Evaluation of Indoor Air Quality (IAQ) in Various Hospitals

I. INTRODUCTION

Indoor Air Quality (IAQ) affects person’s health, comfort and ability to work as they may experience headache, dizziness, nausea, tiredness, lack of concentration and eye/nose/throat irritation. IAQ variables include temperature, humidity, lack of outside air (poor ventilation), mold from water damage, or exposure to other chemicals (Indoor air quality, n.d.). Other parameters may aggravate the effects of IAQ problems such as noise, lighting, ergonomic and job-related psychosocial stressors. In fact, according to Worker Safety In Your Hospital -Occupational Safety and Health Administration of United States Department of Labor, hospital is one of the most hazardous place to work, more hazardous than construction and manufacturing industry.

In this 21st Century, hospital itself is a multifaceted organization with numerous stakeholders and departments where diagnosis and treatment of patients, education and training of medical staff and research are taking place. In this regard, the challenge of each hospital is to have a safe and healthy indoor air quality (IAQ) as there are patients, visitors, medical and non-medical personnel who are exposed to disease-causing microorganisms and predisposed to hospital-acquired (nosocomial) infections (HAI).

Hospital IAQ encompasses not just the health and comfort, but also the well-being and productivity of healthcare workers. All patients who sought treatment in hospital have a 5% chance of developing HAI (O’Neal C., 2000). Yet, medical and non-medical personnel even have a higher risk of being infected as they are constantly exposed. In the Philippines, high HAI prevalence rates from all wards and ICUs were observed (Baja, n.d.). However, it is reported by Lawrence Berkeley National Laboratory that 0.5% to 5% increase in productivity resulted from improved IAQ totalling to $20 billion to $200 billion.

Assessing the IAQ through Work Environment Measurement (WEM) in the hospital would result in the protection of workers’ safety and health, and their ability to work efficiently. At the same time, would ward off the high cost of workplace injuries and illnesses, and lost work days. Also, having the baseline is the first step towards developing IAQ management program for the healthcare workers.

Objective of the Study

The study aims to evaluate the IAQ conditions of different hospitals and to recommend action for improving the working conditions. Specifically, it aims to determine the hazard exposure of hospital workers and the ventilation conditions. Further assessment included some physical hazards.
Significance of the Study

Hospital workers who are at risk of acquiring occupational diseases and injuries due to potential workplace environmental factors will benefit from this study.

Assessment focused on airborne contaminants and physical factors such as general and local exhaust ventilation, illumination, temperature, relative air humidity and others factors that can augment IAQ problems. At the same time, this will quantify the indoor exposure of hospital workers in their work environment. Appropriate control measures shall be recommended to improve the workplace conditions. Furthermore, this study can be an input in developing IAQ management program for healthcare workers in the hospital which can facilitate the identification, control and prevention of IAQ problems.

Statement of the Problem

Hospital activities have the most number of workers on Human Health and Social Work Sector totalling to 102,720 employees based on the 2013 Annual Survey of Philippine Statistics Authority. According to Occupational Safety and Health Standards, Department of Labor and Employment (OSHS, DOLE) Rule 1077.03 (2), the employer shall carry out the working environment in indoor or other workplaces where hazardous work is performed for the safety and health of the worker.

This number of employees is potentially exposed to hospital indoor environment and are at risk of acquiring occupational diseases and injuries. Considering that the medical and non-medical personnel are the front liners in the hospital work setting, thus, it is necessary to assess their exposure to potential IAQ conditions.
II. REVIEW OF RELATED LITERATURE

In the study conducted by Emmanuel S. Baja on Indoor Air Quality, Airborne Infection and Ventilation in Philippine General Hospital (PGH), the key results showed that:

1) There were high concentrations of particulate matter and heavy metals such as manganese, iron and zinc.
2) Prevalence of Hospital-Acquired Infection (HAI) between wards and Intensive Care Units (ICUs) was not significant.
3) However, prevalence of HAI from all wards and ICUs was high, particularly in the Pediatric Ward (40%).
4) Those who are immune-compromised, patients with 2 or more devices/tubes inserted, and those who are advised to stay longer in the hospital are at risk of HAI.
5) Air Exchange per Hour (ACH) gathered in Neonatal ICU (NICU) and Central NICU did not meet the acceptable range set by World Health Organization.

