DESIGNING A RESIDENCE FOR ENHANCING THE INDOOR ENVIRONMENT

A Dissertation

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CHAPTER I

INTRODUCTION

1.1 Present Situation of Environment

Climate change, pollution, environmental deterioration, and resource depletion are some of the most pressing environmental problems today. Being able to breathe is crucial for human survival, so having access to clean air is quite advantageous. The air we breathe needs to be as pure as it can be for the optimum quality of life because it provides oxygen to our lungs, blood, and other organs. Interestingly, even in urban areas, interior air is five to 10 times worse than outdoor air, according to multiple WHO studies. India currently has a 51 percent industrial pollution level, a 27 percent car pollution level, a 17 percent agricultural burning level, and a 5 percent level from other causes. Premature deaths are a result of air pollution. (Environ, 2015)

“Environmental pollution is an incurable disease; it can only be prevented.”

- Baray Commoner

Air pollution is becoming a major health problem that affects millions of people worldwide. In support of this observation, the World Health Organization estimates that every year, 2.4 million people die because of the effects of air

pollution on health. Almost every person on the planet and almost every organ in the body is at serious risk for health problems due to air pollution. Fortunately, it is largely a preventable risk. Health can be affected quickly and significantly by reducing pollution at its source. Shortness of breath, coughing up phlegm, and sore throat, as well as other respiratory and irritant symptoms, go away within a few weeks. In addition, there is a significant decline in school absences, doctor visits, hospitalizations, preterm births, cardiovascular disease and mortality, as well as overall mortality. Cost-effective interventions are used. Strong advantages come from reducing the causes of air pollution and climate change. Despite the fact that areas with high air pollution have the greatest opportunity to improve health, pollution reductions even below international criteria continue to be linked to health improvements. (Martha et al., 2012)

In recent years, there has been a lot of researches done on how air pollution affects health. Exposure to pollutants like ozone and airborne particulate matter has been linked to an increase in hospital admissions and mortality from cardiovascular and respiratory diseases. These outcomes have been discovered in both short-term studies that link daily fluctuations in air pollution and health and long-term studies that have tracked cohorts of exposed people over time. It is uncertain if there is a threshold concentration for particulate matter and ozone below which no adverse health consequences are anticipated to occur, however impacts have been observed at very low levels of exposure.

Finding solutions to balance or harmonize environmental technology, resource protection, and aesthetic content is a challenge in modern architectural practice. There has been tremendous industrial and technical revolution around the world. Despite the revolution's widely acknowledged benefits for humans, it has led to an unsettling degree of environmental interaction. One issue of considerable concern for the eco-system is that as the quantity of greenhouse gases continues to grow, so will the planet's temperature, melting the ice caps and significantly changing weather patterns around the world. According to recent calculations,

the world’s environment is responsible for about one third of all greenhouse gas (GHG) emissions while using 40% of the world's energy. (Akanu Ibiam, 2018)

1.2 Indoor Air-quality

Indoor Air Quality (IAQ) refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. Understanding and controlling common pollutants indoors can help reduce risk of indoor health concerns. Outdoor air can enter and leave a building by: infiltration, natural ventilation, and mechanical ventilation. In a process known as infiltration, outdoor air flows into buildings through openings, joints, and cracks in walls, floors, and ceilings, and around windows and doors. (1)

Air quality issues often result from poor ventilation, which can cause heating and cooling system at the residence to work harder. The utility bill will rise as a result of the system being under higher stress and using more energy. Removing barriers to outside air can help lower interior pollution levels. On a hot or cold day, though, more airflow from the outside requires HVAC (Heating, Ventilation and Air Conditioning) system in the building to make up for it, therefore it's crucial to carefully manage ventilation in a building. Unpleasant odours can come from smoke, combustion products, rodent droppings, mold, and other indoor contaminants. Often, the issue is concealed deep within air conditioning ducts. People in their house or office may become miserable due to offensive odours. Additionally, they may be a sign of more significant issues that could endanger their health and safety. Additionally, a fresher odour makes a space feel more welcoming to visitors, clients, and staff. (Ashna, 2017)

