. The tests were conducted for different weather station supply and extraction sites and different winter and summer border conditions.   To describe the ventilation effectiveness in the occupied area, the pollutant removal effectiveness (CRE) and the local air change index were measured. Cold air during summer presents a potential comfort hazard because it causes high vertical air temperature differences between head and ankle levels. High levels of thermal comfort have been achieved for all winter conditions, due to vertical differences in air temperatures and draft rates. The tip location of the extracted air for summer application has no effect on thermal comfort, but the results show that exhaust at low levels enhances local air change indices. Ralph, et. al., (2015), measured the concentration decay rates of carbon dioxide in a number of locations in the room were monitored after raising the (CO_2) level across the room over (10,000) parts per million. The use of carbon dioxide as a tracer gas to quantify and compare pollutants degradation rates in existing laboratories is a useful technique in monitoring ventilation performance. It is critical that this information be presented in a way that laboratory occupants can easily comprehend in order to ensure that the information is used to prudently apply general laboratory ventilation in handling chemical dangers in their specific job. The concentration half-life of pollutants at specific locations inside the room, rather than the air exchange rate represented in room volume per hour, appears to be a more appropriate explanation for this purpose, according to this study. This study confirms the non-linear nature of pollutants degradation in the lab while describing the inhomogeneity of the room's airflow. Xin, et al., (2016), studied in two similar instructional rooms, researchers looked at human participants' thermal comfort, sick

building syndromes (SBS), and short-term performance while using mechanical ventilation (MV) and passive displacement ventilation (PDV). The tested office room dimensions were (8×8×2.75) m, located in Technological University, Singapore. Because of the high air velocity produced by the overhead diffusers, experimental results revealed that (MV) might provide a substantially larger overall draft sensation than (PDV). The (PDV) room, on the other hand, produced a substantially stronger airflow and a colder sensation in the lower body, whereas the (MV) room's draft distribution was judged to be sufficiently homogeneous in the vertical direction. In both the (MV) and (PDV) rooms, seat arrangement could result in inhomogeneous horizontal sensations. The main cause of (SBS) connected to the head was greater (CO_2) concentration, while (SBS) related to the eyes was caused by both higher (CO_2) concentration and lower relative humidity (RH %). As a result, (SBS) caused by high (CO_2) levels and low (RH %) could result in a drop in short-term performance. Amai and Novoselac (2016)**,** examined air change effectiveness in mixing ventilation. The properties of air distribution are influenced by diffuser selection. The goal of this research is to provide supporting data for the design of air distribution systems for several of the most prevalent types of ceiling diffusers in the cooling and heating regimes.   In this study, four types of diffusers were taken as shown in figure (5) . The experimental tests were conducted in a climatically tested room with dimensions of (5.5m×4.5m×2.7m). The results indicated that the highest percentage of air change efficiency and temperature efficiency (in the heating system) was in the type (round roof diffusers), where their values were (0.85) and (0.72), respectively. As for cooling, the results indicated that the highest percentage of air change efficiency and temperature efficiency was in the type (linear slot diffusers), and its value was (1.12) and (1.11), respectively. Kristina, et al., (2019), investigated the impact of high occupancy density on apartment air quality, energy consumption and moisture conditions. According to this study, depending on how many people will be staying in the flat, increasing occupancy density leads to increased moisture supply It is possible to enhance airflow in high-density apartments so that moisture supply does not reach critical levels, resulting in the apartment damage. When the ventilation airflow is modified to maintain the same moisture content in the air, it is shown that the energy requirement for heating increases as occupancy levels rise. If the occupancy level increases from three to six people, In a (70 m2) apartment, the energy demand for heating the ventilation airflow will practically treble, ranging from (370 to 700 kWh/ m2) per year in Kiruna and (200 to 400 kWh/ m2) per year in Malmö. However, if a ventilation system with heat recovery on the exhaust air is built, the energy consumption for Kiruna and even Malmo can be reduced to around (50 KWh/ m^2) per year. Cheng, et. al., (2020), studied the interplay between the human thermal plume and breathing airflow. as participants sat in a quiet indoor environment. The case study is a room with dimensions of (3.95m×2.35m×2.65m), located at the Norwegian University of Science and Technology's Department of Energy and Process Engineering. To validate the breathing thermal manikin, data from real human participants were used to develop a sitting breathing thermal manikin. The velocity and temperature were measured with and without

breathing in front of and above the breathing thermal manikin in this investigation. Furthermore, the impacts of mouth and nose breathing on the development of the thermal plume were examined. The manikin's surface temperature ranged from (33 to 34 °C), and the ambient temperature was adjusted to (23 ±0.5 °C). At roughly (35 cm) above the head, a maximum value of (0.19 m/s) was attained, which was close to the mouth-breathing case (0.19 m/s) but greater than the nose-breathing case (0.17 m/s).   When compared to breathing modes, non-breathing thermal manikins can create a relatively similar velocity distribution over the manikin's head. Breathing through the nose had a significantly greater effect on the thermal plumes surrounding the manikin than breathing through the mouth, and even changed the flow direction. Xue, et al., (2020)**,** investigated experiments in an operating room with mixing ventilation, researchers looked at the impact of exhaust airflows on the surgical environment. Temperature, humidity, air speed, and indoor quality are all factors that must be met in the indoor environment. The research was conducted in a full-scale operating room lab (8m ×7m×3.8m), as shown in Figure (6), in Trondheim, Norway, at the Norwegian University of Science and Technology. The goal of this study was to determine the impact of different exhaust airflows on air quality in a full-scaled (OR) laboratory with mixed ventilation in a surgical environment. Experiments were carried out with three different ventilation situations at two different air change rates. According to the findings, the ideal location for the instrument table is (1.0–1.5 m) from the wall. In (18 h-1) (ACH), airflow with six exhausts was better, with a contaminant removal efficiency of about (38%) higher than airflow with eight exhausts, while in (20 h-1) (ACH), a four-exhaust strategy was better, with a contaminant removal efficiency of about (35%) higher than airflow with eight exhausts. This study's findings may lead to more efficient operating room ventilation systems. Wang, et. al., (2021)**,** studied in enclosed indoor spaces, particularly those with large population densities, ventilation is critical for COVID-19 prevention and control (for example, underground space buildings, conference rooms, etc.). As a result, larger ventilation rates are recommended to reduce the risk of infection throughout the mission, however, this may result in increased energy consumption and cost. This research provides a low-cost ventilation control technique based on an occupant-density-detection algorithm that takes infection prevention and energy efficiency into account. Using a self-developed low-cost hardware prototype, the ventilation rate can be automatically switched between demand-controlled and anti-infection modes. The YOLO (You Only Look Once) algorithm was used to determine occupancy using video frames from surveillance cameras. In comparison to a standard ventilation mode with a (15%) fixed fresh air ratio, case studies reveal that the suggested ventilation control method can save (11.7%) percent energy while lowering infection risk to (2%). The suggested ventilation management method offers a viable and promising alternative for preventing the spread of infectious diseases (such as COVID-19) in public and private buildings, as well as promoting a healthy and long-term indoor environment. Shah, et al., (2021), studied in the context of COVID-19, an experimental assessment of indoor aerosol dispersion and buildup was conducted, including the effects of masks and

