NATURAL VENTILATION MODEL FOR TUBERCULOSIS TREATMENT CENTERS

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ABSTRACT

Tuberculosis pose a threat to everyone exposed to an infected individual in various TB treatment centers. The study aimed to assess the facilities’ natural ventilation capacity, the probability of TB infection and create a model for Tuberculosis treatment centers. This exploratory type of research has conducted actual observations and calculations using the Gammaitoni-Nucci equation. Data showed that hospitals and clinics have three vital components to lessen tuberculosis transmission, namely: window area, wind speed, and room volume. These three components are directly proportional to air changes per hour (ACH). The observations and findings from hospitals and clinics paved the way for developing a Natural Ventilation Model for TB treatment centers. Two models were designed based on the maximum number of clients it will serve. One model for hospital-based TB center catering to a maximum of 10 clients. The other model is for outpatient clinics/ TB DOTS that can accommodate 40 clients with a lesser probability of TB infection. The proposed natural ventilation models can be used by different healthcare facilities as a reference to reduce the risk of TB transmission.

Keywords: Natural Ventilation, Tuberculosis, Probability of infection, Gammaitoni-Nucci equation

I. INTRODUCTION

One of the main health problems in the Philippines is the transmission of Tuberculosis (TB). As observed, TB remains one of the leading causes of morbidity and mortality, affecting thousands of Filipinos (DOH, 2016). Since it is an airborne infection, TB poses a threat to everyone who has contact with infected individuals. Beggs, Noakes, Sleigh, Fletcher, and Siddiqi (2003) averred that airborne infections are more in confined spaces, involving a large number of people. With this in mind, waiting areas and treatment centers entertaining numerous clients increases the risk of TB transmission.

On the lighter side, the Department of Health has created guidelines in the planning of a hospital and other health facilities in the Philippines. These guidelines provide standards consistent with national building and architectural laws, thereby promoting safety and decreasing the risk of infection (DOH, 2004). Also, RA 10767, known as the Comprehensive Tuberculosis Elimination Plan Act, mandates DOH to increase the number of DOTS facilities to widen target beneficiaries. All regional offices are directed to establish treatment centers for the management and improvement of TB services. However, such directives present a particular challenge since there is no standard TB treatment center model at present. As observed, most of the treatment centers and DOTS centers are located in closed and confined areas.

Various literature has recommended the use of a “negative pressure” mechanically ventilated system in closed space to prevent infection, especially in tuberculosis wards (Escombe, Oeser, Giman, Navincopa, Ticona, Pan, Martinez, Chacaltana, Rodriguez, Moore, Friedland, and Evans, 2007). In a study conducted by Qian and Zheng (2018), increasing the hospital ventilation rate can effectively reduce the risk of long-range airborne transmission. However, WHO (2007) observed that improper installation and maintenance of mechanical ventilation might lead to a high concentration of infectious droplet nuclei. Thus, the Center for Disease Control & Prevention (CDC, n.d.) suggested using natural ventilation for nontraditional facility-based and congregate settings. In these settings, waiting rooms, shelter dormitories, or other rooms in which people gather should have functional open window, door, or skylight as often as possible (CDC, n.d.). Also, local healthcare facilities opt for natural ventilation due to economic constraints. As observed, most of the facilities rely on opening windows and doors or
natural ventilation to reduce transmission. It is, therefore, imperative to understand the extent of implementation of natural ventilation vis-à-vis TB transmission control in healthcare settings.

In global scenario, the World Health Organization (2007) recommends natural ventilation as an environmental measure to reduce the spread of infection. The advantage of natural ventilation is its ability to provide a very high air change rate at a low cost, with a simple system. Although the air-change rate can vary significantly, buildings with modern natural ventilation systems can achieve very high air-change rates by natural forces, which can substantially exceed minimum ventilation requirements (WHO, 2007, Aliabadi et al. 2011). The use of natural ventilation, however, has several drawbacks, such as it is dependent on climatic conditions, difficult to control, only works with natural forces, and reliant on structure (WHO, 2007). To address ventilation issues, one should consider the appropriate building design, planning and site.

