EVAPORATIVE COOLING FOR OCCUPATIONAL HEALTH IN TRPOICAL CLIMATES

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Abstract: Occupational health is a cross disciplinary area concerned with protecting the health of people engaged in work or employment. If is increasingly becoming a serious concern for industries and companies to safeguard the well-being of their employees. When address the physical hazards under occupation health, provision of thermal comfort is very important, especially to avoid hyperthermia condition which could be a vital issue in tropical climates. Hence, there should be a HVAC system like Evaporative cooling which has best performances in terms of thermal comfort as well as the occupational health. Evaporative cooling is a best alternative for providing thermal comfort environment as it is very much energy efficient and also it could control the spreading of Biological hazards such like bacteria, virus and fungi.

Keywords: Occupational health, thermal comfort, evaporative cooling, physical hazards, biological hazards.

1. Introduction to Occupational Health

Human is the one of the key elements of success of any industry or business because humans are the characters who engage in different stages in different manners to move the industry or the business forward. Human brain power and physical actions are very important to plan and execute the activities or functions in order to achieve the expected targets on time. As the humans have distinctly to engage with built work environment when they accompany with activities, they are called the occupants and these occupants' health condition again will be vital factor to decide the success of particular business. Especially, occupants' health should be censoriously focused in order to have a healthy society in present and future.

The nomenclature and definition of occupational health varies in different countries. According to a very narrow definition, occupational health deals only with deceases or injuries caused by conditions of work that is to say occupational deceases and accidents. According to a boarder definition, on the other hand, occupational health includes preventive medicine and medical care for the workers and their departments. In 1950 joint ILO/WHO (International Labour Organization/World Health Organization) experts declared that the term "Occupational Health" and as they defined, occupational health is the promotion and maintenance of the highest degree of physical, metal and social well-being of workers in all occupations by preventing departures form health, controlling risks and the adaptation of work to people and people to their jobs [4]. In 2007, the World Health Assembly endorsed the WHO Global plan of action on workers' health (GAP) (2008-2017) which is a follow up of the WHO Global Strategy on Occupational Health for all endorsed by the World Health Assembly in 1996 [5]. In this point of view, it is clearer that occupational health is a very important topic which should be paid the attention in nowadays.

2. Common hazards affect to occupational health

There are main four categories of hazards which could affect to occupational health in the work place. Those are Mechanical hazards, Chemical hazards, Physical hazards and Biological hazards.

And also there are further sub elements coming under each common hazard and key physical hazards are noise, vibration and heat stress. Heat stress is described as hyperthermia and it is an elevated body temperature due to failed thermoregulation. Hyperthermia occurs when

the body produces or absorbs more heat than it can dissipate when the elevated body temperatures are sufficiently high and hyperthermia is a medical emergency and requires immediate to prevent disability or death [6].

2.1 Indoor air quality (IAQ)

Indoor air quality is a term referring to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. IAQ can be affected by microbial contaminants (mold, bacteria), gases (including carbon monoxide, radon, VOC compounds, particulates or any other mass or energy stressor that can induce adverse health conditions. Nowadays, indoor air is becoming an increasingly more concerning health hazards than outdoor air quality in work environment of the building are using ventilation to dilute contaminants, filtration and source control [9].

Radon:

Radon is an invisible, radioactive atomic gas that results from radioactive decay of radium. This is a heavy gas and thus will tend to accumulate at the floor level. Radon mitigation method include sealing concrete slab floors, basement foundations, water drainage system or by increasing ventilation.

Volatile Organic Compounds (VOC):

Volatile organic compounds (VOCs) are emitted as gases from solids or liquids. VOCs include a variety of chemicals, some of which may have short and long term adverse health effects. Concentration of many VOC is consistently higher indoors (up to ten times higher) than outdoors. OVCs are emitted by a wide array of products. Examples include, paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copier and printers, correction fluids and carbonless copy papers, graphics and craft materials including glues and adhesives, permanent markers and photographic solutions [9].

Carbon Dioxide (CO_2):

Carbon dioxide (CO_2) is a surrogate for indoor pollutants emitted by humans and correlates with human metabolic activity. Carbon Dioxide at levels that are unusually high indoors may cause occupants to grow drowsy, get headache or function at lower activity levels. Humans are the main indoor source of carbon dioxide. Indoor levels are an indicator of the adequacy of outdoor air ventilation relative to indoor occupant density and metabolic activity. To eliminate most of indoor air quality complaints, total indoor carbon dioxide should be reduced a difference of less than 600ppm (parts per million) above outdoor levels. AHSRAE recommends that carbon dioxide levels not exceed 700ppm above outdoor ambient levels [9].