Researches have shown that some people are more susceptible than others to air pollutants. These groups include children, pregnant women, older adults, and individuals with pre-existing heart and lung disease. People in low socioeconomic neighbourhoods and communities may be more vulnerable to air pollution because of many factors. Proximity to industrial sources of air

pollution, underlying health problems, poor nutrition, stress, and other factors can contribute to increased health impacts in these communities. Though everyone breathes the same atmosphere, different concentrations of toxic substances can be present in sealed indoor spaces compared to breezy outdoor spaces. The indoor pollutants are more densely concentrated than outside. Simply because there are limited space and air in residences than the outside, that is why the pollutants are more closely packed and with each breath, people are inhaling a larger volume of pollutants in comparison to outdoors (Ruqun, 2016). The symptoms alone can be uncomfortable. Nobody wants to have nose, eye, or throat irritation, but improving air quality can provide relief. Even a dull headache may be a symptom of something dangerous, such as carbon monoxide exposure. It's therefore important to take note of the symptoms and have indoor air quality checked to be on the safe side. [(2)]

1.3 Importance of Eco-friendly Materials in Interiors

Buildings as they are designed and used in cities today, symbolize uncontrolled consumption of energy and natural resources (such as Stone/Aggregate, Sharp Sand and Wood) with a consequent negative environmental impact and various type of pollutions. The design and construction of buildings based on sustainability concept by use of eco-friendly building materials and application of suitable retrofit options to the existing buildings could significantly improve energy use efficiency as well as better air quality outside as well as insides of a building. (Chen-Yi Sun, 2019)

Ecologically aware architects and interior designers should design buildings with the help of eco-friendly materials as they are cost effective, sustainable and environmentally friendly compared to traditional physio-chemical methods. The concept would be to design a building that creates aesthetic, economic, social and ecological sense. Sustainable architecture seeks to replace human dominion over nature with a more fulfilling relationships with the natural world (Ferreira and Mendes, 2004).

JUSTIFICATION

The pandemic has been an alarming situation worldwide and left us being more alert about our health and air borne diseases. According to studies, there are larger health concerns associated with exposure to indoor air pollution than there are with exposure to outside pollution. Particularly vulnerable populations, such as children, young people, the elderly, or those with chronic respiratory and/or cardiovascular disorders, can be harmed by poor indoor air quality. Although air pollution can come from a variety of places, including the street and the home, its effects can be just as deadly: Injurious health impacts of contaminated air include heart disease, asthma, and other respiratory disorders. This indicates the importance of conducting more studies on eco-friendly ways to control air pollution at residence level in order to enhance our understanding on the cause of problems and associated remedial measures.

Some studies were found through review of literature focusing on eco-friendly housing techniques and awareness like “Implementing Eco-Friendly Housing Techniques in Western Montana: Green Home Montana: Eco-friendly Housing and Living Practices - Final Capstone Portfolio” (Ream,2020), “Green building literacy: a framework for advancing green building education” (Cole,2019), “Evaluation Of Application of Eco Friendly Systems in Buildings in Nigeria” (Ogunde,2018), “A Study on Eco-friendly Building Management with Respect to Feasibility of Implementation” (Ashna,2017). Studies related to indoor air pollution were also found like “Indoor Air Quality and Health” (Cincinelli,2017), Smart homes and the control of indoor air quality (Schiewek,2018).

Related researches had been conducted in the Department of Family and Community Resource Management by Jadia (2014) on “Environment Friendly Practices Followed by Hotel Industry: A Comparative Study Between Two Cities of Gujarat State”, Lokhandwala (2017) on “Sustainable Interior Designing: Influence of Motivators’ Extent of Barriers and Practices Followed by Selected Interior Designers from Ahmedabad City” and Pavasiya (2014) on “Designing Vertical Garden for Residential unit”. Some other researches were found on “Implementing Eco-Friendly

Housing Techniques in Western Montana: Green Home Montana: Eco-friendly Housing and Living Practices - Final Capstone Portfolio", Ream et al. (2020) and "Indoor Air Quality and Health", Cincinelli & Martellini (2017) outside India. However, researches have not been conducted on designing a residence with eco-friendly ways to control air pollution. This encouraged the researcher to undertake this study.