REVIEW OF THE EFFECT OF OCCUPIED DENSITY   **Atheer Hamza Saber**
WITH MIXING VENTILATION ON THERMAL HUMAN   **Alaa Abbas Mahdi**
COMFORT AND INDOOR AIR QUALITY   **Mohammed Wahhab**

ventilation. The continuing COVID-19 epidemic has brought attention to the role of aerosol dispersion in disease transmission in the indoor environments. The current study evaluates the dispersion and build-up of an inhaled aerosol modeled using polydisperse small particles (approximately 1 µm mean diameter) using a seated manikin in a rather large indoor environment. According to measurements, all of the masks investigated provide protection in the immediate vicinity of the host, mostly through the redirection and reduction of expiratory momentum. Even with high-efficiency masks like the (R95 or KN95), leakages are observed to result in significant reductions in mask efficiency compared to the optimum filtration efficiency of the mask material. Far field tests (2 m from the subject) record significant aerosol build-up in the indoor area over a long period of time (10 h).   While higher ventilation capacities are needed to completely minimize aerosol build-up, the study revealed that even low air-change rates (2 per hour) result in the less aerosol build-up when compared to the best-performing mask in an unventilated room.

Numerical works

Xiaojiang and Zhiwei , (2005), studied how to remove dust and contaminants in a large area of workshops, during the polishing process, and effectively when the source of dust is subject to change in the workshops. The PHOENICS software was used to simulate the stratified distribution of air for (3- D) turbulence flow in a great area of (63m× 33m × 17m), with various sorts of interface parameters as a height of terminal air supply, the height of exhaust air grilles and their locations (one or two sides). The governing equations in this study are equations of momentum, conservation of mass, and energy with the use of the (k-ε) turbulence model. Results were compared with the experimental formula, then it was determined that when the height of supply air terminals is similar to that of the exhaust air grille, maintaining the jet flow at a steady state and dividing the area further effectively. Abduljabbar, et. al., (2010)**,** investigated the effect of the volume of heated objects in the room on the effectiveness of ventilation, the concentration of pollutants, and energy consumption. The case study is an office room with dimensions (5.4m×2.5m ×3.6m), with a heated object in the middle of the room at three different heights (1.2,0.6,0.3) m, with the other two dimensions fixed (0.5m× 0.4m). Mixing air supply temperature was (20°C) at an air flow rate (14.7 m^3/min) respectively. (ANSYS FLUENT) software was used in numerical analyses by using (k- ε) as a turbulent model. The results showed that the ventilation efficiency increases with decreasing obstacle volume. The concentration of pollutants (CO_2) and the energy consumed increase with the increase in the size of the obstacle. Cao et al., (2011), investigated how to create a safe, healthy, and productive work medium using a novel ventilation concept to protect office workers from infection by epidemic respiratory diseases in open-plan offices. The case study is an office room with dimensions (4m×2.65m×2m), simulated by using (ANSYS FLUENT) software (RNG k-ώ turbulent model). The basic idea of the idea is to use a high turbulence intensity plane jet

diffuser to provide better indoor air quality (IAQ), a more comfortable thermal environment, and higher energy efficiency. The modern ventilation concept presented here can significantly improve the effectiveness of ventilation to save people from developing epidemic respiratory diseases in open-plan offices and public places and also raise the air quality in the breathing zone (BZ). Sami, et al. (2012), investigated the effect of supply Reynolds number and room aspect ratio on flow and ceiling heat-transfer coefficient for mixed ventilation. Under forced convection conditions, a (CFD) study is undertaken to model turbulent flow and heat transfer inside mechanically ventilated rooms utilizing a mixing air distribution system. Air enters the room through a side wall aperture flush with the isothermal ceiling and exits through a port flush with the floor on the other wall. The (k- ε) turbulence model is used to calculate temperature distributions and velocity using a finite volume technique. The model is then used to investigate the impact of the supply Reynolds number (Re = 4000 to 10,000) and the room aspect ratio (L/H = 0.5-6) on flow and heat-transfer properties within the room.. The correlation of isolated flat plates is compared to the fluctuation of the convection coefficient (hx) along with the ceiling. Results show that ceiling averaged convection coefficient (hav) increases with Reynolds number (Re.) and decreases with the ratio of length to height (L/H). Temperature contours show that temperature variance in the occupied zone is well within (0.5 °C), compared to (10 °C) in the region close to the ceiling, indicating good mixing properties in the occupied zone. Awbi, et al., (2013), investigated the evaluation of comfort and airflow in spaces equipped with mixed ventilation and a cool radiant floor. The effect of different air flow rates and occupant location on the air distribution index applied in non-uniform environments is shown. The case study is an office room with dimensions (2.7m×2.4m× 2.4m), simulated by using (ANSYS FLUENT) software (RNG k-ώ turbulent model) Detailed numerical analysis of thermal comfort, air quality, and heat and pollutant removal efficiency are also presented. As the inlet air temperature is (28°C) and a cold radiant floor has a surface temperature of (19°C). Supply and exhaust diffusers are located above the head level on adjacent walls in the mechanical mixing ventilation system. An acceptable level of thermal comfort for the occupants was found for an air flow rate above (46 l/s), while an acceptable air quality level was found for an air flow rate above (57 l/s). As a result, the airflow rate required to achieve acceptable air quality levels is higher than the airflow rate required to achieve acceptable thermal comfort levels, according to the findings. Serrano, et al., (2013), studied the optimum ventilation temperature and the distribution of carbon dioxide in ventilated cavities based on the effectiveness of ventilation.   The different cavity configurations were studied in terms of the mixture flow gap position in order to find a good ventilation configuration and evaluate the thermal behavior and air quality inside the cavity. Four distinct (CO_2) pollutant source values (500, 1000, 2000, 3000) ppm. Inlet air velocity is a function of Reynolds number (500 ≤Re≤40000). There were four possibilities for the location of the outlet gap of the mixture, as shown in figure(7)   . Based on the results, it was determined that the outlet to the right of the upper wall of the cavity performs better in terms of thermal comfort and air quality.

