

Evaluation of Indoor Environmental Quality Parameters in Green Building rating Systems with respect to COVID-19 guidelines.

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Abstract: -

In the year 2020, the whole world was shaken by the spread of the infectious and deadly COVID-19 virus. Due to this high infection and high mortality rates were seen in 213 countries. According to WHO (World Health Organization) around 69 lakh people died globally and around 5.31 lakh deaths were registered in India. WHO issued important guidelines to be followed by the health sector and building construction sector in order to mitigate the spread of COVID-19. It is very important to check the Green Building Rating Systems used globally are compatible with these new WHO guidelines or not. The study also includes the opinions of doctors as experts regarding the methodology of the application of these guidelines in the Building sector. It was found that these present Green Building Rating Systems require modifications and revisions in the weightage and the structure of the Indoor Environmental Quality parameter.

Keywords:- Green Building Rating Systems, Covid-19, Indoor Environmental Quality.

Introduction:- On 11 March 2020, WHO (World Health Organization) declared a global health emergency due to the worldwide spread of the COVID-19 virus, which originally started spreading from Wuhan, China. This virus is the superior version of SARS-COV-1 which is the cause of the Severe Respiratory Syndrome (SARS) spread in the year 2003. The severity of the COVID-19 infection can be judged by the report of WHO (World Health Organization) [1],[2] which claimed that more than 15 million cases were recorded in 213 countries and more than 69 lakh deaths were registered globally. In India, around 5.31 lakh people lost their life resulting from climate change.

During COVID – 19 Outdoor Air Quality Vs Indoor Air Quality:-

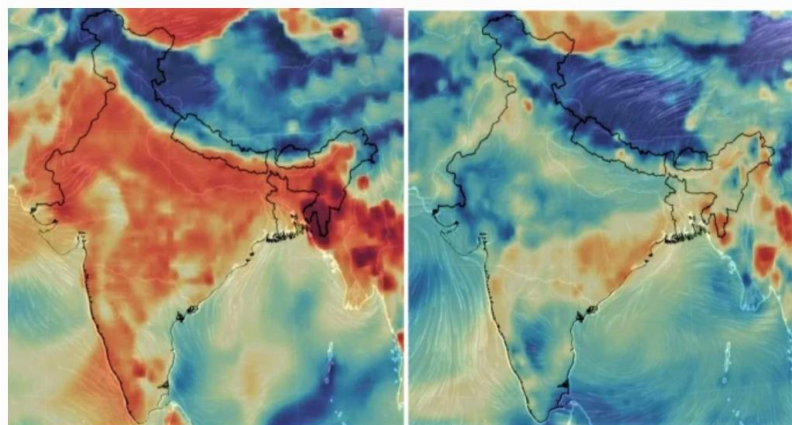


Figure 1:- P.M. in 2019 and P.M. During the lockdown in 2020

Source:- [3]

During the COVID-19, to minimize the spread of the infection the government of India opted for a countrywide lockdown. As per the report published by CPCB (Central Pollution Control Board) there

is an overall surge to around 52% in outdoor Particulate Matter. According to the report [3] and as per **Figure 1**, an overall reduction in the air quality index is also observed. According to the report [3] during the lockdown, major social and economic activities are limited to the residential areas. To mitigate the effects and reduce the spread of this deadly COVID-19 virus, the World Health Organization had released some important guidelines which majorly address the indoor air quality of the building.

Role of Green rating systems:- Green Rating systems are adopted a decade and a half ago to provide better indoor environmental quality to building users and to provide some balance between the development activities and climate. The basic objective behind the adoption of green rating systems is to provide a strong sustainable angle to development activities and to make our buildings resource-efficient and energy-efficient. After Covid- 19 it is essential to check the fundamentals of these Green Rating Systems and to analyse whether they are supporting the guidelines issued by WHO (World Health Organization).

Objectives of the Study: -

- To understand the COVID-19 Virus, and measures are taken by the government and international agencies like WHO (World Health Organization) to prevent COVID-19 infection from spreading further.
- To conduct a questionnaire survey (expert opinion) from doctors to identify the measures to be adopted to make a building more resilient to such severe viral infection.
- To check the structure of the present Green Rating Systems of India on the basis of the opinion given by doctors on design for post covid situation for the identification of the gaps in the existing structure and the solution of the same.
- prepare the Guidelines based on the survey conducted.

Methodology: -

Stage 1

What is Covid – 19 and probable reason of Spreading COVID – 19 inside the built up space.

Identification of the gaps in Green Rating Systems, on the basis of the analysis of the survey.

Stage 2

Guidelines related to COVID-19 issued by WHO and identified on the basis of the survey

Guidelines, and suggestions to improve the Green Rating Systems on the basis of the results of the

As per **Figure 2**, the research methodology consists of 4 stages. The starting stage consists of the study of COVID-19 and the identification of the methods of its spread. The second stage consists of the study of the guidelines released by international agencies like WHO (World Health Organization) to mitigate the effects and minimize the spread of the same. The Second stage also consists of survey-based outcomes from doctors and other experts. The third stage consists of the analysis and identification of the gaps in the Green Building Rating Systems with respect to these guidelines and the government of India’s measures to mitigate the effect of this pandemic. The final stage consists of suggestions regarding the guidelines and modifications in the present Green building rating Systems .

About Corona Virus: -The size of the Coronavirus particle is in the range of 80-160nm (Nanometer). It transferred via infected microscopic airborne particles and contaminated aerosol droplets. It always spread via three different modes – Sneezing, coughing, and talking. The following cases identified show the pattern of the spread of the COVID-19 virus inside space.

Case 1:- **Wuhan- China** - First COVID- 19 patient was identified from Wuhan – China at a Restaurant. Centralized Air Conditioning system is the cause of the spread to other families.

Case 2:- In **Inner Mongolia, China** a person unknowingly enters the room of already affected people and got infected without coming to contact because it is a mechanically ventilated room.

Case 3:- A PIL was filed at Delhi High Court regarding the spread of COVID- 19 virus because of the Air Conditioning systems and it should be stopped in public buildings under Air Act 1981.