It concluded that TB and other communicable / infectious diseases could be transmitted due to poor ventilation system; heavy metals detected are carcinogenic and hazardous to health which also could augment PM-induced diseases; overcrowded ICUs and Wards may intensify HAI. Additionally, the study recommended to have a scientific board that can develop guidelines for the number of patients in wards and ICUs, for setting building standards for new hospitals with natural ventilation and/or mechanically ventilated ICUs (Baja, n.d.).

According to the two-year study period conducted by Dr. Jubert P. Benedicto and Dr. Ma. Teresa Benedicto entitled “Incidence of Active Tuberculosis Among Health Workers with Latent Tuberculosis Infection in Tertiary Hospital Setting”, 84.87% had Latent TB Infection (LTBI), and 22.73% of those who were non-reactive at baseline had LTBI using Tuberculin Skin Testing. Those Healthcare Workers (HCWs) who were always with the patient like nurses and nursing attendants had a higher risk as compared to medical residents. The study also found out that there was no significant association of having LTBI with variables such as tenure and age. Also, only 1.4% had developed active TB. It was concluded that LTBI is prevalent among HCWs, however the incidence of developing active TB is low. In this regard, the study recommended to look at the screening and employment policies and implement infection control strategies in tertiary hospitals (Benedicto & Benedicto, 2012).

Azizpour et al. (2013) have examined the thermal comfort and indoor air evaluation of hospital patient ward in one of the Malaysian hospitals namely Universiti Kambangsaan Malaysia Medical Center (UKMMC). This is a large scale hospital with a 240,000 m² built up area, comprised of three (3) blocks – teaching, clinical and residential blocks. This study was conducted in the 6th floor of clinical block. The measured variables were temperature, air velocity, relative humidity, Carbon dioxide (CO₂), Carbon monoxide (CO), Total Volatile Organic Components (TVOCs), formaldehyde and respirable particles. Results showed that parameter for thermal comfort met the standards. However, some indoor air pollutants such as CO₂ and formaldehyde exceeded the recommended standards of ASHRAE and
Malaysia. It is suggested to increase ventilation rate and supply of fresh air to improve indoor air condition.

According to OSHA Technical Manual - Indoor Air Quality Investigation, most of the employees’ complaints were caused by cigarette smoke, low-level contaminants, poor air circulation, thermal gradient, humidity, job pressures, lighting, work-station design and noise. Also, their complaints were subjective and nonspecific where it cease to exist when they are away from work like headache, dizziness, nausea, tiredness, lack of concentration, eye/nose/throat irritation. The National Institute for Occupational Safety and Health (NIOSH) had approximately 500 investigations for the last ten (10) years. They found that the main sources of IAQ problems were:

- Inadequate ventilation 52%
- Contamination from inside building 16%
- Contamination from outside building 10%
- Microbial contamination 5%
- Contamination from building fabric 4%
- Unknown sources 13%

Noise level in the NICU of PGH has also been studied by Dr. Estrellita Villanueva-Uy and Dr. Theresa de Jesus-Pattugalan in 2002. The key results showed sources of noise level ranging from 55 to 81 dB(A), continuous and episodic, and sources were oxygen monitoring devices, ventilators, infusion pumps, crying of babies, closing of incubator’s door/drawers/ports, and conversations. The Sound and the Expert Review Panel and Center for the Physical and Developmental Environment of the High Risk Infant recommended permissible noise criteria as follows: the overall continuous noise in any bed space or patient care are shall not exceed an hourly averaged sound level of 50 dB(A), maximum of 70 dB(A), all A-weighted, slow response scale. It recommended to have a provision for noise measurement, control and abatement to achieve the recommended permissible noise level (Pattugalan, 2002).

Generally, the sources of noise in the NICU were incubators, ventilators, alarm signals, suctioning devices and portable x-ray machine which are all important to the survival of low birth weight and pre-term neonates. Another contributory noise factors were the everyday NICU activities like opening and closing the incubators’ portholes, placing the medical charts and other items on top of the canopy, discussing medical cases and therapeutic procedures, general staff activities, and visitor traffic. Noisy NICU increased the stress level of the neonates. The American Academy of Pediatrics (AAP) Committee on Environmental Health recommends continuous noise monitoring and the sound level should not exceed 45 dB(A). An environmental survey of the NICU showed that: a) door opening and closing every 2.2 minutes contributed 11 dB(A), b) noise coming from unattended oximetry alarm added 7.5 dB(A), c) transferring furniture or any heavy items and conversing exam protocols increased the sound level to 14.2 dB(A). A total of 32.7 dB(A) has been added to basic noise produced by incubators. In this regard, a quiet hour has been introduced for every last hour of each shift. Results showed that aside from quieter
environment, lesser infants were crying and most of them were in deep or light sleep which is essential for their recovery (Focus on NICU, 2005).