REVIEW OF THE EFFECT OF OCCUPIED DENSITY
WITH MIXING VENTILATION ON THERMAL HUMAN
COMFORT AND INDOOR AIR QUALITY

Atheer Hamza Saber
Alaa Abbas Mahdi
Mohammed Wahhab

In general, it is concluded that a mixed heat load with a Reynolds value of (Re =10,000) is required to generate results that meet the limits of temperature and pollutant concentration. Rui, et al., (2016), studied Several sources of pollution that characterize indoor environments. Some of them can be adequately described by predicting airflow patterns and pollutant dispersal. This study used three locations of internal pollutant sources in the test room (6.86m×3m×3.2m), as shown in Figure (8). Simulated by using FLUENT software (RNG k-ώ turbulent model), by using mixing ventilation. The aim of this research was to simulate, evaluate and compare the locations of different pollution sources within a well-ventilated room. Where the concentration of pollutants in the breathing area (1.1 m) was evaluated. It should be noted that the air entry and exit location were above the left wall with dimensions (0.15m×0.3m) and (0.3m×0.5m) respectively. The results indicated that if the pollution source is close to the prepared air, the concentration of pollutants is lower and the highest concentration of pollutants is when the source is in the middle of the room. Zohir, et al., (2019), presented a thorough analysis of the impacts of outlet air position on thermal comfort and air quality. The airflow enters through a hole in the lower left vertical wall and exits through a hole in one of the cavity's walls. The purpose of this work is to investigate the outlet position effect, and four distinct output port placement configurations are considered. Three are located on the roof's upper side (starting, middle, and end), while the fourth is located on the opposite side of the inlet aperture. On the left vertical wall, a uniform heat and (CO_2) contaminant source is provided. Two significant indices, namely the effectiveness for heat removal (ε_t) and contaminant removal(ε_c) illustrate this. The governing equations for the four cases are solved by (CDF STREAM CODE V11). The results indicate that the best place for air exit is at the beginning of the roof (the side near the entrance), where the value of the contaminant removal effectiveness(ε_c) and heat removal effectiveness(ε_t) were (0.8), (1.25) respectively. Rajesh, et al., (2020), investigated the effects of ventilation on an indoor spread of COVID-19. Increasing research indicates that knowledge of air flows is critical to estimating the risk of contracting COVID-19. According to the available evidence, the transmission of the virus indoors significantly outweighs transmission of the virus outdoors, possibly due to longer exposure times and lower levels of disturbance (and thus dispersal) visible indoors. The case study is an office room with dimensions (4m×3m ×2m) and ventilation rates are set between (5–10) ACH. . In this paper we discuss the role of building ventilation on the potential pathways of airborne particles and make a comparison between displacement ventilation and mixing ventilation, as shown in figure. (9). The results indicate that ventilation leads to a reduction in the rate of infection with the virus and that displacement ventilation appears to be more effective in reducing the risk of infection because it removes warm and polluted air near the ceiling. As for mixed ventilation, its effectiveness is less than displacement ventilation because it distributes air throughout the place and thus does not provide any clean place. Sur and John, (2020), investigated the ongoing COVID-19 pandemic was investigated in confined areas, and social distancing and ventilation were widely emphasized. The ventilation index represents the system-dependent air distribution

efficiency in space, whereas the distance index is derived from a theoretical examination of droplet dispersal and transmission from human respiratory processes. The study indicated that (1.6–3.0 m) ,(5.2–9.8 ft) is the safe social distance when considering aerosol transmission from large exhaled droplets of speech, Providing data for a number of circumstances, including transportation vehicles and building areas, that uses the verified model, (1) even with current ventilation practices, a rise in the social distance (e.g., halving occupancy density) could dramatically lower the rate of infection (20-40 percent) during the first (30 minutes; (2) the ventilation or fresh air requirements should vary with different spacing conditions, exposure time, and air distribution effectiveness. Wang, et al., (2021), determined the effect of the door opening on infection risk at the surgical site and a study in a mixed ventilated operating room. The operating room was taken at the University Hospital of New Karolinska Solna in Sweden, and the dimensions of the room were (8.6m×7.7m×3.2m) simulated by using (ANSYS FLUENT) software (k-ώ turbulent model). Door openings often lead to contaminated and uncontrolled areas. Single-door opening increases total contamination by (2.1) colony-forming units per cubic meter (CFU/ m^3) when the temperature difference is around (3°C). The risk of infection varies greatly depending on the level of total contamination, while the corresponding contamination at the surgical site ranges from less than (1 CFU/m^3) to more than (10 CFU/m^3). In the case examined in this study, the reduction in exhaust flow results in   (20-30%) reduces airborne pollution to a low enough level.

Experimental and numerical works

Brohus, H., & Nielsen, P. V., (1995) **,** determined the personal exposure to a contaminant source in a uniform velocity field. This is done by full-scale measurements and computer simulations to investigate the contaminant concentration of the inhaled air of a thermal manikin located in uniform horizontal flows of different velocities in a wind channel. The effect of movements of the manikin is assumed to be equivalent to the impact of the uniform velocity field. The results showed a significant dependence on the velocity field both regarding the direction and the magnitude. It's also shown that the disturbance created by a person in a flow field may be a very important factor to consider when the person is turning the back to the flow field. It is found that the wake created behind a person is able to entrain contaminants from a distance exceeding the usual operating range. Zhang and Chen, (2006), studied particle transport and distribution in ventilation chambers: experimental data and computational simulations. The dispersion and distribution of particles in the room should be anticipated in order to create and maintain a healthy indoor environment. In this study, particle scattering and concentration distribution in well-ventilated chambers were predicted with dimensions (4.91m ×4.31m×2.44m). Simulated by used (ANSYS FLUENT) software (standard k-ώ turbulent model).   The particle size distribution was monodispersed in all cases studied, with particle diameters ranging from (0.31 to 4.5 μm). The particulate sedimentation rate was neglected and thus only the particles were removed by the aeration system. As a result, the particulate removal

REVIEW OF THE EFFECT OF OCCUPIED DENSITY   Atheer Hamza Saber
WITH MIXING VENTILATION ON THERMAL HUMAN   Alaa Abbas Mahdi
COMFORT AND INDOOR AIR QUALITY   Mohammed Wahhab

