

Analysis of Workplace Airflow and Temperature Factors Affecting Occupational Health

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KEYWORDS: Thermal environment, Garments building, Occupational health, Disease, Production area, Productivity.

ABSTRACT

The ready-made garments (RMG) sector has a superior prospect than any other sectors in Bangladesh in terms of employment and foreign currency earnings thereby reduce poverty and making a major role to the national economy. More than 81% of Bangladesh's export earnings come from the readymade garment industry. However, working condition of workers is not pleasant. Moreover, workers suffer various kinds of diseases due to lack of ventilation and unhealthy thermal condition. Workers are more productive in a positive environment. The research analyzed the problem/issue of ventilation and thermal aspects that effects on health. The study will also explore the relationship among and thermal aspects and existing thermal condition. Geographically, this study focuses on the Chittagong, and can be considered as a contribution to understanding ventilation issue of RMG buildings in Bangladesh. However, the findings may be relevant for other cities as well. A range of distinctive questionnaires survey and related environmental data will be collected from garments, workers, from Delmas Apparels (PVT) ltd located at CEPZ, Chittagong, Bangladesh. The study was summarized on the basis of the information provided by the respondents and environmental data using both qualitative and quantitative tools. With quantitative data, the current version of data analysis program, absolute Figures, graphs, charts, maps, diagrams, tables, percentage and statistical tools such as Pearson R Test, Simple linear regression and Multiple regression is applied whereas qualitative will be made use of description, analysis of description and feedback from interview and personal observation. By studying such impact of ventilation and thermal Environment with regard to occupational safety and health, coherent actions and means of mitigation may be recognized. Such steps can be categorized for improving working atmosphere and health condition. RMG Entrepreneurs, Architects, Engineers, and RMG staffs may be tempted to take these factors into consideration while making or working in such typologies of buildings. On the other hand, Policy makers can take decision cited in this study into consideration while making related regulatory policies and framework.

INTRODUCTION

The Bangladesh garment industry is the largest industrial sector of the country. According to the BGMEA, there were 4300-member firms in 2004-05 of which 2275 were woven garment units, 700 were knitting factories, and 525 were producing sweaters; however, 1300 of these units were closed. In addition, there were 560 units which were exclusive members of the Bangladesh Knitwear Exporters and Manufacturers Association (BKMEA). Thus, the total number of active firms producing garments in Bangladesh in 2005 was 3560, of which 47 percent was woven units, 42 percent knit units, and 11 percent producing sweaters. Total employment generated by these enterprises is estimated to be 1.9 million production workers, or 2 million if all employees are included. Later in the year 2008-09 it quickly rose up to 3 million. As new industries expand, the labor force grew with the economy of the country, at the same times the health hazards for those workers present there in various occupational diseases and accidents highly prevailed among the workers. Health is wealth for employees as well as for managers, realizing this; employers provide a large number of health services to their employees. Health protection is a legal requirement too. Safety means freedom from the occurrence or risk of injury or loss. Industrial safety or employee safety to the protection of workers from the danger of industrial accidents According to WHO (1948), "Health is a state of complete physical, mental and social wellbeing and not merely the absence of diseases or infirmity". Occupational health hazard is concerned with health hazard in relation to work environment. The science of occupational health hazards covers a wide field, like work physiology, occupational hygiene, occupational psychology, occupational toxicology etc. (Bohle, 2000).

Moreover, Due to climate change, global air temperatures are expected to rise with 0.2°C per decade over the next century (Intergovernmental Panel on Climate Change IPCC, 2007). Moreover, extreme weather events will be more common in the future. For example, heat waves will be stronger and they will last longer. This is a problem especially in regions with a warm climate and the consequences include increased occurrence of heat stress and other heat-related diseases. Furthermore, human performance of both mental and physical tasks

diminishes at uncomfortably high temperatures. (Bell, 1981). Human performance of both mental and physical tasks diminishes at uncomfortably high temperatures. Human execution of both mental and physical tasks diminishes at uncomfortably high temperatures. Specially, physical labor results in the increase of body heat which later radiates throughout the surrounding atmosphere hence rising the temperature of the working environment.

The aim of this research is to develop comprehensive understanding of relationship between ventilation, thermal condition and existing health condition. Recommendation will be prepared with the help of the study for improvement of thermal environment at the RMG buildings. It is expected that the occupational health standard will be raised after this research and the factors will be taken into consideration while making any RMG industry in Bangladesh, or implemented presently in the already existing RMG buildings.

METHODOLOGY

This research is an initial attempt with the intention to merely discover the subject and consider the possibilities of undertaking a larger research study, which makes it an explorative research with the objective to make tentative conclusions at the end. For this reason, a descriptive research methodology was used for this study. Then field investigation of thermal environment parameters was done to define the present condition of RMG buildings. A questionnaire survey instrument is used to assess the health condition regarding the quality and condition, maintenance, and improvement of existing circumstance throughout the garments industry of Bangladesh. With quantitative data, the current version of data analysis program, absolute Figures, graphs, charts, maps, diagrams, Tables, percentage Statistical tools such as Pearson R test and Simple linear regression tool was selected for characterizing the thermal environment and Occupational health. Finally, a relation is revealed between thermal environment and health problems by applying this model.