As specified in an ILO Code of practice, published in 1988, "Health and working conditions in the transfer of technology to developing countries" an importance should be given to the followings, especially when factories are built in tropical countries in order to make sure the prevention of most of physical and biological hazards.

a. The effect of tropical heat on the skin
b. The effect of higher temperature on the rate of absorption of toxic substances
c. Heat stress problem in non-accumulated personal, particularly when the use of personal protective equipment is necessary.
d. Parasitic, bacterial, viral, fungal and other biological hazards should be taken in to consideration.

Further, the same code of practice states that the combined effect of the increased respiratory rate produced by a hot climate, the absorption of chemicals owing to excessive sweating and the altered level of normal bodily functions resulting from work at high temperatures should be taken into the consideration when establishing the requirements of safety and working conditions [3].

3. Performance of evaporative cooling in tropical climate

When consider occupational health requirements for built environment in tropical climate, thermal comfort is an energetic request. Due to the severity of the prevailing conditions in the tropical climates, there are times, however, that comfort can't be achieved by the function of body itself even in a building with high performance passive features. Under such circumstances, it is necessary to provide some assistance, either by hybrid or mechanical means to achieve the desired thermal comfort.

Based on the energy facts, the efforts for optimizing energy consumption must focus indoor thermal loads in the buildings to evacuate by mechanical system like evaporative cooling etc;[1].

As shown in Figure 1, an evaporative cooler basically consists with a pump and a motor drives fan that captures and forces outdoor air through water-soaked pads, filtering and cooling the air before driving into the space of air which should be conditioned. Conventional air conditioning system are based on the re-circulation of the same air in the space and but evaporative coolers have a completely different approach. They move cool air into the space, blowing, blowing it into a central location or the different rooms through a duct system causing indoor hot air evaporative cooler requires the opening of windows and rooms during the operation time [7].

The process of evaporation happens all the time and also it a naturally occurs. Whenever dry air passes over water, some of the water will be absorbed by the air. Following the same principle, evaporative cooling naturally occurs near waterfalls, at rivers, lakes and oceans. The hotter and drier the air, the more water that can be absorbed and therefore, evaporative coolers performs well in tropical climates. This high performance is possible because the temperature and the vapour pressure of the water and the air attempt to equalize. At that stage, liquid water molecules become gas in the dry air and this process uses very much less energy to change the physical state of water. Heat moves from the higher temperature of air to the lower temperature of the water[8].

Several researchers have proven that evaporative cooling is practical solution for comfort in tropical climate [2] &[9] and Arandara K. P. et al (2010) have shown that evaporative cooling become a good candidate for day time in tropical climate. The modern evaporative coolers can give a reasonable drop in temperature as 3^0C to 4^0C with a marginal rise in the humidity ratios. Since, people are generally tolerant to high humidity such 70-75% when the physiological cooling effect is also available, evaporative cooling becomes a very good strategy even for warm humid tropical climate such as that prevail in both wet and dry zones of Sri Lanka.

4. Evaporative cooling function supporting for occupational health

4.1 Existing recommendation for HVAC system

Environmentally sustainable design concepts also include aspects related to the industrial and residential heating, ventilation and air conditioning (HVAC). There should be reasonable provisions of the selected HVAC system to support to maintain Indoor Air Quality levels up to the standards. Demand controlled ventilation would be a one technique which could maintain adequate air quality while reduce energy consumption also. Instead of setting throughput at a fixed air replacement rate, carbon dioxide sensors are used to control the rate dynamically, based on the emission of actual building occupants [9].

One way of quantitatively ensuring the health factors of indoor air is by the effective turnover of interior air by replacement with outside air. In the UK for example, classrooms are required to have 2.5 outdoor air changes per hour. In halls, gyms, dining and physiotherapy spaces, the ventilation should be sufficient to limit carbon dioxide to 1500ppm. In the USA, according to ASHRAE standards, ventilation in classroom is based on the amount of outdoor air per occupant plus the amount of outdoor air per unit of floor area and but not the air changes per hour. Since carbon dioxide indoors comes from occupants and outdoor air, the adequacy of ventilation per occupants is indicated by the concentration indoors minus concentration outdoors.

The use of filters can trap some of the air pollutants. The air filtration should have a minimum efficiency reporting value (MERV) of 13 as determined by ASHRAE 52-2-199. Air filters are used to reduce the amount of dust that reaches the wet coils. Dust can save as food to grow molds on the wet coil and also dust can reduce the efficiency of the coils. So, regular filter maintenance is required to avoid those effects [9].

4.2 Heat stress controlled by Evaporative cooling

To ensure a good health conditions for occupants, it is very much need to maintain the indoor air conditions within the specified comfort zone. When it comes to tropical countries, topic of heat stress or hyperthermia is

becoming a prioritized topic. Therefore, mechanical means applied for air conditioning should perform precisely and if it fails, parameters of the air of the particular space may go out of the comfort zone through upper limits of dry bulb temperature. However, as Arandara K. P. et al (2010) havedemonstrated, evaporative coolers could maintain the temperatures within the zone and occupants are thermally comfort.