According to different research, it was found that COVID–19 spread in those spaces where there is a lack of exchange of air. Natural Ventilation is critical to prevent the transmission of COVID-19. According to the ASHRAE standards, 170-2017 the air exchange rate in the healthcare building is around 6-12 per hour. According to the medical expert, the study revealed that the pathogen of Corona Virus can linger in the indoor air space for at least 8 minutes. If there is no possibility of exchange of air this virus will be there in the space for a much longer time and harm the occupants of that space.

Government actions to counter Covid – 19:- There are certain steps the Government had taken in a hurry in order to control the damage started by the Covid -19 which is limited to sanitization, social distancing measures, setup of oxygen plants, and importantly city lockdown which was announced on 24 March 2020. Even the supreme court opted to shut the mechanical ventilation inside the spaces for that particular duration .

Green Building Rating Systems:- According to the research report [4] Green Building Rating Systems are the Building Evaluation tool that analyze the building on the basis of a set of parameters. There are over 400 Green Rating Systems used globally. The majority of the Green Building Rating Systems work on Common parameters(Like energy, water, air, site management, etc). There are seven Green Building Rating Systems selected for the analysis (3 are Indian and 4 are global GBRS.

1)GRIHA V2019:- GRIHA is India’s first adopted national rating system. As per **Figure 3** the overall weightage of Indoor Environmental Quality is 12 points which comprises Indoor Air Quality (6 Points), Thermal Comfort(2 Points), and Visual Comfort(4 Points). The Indoor Air Quality parameter covers the monitoring of Carbon Monoxide(CO), Carbon dioxide(CO₂), Temperature,and Humidity. The details of the distribution of the credits are shown in **Table 1**.

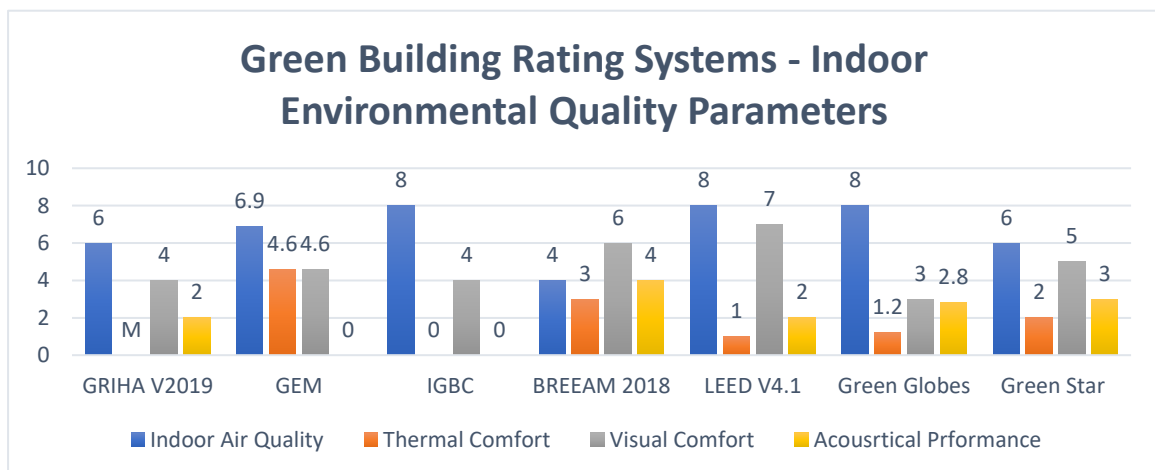


Table 1:- Indoor Environmental Quality – GRIHA Source:- [5],[4]

S.No.	Indoor Environment Quality – GRIHA	Points
1	Visual Comfort:- This parameter covers the sub-parameters and guidelines related to the natural and artificial lighting inside the space. It also covers the mandatory guidelines of (the SHGC) Surface Heat Gain Component. It also covers the guidelines related to (UDI) Useful Daylighting Illuminance	4 Points
2	Thermal & Acoustical comfort:- This parameter covers the mandatory guidelines of thermal comfort and acoustical performance guidelines.	2 Points
3	Indoor Air Quality:- Central pollution control board norms applied	1 Point
4	Minimum requirement:- standard 62.1-2010 by ASHRAE, Section 4-7 Ventilation for Acceptable Indoor Air Quality should be followed or NBC 2016 Volume 2, Part 8, Section 3 for Fresh air could be considered.	1 Point

Figure 3:- Indoor Environmental Quality Parameters of different Green Building Rating Systems used Globally

5	Ensure improved air quality:- by preferring green areas like plants etc, by applying door mats and different, for housekeeping use of green products, Installation of separate exhaust systems for janitor /storage rooms for chemicals, Filtration of microbes, isolation system UVGI system negative ionization, demand control ventilation.	1Point
6	Ensure Continuous monitoring of CO, CO ₂ , temperature and RH and meet the guidelines by ISHRAE standard 10001:2016, Table 6 for all habitable areas and Installation sensors for the spaces	2 Points
7	Ensure that all sealants used have low VOC	1 Point

2) GEM – (Green and Eco-Friendly Movement):- According to the technical manual report[6] , the Green and Eco-friendly Movement (GEM) is the new Green Building Rating System developed by ASSOCHAM and introduced in the year 2019. Under this Green Building Rating System, the evaluation was done on the basis of 28 Principles. The building evaluation was done out of 130 points. As per **Figure 3**, the indoor environmental quality parameters are around 16% and under which indoor air quality 9 points (6.9%), This Green Building Rating System covers CO₂ (Carbon di Oxide) and AQI (Air Quality Index) only. It covers the ASHRAE guidelines 62.1.2010 which focus on required ventilation for different spaces according to the occupancy ratio and also covers the distance between Apart from Air Quality the weightage of Thermal comfort and Visual Comfort is 6 points each(4.6%).

3) IGBC – Indian Green Building Council:- IGBC is the Green building Rating system introduced in the Indian construction market in the year 2001 and was developed by CII (The Confederation of Indian Industries). The overall evaluation of the building evaluation is around 100 points out of which the Indoor Environmental Quality is allotted 12% weightage (12 Points) and according to the **Figure 3** Indoor Air Quality weightage is 8 points (8%) and Visual comfort weightage is 4 points . The details of the point distribution of Indoor Environment Quality in IGBC rating system is shown in **Table 2**.