III. METHODOLOGY

A. Data Profiling:

Data gathering covered the results of the WEM conducted by the Occupational Safety and Health Center, DOLE in different hospitals from 2002 to 2014. A total of nine (9) hospitals - four (4) government and five (5) private hospitals were included in this study with a bed count of 25 – 1600 and hospital category from 1 to 3A.

Each hospital has different set of IAQ parameters. It must be noted that the considered WEM sampling point was the workarea worst case scenario as judged by the Industrial Hygienists during the measurement. All data from the WEM reports were collected and treated as research data.

The data is grouped into the following:

1. Chemical Hazards in the Hospital Indoor Air (dust, organic solvents, toxic gases and inorganic chemicals such as formaldehyde and sulfuric acid)
2. Physical Hazards in the Hospital Indoor Environment (Temperature, humidity, illumination and noise)
3. Ventilation Conditions (general ventilation and local exhaust ventilation such as the evaluation of fume hood)

B. Evaluation of Data

Irrespective of hospital level and ownership, the results of the measurement for chemical and physical hazards were evaluated using the Threshold Limit Values of the Occupational Safety and Health Standards, Department of Labor and Employment (OSHS, DOLE), ACGIH1, IAQ ASHRAE2, CCOHS3, and MAK4. On the other hand the ventilation conditions were evaluated using OSHS,DOLE while the local exhaust ventilation were evaluated using the Manual of Recommended Practices Industrial Ventilation published by ACGIH, American Institute of Architects – Ventilation Requirement for Hospital, and Guide for Periodic Inspection of Local Exhaust Ventilation Systems, Labour Standards Bureau, Ministry of Labor, Japan.

1American Conference of Governmental Industrial Hygienists
2American Society of Heating, Refrigerating, and Air-conditioning Engineers
3Canadian Center for Occupational Health and safety
4Maximale Arbeitsplatz-Konzentration developed by the Deutsche Forschungs Gemeinschaft enforceable in Germany.
C. Analysis of Data

Descriptive statistic was utilized to summarize and describe the measurements gathered. The probable cause for failing from the OSH Standards was also analysed to have an overview or insight of the workplace. Then, appropriate action items were then recommended as apparent inputs for the development of IAQ management program for hospital workers.

D. Scope and Limitation

This study covers those hospitals that had requested Work Environment Measurement from year 2002 to 2014. Thus, the data analysed had been limited to the set of WEM parameters that each hospital has. Also, the hospital names had been withheld for confidentiality. In the absence of some occupational standards locally, appropriate established international occupational standards had been utilized.

IV. RESULTS AND DISCUSSION

A. Chemical Hazards in the Hospital Indoor Air.

The following were the chemicals that had been measured and evaluated using Threshold Limit Value (TLV). TLVs refer to any airborne concentration of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed daily without adverse effect (Philippines. OSHS-DOLE, 2013).

1. Dust and Asbestos
2. Organic solvents – Ethanol, Methanol and Xylene
3. Toxic gases – Carbon monoxide and Methane
4. Inorganic Chemicals – Formaldehyde and Sulfuric acid
1. Dust and Asbestos

### Table 1. Dust Concentration at Different Work Areas, ppm

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Work Area</th>
<th>Dust Concentration, mg/m$^3$</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Respirable</td>
</tr>
<tr>
<td>1</td>
<td>Operating Room</td>
<td>0.34</td>
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<tr>
<td>2</td>
<td>Delivery Room</td>
<td>0.03</td>
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<tr>
<td>3</td>
<td>Dialysis Room</td>
<td>0.01</td>
</tr>
<tr>
<td>4</td>
<td>Intensive Care Unit</td>
<td>0.08</td>
</tr>
<tr>
<td>5</td>
<td>Operations and Management Office</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td><strong>AVERAGE</strong></td>
<td><strong>0.102</strong></td>
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</tbody>
</table>

*Threshold Limit Value-Time Weighted Average* – the time weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day without adverse effects.

**Respirable Dust** – that fraction of total dust which pass through a selector whose size is 7 microns or less in diameter which can be inhaled or deposited in the lungs.