effectiveness of different ventilation systems can be evaluated. The roof and side wall supply systems, as well as the Underground Air Distribution (UFAD) system, were examined. The UFAD system was shown to have better particulate removal efficacy than the study's wall and ceiling supply systems. Lee,et al.,(2007), examined the types of air inlets in mixing ventilation. The aim of the current study is to measure the concentrations of pollutants in a room of dimensions(8.86m×8.86m×2.35m) as shown in figure(10), compare the qualitative and quantitative performance of the wall-mounted jet air intake (WJ) and Diffuser for the ceiling (CD), and to find a more efficient design for the inlet and outlet. The effect of different types of air input on mixed ventilation was studied with two conditions: no occupant and occupant north of the source. The flow rates used were (5.5, 3.3, and 0.9) m^3/min. Tracer gas concentrations (CO_2) were measured automatically at (144) sampling sites using a photo-ionization detector. In general, the (CD) air intake provided more efficient ventilation than the (WJ) inlet, regardless of whether the occupant was present or not, because the ventilation efficiency was greater than (1). Donghyun, et al.,(2010), studied the concentration of carbon dioxide (CO_2) and a comparison was made between displacement ventilation and mixing ventilation in two cases: the first case with one person inside the room and the second case with five people inside the room. Chamber dimensions (4.27m×4.27m×3m), as shown in figure(11), were stimulated by the used ANSYS FLUENT software (RNG turbulent model). The rate of air change was (5 h^{-1}), in both cases.   The results indicate that in the first case (one person), the concentration (CO_2) values in the breathing zone (BZ) under displacement ventilation and mixing ventilation (500 ppm), (525 ppm) respectively, while in the second case (five persons), the concentration values (CO_2) in the breathing area (BZ) under displacement ventilation and mixing ventilation (800 ppm), (835ppm) respectively. We conclude that displacement ventilation provides better conditions in the breathing area (1.1 m) in terms of concentration (CO_2). Glenn, et. al., (2011), examined a ventilation system in a laboratory with dimensions of (6m×3m×3.5m). Simulation has been done Using (ANSYS FLUENT 12.1.1) the program in which the (RNG, k-ε) model is implemented. The focus of the simulation was on the effect of changing the air flow rate to remove spilled pollutants. The results indicated that the best design should not only depend on changing the air flow rate but should also depend on the density and activity of the occupants. Relatively low air velocity is not able to transfer pollutants to the exhaust air grille located in the upper area of the room. This effect intensifies seriously on a large scale as the density of pollutants increases. The pilot study backs up the findings, demonstrating that the amount of air evacuated directly from the exhaust air network has a significant impact on the efficiency of various supply systems. New air passing into the floor area is affected by temperature. Poor results appeared when the inlet air temperature was greater than room temperature. Makhoul, et al. (2013), developed the effectiveness and performance of a ventilation system consisting of a ceiling air diffuser with a personal coaxial ventilation system. The coaxial nozzle is characterized by its highly capable of supplying fresh and cold air to the breathing zone. This study was simulated numerically using effective (CFD) that can

predict the microenvironmental conditions and thermal comfort. Experimental tests were carried out on ten persons who participated in the experiment. Each person was exposed to three different experiments and was allowed to cast their votes on thermal comfort. The deviation between the numerical and the experimental results was within ($\pm$ 20 %). The new ventilation system reduces the consumption of energy by up to (34 %) when compared to traditional mixing ventilation (MV) systems that provide the same level of thermal comfort. Shbeeb and Mahdi,(2016) **,** made a comparison among four turbulence models (realizable k-Ɛ, standard k-Ɛ, RNG k-Ɛ, and SST k-ω) in different cases and different cooling loads to find a suitable model used with the ventilation system in   Iraqi climate. Three cases were studied, two cases as isolated (3m×1.75m×3m) and non-isolated office room (4m×3.5m×3.75m) with a window in a north wall while the third case as a non-isolated classroom (7m×4m×3m) with three windows at north wall. The supply air temperature and velocity for each case were calculated depending on internal and external heat gain. The air supply temperature and flow rate for three cases were (18, 20, and 18˚C) and (20, 50, and 218L/s) respectively. GAMBIT (2.2.30) and (FLUENT 6.3.26) software were used to build, meshed, and numerically analyze three cases. The results found that the (RNG turbulent model) was more accurate than other turbulent models for the predicted air temperature distribution near heat sources, while for predicting air velocity distribution, the four turbulence models gave similarity for different cases. Alaa, et al., (2016), studied experimentally and numerically the spread of airflow and the circulation of pollutants in the ventilation of rooms related and a comparison between displacement ventilation and mixing ventilation to the Iraqi climate. The case study is an office room with dimensions (4m×3.5m×3.75m), as shown in figure(12), simulated by using (ANSYS FLUENT) software (RNG turbulent model). There are many diseases associated with poor indoor air quality in the office. The transmission of pollutants can be controlled and the indoor air quality in the office can be improved through ventilation. (CO_2) concentration is recognized as a reliable indicator for measuring the level of air quality and for analyzing the operation of a mechanical ventilation system that many designers use in assessing indoor air quality. As a result, concentration (CO_2) was used as a trace gas in this investigation, and the rate of carbon dioxide formation (CO_2) by human respiration was taken into account as the source (CO_2). The researchers there used experimental measurement methods and computational fluid dynamics (CFD). Because the concentration of pollutants in the breathing region is lower than that of the mixing system, the results of this study show that ground displacement ventilation can improve indoor air quality by minimizing the danger of cross-contamination. Hameed et al., (2017), examined indoor air quality (IAQ) and diffuser performance, a numerical and experimental study was conducted on three different types of diffusers (three square directional diffusers, a semicircular diffuser, and one square directional diffuser). In this study, the location of the return air grilles was changed three times, whereby the indoor air quality and the performance of air diffusers of all three types were verified each time the return air grilles were relocated. In all types of diffusers, the speed and temperature were equal. All

experimental tests were carried out inside a room (4m×3.2m×4m) used as an office room. This study concluded that placing the air diffuser and the return air network on the same side wall gives good and acceptable thermal comfort for the room occupants. This was concluded based on the values of the air distribution performance index (66.675%) and the temperature effectiveness (1.824). This study found that the best type of diffuser is the three-square-direction type. Yan et al., (2020), tested air-conditioned offices, and the impacts of personal behavior on the thermal environment. Survey results in the hot summers and cold winters zone of China were used to assess typical occupant behavior. The temperature set point, intermittent operation, and door opening were developed as influencing factors in a theoretical model for maintaining thermic comfort with reduced energy usage. The findings showed that continuously opening doors and windows in air-conditioned rooms will increase the amount of energy required to maintain a comfortable indoor temperature. It was discovered that the average interior set point temperature of (25 ˚C) with the door open at (90˚) was equivalent to the average indoor set point temperature of (22 ˚C) with the door open at (45˚). The relative impacts of the behaviors of the tested occupants were also assessed. Saheb, et al.,(2021), studied thermal comfort and indoor air quality were studied for two individuals seated in an office room with dimensions (3m×2.5m×2.5m). At a distance of (50 cm) from the person's face, the office room is provided with mixed ventilation systems and personal ventilation. These systems feature the ability to vary air flow rates (ATD). The results of experimental tests and results were compared with (CFD) analysis utilizing the (k- ε) model and perturbed data on a thermal dwarf that approximated the human body in a sitting position (RNG). The goal of the experiment was to measure the air speed and temperature in various sections of the room, as well as around the thermal dwarf and in the breathing region. In the numerical analysis, thermal comfort, indoor air quality, and detailed airflow around the occupants were evaluated using (CFD) analysis. The usage of personal ventilation systems has been shown to improve indoor air quality and thermal comfort.