Questionnaire surveys are accomplished by a female research assistant. It has been noticed that many of female workers does not respond frequently with presence of a male worker or factory HR/Compliance manager. Regarding this issue the survey is performed in absence of any male workers or factory HR/Compliance manager. Data collector bias was minimized by the researcher's being the only one to administer the questionnaires, and standardizing conditions such as exhibiting similar personal characteristic to all respondents, e.g., friendliness and support. Finally, a relation will be achieved by using statistical tool named "regression" from the data analysis and environmental condition.

LITERATURE REVIEW

Occupational disease is any illness associated to a particular occupation or industry. Such diseases result from a variety of biological, chemical, physical, and psychological factors that are present in the work environment or are otherwise encountered in the course of employment. Occupational medicine is concerned with the effect of all kinds of work on health and the effect of health on a worker's ability and efficiency (Cooper, C.L. and Cartwright, 1994).

Occupational diseases are essentially preventable and can be ascribed to faulty working conditions. The control of occupational health hazards decreases the incidence of work-related diseases and accidents and improves the health and morale of the work force, leading to decreased absenteeism and increased worker efficiency. In most cases the moral and economic benefits far outweigh the costs of eliminating occupational hazards. (Burton, J. and World Health Organization, 2010)

However, with respect to poor indoor environmental quality, there is much harm directly linked to factory workers and owners also.

- a) Absenteeism: In USA Health symptoms and absenteeism result in 5% or less lost salary or wages from time away from work, a value considered normal in work environments (Goetzel 2004).
- b) Lost Productivity: It has been estimated that there may be costs of up to \$2 billion from lost productivity in undetected problem buildings nationwide from the environmental impacts of building deficiencies and energy saving measures on occupant well-being (Woods JE. 1989).
- c) Medical Costs: Where occupants turn to physicians for medical assistance, costs incur to the health care system and to individuals for health insurance policies. It has been estimated that the white-collar work force spends about \$500 million per year for medical assistance to deal with building-related health symptoms (Woods JE. 1989).

There are two categories of human responses to the thermal environment: voluntary or behavioral responses, and involuntary or physiological autonomic responses. Voluntary or behavioral responses generally consist of avoidance or reduction of thermal stress through modification of the body's immediate environment or of

clothing insulation. (Stolwijk, 1977) Physiological responses consist of peripheral vasoconstriction to reduce the body's thermal conductance and increased heat production by involuntarily shivering in the cold, and of peripheral

vasodilatation to increase thermal conductance and secretion of sweat for evaporative cooling in hot environments. Autonomic responses are proportional to changes in internal and mean skin temperatures. Physiological responses also depend on the point in a diurnal cycle, on physical fitness, and on the sex of the individual (Hardy 1961) The human body always generates body heat. Because the body's core must stay within a narrow temperature range, the body nearly always needs to lose this internally generated heat to our environment. The environments' ability to accept that frequent rate of produced heat. To regulate body's heat loss there are three layers between the body core and the environment: a first skin, which is own; a second skin, clothing; and a third skin building (Prek 2005).

Acclimatization is the process in which an individual's organism adjusts to a change in its environment (such as a change in altitude, temperature, humidity,) allowing it to maintain performance across a range of environmental conditions. Acclimatization occurs in a short period of time (hours to weeks), and within the organism's lifetime (Prek 2005). Parameters of the thermal environment that determine/influence the thermal comfort of an individual in that indoor environment can be described according to this Figure

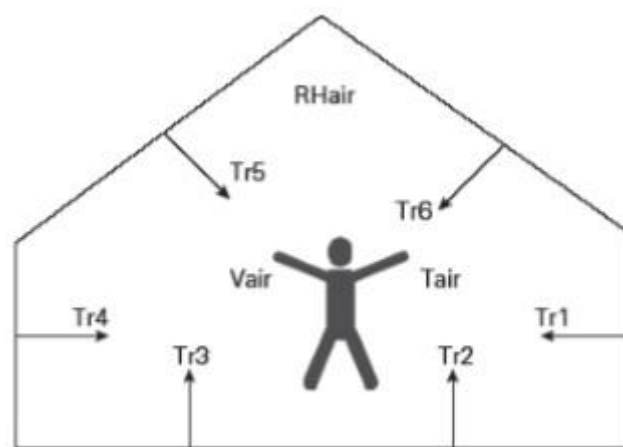


Figure: Thermal parameters of the thermal comfort factor, (Bluyssen 1996)

Tr is the radiant temperature of a surface, RHair is the relative humidity of the indoor air, Vair is the air velocity and Tair is the air temperature. air temperature (Ta) and mean radiation temperature (mean of Tr1 to Tr6).(prek 2005)

The temperature of a system is determined by the average energy of microscopic motions of a single particle in the system per degree of freedom. In simple terms, temperature is a measure of the motion of molecules. Temperature is an objective measurement of how hot or cold an object is. It can be measured with a thermometer or a calorimeter. It is a means of determining the internal energy contained within the system.(De Berg, K.C., 2008)Heat disorders and adverse health effects of people exposed to hot work environments include, in increasing order of severity, irritability, lack of judgment and loss of critical thinking skills, skin disorders (such as heat rashes and hives), heat syncope (fainting), heat cramps, heat exhaustion, and heat stroke (Krake, 2006). Heat syncope happens when blood flow is directed to the skin for cooling, resulting in decreased supply to the brain, and most often strikes workers who stand in place for extended periods in hot environments (Page, 1988). Under the Köppen climate classification the climate of Chittagong is characterized by tropical monsoon climate. The dry and cool season is from November to March; pre-monsoon season is from April to May which is very hot. The sunny and the monsoon season is from June to October, which is warm, cloudy and wet.

