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AIR POLLUTION AND HEAT EXPOSURE STUDY IN THE WORKPLACE IN A GLASS MANUFACTURING UNIT IN INDIA

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Abstract. Air pollution in the workplace environment due to industrial operation have been found to cause serious occupational health hazard. Similarly, heat stress is still most neglected occupational hazard in the tropical and subtropical countries like India. The hot climate augments the heat exposure close to sources like furnaces. In this study an attempt is made to assess air pollution and heat exposure levels to workers in the workplace environment in glass manufacturing unit located in the State of Gujarat, India. Samples for workplace air quality were collected for SPM, SO_2, NO_2 and CO_2 at eight locations. Results of workplace air quality showed 8-hourly average concentrations of SPM: 165–9118 μg/m^3, SO_2: 6–9 μg/m^3 and NO_2: 5–42 μg/m^3, which were below the threshold limit values of workplace environment. The level of CO_2 in workplace air of the plant was found to be in the range 827–2886 μg/m^3, which was below TLV but much higher than the normal concentration for CO_2 in the air (585 mg/m^3). Indoor heat exposure was studied near the furnace and at various locations in an industrial complex for glass manufacturing. The heat exposure parameters including the air temperature, the wet bulb temperature, and the globe parameters were measured. The Wet Bulb Globe Temperature (WBGT), an indicator of heat, exceeded ACGIH TLVs limits most of the time at all the locations in workplace areas. The recommended duration of work and rest have also been estimated.

Keywords: air pollution, glass manufacturing unit, heat stress, Wet Bulb Globe Temperature (WBGT) index, workplace air

1. Introduction

The air pollution problem has become one of the prime concerns for number of environmental, social and aesthetic reasons. The emissions released during various operation in the industry often create adverse impacts by not only threatening the health of the people working nearby but also in their immediate surroundings, which in turn affect their economic and social life. The glass manufacturing unit is considered to be major source of suspended particulate matter (SPM), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2). Its environmental impact cannot be ignored and to some extent is unavoidable as it is evident in some other industries (Goyal *et al.*, 1996; Bhanarkar *et al.*, 2002, 2003; Bonin *et al.*, 1995).

The quantum of the dust particles evolved in the plant area from non-chimney sources is high. These fugitive dusts in workplace have significant importance as they cause serious occupational health hazards. Exposure of SO_2 can cause impairment of respiratory functions, increase airway resistance of lungs. Healthy individuals experience respiratory problems when exposed to high levels of NO_2 for short durations. Epidemiological studies have shown strong association between SPM concentration in ambient air and effect on human respiratory system and mortality (Severr, 1997). High-level concentration of carbon dioxide (CO_2) can cause headache and giddiness, respiratory distress, palpitation of heart and in extreme cases unconsciousness (NIOSH/OSHA, 1981). As the problem of air pollution has become quite important, there is an urgent need for keeping information about the air pollution levels inside the industry. Keeping in view these facts an attempt has been made in the present study to monitor the levels of SPM, SO_2, NO_2 and CO_2 in the workplace environment of glass manufacturing unit.

The heat stress refers to aggregate environmental and physical factors that constitute the total heat load on the body. Heat stress presents main problem to people living in the tropical and sub tropical zones similar to many areas in India. In addition to naturally occurring hot climate, there are many situations in industry and other trades where 'artificial' hot climate may be created by industrial operations. Glass manufacturing is one of such work environment, where some workers are exposed continuously to high temperature. Mild and severe impacts have been reported from both naturally occurring and artificial climates pertaining to heat-related disorders in human body due to limited heat dissipation from the body (Leithead and Lind, 1964; Minard, 1966; Muchler, 1991). However, limited information is available regarding the combined impact of climate as well as industrial heat exposure. Therefore, in addition to pollution monitoring, heat exposure study is also carried out near the furnace and at various locations in a glass manufacturing unit.