CONCLUSIONS

The present review gives an overview of previous research about ventilation systems based on literature published in refereed Journals. The study reached several conclusions:

1- The performance of ventilation systems varies depending on the different usages of the ventilation system.
2- Indoor air quality in the displacement ventilation system was improved and more saving energy compared with the mixing ventilation system because the concentration of pollution in a breathing zone was lower compared with the mixing system.
3- Air flow around a person (especially in a mixing ventilation system) was moved up more than another position inside quipped zone due to the effect of buoyancy force, which led to improving the air quality for the breathing zone.

4- The ventilation effectiveness should be determined depending on removing pollutants, removing heat, and supplying fresh air.

5- The vertical temperature distribution fields of mixing ventilation depended on the number of heat sources inside the equipped zone.

6- Most previous studies dealt with mixing ventilation did not focus directly on occupant density. Therefore, this field needs more investigation to show the effects of the occupant's density on thermal comfort.

7- In hot and dry conditions, especially in the Middle East, there are not enough extensive studies on the effect of passenger density under mixed ventilation on thermal comfort because most of the previous studies dealt with areas with moderate temperatures.

Fig. 1. Displacement ventilation system, (Awbi H.,2008)

REVIEW OF THE EFFECT OF OCCUPIED DENSITY   **Atheer Hamza Saber**
WITH MIXING VENTILATION ON THERMAL HUMAN   **Alaa Abbas Mahdi**
COMFORT AND INDOOR AIR QUALITY   **Mohammed Wahhab**
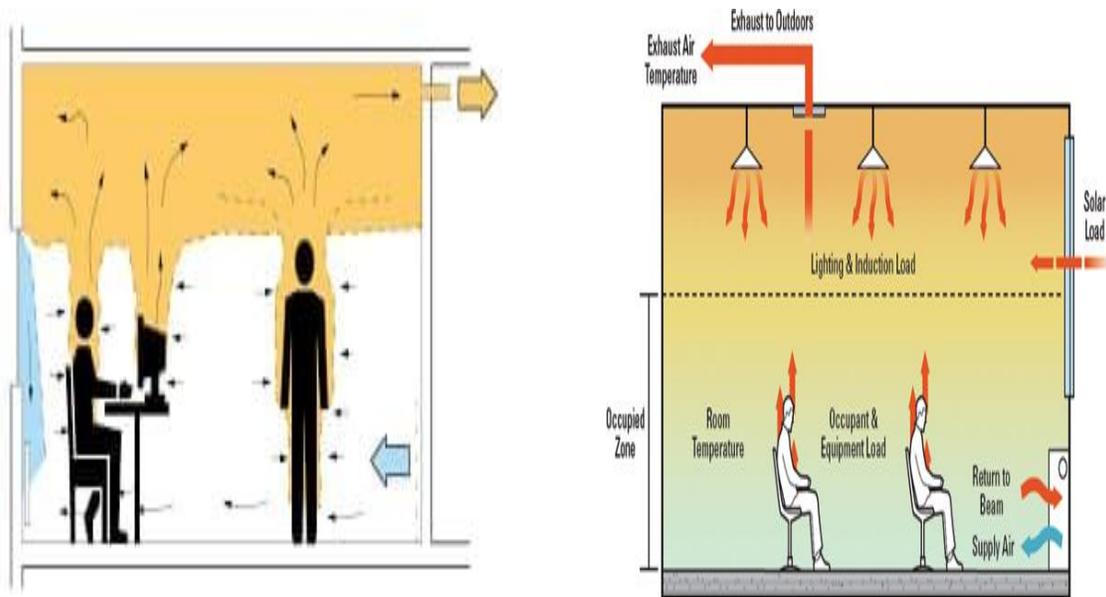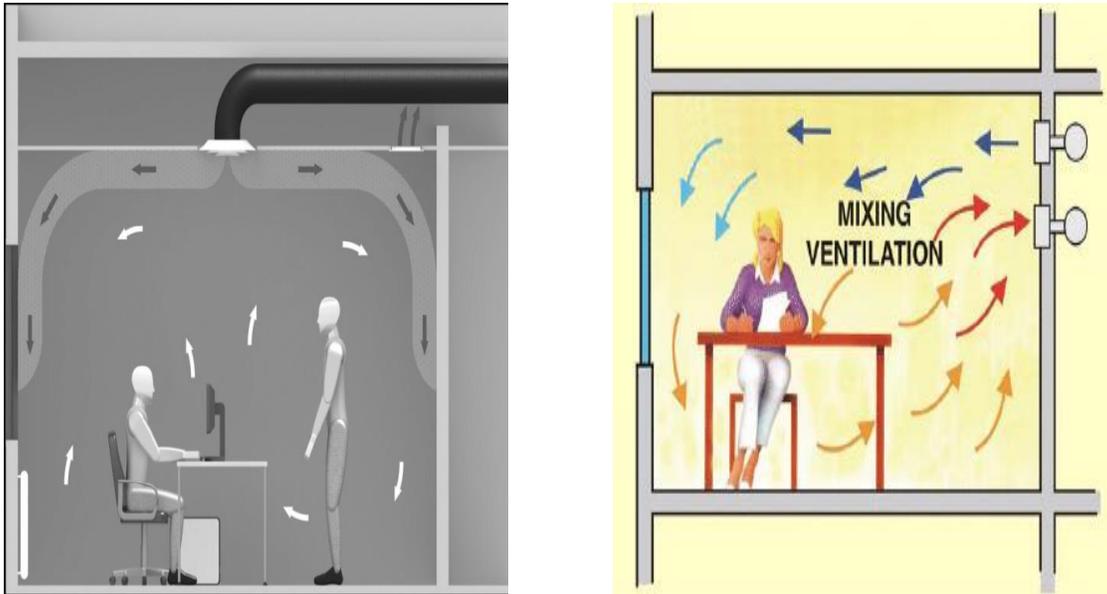
Fig. 2. Mixing ventilation system,(Awbi H.,2007)

Fig. 3. case study by Fong et. al.,2011

Fig. 4. case study by Tomasi , et. al.,2013

a) Linear slot diffuser   b) Round ceiling diffuser

REVIEW OF THE EFFECT OF OCCUPIED DENSITY   **Atheer Hamza Saber**
WITH MIXING VENTILATION ON THERMAL HUMAN   **Alaa Abbas Mahdi**
COMFORT AND INDOOR AIR QUALITY   **Mohammed Wahhab**

c) Louvered face diffuser
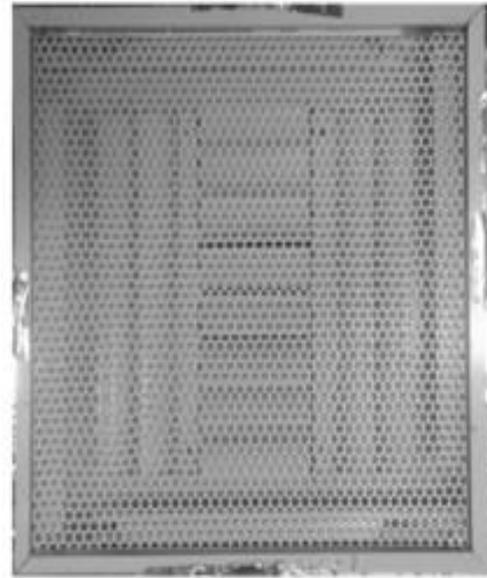
d) Perforated diffuser