Table 2:- Indoor Environmental Quality – IGBC Source:- IGBC [7],[4]

S.No.	Indoor Environmental Quality	Credits
1	Minimum Fresh Air Ventilation:-:- Guidelines of ASHRAE 62.1-2010 standards for mixed and natural ventilation should be followed and for healthcare buildings ASHRAE 170-2008.	Required
2	Tobacco Smoke Control:- to protect the indoor environment from smoke pollutants and to protect the non – smokers from passive smoking.	Required
3	CO₂ Monitoring:- covers only monitoring covers monitoring.&Demand Control ventilation is also useful process to adopt.	1 Point

4	Daylighting:- The natural and Artificial lighting design process	2 Points
5	Outdoor Views:- Visual comfort and aesthetic appeal, value addition in the interior.	1 Point
6	Minimise Indoor and Outdoor Pollutants:- Maintaining Air Exchange rate as per ASHRAE guidelines and selection and application of the sustainable filter to maintain good quality air inside the spaces.	2 Points
7	Low Emitting Material:- the main objective of this sub-parameter is to select the material which does not have contents of Volatile Organic Compounds and formaldehyde.	3 Point
8	Occupants Well Being Facility	1 point
9	Indoor Air Quality after Construction and Before Occupancy:- the primary motive of this sub-parameter is to maintain the air quality standards as per ISO standards. This includes HCHO (27ppb) as per ISO 16000-3, PM ₁₀ (50 mg/m ³) as per ISO 7708, and TVOC (500 mg/m ³) as per ISO 16000-6 and CO (9ppm) as per ISO 4224	1 Point
10	Indoor Air Quality Management During Construction:- Providing good environmental quality during the construction activities for labours.	1 Point

4) **BREEAM 2018 (Building Research Establishment Environment Assessment Methods):-** The green building movement started with the development of the BREEAM rating system in the year 1990. It was the first Green Building Rating System developed in the U.K. Other countries followed the BREEAM rating systems structure to develop there rating systems. The overall weightage for the building evaluation is 100 points. Indoor Environmental Quality is given 17 % weightage out of which Indoor Air Quality is 4% (4 Points) ,Thermal Comfort 3%(3 Points), Visual Comfort 6% (6 points) and Acoustical Performance has 4%(4 points)weightage respectively. The details of the weightage of the same are given in **Table 3**.

Table 3:- Indoor Environmental Quality parameter BREEAM Source:- [8]

S.No.	Indoor Environmental Quality- BREEAM	Credits
1	Indoor Air Quality Plan:- The design decisions that minimize indoor air pollution and maintain air quality inside the building spaces.	Prerequisite
2	Ventilation:- The primary aim is to maintain the standard ventilation rate inside the spaces and to select an appropriate air filter. monitoring of CO ₂ pollutantsis required for spaces having high occupancy. Demand Control Ventilation can be good option .	1 Point
3	Emission from construction products:- Selection of non – VOC and HCHO material	2 Points
4	Post Construction air quality measurement:- The process of the measurement of HCHO should not exceed 100 µg/m ³ over 30 minutes as per the guidelines of WHO. VOC is also measured and should not exceed 500 µg/m ³ over 8 hours. Formaldehyde is as per ISO16000-2 (58) and ISO16000-3 (59) and TVOC is as per ISO16000-2 (58) and ISO16000-3 (59).	1 Point
5	Thermal Comfort:- the basic aim is to provide a comfortable temperature condition inside the space.	3 Points
6	Visual Comfort:-	

Indoor Air Quality Monitoring:- CO₂ monitoring and HCHO and VOC monitoring initially **LEED V 4.1 (Leadership in Energy and Environmental Design):-** It is the most widely used and popular Green Building Rating System of America. According to the report [9][10], **more than 167 plus Countries**. Indoor Environmental Quality parameter is allotted the weightage of 18 credits points. As per **Figure 3**Indoor air Quality weightage is around 8% of the total 100 Points allotted for building evaluation.

Table 4:- Indoor Environmental Quality - LEED V4.1 Source:- Source :- [11]

S.No.	Indoor Environmental Quality Parameters	Credits
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1	Maintaining Indoor Air Quality Performance Required:- application of ASHRAE 62.1-2010 standards natural and dilution ventilation should be followed for healthcare buildings ASHRAE 170-2008.	Prerequisite
2	Environmental Tobacco Smoke Control Required	Prerequisite
3	Minimum Acoustic Performance Required	Perquisite for School
4	Enhancement of Indoor Air Quality Strategies:- design calculations related to Mechanical, Mixed, and Natural Ventilation and required filters as per ASHRAE standards 52.2-2007	1-2 Points
5	Low Emitting Material:- Selection of the material with no VOC and HCHO contents.	1-3 Points
6	Construction Indoor Air Quality Management Plan:- this aims at the well-being of the construction worker during the construction stage.	1 Point
7	Indoor Air Quality Assessment:- It consists of the option of flushing outdoor air to control the temperature and relative humidity. option 2 consists of air testing which includes HCHO, TVOC,CO, CO ₂ ,PM _{2.5} etc after 14 days of occupancy. s	1-2 Points
8	Thermal Comfort	1 Point
9	Interior Lighting	1-2 Points
10	Daylight	1-3 Points
11	Quality Views	1-2 Points
12	Acoustic Performance	1-2 Points

Indoor Monitoring:- The concentration of Carbon Dioxide (CO₂) is also should be monitored inside with the device with a device that has an alarm system

Green Globes Rating Systems:- Green Globes is used in Canada. The total credit points are 1000 and the Indoor air quality is the subset of the Indoor Environment parameter.