The Department of Family and Community Resource Management, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, offers course on "Residential Space Designing" as well as "Ecology and Environment" at Bachelors level, "Interior Space Designing- Residential and Commercial" and "Green Interiors" at Master's level. Hence, the information gathered through the present research will widen the database and will help in strengthening the curriculum. The study will be helpful for the Owners and residents of the residences, as the researcher prepared a booklet to enhance the knowledge on eco-friendly ways to improve the air quality in interior spaces of Residences. The eco-friendly design of a residence developed by the researcher will be helpful for Interior designer, Architects and Civil Engineer as a reference while designing new residences in creating a healthier atmosphere indoors as the research findings would provide strong data base reflecting various eco-friendly materials which can be used to reduce air pollution inside the residences.

Statement of Problem

The present study was aimed to design a residence for enhancing the indoor environment.

Objectives of the study

1. To observe the indoor air environment of the existing residences.
2. To design an ideal residence for enhancing indoor air environment.
3. To design a booklet for the homemakers to enhance their knowledge regarding ways to enhance indoor air environment in residences.

Delimitations

1. The study was limited to 90 residences of Vadodara city.
2. The study was limited to designing a residence with enhanced indoor air environment.

CHAPTER II

REVIEW OF LITERATURE

A literature review is a description of the work done by qualified scholars and researcherson the subject. It is a comprehensive literature review and of previous journals, articles, books, articles and data from other researchers, providing insight into research done in the same field as the current study. Therefore, a thorough literature search was performed to become familiar with previous studies in thefield of the selected research topic of Designing a Residence for Enhancing the Indoor Environment. This exercise is fruitful in the systematic planning for conducting this research. This chapter appears under two headings. Theoretical Orientation and Related Research Studies.

2.1 Theoretical Orientation

For the presentation, the theoretical literature was divided into the following subheads namely.

2.1.1 Indoor Environment

2.1.2 Factors affecting Indoor Environment

2.2.3 Methods of Enhancing Indoor Environment

2.2.4 Negative effects of Poor indoor Environment

2.2.5 Advantages of good Indoor Environment

2.2 Empirical Studies

2.2.1 Researchers conducted Abroad.

2.2.2 Researchers conducted in India.

2.3 Conclusion on Review of Literature

2.1 Theoretical Orientation

2.1.1 Indoor Environment

Most people spend the majority of their time at home, where they also carry out their essential daily tasks (ADL) and sleep. As a result, it is crucial. To determine how content the residents are with their indoor surroundings. Studies (Brower 2003; Kaplan 1985; Langdon 1988; Lipsetz 2000; Mesch and Manor 1998) demonstrate that residing in a housing environment that is sustainably planned results in higher emotions of comfort, safety, and contentment as well as positive attitudes. Intentions are also influenced by residential contentment. The relationship between satisfaction and sustainability is rarely explored, despite the fact that several research cover various aspects of dwelling satisfaction in various nations among various ethnic groups.

According to an investigation by the Environmental Protection Agency, more than 75% of the population throughout the world live in towns and cities and spend almost 90% of their time inside buildings. Human beings usually perform many indoor activities related to work, shopping, leisure, dining, sport, and so on. To facilitate these human activities, an indispensable factor is the availability of indoor spatial information representation for satisfying the requirement of different applications. Moreover, with the rise of urban populations and the prevalence of large-scale buildings (e.g., airports, train stations, shopping malls, and hospitals) in current society, there is also a growing demand for up-to-date spatial layouts of indoor environments and information regarding the objects contained within them.

2.1.2 Factors affecting Indoor Environment

(IEQ) Many studies indicate that there are various factors which have profound effects on occupant satisfaction in indoor environments. These factors should be considered integrated components; the qualities of one factor significantly affect those of another. The caveat is that every IEQ

decision should be regarded as having potential positive or negative consequences in each of these factors. The effect of poor IEQ is not only on physical health of the building occupants, Building Simulaion Cairo 2013 - Towards Sustainable & Green Life, Cairo, June 23rd - 24th Topic name: Indoor Environmental Quality but also on their psychological health. The study investigates the different factors, which affect both physical and psychological health of occupants in healing environments. These factors are classified into two categories: spatial factors and environmental factors.