2. Manufacturing Process

A case study of glass manufacturing unit located in Gujarat State in India is presented in this article. The maximum temperature in the Gujarat State range from 32–43 °C. The unit manufactures amber colored bottles and Borosilicate vials with a total capacity of 238 tonnes per day (TPD) in four different units of 15, 18, 75 and 130 TPD capacities. Glass bottle manufacturing consists of bottle preparation from raw materials, melting, annealing, inspection and packaging. The flow chart of the manufacturing process in use in the unit studied is presented in Figure 1. The operation, which involves sources of fugitive air pollution and heat levels and the possibility of exposure to workers have also been indicated in the figure. In the process of glass making first the raw material in the required ratio is mixed in the batch house, which goes to furnace where gobs are formed. The furnace

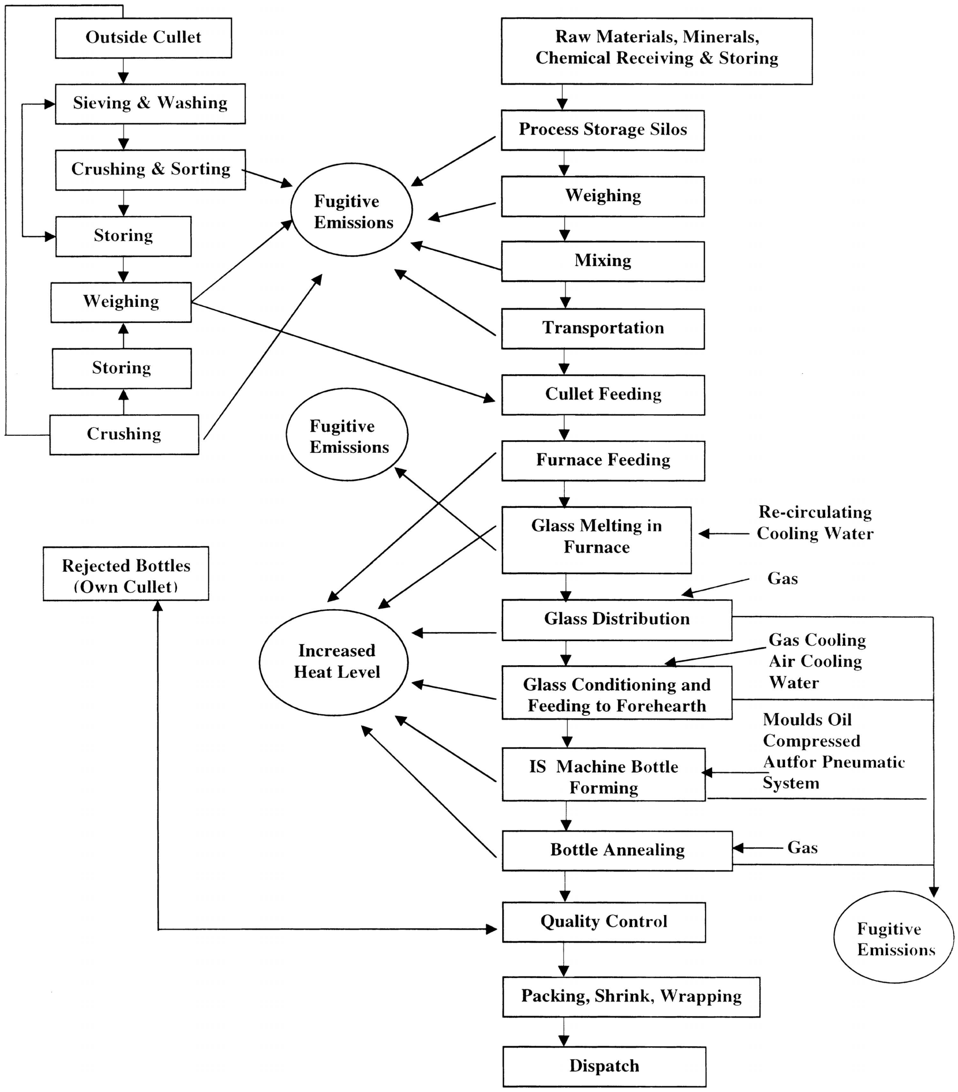

Figure 1. Flow chart of glass manufacturing process.

presents a dominant source of radiant heat. The temperature is very high around the furnaces and the individual section (IS) machines, where final products are formed. Throughout the furnace section, molten glass is maintained at a temperature of 1590 °C at all points. Molten glass passes through a throat to moulds, where the temperature is maintained at about 1300 °C. During formation, the temperatures of IS machines area maintained at around 800–900 °C. In the annealing section, where a temperature range of about 300 °C is maintained, glass gains strength. After finishing, it is sorted by quality control department and then packed.