Table 5:- Green Globes - Indoor Environmental Quality

Source :- [12]

S.No.	Indoor Environment Credits (150) – Green Globes	Credits
1	Ventilation:- ASHRAE guidelines 62.1-2007 standards for mechanically and Natural Ventilated areas. It also covers CO ₂ Monitoring and the use of appropriate filters to reduce air pollution.	33 points
2	Source Control and Measurement of Indoor Pollutants:- it covers avoiding the use of products with VOC content, methodology of resistance of mould growth, maintenance of HVAC systems, Carbon Monoxide monitoring where there is the source of combustion, domestic hot water system , and use of dehumidification of air.	47 Points
3	Lighting Design and Systems	30 Points
4	Thermal Comfort	12 Points
5	Acoustic Comfort	28 Points

Green Star Green Rating System:- The Green Star Rating System is used in Australia for the evaluation and certification of buildings. According to the **Figure 3** the overall weightage given to the Indoor Environmental Quality is around 16% out of total 100 points which covers Indoor Air Quality 6% (6 Points) Thermal Comfort 5%(5 Points), Visual Comfort 5%(5 Points), Acoustical Comfort 3%(3Points).

Table 6:- Indoor Environmental Quality Source :-

S.No.	Indoor Environmental Quality Parameters	Credits
1	Indoor Air Quality:- evaluation of air quality	4 Points
2	Acoustic Comfort	3 Points
3	Lighting Comfort	3 points
4	Visual Comfort	2 Points

5	Indoor Pollutants:- monitoring of the pollutants inside the building space	2 Points
6	Thermal Comfort	2 Points

WHO Guidelines and Expert Opinion:-WHO had released many guidelines for every nation to follow in order to protect life and control mortality rates because of infection. The Guidelines covers treatment measures and procedure, medicines, building design and social distancing measures, waste treatment, ventilation, lighting, design of isolation centers, etc.,and that are as follows:-

Table 7:- WHO Guidelines to counter COVID - 19 Spread and Cure

WHO Guidelines for Design for COVID-19		
S.No.	Building Level	Urban Level
1	Increase in Landscape area	Reducing dependency on public transport
2	Ventilation	Landscape Area
3	Lighting	Increase in the use of Cycle Tracks
4	Visual Comfort and windows	Pedestrians
5	Material Selection	Wastewater Treatment
6	Stairs and Lift	Waste Management
7	Wastewater Treatment	Entrance
8	Waste Management	
9	Interior Material Selection	
10	Entrance	

Experts Opinion :- The questionnaire was designed using the guidelines given by WHO (world health organization) for COVID – 19 and also various guidelines issued by the Government of India on different stages of the infection and the reliability of the questionnaire using the throwback alpha test comes out to be 0.77 which is equal to 77% and which is usually high. This also means that the response to the question does not vary much as compared to the overall response given by doctors.

Findings Based on Expert Opinion	
Experts Response	Analysis
<p>Figure 4:- Covid- 19 Spread Through Air</p>	<p>According to Figure 4 around 66.67% of the doctors strongly agree and 21.43% of the doctors are in favour that COVID – 19 spread through the air. They also expressed that there is always a possibility that an infected person in a mechanically ventilated room will give the infection to the other present in the room.</p>
<p>Figure 5:- Type of Ventilation System preferred</p>	<p>As shown in Figure 5 around 71.43% of the doctors suggested that natural ventilation should be given priority in designing a resilient building like that of COVID – 19. On the other hand, almost 37% of the doctors are in favour of mixed ventilation systems (HVAC + Natural Ventilation). Comfort conditions are also very important and therefore in some states of India where there is extreme heat and cold conditions, mechanical ventilation has to be used but with an air exchange system regularly.</p>

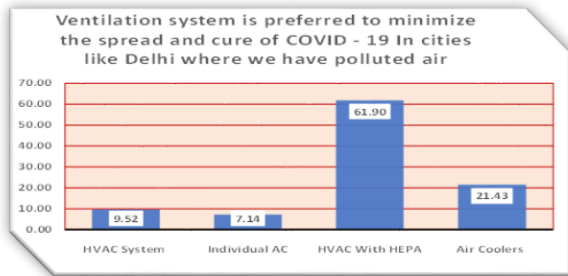


Figure 6:- Ventilation system preferred in cities with already polluted air

As shown in **Figure 6** around **62% of the doctors suggested** that in the cities where there is extremely polluted air (e.g. Delhi etc.) An **HVAC system** is a better solution than the other but it is useful only when it is used **with a HEPA filter**. The cities where a high concentrations of pollutants are found the HEPA filter can purify the air inside the building spaces and make it fit for humans.

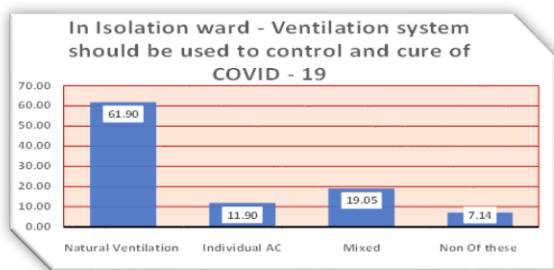


Figure 7:- Ventilation system preferred for isolation ward

As per On asking about the preferred Ventilation system **for the isolation ward around 62% of the doctors opted for Natural Ventilation** as there is a danger of the spreading of this virus in case of the ward having mechanical ventilation. Around 19.05% of the doctors opted for mixed ventilation. WHO guidelines also advocated for the natural ventilation particularly for isolation ward.

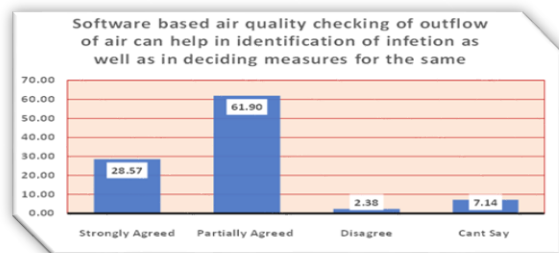


Figure 8:- Software-based air quality checking

According to the **Figure 8** software-based quality checking and monitoring are necessary as around **29% of the doctors strongly agreed** to the same and **62% of the experts partially agreed**. According to the experts, software monitoring is required as it will provide us with information about the infection and its severity and we can plan further actions according to that information.