**Total Dust** – all dust particles in the work area.

Of the five area dust samples collected from two hospitals, four passed the threshold limit value of 0.15 mg/m$^3$ for respirable dust based from Environmental Protection Agency - National Ambient Air Quality Standards (EPA-NAAQS) and two area dust samples passed the TLV of 0.26 mg/m$^3$ for total dust based on ASHRAE IAQ Exposure Standards (Please see Chart 1). However, as shown in Table 1, one or 20% of respirable dust sample with a
concentration of 0.34 mg/m³ exceeded the TLV. However, the average respirable dust concentration (0.102 mg/m³) did not exceed but it was more than half of the TLV. Also, three or 60% of total dust samples with concentrations of 0.33, 0.86 and 1.49 mg/m³ exceeded their corresponding TLVs and so with its average concentration of 0.594 mg/m³.

High levels of both respirable and total dust were collected at the Operating Room and other areas with high levels of total dust were collected at the Delivery Room and Intensive Care Unit. Low levels of nuisance dust samples were collected at the Hospital Operations and Management Office and at the Dialysis Room. It must be noted that respirable dust size up to 10 microns in diameter can reach up to the gas exchange portion of the lungs while total dust size up to 100 microns in diameter can be deposited anywhere in the upper respiratory tract.

High level dust concentration can be attributed to the non-usage of HEPA filters during respirable dust collection since it was only used for normal operation. While the source of total dust infiltration came from staff uniforms, other clothing, shoes and belongings, hospital linens, equipment, janitorial services and outdoor air intakes. Other sources were from dust accumulated in hospital furnishings such as carpets, shelves, counters, curtains and other textiles.

On the other hand, asbestos dust was not detected in four hospital boiler rooms.

Continuous utilization and maintenance of HEPA filters is recommended which may greatly reduce the nuisance dust in the area. 5S of Good Housekeeping is essential to maintain a dust-free room.

2. Organic Solvents

<table>
<thead>
<tr>
<th>Organic Solvent</th>
<th>Area Concentration, ppm</th>
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<tbody>
<tr>
<td></td>
<td>Ethanol</td>
</tr>
<tr>
<td>Anatomy Pathology</td>
<td>7.28</td>
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<tr>
<td>Main Laboratory</td>
<td>4.56</td>
</tr>
<tr>
<td>Histopath Room</td>
<td>14.22</td>
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<tr>
<td><strong>Average</strong></td>
<td><strong>5.27</strong></td>
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</table>

All measurements gathered through area sampling in three private hospitals did not exceed the TLV’s of 1000 parts per million (ppm) for ethanol, 100 ppm for xylene and 200 ppm for methanol based on the TLV’s for Airborne Contaminants prescribed by the OSHS. Also, the average concentrations of the measured organic solvents did not exceed the said standard. The highest concentration obtained for ethanol, methanol and xylene were 14.22 ppm, 4.58 ppm and 1.61 ppm respectively as shown in Table 2.
The samples were taken from an enclosed air-conditioned Anatomy/Histopath Rooms and Main Laboratory wherein these solvents were used for sample preparation, staining and cleaning of slides and bacteriological procedures and various analyses.

Though the measurements were below the occupational standards set by OSHS, DOLE, it is important to reduce to the lowest concentration possible and take extra precautions in handling organic solvents such as Ethanol, Xylene and Methanol. Always wear appropriate personal protective equipment and clothing, avoid contact with skin and eyes and provide appropriate and tested exhaust ventilation when working with organic solvents to keep the vapor concentration below the threshold level. When handling and storing, place in a cool, well-ventilated area; put away from sources of ignition (spark or flame) and heat; ground all approved containers and keep it tightly closed.

3. Toxic Gases

![Chart 3A. Concentration of Carbon Monoxide](image)

![Chart 3B. Toxic Gases Measurement Evaluation](image)
Gases such as carbon monoxide was monitored at the non-air-conditioned basement parking areas of two private hospitals and methane at the sewage pit of a private hospital. Majority of the results showed low concentration readings of carbon monoxide gas that did not exceed the TLV of 50 ppm based on DOLE OSHS. However, there is one or 3.8% of CO sample taken at the basement parking reached the action level in which the air concentration reached 50% of the TLV. This level indicates that the level of concentration requires exposure monitoring and medical surveillance; an action to prevent exposure that might become harmful to workers. While, methane gas which is not included in the DOLE OSHS, was not detected using the Multiple Gas Detector (Industrial Scientific Brand, models TMX 412 and IBRID).

In order to prevent CO accumulation, it is sensible that supply and exhaust ventilation equipment in the basement parking be turned on as soon as the parking areas are opened to continuously pull in the fresh air and push out the contaminated air. Also, remote CO gas monitors be installed in strategic locations to check the CO concentration and can make immediate emergency action if needed. Any training related to toxic gas awareness for basement parking personnel is essential to prevent untoward accident.