3. Methodology

The workplace air quality was monitored inside the plant area to establish the existing workplace air quality status, which include the impact of operations of plant. Sampling stations were identified on the basis of the site survey to get entire coverage of surroundings. Meteorological parameters such as wind speed and direction were considered in locating the sampling stations. To obtain the representative data in a year, samples were collected at eight sampling stations on 12 occasions, once every month in a year. Sampling were carried out throughout the year with a view to assess the combined effect of workplace and atmospheric heat. Samples for SPM, SO_2, NO_2 and CO_2 were collected on 8-hourly basis. For measurement of SPM and gaseous pollutants samples were collected using high volume samplers. Collected samples were then analyzed by standard methods for computation of concentrations of SO_2, NO_2 and CO_2 (Katz, 1977).

Heat stress study was carried out near the different operations in glass manufacturing unit. The locations for the measurements of indoor heat exposure study were carefully selected so that the data acquired would be meaningful in terms of heat exchange between man and the environment. The heat stress on the workers depends on the four environmental factors, namely, air temperature, humidity, mean temperature of the surroundings and the air movement. Several indexes for assessing the heat stress have been defined. The Wet Bulb Globe Temperature (WBGT) index, intended originally as a simple expression of the heat stress, proved to be very successful in its monitoring and in minimizing heat causalities. Consequently it has been adopted as the most acceptable index for heat stress (Muchler, 1991; AIHA, 1973; NIOSH, 1973, 1986; Olsen and Madsen, 1998; ACGIH, 1999). Therefore, the heat exposure parameters including the air temperature, the wet bulb temperature, and the globe temperature (GT) were measured at all the selected locations in glass manufacturing unit. Heat stress index (WBGT) were estimated by using following equations:
WBGT at locations, indoors and outdoors, with no solar load is defined as

$$\mathrm{WBGT} = 0.7\mathrm{WB} + 0.3\mathrm{GT}$$

Where, WB is wet bulb temperature and GT is the globe thermometer temperature. At locations outdoors with solar gradation load, WBGT is

$$\mathrm{WBGT} = 0.78\mathrm{WB} + 0.2\mathrm{GT} + 0.1\mathrm{DB}$$

Where, DB is the dry bulb temperature.

The total heat load is estimated by taking into account the heat produced by the body as well as the environment. Workload category is determined by averaging the metabolic rates for the tasks and then ranking them. Light work is categorized as up to 200 Kcal/h, moderate work in the range of 200–350 Kcal/h and heavy work in the range of 350–500 Kcal/h. In glass manufacturing unit under study, the workers near the furnace and bottle making area required to move around the area with moderate lifting and pushing. According to American Conference for Governmental Industrial Hygienists (ACGIH) classification, this type of workload may be considered as moderate category. The workload of the workers in these locations has been assessed as prescribed by ACGIH (ACGIH, 1999). Based on the WBGT and workload, rest periods for workers in these areas have been assessed.

4. Results and Discussion

Workplace air quality status with reference to SPM, SO_2, NO_2 and CO_2 monitored at eight locations is presented in Table I. The results of workplace air quality showed that the 8-hourly average concentration of SPM ranged between 165–9118 $\mu g/m^3$. The levels of SO_2 and NO_2 in workplace air of the study area were found to be 6–9 $\mu g/m^3$ and 5–42 $\mu g/m^3$, respectively. The concentrations of all these parameters were found to be below the threshold limit values (TLVs) for workplace environment (NIOSH/OSHA, 1986). Although the concentrations of SPM were within the limit but combination of low concentrations of SO_2, NO_2 and SPM can have impact on human health, plants, animals, materials exceeded the specified workplace standards as given in Table I (Barker and Tinsey, 1992). Further, the levels of CO_2 were found to be below TLV, but much higher than the normal concentration of 325 ppm or 585 mg/m^3 of CO_2 present in the ambient air. At most of the stations levels of CO_2 was very high indicating poor ventilation in the workplace.