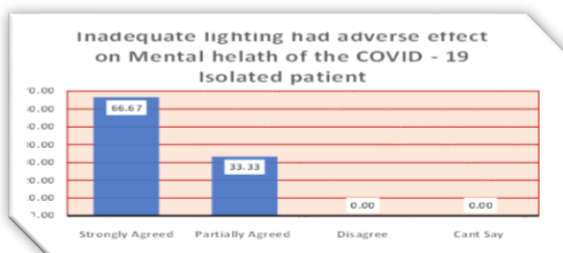


Figure 9:- Role of Natural Lighting in treatment of COVID

According to **Figure 9** Natural light is also very necessary in the treatment of COVID- 19 patients this can be seen in the survey response as **67% of the experts strongly advocate the role of Natural Lighting** as they feel that natural light provides positivity to the COVID- 19 patients. Around 33% of the experts partially agree on the same.

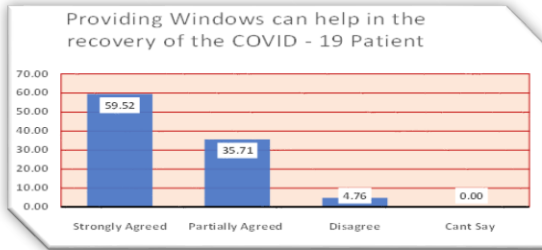


Figure 10:- Windows can help in the recovery from COVID

According to **Figure 10** Around 60% of experts believe that designers should more focus on designing windows in the proper quantity and in the proper direction to give comfortable conditions to the residents/patients. Around 36% of experts also partially agreed on the same. It is also responsible for maintaining the air exchange inside the room regularly. Around **20% of the experts partially agree with the above facts.**

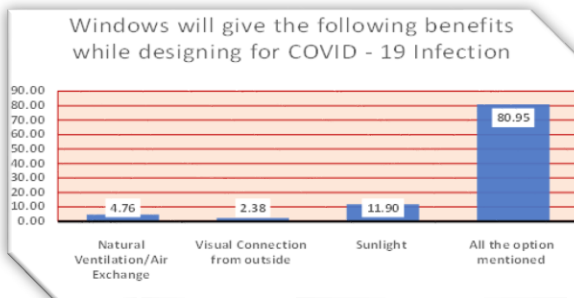


Figure 11:- Windows will give the following benefits

According to **Figure 11** on asking about the benefits of the windows in the treatment of COVID- 19 patients and around **80% of the experts agreed on the benefits of windows** as they most importantly provide natural lighting to the patients/ residents and secondly connection to the outside world and a patient/resident in isolation feel connected with the outdoor activities through visual connection.

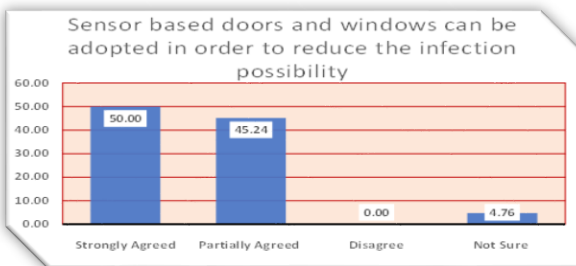


Figure 12:- Sensor-based doors and windows can help

According to **Figure 12** to minimize the contact-based spreading of COVID- 19 viral infection around **50% of the experts** suggested designers provide them with a **solution which is contactless** they strongly agreed on the use of **sensor-based doors and windows. 45.2% of experts partially agreed on the same.**

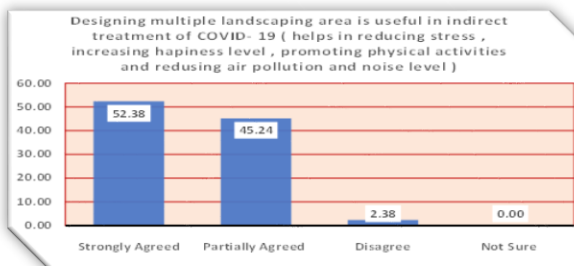


Figure 13:-Designing Multiple landscape area can be useful

According to **Figure 13** around **53% of the experts are in favour of designing landscape areas nearby the building** or they have encouraged the designers to design small pockets of the landscape areas nearby the building as it helps in reducing stress, contributes to increasing the happiness level, promoting physical activities and reducing air pollution and noise level. around 45% of the experts partially agreed with the same.

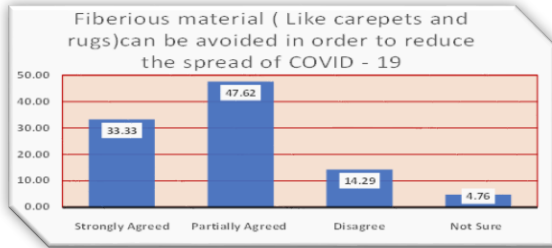


Figure 14:- Fibrous material can be avoided

According to **Figure 14** around 53% of the experts are in favour of avoiding the use of fibrous materials like carpets and rugs as it increases the living time of viruses in the interior space. Around 47.52% of the experts also partially agreed with the same.

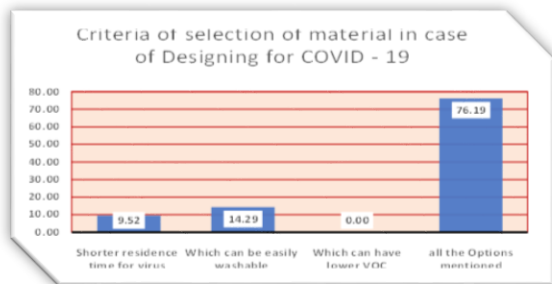


Figure 15:- Criteria for selection of material

According to **Figure 15** for the type of material selection 76.19% of the experts are in favour of the material which has properties like less residence time of the COVID – 19 virus, which can be easily washable, and has lower volatile oxidation compound so that it will reduce the possibility of the spreading of the viral infection and there is a less liveable environmental condition in the interior spaces for the virus.

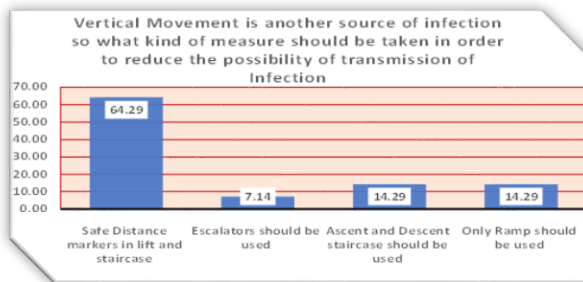


Figure 16:- Vertical movement is another vector for virus spread of COVID – 19.