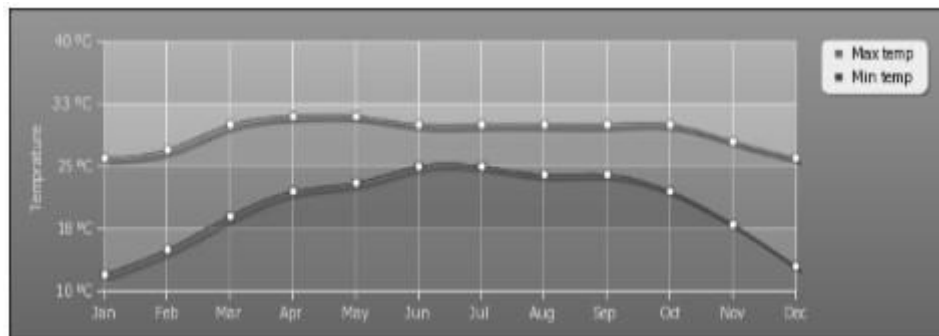


Figure: Average min and max temperature, Chittagong (Data source: B. M. D., 2017)

The Figure shows that on average, the temperatures are always high. A lot of rain (rainy season) falls in the months: April, May, June, July, August, September and October. Chittagong has dry periods in December and January. On average, the warmest month is April. On average, the coolest month is January. July is the wettest month. January is the driest month. Humidity is an important factor in controlling thermal comfort and air quality. Relative humidity is the ratio of water vapor in the air compared to the amount it could hold if it was totally saturated.

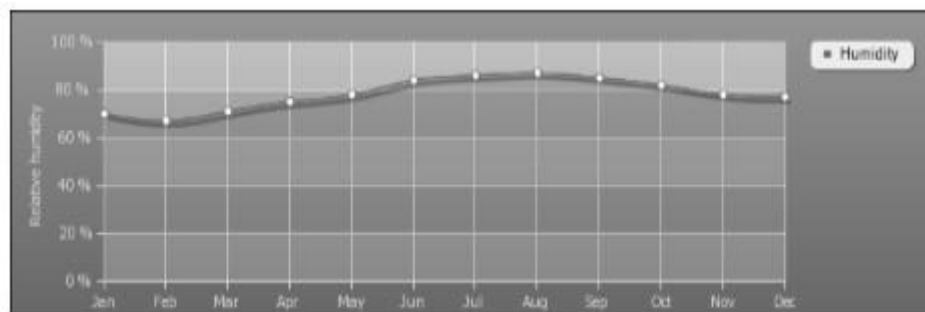


Figure: Average relative humidity in Chittagong (Source : Data source: B. M. D., 2017)

A RH of 30% means that the air contains 30% of the moisture it could hold if it was totally saturated to 100%. As the air temperature increases, so does the air's capacity to hold moisture. If the air temperature rises and its moisture content stays the same, the RH becomes lower. (Fang, 1998). However, Chittagong experiences an average high humidity level entire year especially it is reached more than 80 % during June to October. Relative humidity is consistently highest in the monsoon and comparatively low in the winter seasons in Chittagong

Air speed is caused by air moving from high pressure to low pressure, usually due to changes in temperature. Air speed is measured by its velocity (v , in m/s) and it also affects the evaporation of moisture from the skin, thus the evaporative cooling effect.

When the temperature and humidity is relatively more difficult to modify, indoor air motion (wind) plays an important role by creating direct physiological cooling. Ventilation means supply of fresh air and removes used air and odors (Wyon, D.P., 2004).

Chittagong are characterized by seasonal reversals between summer and winter. During the winter season, a center of high pressure lies over the northwestern part of India.

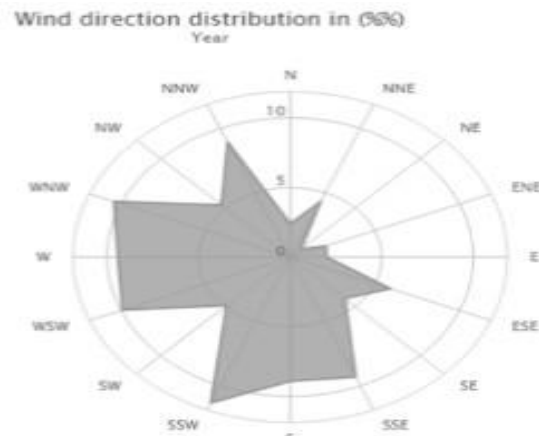


Figure: Yearly Wind direction e of Chittagong (source: www.windfinder.com)

On the other hand, during the summer season, a center of low pressure develops over the west-central part of India because of intense surface heat.

As a result, a stream of warm and moist air from the Bay of Bengal flows toward the above-mentioned low pressure through Bangladesh (similar flow prevails from the Arabian Sea toward India).