While much has been written concerning the use of natural ventilation, its international standards, and airborne prevention, fewer studies have incorporated it locally. The identified variables that need to be explored more are room volume, window area, wind speed, air changes per hour, number of infectors, and exposure time. These variables were identified by various research as indicators for the effective use of natural ventilation. Also, there is a need to evaluate other means and building design that work best in controlling TB transmission in the real setting.

II. OBJECTIVES

The study aimed to assess the health facilities’ natural ventilation vis-à-vis TB transmission control of various treatment centers in Bukidnon. Specifically, it seeks to 1). Assess the facilities’ natural ventilation capacity and probability of infection; and 2). Create a natural ventilation model for TB treatment centers.

Theoretical/Conceptual Framework

Florence Nightingale’s Environmental Theory is anchored in this study. Florence Nightingale stressed that manipulating the physical, social, and psychological environment will put the person in their best possible condition for nature to act. Moreover, it is identified that ventilation is one of the main areas of the environment the nurse could control. A patient who repeatedly breathed his/her air would become sick or remain sick (Udan, 2020). She further emphasized on proper ventilation as a source of disease and recovery. However, specific measures to prevent infection are limited in the discussion of the theory.

In application, there are two guidelines more specific in giving standards for healthcare settings to follow. The guidelines set by the WHO’s in Natural Ventilation for Infection Control in Health Care settings (2009) and DOH’s Infection Control for Tuberculosis and other Airborne Infectious Diseases in Healthcare Settings (2011) were utilized in the study. Both recognized natural ventilation as an efficient environmental measure to reduce the risk of infection in health care settings. These agencies describe how an airborne precaution room and its adjacent areas can be designed to provide natural ventilation control of all airborne/droplet diseases like TB.

Figure 2 illustrates the application of the theory and concepts in the study. Based on the Environmental Model, and guidelines, two variables emerged: natural ventilation and infection control for Tuberculosis. The said variables are essential in the creation of the Natural Ventilation Model for TB treatment centers.
III. METHODOLOGY

This quantitative study will explore the healthcare facilities’ natural ventilation system and its capacity to decrease TB transmission. Specifically, it looked into the existing TB health facilities and computation of the probability of susceptible individuals. A TB treatment model design were developed aided by mathematical calculation.

The research is conducted in the Province of Bukidnon, specifically on four major government hospitals and three TB DOTS Treatment Centers. Documentary and Archival Analysis were conducted to determine the number of infectors and susceptible individuals per healthcare facility for the last 3 years. These data were also validated by nurses and TB-DOTS personnel. Adherence to ethical considerations was followed throughout the study, such as observance of proper protocol, informed & written consent, confidentiality, and anonymity.

Actual observations were conducted in the identified healthcare facilities. The Gammaitoni-Nucci equation was used to determine the probability of TB infection among susceptible individuals. The said equation reflects the exponential increase in the number of new cases of infection or percent of susceptible persons infected with time for steady-state quanta levels in a room space (Beggs et al., 2010), taking into account transient behavior over short periods expressed as:

\[
P = 1 - e \left[ -\frac{pI\varnothing}{V} \left( \frac{Nt - e^{-Nt}}{N^2} \right) \right]
\]

Where \( P \) is the probability of infection of susceptible individuals; \( p \) is the pulmonary ventilation rate of vulnerable individuals set at 0.6 m\(^3\)/h (Escombe et al., 2007); \( I \) is the number of infectors; \( \varnothing \) is the number of infectious “quanta” produced per hour by infectors; \( V \) is the room volume (m\(^3\)); \( N \) is the room ventilation rate (air changes/h), and \( t \) is the exposure time for susceptible individuals express in an hour.

According to Escombe et al. (2007), a “quantum” is used to describe the “infectious dose” for TB. Quantum is the number of infectious particles required to cause infection in \((1 - e^{-1})\) of a susceptible population when each person breathed, on the average, one quantum of infectious particles. Also, the exposure duration was set at 24 hours, and the individuals were assumed to be unprotected by particulate respirators. To allow comparison between isolation and shared rooms, all patients in each room were presumed to have TB and produce 13
infectious quanta per hour \( (q = 13) \), this is the rate determined for an untreated TB case in a well-documented outbreak (Escombe, et al., 2007).