According to **Figure 16** vertical movement is also very critical when comes to infection-free design. There are not many solutions available till now about the same. Therefore around 63.3% of experts and doctors opted for the use of lifts and staircases with safe distance markers to maintain social distancing. Around 14.3% of the experts had opted for separate ascent and descent staircases.

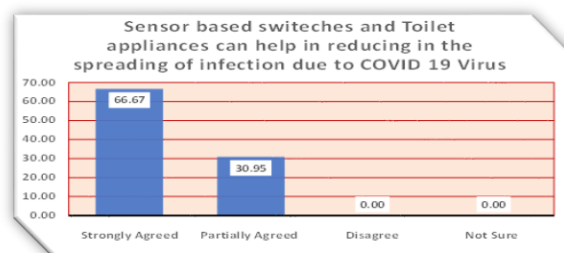


Figure 17:- Sensor-based switches and toilet appliances

According to **Figure 17** on asking about using sensor-based switches and toilet fixtures, 70% of the doctors strongly agreed and around 30% of the doctors partially agreed. Experts had advised designers to be more focused on using touch-free appliances to reduce the possibility of spreading viral infection.

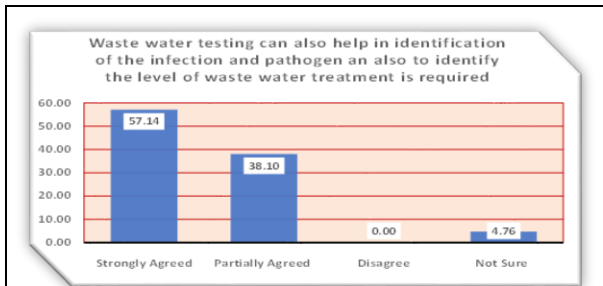


Figure 18:- Waste Water testing can be useful

According to **Figure 18** around 58% of the experts feel that testing and monitoring the wastewater to get information regarding the type of infections it has and also the degree of the treatment of the same is required to treat the same. Around 38% of the experts agreed to the same as well.

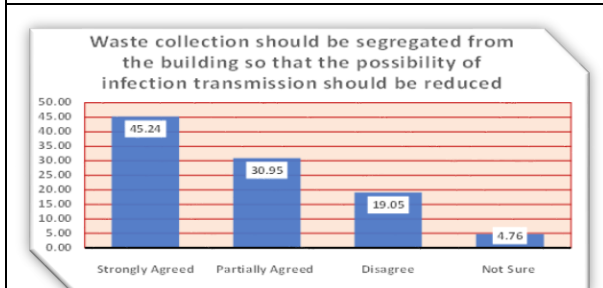


Figure 19:- Waste collection should be segregated.

According to **Figure 19** the experts, waste segregation is also a very important aspect of viral infection-free design therefore around 45% of the experts strongly agreed with designing with the approach of designing the Waste collection zone segregated from the building itself. Around 31% of the experts agreed on the same.

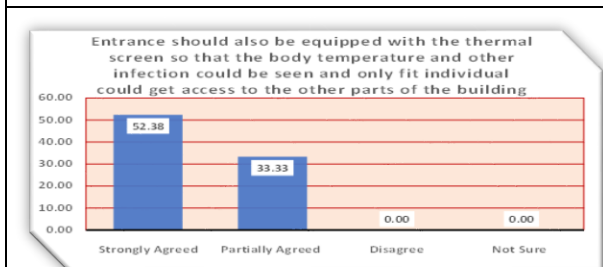


Figure 20:- Entrance - equipped with the thermal screening

According to **Figure 20** the survey response it is important to note that the experts are in favour of thermal screening at the entrance of the building/campus. This is to identify and restrict the infected person at the entrance of the building. Around 52% of the doctors strongly agreed and around 33% of the doctors agreed on the same.

Questionnaire-based on Design For COVID- 19 Parameters							
Indoor Environmental Quality							
Points of Consideration	Hypothesis	Sample proportion ' s '	Expected Population proportion ' p ' & q=1-p	Z calculated = s-p/√[(p*q)/n]	Z Tabulated	Result	Inferences
Indoor Environmental & Air Quality							
1) Covid – 19 Spread through Air?	H ₀₁ =It is expected that 70% of doctors agree that covid 19 is spread through the air. H _{a1} = It is expected that more than 70% of doctors agree that covid 19 is spread through the air.	.8809	.70	2.55	1.645	H ₀₁ is Rejected H _{a1} is Accepted	More than 70% of the doctors opined that COVID – 19 spread through Air.
2)Ventilation	H ₀₂ =It is believed that 70% of	.714	.70	.202	1.64	H ₀₂ is	70% of the