It is found that thermal environment of workplace concerned with a variety of physical conditions within work environments modified through architectural, interior design, site planning interventions and local climatic features. This study highlighted a relationship between various occupational health diseases related to the thermal environmental features.

FIELD SURVEY AND ANALYSIS

Delmas Apparels (PVT) LTD is located in Plot No-05 Sector No-02 A Road, No-01, Cepz Chittagong, Bangladesh. **Delmas Apparels (Pvt.) Ltd.** is an exporter from Bangladesh. The company exports Men's Woven Winter Nomad Jacket from Singapore and lading goods at the products and country of origin is Bangladesh.

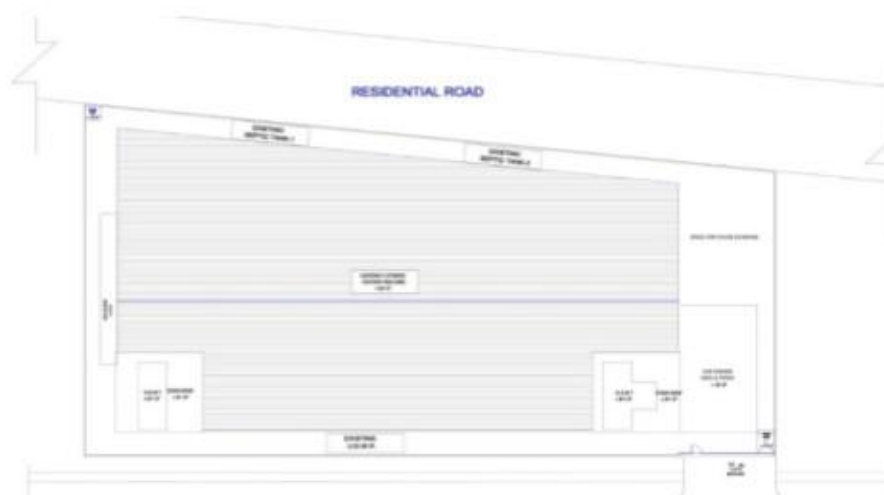


Figure: Site plan of Delmas Apparels (PVT) LTD.

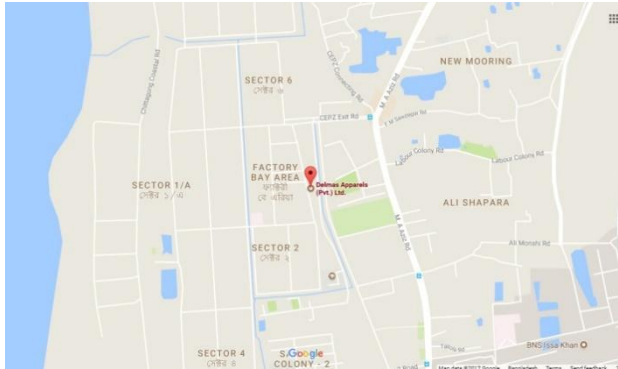


Figure: Google location of Delmas Apparels (PVT) LTD.



Figure : Surrounding area of Delmas Apparels (PVT) LTD.

From the above image it is shown the Building form is trapezoidal in shape but the optimum orientation would be a east-west orientation with the long facade facing towards the equator minimizing the facade areas facing north and south. So, the building receives more solar energy than north-south oriented building. Thus, the indoor temperatures are high and consequently, the thermal comfort is affected.



Figure: Front view of Delmas Apparels (PVT) LTD.



Figure: Facades window orientation.

Large opening in all Facades is negative for the building which increases the heat in warm humid climate. There are not enough sunshade in all façade and windows of all facades are sliding which allows heat in indoor area.



Figure: Ground floor plan

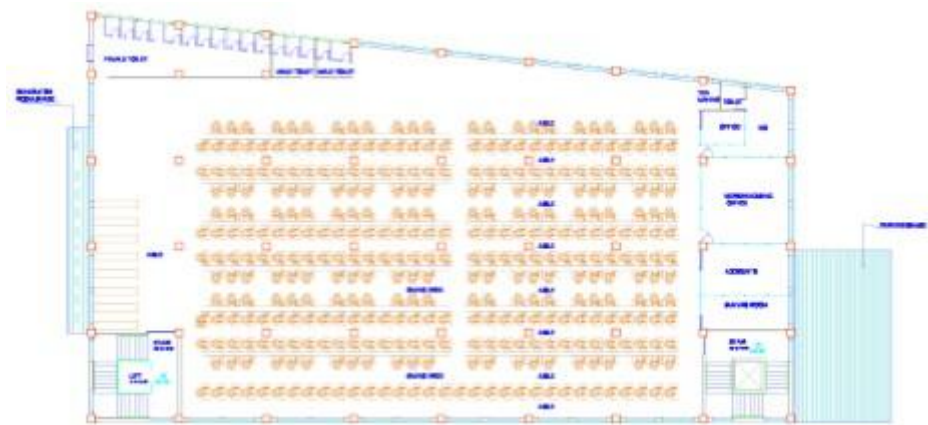


Figure: 1st floor plan

Sliding Windows are placed in all facades of the building which allows 50% of cross ventilation into the indoor area but without shading devices it also increases heat into the indoor area.