3.1. Spatial factors

To promote the speed of postoperative recovery and to achieve satisfaction during hospitalizations, it is important to provide patients with not only the best treatment possible, but also to remove such sources of stress and to counter them with positive distractions, which can affect the perceived waiting time positively Positive distractions refer to a small set of environmental features or conditions that effectively reduce stress. Distractions can include certain types of music, furniture layout, Indoor plants and landscaping, wayfinding and orientation, color scheme, art objects, views of nature and virtual reality (VR) intervention.

Environmental factors

There has recently been heightened recognition that environmental factors can influence health, which in turn affect the satisfaction of patients [16]. Air quality and freshness, availability of daylight, thermal comfort and acoustical quality are the important factors of IEQ in healing environments, which affect occupant satisfaction. (2)

2.2.3 Methods of Enhancing Indoor Environment

2.2.3.1 Methods of enhancing Indoor Air Quality

1. Purchase Air Filters

Air filters are used in residential and business structures. They are important tools when it comes to cleaning the air in a building. These filters can be purchased and changed on a monthly basis. This is especially essential for individuals with allergy issues.

2. Professional Carpet Cleaning

Many allergens and pollutants rest in the carpeting of an area. Regular vacuuming is important for cleaning efforts. Thorough professional cleaning can provide an extra form of cleaning. Many companies offer special services when it comes to pet treatment and allergens.

3. Furniture Cleaning

Along with odours furniture can also absorb germs, pollutants and pet dander. Cleaning upholstered furniture on a regular basis is very important. This is an effective way to improve indoor air quality in the home or the office.

4. Mop Floors

Hardwood floors, tile and other surfaces collect dirt and dust. These can be problem areas for keeping good air quality. Mopping these areas with non-abrasive products is a great approach. We can not only improve the air but apply care techniques to your floors.

5. Clean Walls

Walls can also hold onto germs and pollutants. Cleaning techniques can prevent this and protect your air. There are appropriate cleaning products that do not cause harm to surfaces. They allow one to maintain healthy indoor air.

6. Floor Mats

These are important tools to place at the entrance of every door way. Materials tracked on the feet can easily get into the air. These mats are used to clean shoe bottoms. They are useful products for homes and for businesses to purchase.

7. Air Purifier

There are different shapes and sizes of air purifiers on the market. There are mobile versions than can easily be placed in various spaces. These machines plug into the wall and work to purify the air where they are placed. Individuals with allergies can benefit from the use of these machines.

8. Healthy Humidity

It is important to have a balance of humidity in living spaces. This means a healthy humidity level of 30-50%. Mold and dust mites grow in areas where there is too much humidity. It is important to monitor this in both homes and businesses to improve indoor air quality.

9. No Smoking

Residents where there is cigarette or cigar smoking often have poor air quality. This smoke is not just in the air. It is absorbed into the furniture, carpet and bedding. This can lead to a variety of breathing and health concerns in the home.

10. Fix Leaks

Leaky appliances can cause a variety of problems in the home. This water can lead to the growth of mold, which affects air quality. It is also a cause for allergic reactions and asthma attacks. Repairing appliances will protect your property, the air and your family.

11. Radon Tests

Radon tests are important when it comes to protecting the home and improving the air. Certain parts of the country have more problems with radon than others. Basements are popular spaces where radon is found. Detectors can be purchased to ensure the air is safe.

12. Eliminate Aerosols

Aerosol products can pollute the air indoors. These are used in a variety of different products. Hair spray, deodorant and cleaning supplies are just a few of these. Eliminating the use of these can protect the air in the home or business.

13. Pet Cleaning

Pet dander is one of the issues related to having indoor pets. Many of these issues can cause poor air quality. Regular cleaning of pets, get rid of excess fur and dander. This is a good process for protecting the air. It is also helpful for those who have allergies in this area.

14. Air Conditioner Drip Pans

Air conditioning units often have drip pans where water is stored. This can cause problems over time. Mold is one example in this category. Emptying these pans regularly can prevent the growth of mold. It is also an important task to ensure air quality.

