Proposal Procedure toDesign AnOptimum Ventilation System For Chemical Laboratory

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ABSTRACT: This paper aims to provide a proposal for design of an optimum ventilation system for: Good and safe environment,Comfortable workplace for laboratories occupants and Ensure the health of the surrounding environment while minimizing the energy consumption. Concentration level of materials in laboratory is analyzed in correlation with air exchange rate, toxicity and area of laboratory.
Keyword: laboratory ventilation, air changes per hour, PEL.

I.   INTRODUCTION

The laboratory ventilation system is designed to correct the laboratory environment.

All types of laboratories (chemical, biology, and microbiology) may generate pollution by harmful chemical gases and vapors. Particulates and biological agents, this pollution is processing by a correct ventilation system to remove this hazardous substance.

Proper ventilation of laboratory settings is required to promote and maintain laboratory safety and protection to life and property. Items such as fume containment, worker safety, and proper cleanliness through pressure relationships, filtration and air changes per hour (ACH), point of fume capture, temperature, and relative humidity requirements are elements necessary to design the ventilation system depending on the laboratory type.

The requirements[6] listed below illustrate some of the basic health and safety design features required for new and remodeled laboratories. Variations from these guidelines require approval from the Environmental Health & Safety Department (EH&S):

Building Requirements :

professional designer type and quantities of chemicals material would be uses to determine the final design environmental permits

laboratory design considerations

A process that integrates key decision makers (e.g., health and safety, users, facility operators) into the design team should be usedThe laboratory shall be completely separated from outside areas (i.e., shall be bound by four walls and a roof or ceiling).Design of the laboratory and adjacent support spaces shall incorporate adequate additional facilities for the purpose of storage and/or the consumption of food, drinks, tobacco products, and the application of cosmetics.

Mechanical climate control should be provided as needed

Laboratories should be designed with adequate workstation space, e.g., computers for instruments or data entryLaboratory benches' standard depths are 30 inches for a wall bench, and 66 inches for an island bench. Bench lengths usually allow for 72 inches of free counter space per laboratory worker, in addition to the counter space allotted for equipment.

Deskwork areas in laboratories shall be separate from areas where hazardous materials are used. Specifically, fume-hood openings shall not be located opposite desk-type work areas.Workstations in the laboratory need to accommodate computer monitors, keyboards, and work holders, and should have height adjustable work surfaces to minimize injuries from repetitive-motion stressEnsure that casework has no vibration/ movement or loading limitations, is not seismic sensitive,

interacts with laboratory equipment, is ergonomically designed, and is responsive to ADA concerns Floor loading should be no more than 100–125 pounds/in2. Heavy support columns should not be placed in open laboratory areas, but should be incorporated into lab benches, if possible.

Avoid wet sprinklers in ductwork; avoid non-fireproof material in interstitial spacesLocate eyewash/safety shower near door. Do not include a floor drain for the showerWhere hazardous, biohazardous, or radioactive materials are used, each laboratory shall contain a sink for hand washing. The sink drain shall be connected either to a retention tank or building plumbing.The lab bench shall be resistant to the chemical actions of chemicals and disinfectants

Design easy to clean

The walls will be nonporous and painted with a durable, impervious finish in such a manner to facilitate decontamination. High-gloss paint is recommendedPorts should be provided for obtaining samples of effluent from building laboratory drains. Vented cabinets with electrical receptacles and sound insulation should be provided for the placement of individual vacuum pumps, where their use is anticipated. A one- to two-inch hole for the vacuum line hose from the cabinet to the benchtop shall be provided. Laboratory areas should be well lit to avoid spills and other accidents that could result in contamination buildup

Previous Work done

(O. A. Seppänen, etl; 1999), He reported that for CO_2[7], the ventilation leads relative risks of 1.5–2 for respiratory illnesses and 1.1–6 for sick building syndrome symptoms for low compared to high low ventilation rates.

(MingangJin, FarhadMemarzadeh , Kisup Lee, and Qingyan Chen),are reported that for Experimental Study of Ventilation Performance in Laboratories with Chemical Spills[5], This experimental study investigated the ventilation performance under different ventilation rates in a chemistry laboratory mock-up. This investigation also studied the ventilation performance with and without the use of bench hood exhausts.

(Robert C. Klein , Cathleen King & Paula Castagna)[8] ,Controlling Formaldehyde Exposures in an Academic Gross Anatomy Laboratory, This report describes efforts over a more than a 15-year period to improve air quality and reduce exposures to formaldehyde during anatomical dissections at the Yale University School of Medicine, by installation of the ventilated tables.