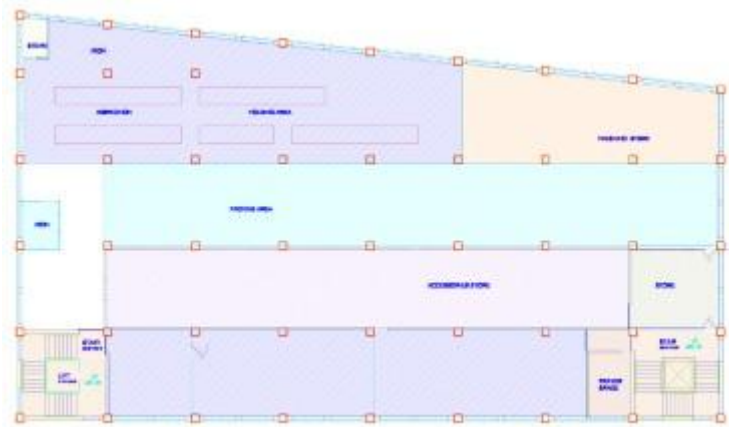


Figure: 2nd floor plan

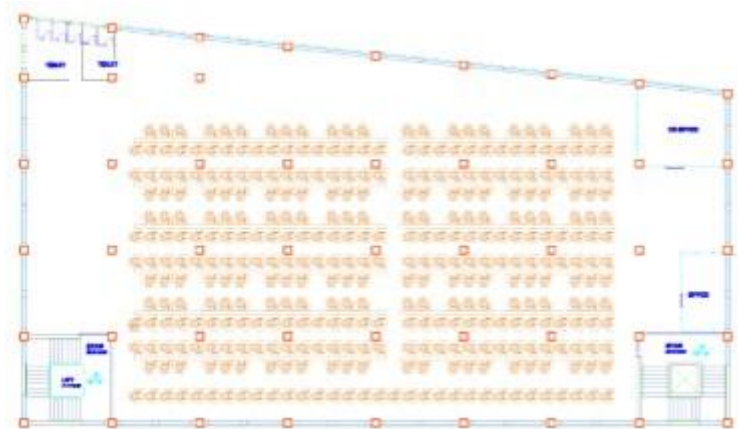


Figure: 3rd floor plan

All the external walls are made of 5inch masonry work and the roof is flat roof about 5inch thick R.C.C slab. The windows are Sliding and have 5 mm thickness clear glass. The Window to floor area ratio (WFR) and Window to wall area ratio (WWR) are calculated.

Table: Window to floor area ratio(WFR)

Window orientation	Wall area	Window area	Window area operating (Sliding window)	Ratio
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North	5524 sft	1419 sft	730 sft(50%)	3.8: 1
South	5529 sft	1285 sft	642 sf t(50%)	4.3 :1
East	9388 sft	2966 sft	1483 sft (50%)	3: 1
West	9527 sft	3007 sft	1503 sft (50%)	3: 1

Table: Window to wall area ratio(WWR)

Area orientation	Total area	Window area	Ratio
Ground Floor	10234.85 sft	1569 sft	6.5: 1
Typical Floor	10015 sft	1175 sft	8.5: 1

Figure: Fan Position

There are a 54 no of ceiling fan (52" radius) is incorporated in production area to achieve thermal comfort.



Figure: Third floor production area



Figure: Opening at southwest wall



Figure: Ceiling fan used for thermal comfort



Figure: Dining Area at top Floor



Figure: Store at top floor



Figure: Sliding window used for ventilation

For the purpose of study, various environmental data such as temperature, humidity, air flow were taken at different zones of the following RMG building at four different times of day.

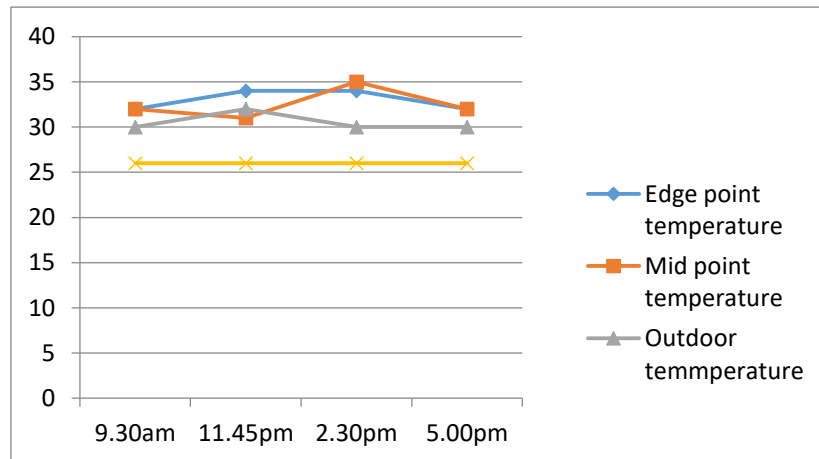


Figure: Comparison between Production space temperature and global temperature.