4. Inorganic Other Chemicals

Chart 4A. Formaldehyde (CH₂O) Measurement

![Chart 4A. Formaldehyde (CH₂O) Measurement]

Chart 4B. Inorganic Chemical Measurement Evaluation

![Chart 4B. Inorganic Chemical Measurement Evaluation]
Out of twenty-two (22) formaldehyde (CH$_2$O) area samples, 4.5% of the samples taken from air-conditioned Delivery Suite – Decontamination Room exceeded the TLV of 5 ppm based on OSHS, DOLE. Whereas, Sulfuric acid samples from enclosed chemical treatment room for waste water passed the TLV of 0.25 ppm based on OSHS, DOLE. All samples were gathered from one (1) government and four (4) private hospitals.

The formaldehyde area sampling concentration failed in the Delivery Suites - Decontamination Room. The work process during the said sampling was pouring of the said chemical manually from its plastic container into plastic ice bag to be used for storing tissues and organs for biopsy.

To lessen ambient concentration, it is essential to implement controls:

a) **Engineering Control.** Working with formaldehyde should be conducted under Local Exhaust Ventilation (LEV). In case that LEV cannot be installed, if feasible, the activity should be done in non-airconditioned room and ensure the supply and exhaust of air is sufficient enough to ventilate the room properly, i.e. to flush out the contaminated air and replace it with fresh air.

b) **Administrative Control.** Isolate or segregate the said activity to lessen the number of exposed workers. Also, educate workers on awareness of chemical hazards and how to protect them. More so, for safety purposes it is better to use appropriate vessel such as wide mouth plastic bottle with lid cover instead of plastic ice bag.

c) **Appropriate Personal Protective Equipment (PPE)** should also be worn at all times such as cartridge-type respirator specifically for formaldehyde vapor and acids, goggles and apron in case of splashing, and use of latex/nitrile gloves.
B. Physical Hazards in the Hospital Indoor Environment

1. Temperature and Humidity

**Chart 5A. Ambient Temperature Measurement**

<table>
<thead>
<tr>
<th>No. of Measuring Point</th>
<th>Ambient Temp., Deg. Celsius</th>
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- Ambient Temperature
- Lower Range
- Upper Range

**Chart 5B. Relative Humidity Measurement**

<table>
<thead>
<tr>
<th>No. of Measuring Point</th>
<th>Relative Humidity, %</th>
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- Relative Humidity
- Lower Range
- Upper Range
Out of 238 data on ambient temperature readings from one (1) government and five (5) private hospitals, 188 measuring points or 79% were out-of-recommended range and only 50 or 21% of the sampling points are within the Optimum / Acceptable Range of 23 °C to 26 °C (Please see Charts 5A and 5C) based on IAQ Health and Safety Guide of CCOHS equivalent. While, most of the data (81%) on Relative Humidity (RH) are within the range of 30% to 60% (Please see Charts 5B and 5C) based on the said standard and none of it is below the recommended range. The highest temperature reached was 35 degree Celsius (°C) at the basement parking and the lowest was 16°C at the dialysis room. While the highest RH reached up to 73% at the Chemical Treatment Area of a private hospital.

Most of the areas that are above the recommended optimum / acceptable ambient temperature range are non-airconditioned and/or enclosed such as in the basement parking and chemical treatment room. However, some “busy zones” of the hospitals where individuals would come and go and there is heat process like cooking have ambient temperature that are also above the range such as:

- Enclosed and non-airconditioned old building, annex hallway, nurse station, dietitian’s office, and housekeeping department,
- Enclosed and airconditioned admin office, information area, post anesthesia care unit and delivery room.

While those areas that are below the recommended temperature range are delicate and sensitive zones such as Intensive Care Unit (ICU), Operating Room (OR), Dialysis Room, and Histopath. Nonetheless, most of the hospital laboratories are within the temperature range such as main laboratory, anatomy pathology, bacteriology, mold room and some parts of ICU, OR, and delivery room.

Generally, the RH measurements in areas that are old and/or utilizing volumes of water and aged structure are above the recommended range such as Dietitian’s office / kitchen / dish washing, housekeeping department, sterilization, chemical treatment areas
and old building hallway. Basically, relative humidity is the amount of water vapor in the air. Human body expels waste heat through perspiration and cools itself through evaporative cooling. Under high humidity “humid” condition, perspiration evaporates slowly and the body feels the heat load. Thus, workers may feel uncomfortable.