Based on the WHO’s policy on TB infection control in healthcare facilities (2009) air changes per hour can be measured using a standardized formula. ACH is the simplest way to assess ventilation, where one ACH means that the volume of air in a room is replaced in one hour. Further, WHO (2009) recommends a higher ACH (at least 12 ACH), the better the dilution and the lower the risk of airborne infection.

Different materials were also used, such as anemometer, laser distance measuring device, candle & match (for Smoke Test), calculator, and notepad. Airflow rate, room volume, and ACH were computed using this equipment and materials. The Airflow rate is the ACH numerator, while the Room Volume is the denominator of ACH (WHO, 2009). Therefore, ACH is computed as:

\[
ACH = \frac{Airflow \ (m^3/h)}{Room \ volume \ (m^3)}
\]

Where,

\[
Airflow = (\text{window length} \times \text{width}) \times (\text{air velocity} \ m/sec)
\]

\[
Room \ volume = width \times depth \times height
\]

Also, checking wind speed is done by assigned assistants every 2 hours, for the 8-hour duration. Using an anemometer, the wind speed were assessed per window. The average wind speed was used in the calculation of the probability of infection.

IV. RESULTS AND DISCUSSION

Assessment of Healthcare facility and Probability of Susceptible Individual: Hospital

Table 1 showed the probability of susceptible individuals to Tuberculosis in hospital settings. It is interesting to note that Hospital C has the highest chance of susceptibility with 27.44% of 22 individuals can have TB; a total of 6 new infections can occur in a given time.
Table 1: The Probability of Susceptible Individual to TB in Hospital Setting.

<table>
<thead>
<tr>
<th>DATA</th>
<th>Hospital A</th>
<th>Hospital B</th>
<th>Hospital C</th>
<th>Hospital D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room Volume (m$^3$)</td>
<td>45.00</td>
<td>21.00</td>
<td>94.50</td>
<td>42.00</td>
</tr>
<tr>
<td>Window Area(m$^2$)</td>
<td>2.25</td>
<td>2.25</td>
<td>3.75</td>
<td>4.50</td>
</tr>
<tr>
<td>Wind Speed (mph)</td>
<td>0.10</td>
<td>1.20</td>
<td>0.10</td>
<td>0.70</td>
</tr>
<tr>
<td>Air Changes Per Hour (ACH)</td>
<td>18.00</td>
<td>462.80</td>
<td>14.29</td>
<td>270.00</td>
</tr>
<tr>
<td>No. Of Infectors</td>
<td>3.00</td>
<td>2.00</td>
<td>7.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Exposure Time Of Susceptible Individuals (hrs)</td>
<td>8.00</td>
<td>8.00</td>
<td>8.00</td>
<td>8.00</td>
</tr>
<tr>
<td>No. Susceptible Individuals</td>
<td>9.00</td>
<td>5.00</td>
<td>22.00</td>
<td>13.00</td>
</tr>
<tr>
<td>Probability of Susceptible Individual</td>
<td>20.51%</td>
<td>1.28%</td>
<td>27.44%</td>
<td>2.71%</td>
</tr>
<tr>
<td>Number of New Infection (person)</td>
<td>18.5</td>
<td>0.06</td>
<td>6.94</td>
<td>0.35</td>
</tr>
<tr>
<td>Smoke Test</td>
<td>No Air</td>
<td>With Air</td>
<td>No Air</td>
<td>With Air</td>
</tr>
<tr>
<td></td>
<td>Movement</td>
<td>Movement</td>
<td>Movement</td>
<td>Movement</td>
</tr>
</tbody>
</table>

Further investigation suggests that the higher air changes per hour, as seen in hospital B (462.80 ACH), can contribute to the decreased probability of TB infection with only 1.28%. This data is consistent with WHO’s (2009) findings stating that the higher the ACH, the better dilution, and the lower the risk of airborne infection.

The same scenario was also noted in Hospital D with a window area of 4.50m$^2$, illustrating a low probability of susceptible individuals to TB infection with 2.71%. The presence of a larger window area allows good airflow and changes, thereby providing an avenue for faster removal of droplet nuclei in a given area. This result is supported by the smoke test, visualizing the movement of air inside the room. Hospital B with 462.80 ACH, and Hospital D with 270 ACH, showed positive air movements. Thus, the bigger the window area with high ACH, the lower the risk of infection.