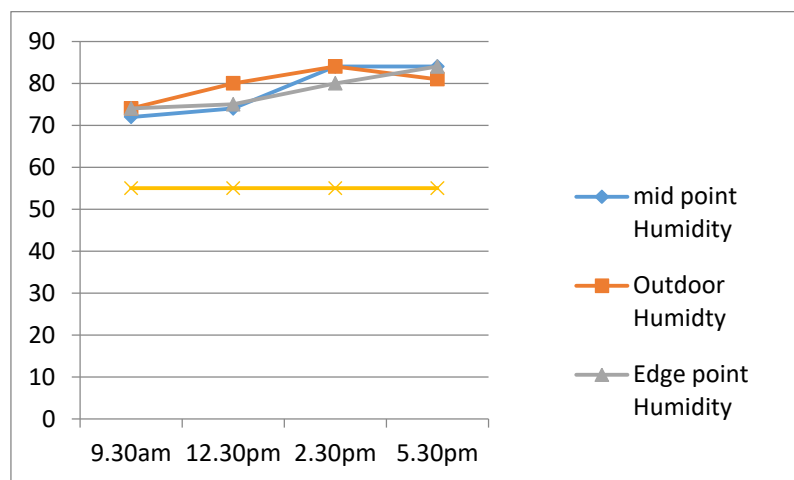


Figure: Comparison between production space Humidity and global Humidity.

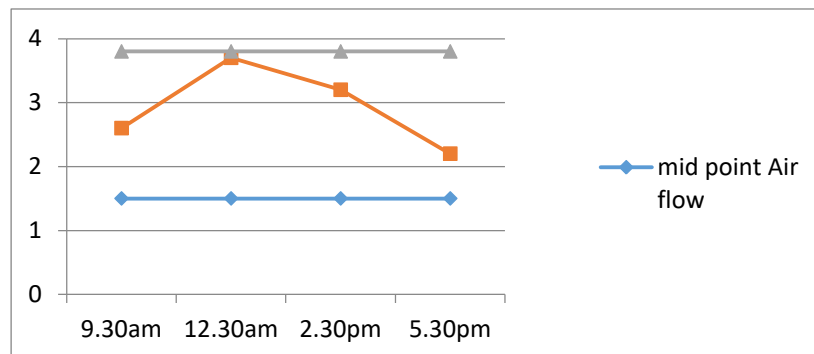


Figure: Comparison between production space Air flow and global airflow.

Questionnaire surveys were conducted during the period of the environmental parameter measurements. The subjective assessments were based on the occupants' health condition and environmental condition of the production spaces of the garments factories. The selection process of the workers as respondents is random. The whole production area divided into 3 different segments and maximum 4 workers were randomly selected from each segment. A total 80 respondents were randomly selected from different floor & different part of production area. During working hour workers are suffered from 33% smoke, 13% from fresh air etc. A good observation also found that workers have 100% fixed working hour.

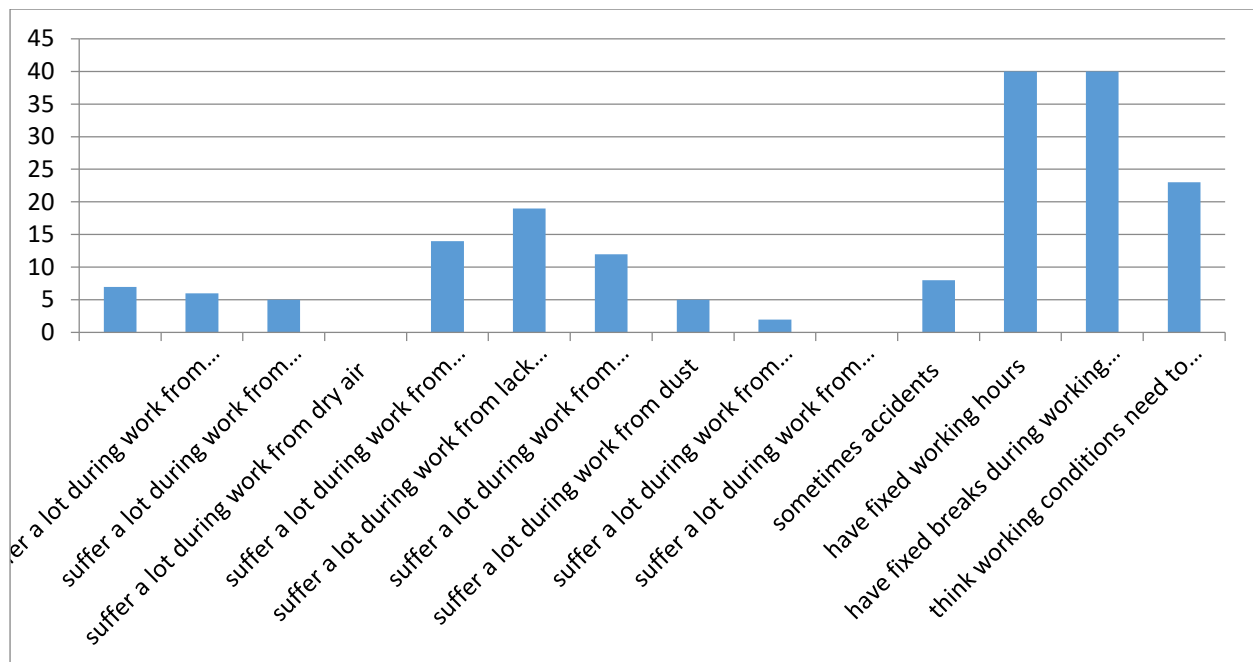


Figure: Workplace factors

The respondents stated that, many of them suffer from various illnesses after starting work in the garment industries Cough, cold, eye-pain, headache, chest-pain, breathing problems are most common health problems among the garment workers as mentioned by the respondents.