Fig. 5. tested diffuser types , studied by Amai and Novoselac ,2016

Fig. 6. case study by Xue, et al.,2020
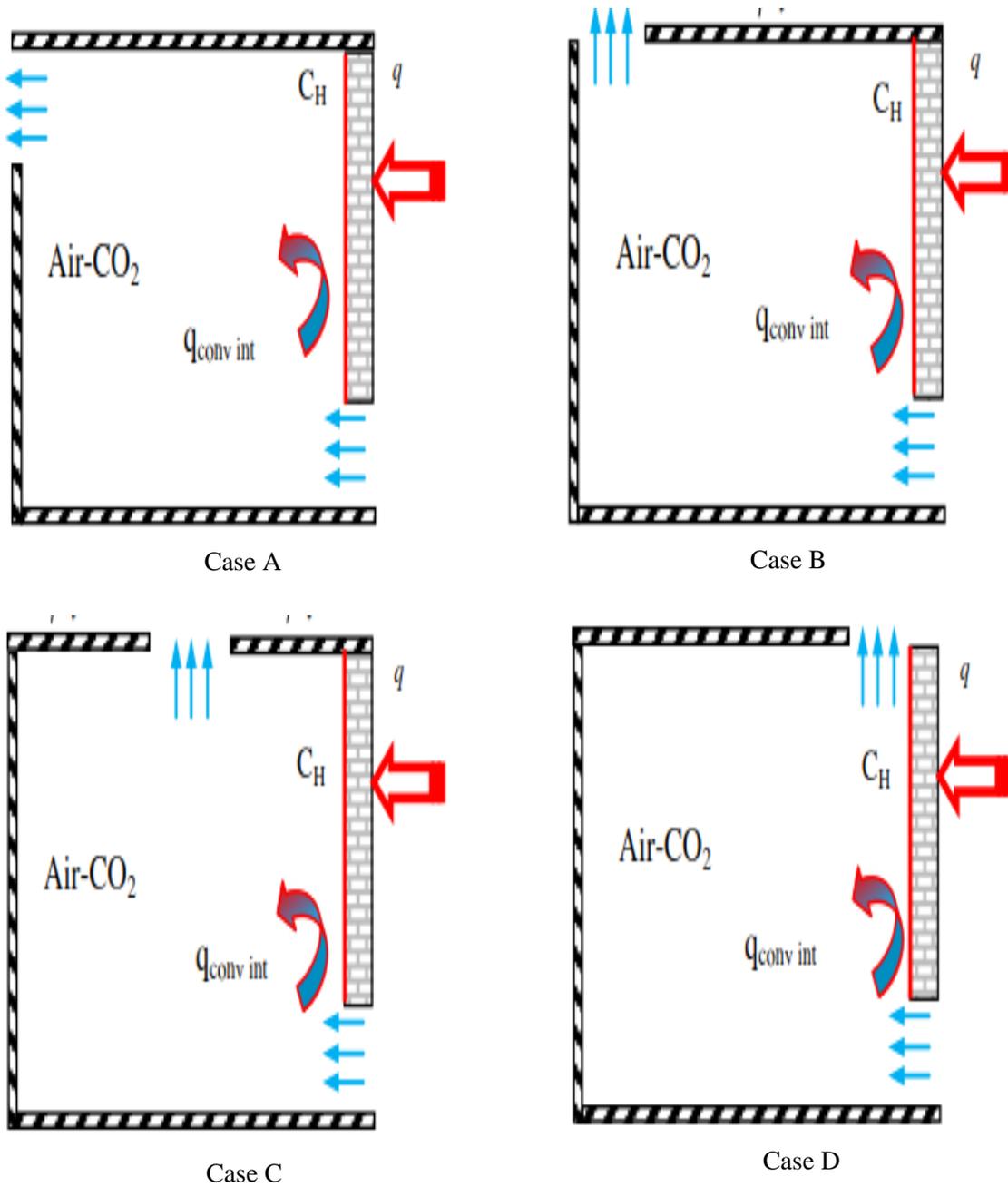
Fig. 7. Tested outlet location , studied by Serrano, et al., 2013
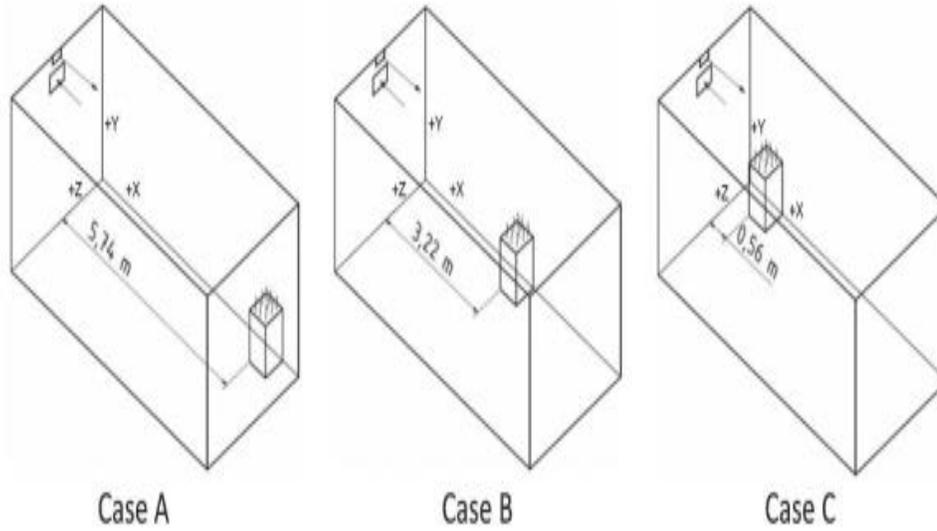
Fig. 8. Case study by Rui , et al. 2016