Moreover, a thorough assessment of Hospital B and D showed commonalities in the increase of ACH but vary in contributory factors. Hospital B’s ACH is due to an increase in wind speed of 1.20m/s. This factor is due to the hospital’s geographic location and elevation, where air can move in various directions. Another factor is the small room volume (21 m$^3$) of Hospital B, with two casement windows on different sides. One window has an area of 1.5 m$^2$, and the other one has .75 m$^2$, allowing better air movement. Both room volume and windows increased ventilation and enhanced the air exchange in the hospital.

On the other hand, Hospital D has a high ACH due to a window area of 4.5 m$^2$. The room is surrounded by three casement windows, one window with an area of 1.5 m$^2$ and two adjacent windows, both have an area of 1.5 m$^2$, almost occupying the room's wall. The findings are supported by the CDC (2005), observing that operable windows, doors, or skylights must be kept open as often as possible in facilities with infectious people. Therefore, the presence of open windows is a medium for good air movement in and out of the room.

Moreover, the design of Hospital D’s isolation room is located outside the main building. The building follows the WHO’s guidelines on Natural Ventilation on Infection Control in Healthcare Settings (2009), stating that healthcare facilities should have an overall airflow bringing air from the agent sources to areas where there is sufficient dilution, and preferably to the outdoors. Also, the room volume complements the design with a 45 m$^3$ area allowing enough spacing per patient.

Another factor noted to contribute to ACH is the presence of fans. Hospital D has functional fans located at the entrance door facing the windows of the room. This observation complies with the Curry International Tuberculosis Center (2011) guidelines that fans should be present and functioning to increase air mixing and directional airflow and occupy the parts of the room. However, to add to natural ventilation currents, room fans must be placed in a strategic location. Thus, it is vital to check the site of air currents before placing fans in the room.

Table 2: The Probability of Susceptible Individual in Clinic Settings

<table>
<thead>
<tr>
<th>DATA</th>
<th>CLINIC 1</th>
<th>CLINIC 2</th>
<th>CLINIC 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room Volume (m$^3$)</td>
<td>27.50</td>
<td>72.00</td>
<td>72.00</td>
</tr>
<tr>
<td>Window Area(m$^2$)</td>
<td>3.00</td>
<td>1.75</td>
<td>23.63</td>
</tr>
<tr>
<td>Wind Speed (mph)</td>
<td>1.00</td>
<td>0.10</td>
<td>1.50</td>
</tr>
</tbody>
</table>

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Assessment of Healthcare facility and Probability of Susceptible Individual: Clinic

Table 2 illustrated the probability of susceptible individuals in clinic settings, where most infectors are outpatient. According to the data, most clinics cater to an average of 21 patients per day. In terms of the probability of susceptible individuals, Clinic 2 has the highest result of 70.17%, which means they have a higher risk of TB transmission. A total of three new infections out of four number of susceptible individuals can have Tuberculosis. The findings of Clinic 2 are due to the low wind speed of 0.10 m/s, little air changes per hour of 8.75 ACH, and a small window area of 1.75 m². The smoke test showed no air movement, which means there are concentrations of droplet nuclei in the room for some time capable of infecting the individual. As witnessed, the clinic has small wooden jalousie windows with limited air movement due to its location in the building.

In contrast, Clinic 3 has the highest number of infectors serving 40 outpatient per day. However, the probability of susceptible individuals is only 1.94%, with 0.04 number of new infections. This result is consistent with the data showing the clinic has a big window area, high wind speed, and high ACH. During an actual assessment, this clinic has a big opening on all sides of the receiving/waiting area.

Overall Observation among Hospitals and Clinics

Generally, data from hospitals and clinics clearly showed three vital variables to lessen the transmission of Tuberculosis, namely: window area, wind speed, and room volume. These three components are directly proportional to air changes per hour (ACH). But among the three variables, wind speed has a better influence on individuals' susceptibility towards TB.