TABLE I
Workplace air quality in glass manufacturing unit

	Concentration (ug/m^3)			
Location	SPM (10 mg/m^3)$^+$	SO_2 (5 mg/m^3)$^\#$	NO_2 (6 mg/m^3)$^\#$	CO_2 (8849.5 mg/m^3)$^\#$
W1	9118	6	36	1938
W2	5741	9	31	2197
W3	4750	6	5	2886
W4	647	6	13	953
W5	1691	8	17	5
W6	165	6	42	10
W7	203	6	17	977
W8	978	6	5	827

*Values in the parenthesis are TLVs (8-hourly average).
$^+$World Bank Environment, Health and Safety Guidelines.
$^\#$OSHA standards.
All these values are average of 12 measurements.

TABLE II
Heat exposure parameters in a glass manufacturing unit

SI	Locations	Temperature (°C) WB	DB	GT	WBGT	Predominant work type*	WBGT TLV continuos work (°C)
15 TPD							
1.	Furnace	36.0	46.0	46.0	39.0	Moderate	26.7
2.	IS machine	29.0	39.0	42.0	32.9	Moderate	26.7
3.	Charger	34.0	45.0	43.0	36.7	Light	30
18 TPD							
4.	Furnace	31.0	46.0	50.0	36.7	Moderate	26.7
5.	IS machine	36.0	45.0	47.0	39.3	Moderate	26.7
6.	Charger	34.0	40.0	44.0	37.0	Light	30
75 TPD							
7.	Furnace	35.0	46.0	48.0	38.9	Moderate	26.7
8.	IS machine	34.0	37.0	49.0	38.5	Moderate	26.7
9.	Charger	33.0	45.0	47.0	37.2	Light	30
130 TPD							
7.	Furnace	33.0	45.0	47.0	37.2	Moderate	26.7
8.	IS machine	34.0	37.0	49.0	38.5	Moderate	26.7
9.	Charger	33.0	45.0	47.0	37.2	Light	30
Around the Unit							
13.	Maintenance room	33.0	36.0	46.0	36.7	Light	30
14.	Compressor room	31.8	38.0	42.0	33.7	Light	30
15.	Chemical laboratory	28.0	34.0	30.0	28.6	Light	30
16.	Open yard	26.0	30.0	42.2	30.0	Light	30

*Moderate: 200–300 Kcal/h; Light: 150–180 Kcal/h.

The results of heat exposure study at different locations are presented in Table II. The global thermometer temperature observed at all the locations except at the chemical laboratory was higher than the dry air temperature indicating that all the surfaces which surrounds the globe were warmer than air, thereby radiating heat to atmosphere. It is observed that WBGT peaked to 40 °C against the ACGIH TLVs of 26.7 °C for moderate work in front of IS machine whereas a temperature of 37 °C was observed as against ACGIH TLVs of 30 °C for low work near maintenance room. The results presented in the Table II indicate that the level of WBGT at different locations in the manufacturing section exceeds TLV limits. The levels of radiant heat are very high in the workplace areas surrounding IS machines and furnaces which may have health implications. The WBGT observations calls for a rapid action to control the problem of heat stress in the manufacturing section of glass manufacturing unit. On the basis of the observed values of WBGT and workload, workers require 25% work and 75% rest; and 50% work and 50% rest each hour working near IS machines and in the front of furnaces, respectively. At other places 75% work and 25% rest each hour is desirable.