In order to maintain the indoor ambient temperature and relative humidity within the acceptable range, it is suggested to (United Kingdom HSE, 1999):

a) At the source
   • Adjust the temperature control as needed
   • Insulate the source of heat or cold
b) Control the environment
   • Increase air movement by ventilation
   • If feasible, provide airconditioning or controlled working environment
c) Separate the source of heat and cold by erecting barriers, shielding the workarea or restricting access.
d) Control the task
   • Limit the exposure time
   • Control the work load
e) Protect the worker
   • Provide appropriate working clothes
   • Provide suitable ventilating equipment
f) Monitor the worker
g) Supervise the worker

Other variables may also be considered like environmental factors – radiant heat received and climate and seasonal variation, and personal factors like state of health and group of workers whether young or pregnant. It is also essential to look at the building design and layout, materials used for thermal insulation, and others.
2. Illumination

<table>
<thead>
<tr>
<th>Chart 6. Illumination Measurement Evaluation</th>
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<td><img src="chart.png" alt="Illumination Measurement Chart" /></td>
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</table>

Out of 85 measuring points taken from one (1) government and three (3) private hospitals, 46 or 54% did not meet the required illumination level on the type of work done in a particular work area. These areas were offices or office-like such as admin, dietitian’s, information area and nurse station. Also, some failed sampling points were measured in the ICU and OR; It is important to note that at the time of sampling, no special lights were in operation. However, the hospital staff were into their day-to-day activities such as paper and computer works, review of patient charts and medical records, operation and monitoring of medical equipment, checking / counting of surgical apparatus, and others.

Based on the OSHS-DOLE, a minimum of 300 lux shall be provided where close discrimination of details is essential such as for medium bench and machine work, medium inspection, fine testing, or for office desk work with intermittent reading, writing, filing and mail sorting and other related or similar activities. Also, a minimum of 50 lux shall also be provided where discrimination of detail is not essential, such as for passageway, corridors, stairways, warehouses and storerooms for rough and bulky materials.

Generally, to attain prescribed illumination level the following can be implemented:

1. Re-arrange lighting fixtures or workstations in such a way that light is directed or falls directly without shadows on the material or object that are being worked on. The feasibility of this plan should be considered.

2. The present light intensity especially in the failed areas can be improved by replacing all busted and flickering lamps, installing additional lightings, maintaining / cleaning lighting fixtures such as diffusers and reflectors, and cleaning of all bulbs installed. Dirt and grime on lamps can decrease lighting to about 10 to 20% of illumination.
3. Use all available sources including natural lighting. Venetian blinds can be installed to control daylight and glare. Always keep clear glass windows clean and open where applicable.

3. Noise

![Chart 7. Indoor Noise Measurement](image)

All 56 measuring points taken from one (1) private and one (1) government hospitals failed the Office Noise Level based on Indoor Air Quality Health and Safety Guide published by CCOHS. These areas were in the Neonatal Intensive Care Unit (NICU), and Dietitian’s Office and Dishing Out/Preparation Areas. The noisiest level was 83 dB(A) and none of data attained the 50 dB(A) level noise standard.

At the time of measurement, the sources of noise were compressor of water pump, fan of the updraft/canopy-type hood, airconditioning unit (ACU), crying of babies, casual conversation of the staff, opening and closing of incubator doors/ports/drawers and NICU equipment such as oxygen monitoring device, infusion pump, suction set-up, life scope monitor and ventilator.

Some of the noise sources are intrinsic in the workplace such as crying of babies and noise coming from machines and ACU yet controllable. Regular maintenance of the equipment/ACU and relocation of noisy equipment or the office itself away from the noise source could lessen the noise level. Also, some sources can be regulated such as maintaining the quietness and low-volume casual conversation, and opening and closing the incubator door/port/drawer slowly. In this regard, development of awareness of the noise level among hospital staff through training, noise reduction policy both environmental and behavioural modification, shift endorsement meeting, posting of information materials/posters and others is essential.
C. Ventilation in the Hospital Indoor Air

OSHS, DOLE prescribes under Rule 1093 that ventilation and exhaust equipment be inspected and tested periodically for safe and efficient operational performance.