Also, an auxiliary use of fans is seen to be effective in augmenting the natural ventilation system. This data is supported by Curry International Tuberculosis Center (2011), stating that buildings without operational central forced-air heating and air conditioning systems should use both natural ventilation and fans to provide fresh outdoor air to all occupied rooms in the building. Further, a place with an open window and a fan would have less TB-transmission risk than an enclosed space with no fan, an enclosed room with a fan, or a room with an open window but no fan (Curry, 2011).

Natural Ventilation Model (NVM) for TB treatment centers

The observations and findings from hospitals and clinics pave the way to developing a Natural Ventilation Model for TB treatment centers. There are two models developed based on the maximum number of clients it will serve. The hospital-based TB center model can accommodate a maximum of ten clients. The other model is for outpatient clinics that can cater to a maximum of 40 clients.

Hospital-based TB Isolation Ward

Figure 2 displayed a TB isolation ward model, considering the following components observed in the study: window area, wind speed, and room volume. The goal is to decrease the number of susceptible individuals in a given TB ward. The TB ward can accommodate ten patients/infectors, with a maximum of six susceptible individuals (2 health workers per shift) and a wind speed of 0.1 m/s.

Figure 2: TB Isolation Ward Model
The proposed TB ward is at 128m$^2$ or 6.44m (W) x 20m (L) in dimension. The said dimension considers the DOH Guidelines (2007), stipulating that the Isolation Room should be at 9.29m$^2$ space or 3.65 m distance. In application, the model utilized the said guidelines ensuring that the ten beds have the mandated spacing for an isolation ward.

In terms of room volume, the proposed model is at 471m$^3$ or 6.44m (W) x 20m (L) x 3.20m (H), plus the area provided for the streamlined roof where the louver is attached set at 6.44m (W) x 20m (L) x ½ of 1m (H) as seen in Figure 3.

Specifically, the louver is at 20m in length by 0.70m in height, affixed in one side of the building. The presence of louver will allow a passive cooling effect, which receives 50% of airflow. Thereby ensuring additional natural ventilation in the proposed TB ward.

Figure 2; Louvers For Passive Cooling
To ensure maximum ventilation, our model proposed to have 12 windows with a total of 63.5m², with various sizes. Windows situated in front of the ward are: W1 is at 3.85m (W) x 1.65m (H), W2 at 2.50m (W) x 1.65m (H), W3 at 2.50m (W) x 1.65m (H), and W4 at 3.85m (W) x 1.65m (H). Windows situated at the rear portion are: W5, W6, W7, and W8; all have measurements of 3.85m (W) x 1.65m (H). Windows located at both sides have the following dimensions: W9 & W12 have 1.40m (W) x 1.65m (H); W10 & W11 have 1.50m (W) x 1.65m (H). All windows have casement design, allowing 100% airflow when fully opened. The dimensions and design of the window permit maximum ventilation even without the presence of fans.

The model used double-acting entrance doors, measuring 2m (W) x 2.10m (H), allowing full access for medical equipment such as but not limited to stretchers and other medical apparatuses. Also, the TB ward has two separate swing doors leading to toilets and emergency exits at opposite sides. Both doors have 1m (W) x 2.10m (H) in dimension. In compliance with the fire code, the ward provided 2 emergency exit using the panic door.

Moreover, the model also complies with other requirements such as hallways, toilets, ramps, and fire exits, as set by various laws. In terms of lobbies, the model complied with the DOH guidelines using 2.44m (W) to ensure no obstruction of movement, stretcher, and other equipment. For lavatories, the National Building Code (PD 1096), was considered stating that the hospital ward should have at least one room toilet for males and one for females. However, the model provided two usable lavatories on both sides of the ward for both sexes. Considering the elongated design plan of the proposed TB ward, the construction of two toilets can minimize TB transmission and ensure easy access to toilet use.
The design follows the fire safety construction guidelines as stipulated in Republic Act 951418. This includes presence of fire exits and smoke alarms. Also, Batas Pambansa (BP) 34417 requires all buildings to provide space or structure accessible to disabled persons. These provisions include setting up ramps for persons with disabilities. In our study, we have incorporated ramps and rails to ensure adherence to the said law.