4.2 Biological hazards mitigated by Evaporative cooling

Because evaporative cooler is functioning within a high speed fan, it can be regulated with several speed levels. In case of a direct evaporative cooling system observed in a factory in Kegalle district in Sri Lanka, there are five speed levels. Speed 3 to 5 provides significant air flow rate and it will result acceptable ventilation across the space. So, increased ventilation supports to dilute or remove gases such like radon and VOC compounds.

Also, evaporative cooling system is functioning under opened conditions as shown in Figure 2. Therefore, it allows outdoor air to mix with indoor air during the operation. As a result of that, CO_2 concentration is significantly reduced and values are within the standards recommended by ASHRAE. It is further validated by the figures which are relevant to several building spaces functioned with both evaporative coolers and conventional air conditioners in Sri Lanka and readings are given in Table 1.It is very clear that there CO_2 concentration of a space connected to evaporative cooling system at the same time with higher number of occupants is lesser than a space connected to conventional air conditioner even with lesser number of occupants.

The air filters fixed to evaporative cooling unit itself trap the air pollutants which would be in air extracted through wet pad. Filters of an evaporative cooling unit are show in Figure 3. These particular filters leads to extract pollutants free fresh air from outdoor. As the dust level is comparatively high in tropical climate zone, with function of filters, evaporative cooling units are showing the required qualifications to maintain thedust levels within the standards. In addition to that these filters are more durable and could be repetitively used after properly cleaning appropriately.

5. Operational controls for evaporative cooling in occupational health point of view

There are several actions to be taken as operational controls for evaporative cooling in order to further support for occupational health. In the installation stage, the electrical wiring and power supply connections should be properly connected in a water proofed manner. Otherwise, there is a critical safety risk with electricity for maintenance parties. Properly installed electrical earthing system will be added guard the evaporative coolers and people who associate with it.

In case of direct evaporative cooling system, it is very significant to keep the pad in wet condition full time during the operation in order to avoid bad smell formed from cellulose based pad at dry state. Therefore, a continuous water flow to the pad should be confirmed. And also, it is necessary to supply treated water or pollutants free water to cooling units to make sure that there is no foreign bacteria or virus entering to the supply air through evaporation process.

Further, evaporative cooling fan can be mounted with the support of rubber bush and it will reduce the possible vibrations due to rotation of the fan in cooling unit. Therefore, the noise level could be further reduced and maintained within the desired standards.

5. Conclusions

When service engineers design HVAC system for buildings they should make the attention for occupational health as well as the operational cost and energy saving etc; because occupational health is becoming a more important factor for both domestic and industrial type buildings.

Even though conventional air conditioning systems are having best performance in terms of thermal comfort and but those systems are consuming higher energy portion while making significantly negative impacts for occupational health. Under these prevailing conditions, evaporative cooling is a best alternate solution for thermal comfort because it is very much energy efficient with respect to conventional air

conditioning systems. At the same evaporative cooling is having remarkable performance in terms of occupational health especially in tropical climate. Evaporative coolers could manage the indoor CO_2 levels within the ASHRAE standards.

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Figure 1: The Pump and the fan within an evaporative cooling unit

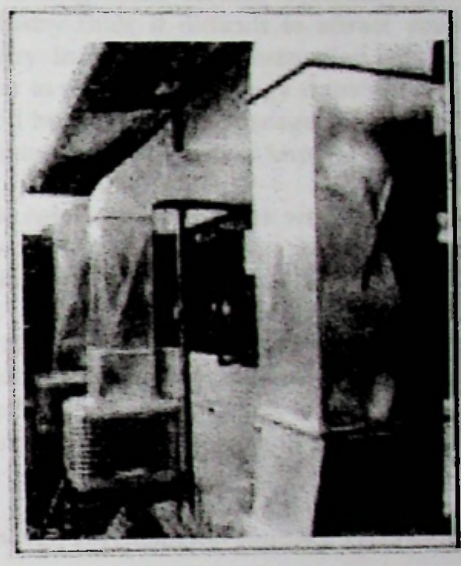

Figure 2: Evaporative cooler are running under non-air tighten condition (Opened windows) (Source:http://www.holcimfoundation.org/Portals/1/docs/Book_MAS_SriLanka.pdf)

Figure 3: Air filter of an evaporative cooling unit

Table 1: Indoor air quality measures – Different HVAC systems

No	Type of HVAC system	Space area (Sq.ft)	No of Occupants	Avg. CO_2 concentration	ASHRAE limit
1	Conventional Air conditioning	256 (16x16)	2	497ppm	700ppm
2	Evaporative cooling	256 (16x16)	2	391ppm	700ppm
3	Evaporative cooling	1,043 (158x66)	300	425ppm	700ppm