This is mainly due to overwork and uncongenial working environment. But the workers are totally deprived of any kind of treatment facility. None of the factories have a regular doctor and none of the respondents received treatment facilities from the garment authorities. Treatment facility is only provided for major accidents while working in the factories. In some cases, the management refuses to give compensation for accidents.

The steel net & sliding type window system helps to gain heat in indoor areas which is very negative in summer months. In the 5th floor, store and a staff canteen is provided in the hall. A huge portion of roof is heat up by the sun at daytime and increases the indoor temperature at 5th floor. To mitigate the excessive heat transmitted from the roof layer of insulation is integrated with the roof material. But this reduces direct heat gain at 4th floor.

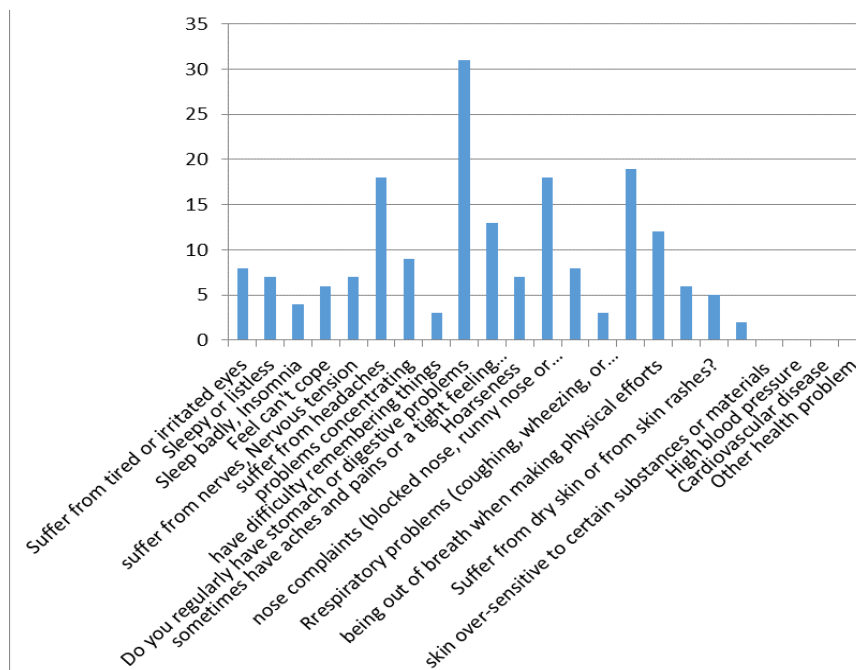


Figure: Pattern of disease

In the bar chart, we can see that workers are suffered a lot from stomach disease in regular basis. They also suffer from Headaches, blocked noses and respiratory problems etc. The respondents stated that, many of them suffer from various illnesses after starting work in the garment industries Cough, cold, eye-pain, headache, chest-pain, breathing problems are most common health problems among the garment workers as mentioned by the respondents.

This is mainly due to overwork and uncongenial working environment. But the workers are totally deprived of any kind of treatment facility. None of the factories have a regular doctor and none of the respondents received treatment facilities from the garment authorities. From the field study survey, a relation is found between temperature, humidity, air flow and number of affected disease is formed to reveal a suggestion.

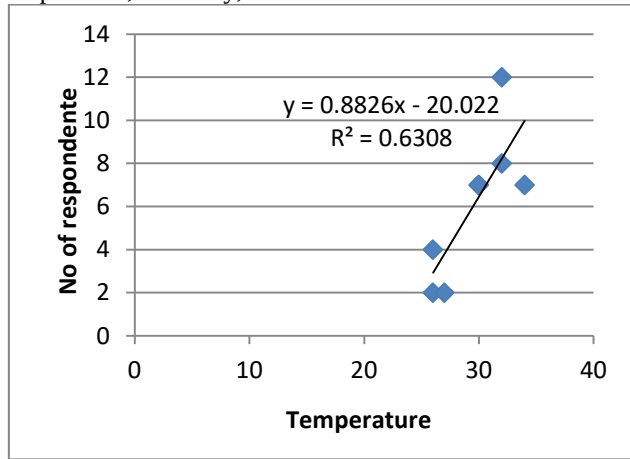


Figure: Scatter Diagram and Linear Regression Line of number of disease as a function of temperature.