1. General Ventilation

a. Air Exchange

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<th>Chart 8A. General Ventilation - Air Exchange Measurement</th>
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There were 39 work areas that had ACH measurement. The said measurement was conducted in five (5) private and two (2) government hospitals. The result showed that a third (33%) of it did not reached the recommended Air Exchange Standard of four (4) to eight (8) ACH of OSHS, DOLE for thermal comfort. These areas were in the enclosed and airconditioned (window-type or centralized AC system) Intensive Care Unit (ICU), Post Anesthesia Care Unit, Doctor’s Clinic, Isolation Room, Operating Theater, Pediatric Emergency Room and Recovery Room. It is important to note that some areas may have chemical and biological emissions in which the OSHS, DOLE standard may not be accurate for the said hazards. Based on American Institute of Architects – Ventilation Requirement for Hospital, the ventilation requirement for Surgery and Critical Function Spaces such as Operating, Delivery, Nursery Suite and Trauma Rooms is five (5) ACH while for the rest, it is two (2) ACH.
Room Air Exchange is a measure of volume of room air replaced per hour. Also, it is used to dilute concentration of air contaminants and removed stale air, and then the room will be filled again with fresh air. To measure ACH, the system must have a means for supplying fresh and exhausting contaminated air. Some ACUs such as window-type and centralized system have air vents where it can be opened and closed as the need arises.

To improve the hospital ventilation, it is advised to:

- For the ducting (centralized AC system): a) always check and re-work the ducting system that has criss-cross lay out, b) label the ducting system such as ductworks, diffusers, supply and return air outlets for easy repair and maintenance, and c) regularly clean and inspect to remove dirt clogging and loose connections as these can cause air contamination and contribute to air losses, respectively.
- For AC System filter: a) regularly clean and maintain the AC filter, and b) if feasible, High Efficiency Particulate Air (HEPA) filters with 99% efficiency at 0.3 micrometer filtration should be utilized to ensure no biological contamination.
- Remove any wall-mounted exhaust fan leading to another room as this decreased the efficiency of the AC system.
- Inspect regularly the supply and exhaust system to ensure that the system is working at its full capacity. Also, document such IAQ activity.

b. Air movement

![Chart 8B. General Ventilation - Air Movement Measurement](chart)

Out of 39 air velocity readings using thermoanemometer conducted in three (3) private hospitals, eleven (11) or 28% of the measuring points failed the 0.25 meter per second (m/s) air movement based on TLV of OSHS, DOLE. These failed areas were all in the non-airconditioned basement parking. The OSHS, DOLE prescribes that suitable atmospheric conditions shall be maintained in workareas by natural or artificial means to
avoid insufficient air supply, stagnant air and harmful drafts (excessive air velocity). The hospital may install mechanical fans or if feasible utilized natural ventilation to improve mixing and dilution of contaminated in the failed areas. However, it must be worked together with air exchange measurement to exhaust and avoid re-circulation of concentrated contaminated air, and also to have good supply of fresh air. As per observation from the Toxic Gas measurement data (Please see Chart 3), the CO level reached an action level, and the ambient temperature (Please see Chart 5A) was up to 35°C both at the basement parking area.

2. Local Exhaust Ventilation (LEV)

a. Enclosure-type hood

![Chart 9. LEV - Enclosure-Type Hood Capture Velocity Measurement](image)

Out of 35 measuring points from five (5) enclosure-type hoods conducted in one (1) private and one (1) government hospitals, 18 data points or 51% did not meet the ACGIH control velocity standard of 0.5 m/s for air capture velocity of enclosure-type hood. These failed sampling points were gathered from three (3) hoods: in the enclosed mold room (hood used for the control of lead fumes during melting process), and histopath (hood used during mounting of samples into the glass slides) and gross rooms (hood used during dissecting / cutting of specimen) both enclosed and airconditioned.

Measurements were taken at 3-by-3 grid points at the hood opening; at the upper, middle and lower levels of hood opening particularly at the left, middle and right sides of each level of hood. It is important to note that even if one measuring point did not meet the ACGIH standard of 0.5 m/s air capture velocity, the enclosure-type hood has reduced efficiency. This prescribes the need for preventive maintenance activity like check, clean and replace appropriate hood filter, and some engineering method to increase capture velocity such as providing sash cover or PVC plastic cover to reduce hood opening.
b. Updraft hood

![Chart 10A. LEV - Updraft Canopy Hood Air Capture Velocity Measurement](chart)

All thirteen (13) measuring points from one (1) private and one (1) government hospitals did not reach 0.25 m/s updraft canopy hood air capture velocity standard of ACGIH. These two hoods were at the enclosed and non-airconditioned Dietitian’s Area – Kitchen, and Nutrition and Dietetics Service Area used for cooking process.