II.   METHODOLOGY:

Proper ventilation in laboratories depend on knowing and measuring several units of measurement like humidity , air speed and pressure ratio within the laboratory and other rates of potential to reach perfect ventilation. This proposal was based on the rate of change air inside the laboratory and its ability to dilute the concentration of the materials to PEL. Analysis is carried for the concentration of the vapors in normal condition and when accident of spillage occurred .the results are compared to the PEL concentration. The experiment is carried out for laboratories of 100m^{3}volume with an area of 1m^2 of spill chemical, with assumption of air velocity of .2 *m/s*. In the table below a list of selected materials most commonly used in university laboratories based on previous survey made by rated by severity to slightly hazardous (2) ,hazardous (3) and extremely hazardous (4).

Liquid	Health Hazard	PEL ppm
Acetic acid	2	15
Formaldehyde	4	2
Xylene	3	5
Nitric acid	4	4
Ethanol	2	1000

The calculations are based on heat-mass transfer analogy applied to steady state conditions of a parallel flow over smooth liquid surface, at uniform liquid and air temperature. The mass flow rate (*kg / s*) from convective evaporation was determined by equation:

$m_{v=} h_m A_v (\rho_{v,s} - \rho_{v,\infty})$ (1)

Where $h_m(m/s)$ is the average mass transfer coefficient. Av (m^2) is the area of mass transfer, $\rho v,s (kg/m^3)$ is the vapor density at liquid-air interface and $\rho v,\infty$ the vapor density in the free stream of air. $\rho v,\infty$ may be considered negligible in respect to surface conditions and by approximating the vapor as perfect gas, equation (1) can be expressed as:

$m_{v=} h_m A_{v\frac{p_{v,s}}{RT}}$ (2)

Where $P_{v,s}$ (N/m^2) is the vapor pressure at liquid –air interface, R is the specific gas constant in $(J/Kg.K)$ and Tis the air temperature in (K).
The mass transfer coefficient was evaluated from heat and mass transfer analogy [4]

$$h_m = sh\left(\frac{D_V}{L}\right) \quad\quad (3)$$

Where *Sh*is the Sherwood number, $D v$ (m^2/s) is the diffusion coefficient of vapor into air, and L $(m)$the characteristic length of the mass transfer surface.
In all the applications analyzed below, a parallel flow over a flat plate was approximated. In all the cases, the flow resulted to be laminar *(Re = VL /ν <5×10^5)*, where V is the free stream air velocity, and ν the kinematic viscosity. Sherwood number was evaluated by equation (4)
$Sh= 0.664Re^{1/2}Sc^{1/3}$ $(0.6 <Sc <50$ (4)

Schmidt number $(SC = ν /D_v)$ was calculated using $D v$ values from CRC Handbook[1]
Volumetric concentration $C_{v100}(ppm)$ was calculated

$$C_{v_{100}} = \frac{\left(\frac{m_v}{\rho_{v,s}}\right)}{Q_{100}} \times 10^6 \quad\quad (5)$$

Where Q_{100} $(m^3/s)$is the air exchange rate in the 100 m^3 volume.
Concentration level and adjusted air changes per hour in laboratory volumes L V other than 100 $m3$ can be evaluated as

$C_{vL} = C_{v_{100}} \frac{V_L}{100}$ (6)

$ACH = \frac{100}{V_L} \times ACH_{100}$ (7)
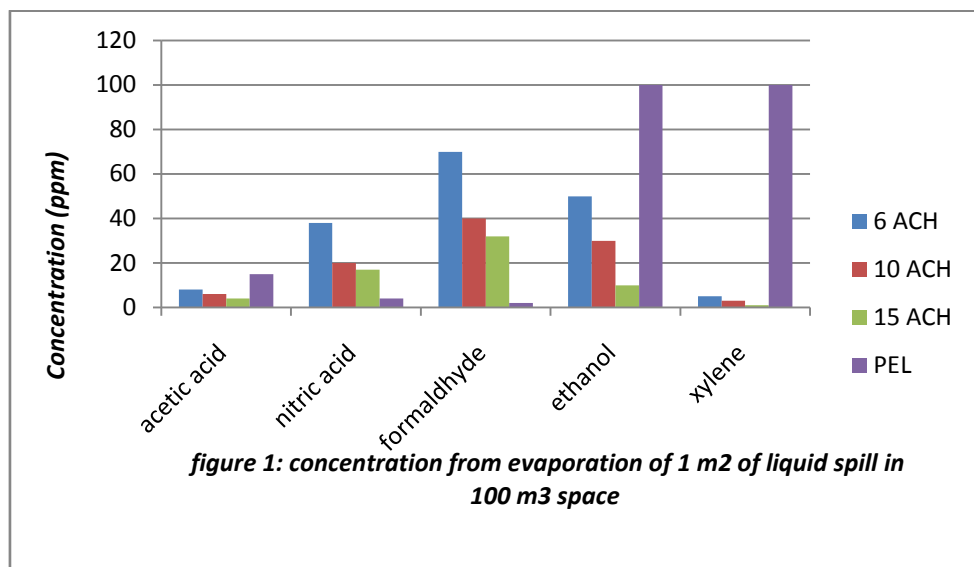
III.   RESULT
Health Hazard Analysis:

figure 1: concentration from evaporation of 1 m2 of liquid spill in 100 m3 space

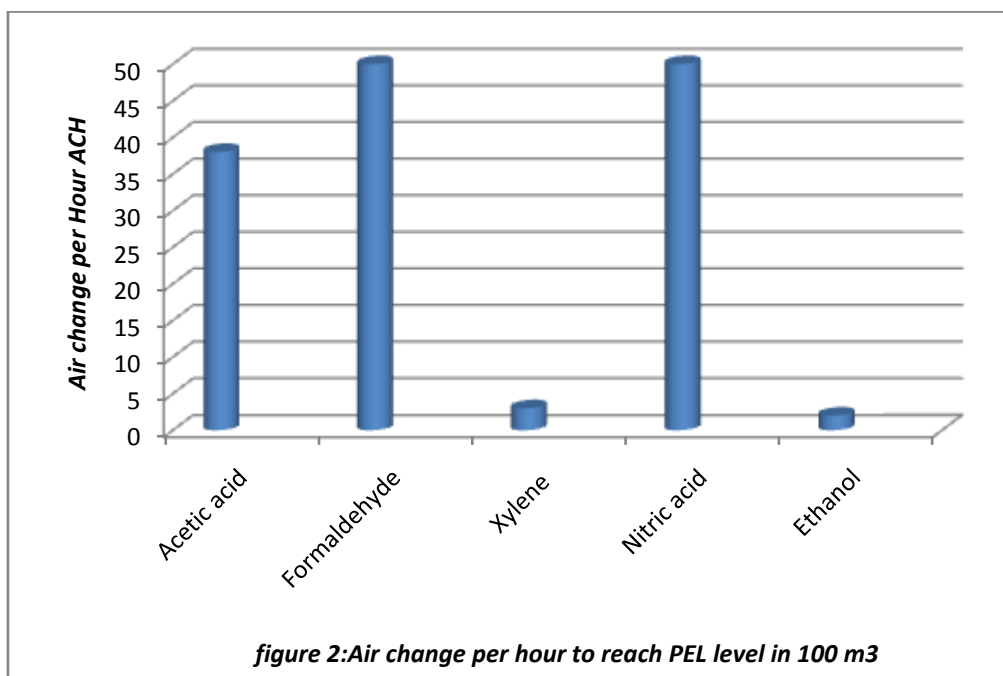**figure 2:Air change per hour to reach PEL level in 100 m3**

Figure 1:shows the concentration of five substances used frequently in laboratory   at 6, 10 and 15 air changes per hour, resulted from evaporation of a 1 $m2$ spill in 100 $m3$ laboratory spaces. The concentrations are compared with PEL concentrations. The results show that extremely hazardous chemicals, with PEL level of 5 or less, evaporate at a rate that substantially exceeds the permissible level for short time exposure, even diluted in 15 ACH air flow. The substances less hazardous appear diluted to safe concentrations.

Figure 2 :shows the number of air changes per hour required to bring the concentration of the evaporated liquid to the PEL limit. It could be noticed that that moderate and low hazardous substances can be safely diluted in air flow rates below 6 ACH.

IV.   CONCLUSION

Through theoretical calculations of the concentrates of materials within the laboratory, based on mass transfer analogy assuming a constant air velocity.2 m/s, we have got a high dilute for slightly hazardous material affinity to PEL, whereas the extremely hazardous substance are still in high in concentrations above the allowable. If any additional ventilation like exhaust and central air condition unit   was added inside the laboratory during experiments so that we increase the rate of air change and air velocity inside the laboratory to more than .2 m/s, we obtain to the affinity optimum ventilation inside the laboratory.

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