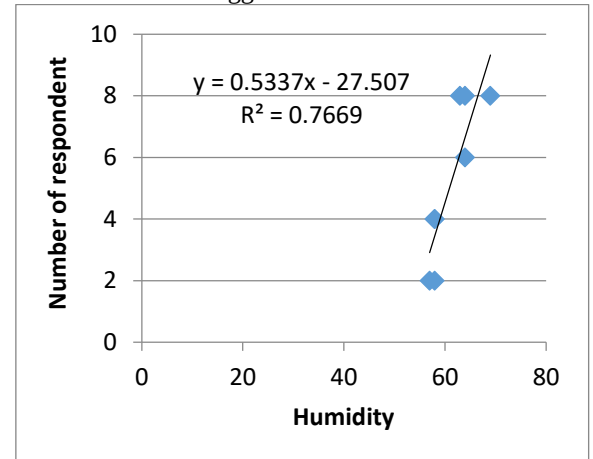


Figure: Scatter Diagram and Linear Regression Line of number of disease as a function of Relative humidity

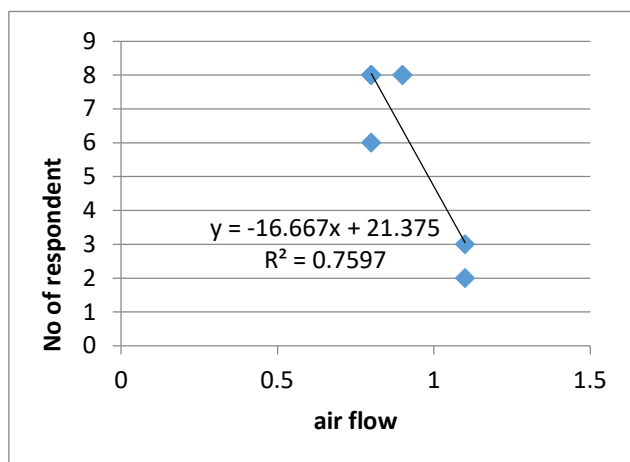


Figure: Scatter Diagram and Linear Regression Line of no of disease as a function of Air flow.

From the above analysis and chart, it is observed that number of diseases is correlated to temperature, humidity and air flow changes. When the temperature and humidity are increased, the number of diseases is also increased gradually but when air flow is increased, the number of diseases is decreased. Staff are working in higher temperature at long westside of 1st & 3rd floor. The health condition of 3rd floor is moderately better because of getting shade from extended steel made dining hall on roof.

RECOMMENDATION

The following recommendations would be drawn based on the findings of the study in order to improve the present health condition of the RMG workers. The following specific as well as some general recommendations are drawn from this research.

- A mapping operation requires a sufficient number of electronic data logging monitors to ensure that the temperature distribution in the space to be mapped is adequately characterized.
- Temperature and relative humidity should be systematically measured and recorded.

- A screening to estimate metabolic heat load should be calculated for each worker who is performing light, moderate, or heavy work. The metabolic heat rate should be determined in order to determine whether the total heat exposure exceeds the applicable RAL or REL.
- Proper work place policy to ensure the basic rights of garments workers.
- Ensure basic occupational health continuing education at factory level for all new and current workers.
- Increasing heat tolerance by instituting a heat acclimatization plan and by increasing physical fitness.
- Adjustment of air flowing Fan/outlets to reduce temperature stratification with regard to production line.
- Upgrading of mechanical systems to improve temperature control and performance such as fan speed and design
- Although thermal environments in the surveyed garments and global data were relatively extreme, change their seat as they are far from the window or near the exhaust fan alternately.
- Design Production space considering solar geometry especially west and south facades.
- Avoid Production space in rooftop floor and under non-insulated roof sheet.
- Wear relaxing dress to avoid unnecessary heat gain.
- Installation of adequate climate controls and operation of them to maintain thermal environment standards especially Incorporate evaporative cooler in case of extreme condition.
- Maintain work/rest cycle by following OSHA standard such as limiting the time the worker spends each day in the hot environment by decreasing exposure time in the hot environment.

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APPENDICES



Figure: Environmental data on 9.30am.



Figure: Environmental data on 11.45am.

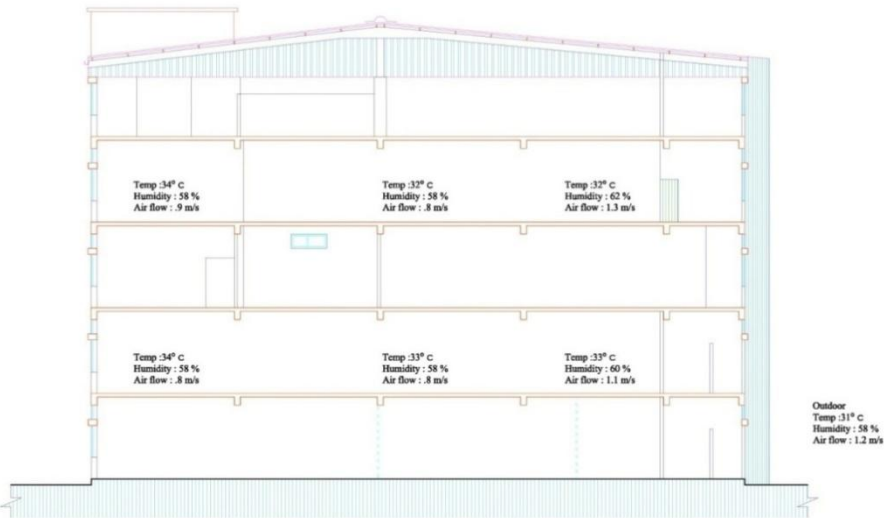


Figure: Environmental data on 2.30pm.



Figure: Environmental data on 5.00 pm