System is preferred to minimize the spread of COVID – 19	doctors agree that Natural Ventilation is the preferred choice to minimize the spread of COVID- 19 H _{a2} = It is believed that greater than 70% of doctors opted for Natural Ventilation as their preferred choice to minimize the spread of COVID- 19	3			5	not rejected H _{a2} is Rejected.	experts had chosen Natural Ventilation as their preferred choice.
3)Ventilation system is preferred in the city where there is already polluted air	H ₀₃ =It is believed that 49% of doctors agree that HVAC + HEPA is the preferred choice for COVID-19. H _{a3} = It is believed that greater than 49% of doctors opted for HVAC+ HEPA as the choice of the ventilation system in the city which has polluted air	.619	.49	-2.82	1.64 5	H ₀₃ is rejected H _{a3} is Accepted	The majority of the experts had chosen HVAC + HEPA filter as their preferred choice.
4)Preferred Ventilation Systems for the Isolation Ward to control and cure the COVID – 19 Virus.	H ₀₄ =It is believed that 49% of doctors agree that Natural Ventilation is the preferred choice for COVID- 19. H _{a4} = It is believed that greater than 49% of doctors opted for Natural Ventilation as the preferred choice for the Isolation wards in the treatment of COVID – 19.	.619	.49	1.67 2	1.64 5	H ₀₄ is rejected H _{a4} is Accepted	Above 49% of the experts had chosen Natural Ventilation as their prime choice for COVID- 19 Isolation Ward.
5)For cities where there is tremendous air pollution, what kind of ventilation system is preferred for ICU - Covid Wards	H ₀₅ =It is believed that 70% of Experts agreed that HVAC + UVGI is the preferred choice for COVID- 19 ICU ward in the city where there is already polluted air. H _{a5} = It is believed that greater than 70% of doctors opted for HVAC+ UVGI as the preferred choice for COVID- 19 ICU in the city where there is already polluted air.	.5	.7	-0.2	1.64 5	H ₀₅ is not rejected. H _{a5} is rejected	70% of the Experts had chosen the HVAC+ UVGI Ventilation system. investigation is needed
6)Software-based monitoring of the outflow of air to get the information regarding kind of infection.	H ₀₆ =It is believed that 70% of doctors agree that Software-based monitoring will help to get the information regarding the type of infection. H _{a6} = It is believed that greater than 70% of doctors opted for Software-based monitoring will help to get information regarding the type of infection.	.89	.7	2.68	1.64 5	H ₀₆ is rejected. H _{a6} is Accepted	Above 70% of the experts are in favour of having software monitoring of the air outflow to decide about the further treatment of

							the same.
7)Inadequate lighting affects the mental health of the COVID- 19 Patients.	H ₀₇ =It is believed that 70% of doctors agree that an Inadequate level of lighting affects the mental condition of COVID-19patients. H _{a7} = It is believed that greater than 70% of doctors agree that an Inadequate level of lighting affects the mental condition of COVID-19patients.	1.0	.7	4.24	1.64 5	H ₀₇ is rejecte d. H _{a7} is Accept ed	Above 70% of the experts feel that the absence of natural lighting affects the mental health of the COVID – 19 patients.
8)Providing windows in the room will help in the recovery of COVID-19Patients.	H ₀₈ =It is believed that 70% of doctors agree that providing windows in the room will help in the recovery of the COVID-19 patient. H _{a8} = It is expected that more than 70% of doctors agree that providing windows in the room will help in the recovery of the COVID-19 patient.	.952 3	.7	3.56	1.64 5	H ₀₈ is rejecte d. H _{a8} is Accept ed	Above 70% of the experts feel that windows play a very important role in the recovery of COVID-19 patients.
9)Windows will give you the benefits Such as Natural lighting, Connection with the outdoor environment and Air exchange which is helpful in the recovery of COVID-19 patients	H ₀₉ =It is believed that 70% of doctors agree that windows will provide natural lighting, connection with the outdoor environment, and air exchange which is helpful in COVID–19Treatments. H _{a9} = It is expected that more than 70% of the experts agree that windows will provide natural lighting, connection with the outdoor environment, and air exchange which is helpful in COVID–19Treatments.	1.0	.7	4.24	1.64 5	H ₀₉ is rejecte d. H _{a9} is Accept ed	Above 70% of the experts feel that Windows provides Natural Light, Visual Connection from Outside, and air exchange and helps in the treatment of COVID-19.
10)Sensor-based Doors and Windows can be adopted to reduce the possibility of spreading viral infection	H ₁₀ =It is believed that 70% of doctors agree that sensor-baseddoorscan be adopted to minimize the spread of viral infection through touch. H _{a10} = It is expected that more than 70% of doctors agree that sensor-baseddoors can be adopted to minimize the spread of viral infection through touch.	.952 4	.7	3.56 9	1.64 5	H ₁₀ is rejecte d. H _{a10} is Accept ed	More than 70% of the experts are in favorof adopting sensor-based doors and windows.
11)Designing Multiple Landscape	H ₁₁ =It is believed that 70% of doctors agree that the Multiple Landscape areas near the	.976 2	.7	3.90 6	1.64 5	H ₁₁ is rejecte d.	More than 70% of the doctors feel

areas near the building is useful in the indirect treatment of COVID-19	building are useful in the indirect treatment of COVID-19. H _{a11} = It is expected that more than 70% of doctors agree Multiple Landscape area near the building is useful in the indirect treatment of COVID-19.					H _{a11} is Accepted	that that multiple landscape spaces helps in indirect treatment.
12)Material Selection criteria for Design concerning COVID-19.	H ₁₂ =It is believed that 64% of doctors agree that material having a shorter residence time of virus, which can be easily washable and which have a low VOC value is more suitable. H _{a12} = It is expected that more than 64% of doctors agree that material having a shorter residence time of virus, which can be easily washable and which have a low VOC value is more suitable.	.76	.64	1.64 58	1.64 5	H ₁₂ is rejected. H _{a12} is Accepted	greater than 64% of doctors agree that material having a shorter residence time of virus, which can be easily washable and which have a low VOC value is more suitable.
13)Fibrous materials like carpets and rugs should be avoided.	H ₁₃ =It is believed that 69% agree that Fibrous materials like carpets and rugs should be avoided to reduce the possibility of the COVID-19 virus. H _{a13} = It is expected that more than 69% of doctors agree that Fibrous materials like carpets and rugs should be avoided to reduce the possibility of the COVID-19 virus.	.80	.69	1.67	1.64 5	H ₁₃ is rejected. H _{a13} is Accepted	greater than 69% of doctors agree that Fibrous materials like carpets and rugs should be avoided to reduce the possibility of the COVID-19 virus.
14)Vertical Movement is another vector of the spread of COVID-19 Infection. Measures to be adopted to reduce the spread.	H ₁₄ =It is believed that 70% of doctors agree that for vertical movement safe distance markers in staircases and lifts should be adopted. H _{a14} = It is expected that more than 70% of doctors agree that for vertical movement safe distance markers in staircases and lifts should be adopted.	.64	.7	-0.80	1.64 5	H ₁₄ is not rejected. H _{a14} is rejected	70% of doctors agree that for vertical movement safe distance markers in staircases and lifts should be adopted.
15)Sensor-based switches and toilet appliances should be used	H ₁₅ =It is believedthat 70% of doctors agree that for vertical movement safe distance markers in staircases and lifts should be adopted.	1	.7	4.24	1.64 5	H ₁₅ is rejected. H _{a15} is accept	Greater than 70% of doctors agree that for vertical