Mixing ventilation

displacement ventilation
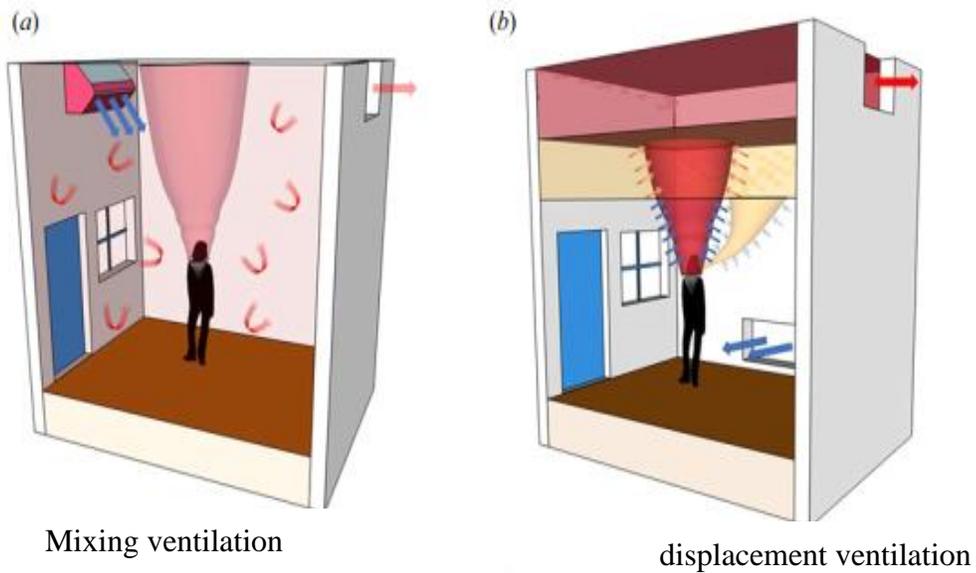
Fig. 9. Case study by Rajesh , et al., 2020
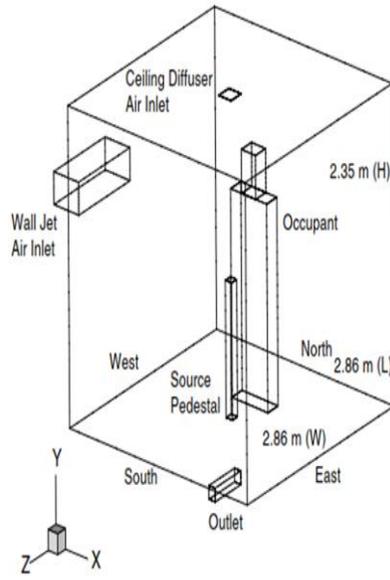
Fig. 10. case study by Lee , et al., 2007

Fig. 11. Case study by Donghyun, et al. ,2010

(a)Displacement ventilation   (b)Mixing ventilation
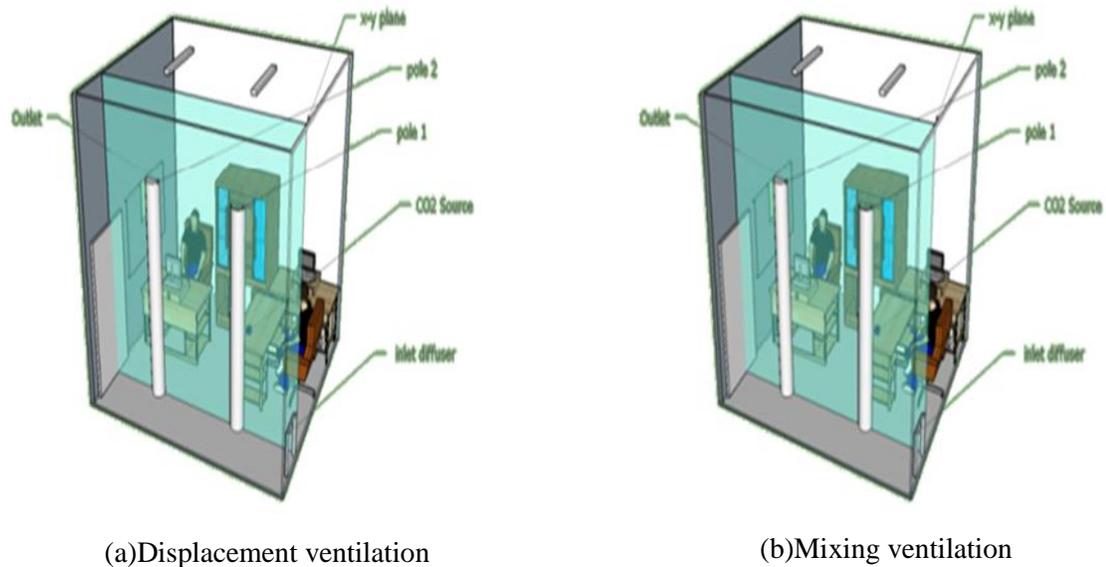
Fig. 12. case study by Alaa , et al. ,2016

REFERENCE

Awbi H. "Ventilation of buildings. London: Taylor and Francis. Second edition; 2003.

Awbi, H. "Ventilation Systems: design and performance", Taylor and Francis. First edition ;2007.

Awbi H. Ventilation of Buildings. Taylor and Francis group. Second edition; 2008.

Ambi, H., & Novoselac, A. Experimental study on air change effectiveness in mixing ventilation. Building and Environment, Vol.109, pp.101-111, 2016.

Abduljabbar Muttair Ahmed, Mukhtar Ahmad and Abdur Rahim, "Effect of size of heated obstruction within room on three dimensional air flow characteristics", American J. of Engineering and Applied Sciences, Vol.3, No. 2, pp.372-379, 2010.

Al-Sanea, S. A., Zedan, M. F., & Al-Harbi, M. B. Effect of supply Reynolds number and room aspect ratio on flow and ceiling heat-transfer coefficient for mixing ventilation. International Journal of Thermal Sciences, Vol.54, pp.6-187, 2012.

Brohus, H., Knudsen, H. N., Nielsen, P. V., Clausen, G., & Fanger, P. O., "Perceived air quality in a displacement ventilated room", Aalborg: Department of Building Technology and Structural Engineering, Nagoya, Japan, 1996.

Bhagat, R. K., Wykes, M. D., Dalziel, S. B., & Linden, P. F. Effects of ventilation on the indoor spread of COVID-19. Journal of Fluid Mechanics, 2020.

Brohus, Henrik, Nielsen, and Peter Vilhelm, "Personal exposure to contaminant sources in a uniform velocity field", Aalborg: Dept. of Building Technology and Structural Engineering. Indoor Environmental Technology, Vol. R9540, No. 53, pp. 155-160, 1995.

Chen H. Experimental and numerical investigations of a ventilation strategy – impinging jet ventilation for an office environment. MSc. Thesis, Linköping University; 2014.

Cho Y, Awbi H, Karimipanah T. Theoretical and experimental investigation of wall confluent jets ventilation and comparison with wall displacement ventilation. Building and Environment; Vol.43, pp.1091–1100, 2008.

Cheng, Z., Guangyu, C., Aganovic, A., & Baizhan, L. Experimental study of the interaction between thermal plumes and human breathing in an undisturbed indoor environment. Energy and Buildings, Vol. 207, No.12, 2020.

Cao, G. Y., Jorma Heikkinen, and Helena Järnström. "Protection of office workers from exposure to aspiratory diseases by a novel ventilation system." Proceedings of indoor air ,2013.

Conceição, E. Z., Lúcio, M. M. J., & Awbi, H. B. Comfort and airflow evaluation in spaces equipped with mixing ventilation and cold radiant floor. In Building Simulation, Vol. 6, No. 1, pp. 51-67, 2013.