5. Conclusion

The air quality measurements taken at various locations in workplace areas inside the glass-manufacturing unit indicate that the fugitive concentrations of pollutants such as SPM, SO_2 and NO_2 were within industrial threshold limits of standards. However, high values of SPM are observed at most of stations in workplace environment. Therefore, it is imperative that appropriate management measures must be taken to minimize fugitive emissions of dust. Level of CO_2 in the workplace air of glass manufacturing unit area are found to be much higher than the normal concentration of CO_2 in the air. Ventilation system in the workplace needs improvement to reduce the levels of CO_2.

Heat exposure presents a human factors problem in the various operation of the factory studied that may have negative impact on workers efficiencies and consequently, on the production of the unit. The radiant heat from industrial operations in the IS machines and furnaces of glass manufacturing units adds more heat load to environment of this unit. The workers in the area are subjected to unacceptable levels of heat, which may have severe health implications. It may be concluded that to avoid heat stress problem in glass manufacturing unit the recommendation of ACGIH should be taken, as the indicative of stress areas and workers should be under constant medical supervision. This would enhance the efficiency of workers resulting in reduced reject quantity, improved production and hence increased profits.

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References

ACGIH: 1999, *Threshold Limit Values (TLV) and Biological Exposure Indices 1999*, American Conference of Governmental Industrial Hygienists, Cincinnati, OH, U.S.A.

AIHA: 1973, *The Stress of Hot Environment*, American Industrial Hygiene Association, Fairfax, VA, U.S.A.

Baker, J. R. and Tinsey, D. T.: 1992, *Air Pollution Effects on Bio-diversity*, Catlong, Card, Number 91–47171, U.S. Library of Congress, U.S.A.

Bhanarkar, A. D., Gajghate, D. G. and Hasan, M. Z.: 2002, 'Assessment of air pollution from small scale industry', *Environ. Monit. Assess.* **80**, 125–133.

Bhanarkar, A. D., Gajghate, D. G. and Hasan, M. Z.: 2003, 'Assessment of impacts of fossil fuel based power plant', *Int. J. Environ. Studies* **60**, 225–233.

Bonin, M. P., Flower, W. L., Renzi, R. F. and Peng, L. W.: 1995, 'Size and concentration measurement of particles produced in commercial chromium coating process', *J. Air Waste Manag. Assoc.* **45**, 902–907.

Goyal, P., Singh, M. P. and Gulati, A.: 1996, 'The long-term average concentration of sulphur dioxide at Taj Mahal due to Mathura Refinery', *Atmos. Environ.* **30**, 1159–1166.

Katz M.: 1977, *'Air Quality Sampling & Methodology*', 2nd edn. APHA press, INC. Spring field, VA.

Leithead, C. S. and Lind, A. R.: 1964, *'Heat Stress and Heat Discharge*', Davis Co., Philadelphia, PA.

Minard, D.: 1966, 'Evaluation of Heat Stress Under Working Conditions', in: *Proceedings of the VI Conference of the Industrial Council for Tropical Health*, Harvard School of Public Health, Boston, MA.

Muchler, J. E.:1991, 'Heat Stress: Its Effects. Measurements and Control', in: C. D. Clayton and F. E. Clayton (eds), *Patty's Industrial Hygiene and Toxicology, Vol. 1-A*, 4th edn., Wiley, New York, NY, U.S.A.

NIOSH: 1973, *The Industrial Environment: Its Evaluation and Control*, National Institute of Occupational Safety and Health, Cincinnati, OH, U.S.A.

NIOSH/OSHA: 1981, *Occupational Health Guidelines for Chemical Hazardous*, National Institute of Occupational Safety and Health. Cincinnati, OH, U.S.A.

NIOSH/OSHA: 1986, *Occupational Exposure of Hot Environments: Revised Criteria*, Pub. No. 86–113, National Institute of Occupational Safety and Health. DHHS (NIOSH), Cincinnati, OH, U.S.A.

Olsen, W. and Madsen, T. L.: 1998, *Measurements of Physical Parameters of the Thermal Environment*, Heat Stress Indices, EEC Symposium, 25–26 October, Luxmbourg.

Severr, V.: 1997, 'Ambient particles and health: Lines that divide', *J. Air Waste Manag. Assoc.* **47**, 551–571.