It has been noted that during measurement that the ventilating fans crossed draft the exhaust airflow of the hood in the Nutrition and Dietitics Service Area. Ventilating fans were used by the workers as hot air is generated during cooking process. *This disturbed the capturing of the heat given off.* There was also the presence of wall-mounted exhaust. However, it is likewise essential to install supply fan to bring in fresh air from outside sources where it can dilute the hot air in the workarea. Additionally, the kitchen updraft canopy hood should have appropriate air-cleaning device such as wire mesh filter to screen oil mist and dirt. Thus, prolonging fan motor life, preventing clogging in the ducting system, and eventually increasing airflow.
All six (6) measuring points taken from one (1) private hospital did not reach the recommended 1.0 m/s air capture velocity for organic solvents (O.S.). These data points were measured from two (2) updraft hoods canopy-type used to capture O.S. during soaking and washing processes of equipment in the enclosed and air-conditioned diagnostic area. It is advised to install PVC plastic strip or any appropriate material on the canopy to increase capture velocity and regularly check, repair and maintain the said hood.

Only one (1) out of five (5) data points measured from one (1) private hospital with enclosed and airconditioned Histopath Laboratory passed the 0.5 m/s air capture velocity for semi-enclosed updraft-type canopy hood in which the rear side is already covered. It is recommended to place side coverings and provide sliding sash at the hood opening to reduce large hood entry losses and thereby, increase the capture velocity.
V. CONCLUSION

This study has shown the following IAQ findings:

- 79% of the ambient temperature and 24% of the relative air humidity measurement were not in the acceptable range.
- Additionally, 20% of the respirable, 60% of the total dust and 4.5% of Formaldehyde gas samples did not pass the recommended occupational standards.
- Also, 3.8% of CO gas samples reached the 50% of the TLV a.k.a. action level.
- On general ventilation, 33% of air exchange data from different work areas and 28% of air movement measuring points also did not meet the required ACH and air velocity, respectively.
- As with LEVs, almost all data points did not reach the recommended air capture velocity.
- However, organic solvent levels passed occupational standards based on OSHS, DOLE.
- It is also important to note that 54% of the illumination measuring points failed the required illumination level particularly in the offices and office-like workareas.
- Also, excessive noise levels were measured in the NICU and some hospital offices.

Based from the result, the following IAQ parameters need to be addressed to ensure the safety and health of hospital workers – ambient temperature, relative air humidity, respirable and total dust, CO and formaldehyde gas. Also, the hospitals need to look at its preventive maintenance schedule for full efficiency of ventilation systems both general ventilation and LEVs. Though, organic solvent levels are below the recommended occupational standards based on OSHS, DOLE, then it does not mean that O.S. should not be checked regularly. Other factors that can intensify IAQ problems such as poor illumination and excessive indoor noise levels also need to be checked regularly.

For general ventilation specifically air exchange, the cycle of constant supply of fresh air and continuous exhaust of contaminated air is needed, as well as cross drafting should also be inspected. More so, provision of mechanical fans and utilization of natural ventilation are encouraged to enhance air movement specifically in the basement parking of the hospital. At the same time, most of the LEVs have to install side and front coverings to increase capture velocity and avoid dissipation of contaminated indoor air.
VI. RECOMMENDATION

For further evaluation, it is recommended to have continuing study on hospital IAQ per hospital classification as there are many differences in technology and service provided offered in each hospital level.

As far as the data have shown, it is essential to have guidelines intended to alleviate hospital IAQ problems through the development of IAQ management plan. This will serve as a step-by-step guide in solving IAQ problems. The following are the suggested steps (United States NIOSH, 1998):

Step 1. Delegation of IAQ Manager
Step 2. Development of hospital IAQ Profile through reviewing of existing records and walkthrough survey.
Step 3. Address the existing and potential IAQ problems, both source- and ventilation-related.
Step 4. Train / educate hospital building personnel about IAQ.
Step 5. Development and implementation of a plan for facility operations and maintenance (HVAC operation, housekeeping, prevention maintenance, unscheduled maintenance)
Step 6. Management of processes or special activities to control contaminant source including remodelling and renovation, painting, pest control, shipping and delivery of medical supplies, smoking, and others
Step 7. Communication with tenants and building occupants on hospital IAQ activities, plan and policy.
Step 8. Establishment of IAQ complaints procedures

The success of IAQ program will depend on the joint efforts of engineering, healthcare, administrative and support staff. This program will have a domino effect to the hospital constituents as IAQ awareness will also raise.
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**SOURCES OF DATA:**


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