Donghyun Rim, and Atila Novoselac, "Ventilation effectiveness as an indicator of occupant exposure to particles from indoor sources", Building and Environment, Vol.45,No.5, pp.1214–1224, 2010.

Fong, M. L., Lin, Z., Fong, K. F., Chow, T. T., & Yao, T.. Evaluation of thermal comfort conditions in a classroom with three ventilation methods. Indoor Air, Vol.21, No. 3, pp.231-239, 2011.

Glenn Reynders, and Dirk Saelens, "Numerical and experimental evaluation of ventilation in laboratories: a case study", Building Physics Section, Department of Civil Engineering, K.U.Leuven, Belgium, Vol. 32,No.2, 2011.

REVIEW OF THE EFFECT OF OCCUPIED DENSITY   Atheer Hamza Saber
WITH MIXING VENTILATION ON THERMAL HUMAN   Alaa Abbas Mahdi
COMFORT AND INDOOR AIR QUALITY   Mohammed Wahhab

Haghighat F. Thermal comfort in housing and thermal environments. sustainable built environment: Vol. 1, 2009.

Krajčík, M., Simone, A., & Olesen, B. W. Air distribution and ventilation effectiveness in an occupied room heated by warm air. Energy and Buildings, Vol.55, No. pp.01-94, 2012.

Loomans M. The measurement and simulation of indoor air flow. PhD. Thesis, University of Eindhoven; 1998.

Lee, E., Khan, J. A., Feigley, C. E., Ahmed, M. R., & Hussey, J. R. An investigation of air inlet types in mixing ventilation. Building and environment, Vol.42, No.3, pp. 1089-1098, 2007.

Müller D, Kandzia C, Kosonen R, Krikor A, Vilhelm P. Mixing Ventilation. Guide on mixing air distribution design REHVA Guidebook. First edition; 2013.

Mjörnell, K., Johansson, D., & Bagge, H. The effect of high occupancy density on IAQ, moisture conditions and energy use in apartments. Energies, Vol.12, No. 23, 2019.

Makhoul, A., K. Ghali, and N. Ghaddar. "Thermal comfort and energy performance of a low-mixing ceiling-mounted personalized ventilator system." Building and Environment, Vol. 60, pp. 126-136,2013.

Mahdi, A. A., & Jasim, Z. H. Experimental and Numerical Study of Air Flow Diffusion and Contaminants Circulation in Room Ventilation Related with Iraqi Climate. International Journal of Mechanical Engineering and Applications, Vol.4, No. 2, pp.24-42, 2016.

Muna Hameed, "experimental and numerical investigation on air flow and temperature distribution under different geometries of displacement ventilation devices in an office room", M.Sc. Thesis, University of Babylon, 2017.

Pitarma, Rui, Miguel Lourenço, and João Ramos. "Improving occupational health by modelling indoor pollutant distribution." Facilities 2016.

Robert B. and Son. Natural and artificial methods of ventilation. London. First edition ,1899.

Ralph Stuart, Ellen Sweet and Aaron Batchelder, "Assessing general ventilation effectiveness in the laboratory", chemical health and safety, Vol. 22, No.3, pp. 2- 7, 2015.

Shan, X., Zhou, J., Chang, V. W. C., & Yang, E. H. Comparing mixing and displacement ventilation in tutorial rooms: Students' thermal comfort, sick building syndromes, and short-term performance. Building and Environment, Vol.102, pp.128-137, 2016.

Shah, Y., Kurelek, J. W., Peterson, S. D., & Yarusevych, S. Experimental investigation of indoor aerosol dispersion and accumulation in the context of COVID-19: Effects of masks and ventilation. Physics of Fluids, Vol.33, No.7, pp.5-8, 2021.

Serrano-Arellano, J., Xamán, J., & Álvarez, G. Optimum ventilation based on the ventilation effectiveness for temperature and CO_2 distribution in ventilated cavities. International Journal of Heat and Mass Transfer, Vol.62, pp.9-21, 2013.

Sun, C., & Zhai, Z. The efficacy of social distance and ventilation effectiveness in preventing COVID-19 transmission. Sustainable cities and society, Vol. 62, pp.3-7, 2020.

Shbeeb A. and Mahdi A. Experimental and numerical investigation of displacement ventilation system with assessment of four turbulence models. Ms.C theses. Babylon University, 2016.

Saheb, Hussien, Alaa Mahdi, and Qusay Al-amir. "a numerical and experimental study of the effect of using personal ventilation system on indoor air quality in office rooms." Frontiers in Heat and Mass Transfer (FHMT) ,2021).

Turiel I. indoor air quality and human health. Taylor and Francis group. First edition; 1985.

Tomasi, R., Krajčík, M., Simone, A., & Olesen, B. W. Experimental evaluation of air distribution in mechanically ventilated residential rooms: Thermal comfort and ventilation effectiveness. Energy and Buildings, Vol.60, pp.28-37, 2013.

Wang, J., Huang, J., Feng, Z., Cao, S. J., & Haghighat, F. Occupant-density-detection based energy efficient ventilation system: Prevention of infection transmission. Energy and Buildings, Vol.240, No.2, pp.5-9, 2021.

Wang, C., Holmberg, S., & Sadrizadeh, S. Impact of door opening on the risk of surgical site infections in an operating room with mixing ventilation. Indoor and Built Environment, Vol.30, No.2, pp.166-179, 2021.

Xue, K., Cao, G., Liu, M., Zhang, Y., Pedersen, C., Mathisen, H. M., ... & Skogås, J. G. Experimental study on the effect of exhaust airflows on the surgical environment in an operating room with mixing ventilation. Journal of Building Engineering, Vol.32, No.12, 2020.

Ye, X., & Lian, Z. Air distribution numerical simulating of isothermal jet with interference parameters in large space. Simulation Modelling Practice and Theory, Vol.13, No.2, pp.39-155, 2005.

REVIEW OF THE EFFECT OF OCCUPIED DENSITY   **Atheer Hamza Saber**
WITH MIXING VENTILATION ON THERMAL HUMAN   **Alaa Abbas Mahdi**
COMFORT AND INDOOR AIR QUALITY   **Mohammed Wahhab**

Younsi, Z., Koufi, L., & Naji, H. Numerical study of the effects of ventilated cavities outlet location on thermal comfort and air quality. International Journal of Numerical Methods for Heat & Fluid Flow, 2019.

Yan, B., Meng, X., Ouyang, J., & Long, E. Typical effects of occupants' behavior on indoor air-conditioned environments in the hot summer and cold winter region of China. Indoor and Built Environment, Vol.30, No. 5, pp.606-620, 2021.

Zhang, Z., & Chen, Q. Experimental measurements and numerical simulations of particle transport and distribution in ventilated rooms. Atmospheric environment, Vol.40, No.18, pp.10-13, 2006.