Table 3 shows the probability of susceptible individuals using the Gammaitoni-Nucci equation for the TB Ward model. The tabular value indicated that the model has 2.69% or 0.16 to no new infection. The data confirms that the model is a suitable design to decrease the risk of TB transmission.

<table>
<thead>
<tr>
<th>DATA</th>
<th>PROPOSED HOSPITAL MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room Volume (m³)</td>
<td>471.00</td>
</tr>
<tr>
<td>Window Area (m²)</td>
<td>63.50</td>
</tr>
<tr>
<td>Wind Speed (mph)</td>
<td>0.10</td>
</tr>
<tr>
<td>Air Changes Per Hour (ACH)</td>
<td>49.59</td>
</tr>
<tr>
<td>No. Of Infectors</td>
<td>10</td>
</tr>
<tr>
<td>Exposure Time Of Susceptible Individuals (hrs)</td>
<td>8</td>
</tr>
<tr>
<td>No. Susceptible Individuals</td>
<td>6</td>
</tr>
<tr>
<td>Probability of Susceptible Individual</td>
<td>2.69%</td>
</tr>
<tr>
<td>Number of New Infection (person)</td>
<td>0.16</td>
</tr>
</tbody>
</table>

Moreover, the number of susceptible new infections can be lowered if the wind speed will be increased, thereby changing the air changes per hour. Also, CDC (n.d.) recommends the use of fans to help distribute the air in a given area. If the direction of airflow is unknown, then healthcare personnel should be situated near the fresh air source and TB clients should sit near the exhaust location. This set-up will help protect the healthcare team from droplet nuclei expelled by TB patients (CDC, n.d.). Thus, considering the wind direction in building the TB ward model is a must.

**Outpatient TB Directly Observed Treatment, Short-Course (DOTS)**

Figure 4 exhibits a model for outpatient TB DOTS center, with the same goal of decreasing the number of susceptible individuals in a given OPD center. The model sets to accommodate 40 patients/infectors, with a maximum of four vulnerable individuals, and wind speed at 0.1m/s.

The design of the OPD TB DOTS has a floor area of 178m². The front building dimension measures 16m; the left side is 12.80m; the rear side is 9.5m; the right side near the counseling area is at 4m; a rear portion at the back of the sputum area is 6.60m, and right side of the building is 8.60m in dimension. The model is based on the space requirements, accommodating at least 40 patients and the one-way traffic pathway for both patients and healthcare providers. Also, the one-way traffic pathway has paved the way for the creation of separate entrance and exits of patients and health workers in the said building. This pathway shows a one-way flow of movements, lessening the risk of TB transmission.

In terms of room volume, the proposed model is set at 712m³ or 178m² (FA) x 4m (H), as seen in Figure 4. The planned design of room volume can accommodate the maximum number of clients and ensures no obstruction of movements. It also adapts the mandated 1.83m requirement of hallways according to DOH guidelines (2014). The model has 2.90m center spacing, 2m both sides, and 1.83m at the back portion. It also provides a bigger space in front of 3m to ensure a one-way traffic pathway and movement. This model shows compliance with the minimum requirements set by various laws.

Figure 4: OPD Clinic Ground Floor Plan
In terms of ceiling height, the model proposed to have 4m, more than the required minimum standard height of 2.7m, according to the National Building Code (PD 1096). The ceiling height ensures enough space for the placement of louvers, as seen in Figure 5. The proposed louvers are attached to all sides of the building. Specific dimensions are as follows: Front Louver set at 16m (L) x 1m (H); Left lover at 12.80m (L) x 1m (H); Rear louver at the back of counseling area set at 9.60m (L) x 1m (H); Right portion of the counseling area measuring 4.20m(L) x 1m (H); Rear portion at the back of sputum area at 6.60m(L) x 1m (H); and Right portion of the building at 8.60m(L) x 1m (H). The presence of louvers in all sides of the building ensures passive cooling effect, and additional ventilation considering the big bulk of patients.