to reduce the possibility of spreading COVID – the 19 viruses through touch.	H _{a15} = It is assumed that more than 70% of doctors agree that for vertical movement safe distance markers in staircases and lifts should be adopted.					ed	movement safe distance markers in staircases and lifts should be adopted.
16)Wastewater testing and monitoring can help in the identification of the viral infection and its treatment.	H ₁₆ =It is believed that 70% of doctors agree that Wastewater testing can help in the identification of the viral infection and the degree of treatment required to control the viral infection. H _{a16} = It is expected that more than 70% of doctors agree that for vertical movement safe distance markers in staircases and lifts should be adopted.	.952 4	.7	3.56	1.64 5	H ₁₆ is rejected H _{a16} is accepted	Greater than 70% of doctors agree that for vertical movement safe distance markers in staircases and lifts should be adopted.
17)Waste collection should be segregated from the building.	H ₁₇ =It is believed that 70% of doctors agree that waste collection should be segregated from the building H _{a17} = It is expected that more than 70% of doctors agree that waste collection should be segregated from the building.	.761 9	.64	1.64 58	1.64 5	H ₁₇ is rejected. H _{a17} is accepted	Greater than 70% of doctors agree that waste collection should be segregated from the building.
18) Entrance should be combined with a separate sanitization zone.	H ₁₈ =It is believed that 70% of doctors agree that the Entrance should be combined with a separate sensitization zone. H _{a18} = It is expected that more than 70% of doctors agree Entrance should be combined with a separate sensitization zone.	1	.64	4.24	1.64 5	H ₁₈ is rejected. H _{a18} is accepted	Greater than 70% of doctors agree that waste collection should be segregated from the building.
19)Entrance should be equipped with thermal screening	H ₁₉ =It is believed that 70% of doctors agree that the Entrance should be combined with a separate sensitization zone. H _{a18} = It is expected that more than 70% of doctors agree Entrance should be combined with a separate sensitization zone.	.857 1	.7	2.22 17	1.64 5	H ₁₉ is rejected. H _{a19} is accepted	Greater than 70% of doctors agree Entrance should be combined with a separate sensitization zone.

The above table shows the hypothesis-based testing based on experts' perceptions.

Conclusion:-After analysis of different Green Building Rating Systems used globally and the guidelines issued by WHO (World Health Organization) to counter the spread of the COVID-19 virus, it could be observed that there are significant modification and revision is required in the present structure and weightage of the Indoor Environmental Quality of the Green Building Rating Systems.

WHO guidelines focused on Indoor Air Quality, Material Selection, Visual Comfort, and Design application. Some of the guidelines are not covered in the rating systems and therefore required addition and some of the guidelines are inversely mentioned so needed correction and revision according to the same. The following are the inferences drawn from the expert's survey and analysis of the rating systems: -

A) Air Quality Parameter: -

1) **Revision in the structure and weightings of the Indoor Air Quality parameter:** - on analysis of different Green Building Rating Systems it was found that the weightage allotted of the same is around 6% to 8% which is very less and should be raised. The percentage raise in the weightage is subject to further research.

2) **Air Monitoring:** - Majority of the Green Building Rating Systems are covering CO₂ (Carbondioxide) & CO(Carbon monoxide) only. But the other pollutants like HCHO (formaldehyde) VOC (Volatile Organic Compound) , PM_{2.5}(Particulate Matter), are not covered in the monitoring systems. In order to provide building users healthy and safe environment the above mentioned air pollutants should be monitored regularly specially in the high occupancy zone.

3) **Natural Ventilation , Dilution Ventilation and Demand Control Ventilation should be given more preference than the conventional mechanical ventilation system:-** In order to give building users safe and infection free environment , Natural Ventilation should be preferred. If Mechanical Ventilation cannot be ignored then Dilution Ventilation (mixed ventilation system) or Demand Controlled Ventilation (a sensor based ventilation system in which air exchange rate increases on the increase in the concentration of the pollutants inside the space due to increase in the occupancy).

4) **Use of Appropriate filter :-** In order to provide infection free air inside the space to the building users , HEPA filter (High efficient particulate air filter) or UVGI (Ultraviolet Germicidal Irradiation is the use of Ultraviolet energy to kill viral, bacterial and fungal organisms) could be used.

5) **Analysis of the outflow of air through air quality software:-** in order to get the information about the severity of the infection, Air Quality software could be used to analysis the outflow of air from working spaces , service spaces and toilets.

B) Visual Comfort:-

1. **Natural Lighting:** - Natural Light reduces mental stress and also reduces the pressure on the person who is being treated in isolation. The lack of sunlight in the building inside hurts the occupant's mental health.

2. **Windows and outside view:** - windows are one of the essential component as it allow access to natural ventilation and sunlight.. The view from the window gives a psychological advantage to the person undergoing treatment in isolation.

C) Material Selection: -

1. **Material Selection:** -Use of material with a shorter residence time for the virus and the use of an easily washable surface can be applied instead of conventional option. Material like copper can be used in the interiors as it has less residence time for virus.

2. **Avoid the use of carpets and rugs: -** In Green Building Rating Systems the use of carpets and rugs are encouraged in order to have good acoustics inside the space. But as per WHO guidelines, the use of carpets and rugs should be avoided.

D) Vertical Movement: -

1. **Stairs and Lifts:** - **Vertical** movement in the building is also critical and using lifts for vertical movement is also an important vector of the viral infection. Safe distance markers in the lift and staircase should be applied.

E) Waste Management: -

1. **Waste Water Monitoring and Management:** -This monitoring is useful for identifying pathogens and extra-polluting particles. According to the testing report, the level of treatment can be decided. The monitoring can be done monthly but the treatment should be done daily.

2. Waste Management: -another transmission of infection vector. There should be small waste collection zone should be designed to reduce the transmission of infectious disease. And this should be kept away from large gathering spaces.

F) Sanitization Zone: -a small sanitization zone should be provided at the entrance along with spaces for leaving clothes and potentially contaminated objects.

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