Figure 5: Rear Elevation, Louver Detail, & Front Elevation Schedule of Windows
Figure 6: Front Elevation Schedule of Windows
The model proposed to have 11 windows with a total of 90m², with various sizes as seen Figure 5. Windows situated in front of the OPD are: W1 is at 2.50m (W) x 1.65m (H), W2 at 2.00m (W) x 1.65m (H), and W3 at 5.50m (W) x 1.65m (H). The W4 situated at the right side of the building measures 3.30m (W) x 1.65m (H). The W5 is 3.50m (W) x 1.65m (H). W6 at 3.35m (W) x 1.65m (H); W7 3.50m (W) x 1.65m (H). For the rear portion, W8 at the back of the counseling area measures 2.18m (W) x 1.65m (H). All windows from 1 to 8 have casement design, to allow 100% airflow when fully opened and maximizing the natural ventilation in the OPD center. However, windows 9 to 11 have jalouplus, design to have broader coverage of the opening, thus allowing more airflow. The windows have the following dimensions: W9 is at 1.50m (W) x 2.65m (H), W10 set at 2.40m (W) x 2.65m (H), and W11 measures 5.70m (W) x 2.65 m (H). The design showcases the maximum opening of windows, considering the number of patients inside the OPD area. The bigger the window sizes, the better the ventilation, the lesser the transmission of TB.

The model proposes to have four doors, one entrance door for patients with 2m (W) x 2.10m (H) dimension; 1 door for health workers entrance and exit with 2m (W) x 2.10m (H); one emergency exit located at the right side of the building with 2m (W) x 2.10m (H); and one exit door for patients going to the sputum area with 2m (W) x 2.10m (H) dimensions. The model used a double-acting swing door, allowing full access for individual and medical equipment.

Also, the model complies with other requirements such as toilets, ramps, and fire exits, as set by various laws. For the provision of toilet, the design provided two separate lavatories for males having two water closets and one urinal and for females having three water closets. It is situated adjacent to the OPD center, to ensure that the OPD building will have the maximum windows all sides. The sputum is separated outside the proposed OPD building. The said area is an open space located at the rear portion of the building, allowing only those for sputum collection to access the site. In terms of the presence of ramps and fire exits, the provisions were set by BP 344 and RA 9514.
In terms of the probability of susceptible individuals, the OPD TB DOTS model has only 7.39% or 0.30 to no new infection even in areas catering to a large number of TB clients. The model is effective in decreasing TB infection based on the computation, using larger room volume and window area. However, to increase the wind speed, the model proposed to build the structure where there is high airflow/current. To sum it up, the satisfaction of three variables, such as room volume, window area, and wind speed, can lead to less to no TB infection.

Table 4: Proposed Clinic Model

<table>
<thead>
<tr>
<th>DATA</th>
<th>PROPOSED CLINIC MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room Volume (m³)</td>
<td>712.00</td>
</tr>
<tr>
<td>Window Area (m²)</td>
<td>90.00</td>
</tr>
<tr>
<td>Wind Speed (mph)</td>
<td>0.10</td>
</tr>
<tr>
<td>Air Changes Per Hour (ACH)</td>
<td>45.51</td>
</tr>
<tr>
<td>No. Of Infectors</td>
<td>40</td>
</tr>
<tr>
<td>Exposure Time Of Susceptible Individuals (hrs)</td>
<td>8</td>
</tr>
<tr>
<td>No. Susceptible Individuals</td>
<td>4</td>
</tr>
<tr>
<td>Probability of Susceptible Individual</td>
<td>7.39%</td>
</tr>
<tr>
<td>Number of New Infection (person)</td>
<td>0.30</td>
</tr>
</tbody>
</table>

V. CONCLUSION:

The study concludes that: First, there is a decreased probability of TB infection if the window area, wind speed, and room volume are modified. Second, the larger the window area and room volume, the higher the airflow, the lesser the risk of TB transmission. Lastly, the proposed natural ventilation models can be used as a reference to decrease the risk of TB transmission in the isolation ward and OPD TB DOTS centers.

Recommendations:

Based on the findings of the study, the researchers recommended this to various Health agencies to apply the Natural Ventilation Model for TB treatment centers. This model serves as a guide TB structure to decrease TB infection and transmission. Also, Hospitals and TB DOTS centers can use this model as a reference for their renovation or construction of their TB facilities. Lastly, this study will serve as a model for other researchers to validate and utilize as a reference in their future research.

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