15. Non-Scented Paint

There are many paint products on the market today. One can find those that have no scent at all and are designed to promote good air quality. This is important for doing any type of home renovation or improvement job. Finding products that are environmentally friendly is essential.

16. Smoke Detectors

Smoke detectors are extremely important to any physical structure. They are not only useful in alarming when there is a fire. These detectors inform you when there is any smoke in the air. This is a good tool to have to ensure air quality in living spaces.

17. Circulate Air

It's a good idea to regularly circulate the air in living spaces. Ceiling or portable fans are useful in this way. This should be done during various times of the year. One can reverse ceiling fans in the winter. This keeps warm air circulating around the room.

18. Monitor Ventilation

There are various points of ventilation in the average structure. This keeps air moving and diverts to the outdoors. Monitoring ventilation is a good way to improve indoor air quality. Poor ventilation can result in odours and contaminants in the home environments.

19. House Plants

House plants serve more than one goal in this environment. These plants actually work to improve air quality. One can place plants in various rooms of the home to achieve this goal. Studies have shown that they help produce fresher air, as well.

Indoor plants can improve indoor thermal environment, relieve the anxiety, and reduce the CO_2 concentration especially in enclosed rooms with air-conditioning and heating. However, owing to the space limitation and the light requirement, it is very difficult to maintain traditional large-scale plantings indoors**.** (4)

20. Clean Bedding

There are many pieces of home décor that attracts dirt, debris and odour. Dust mites and mold can also be a problem for these items. Cleaning bedding components regularly is a way to avoid these issues. Washing blankets, sheets and comforters can improve indoor air quality in living spaces.

21. Outdoor Hobbies

There are a variety of hobbies that produce some sort of emissions. They can serve to pollute the air even if minimally. Wood working, carving, painting and other activities may be best done outdoors. This is a good way to improve the overall air quality in your home and living spaces.

22. Car Exhaust Control

Many homeowners allow their cars to idle or warm up during the winter months. This could be a cause for pollution or poor air quality. The problem exists more for homes with attached garages. It is important to keep this in mind when the garage door is closed, as well.

23. Remove Shoes

Removing your shoes at the door can protect the air. Although floor mats are effective in many instances, they can’t prevent all debris and materials being tracked into the home. You can improve the air quality by encouraging everyone to do this one thing on a regular basis.

24. Smoke Fans

Over most stoves these days is a fan designed to address smoke. This can be used when cooking certain types of dishes. The fan works to clear and purify the air. There are some microwaves with similar fan designs, as well. They provide you with a way to protect the air in your home.

25. Reduce Fragrances

There are a variety of products that are used in homes and businesses that have fragrances. Usually these are focused on preventing foul odours in the air. At the same time, these products can work to pollute the air. Reducing the use of these is a way to improve indoor air quality.

Indoor air quality typically focuses on the air that is inside of and surrounding specific structures. Applying certain practices is an effective way to accomplish this objective. It is a way for commercial business to provide a safe environment. This is important whether your business is a manufacturer or not. Residents in certain parts of the country find that monitoring indoor air quality is paramount. This involves regular monitoring and the application of effective practices (3).

2.2.3.2 Methods of enhancing Indoor Environment Quality

IEQ encompasses indoor air quality (IAQ), which focuses on airborne contaminants, as well as other health, safety, and comfort issues such as aesthetics, potable water surveillance, ergonomics, acoustics, lighting, and electromagnetic frequency levels. IEQ improvements to an existing building can occur at any point during the use of a building.

During the facility/renovation design and development process, federal projects must have a comprehensive, integrated perspective that seeks to:

- Facilitate quality IEQ through good design, construction, commissioning, and operating and maintenance practices;
- Value aesthetic and wellness concerns such as the importance of views or the integration of natural and man-made elements;
- Provide thermal comfort with a maximum degree of personal control over temperature and airflow;
- Supply an adequate quantity and quality of ventilation and intake of outside air to ensure acceptable indoor air quality;

- Prevent airborne bacteria, mold, and other fungi, as well as radon, through building envelope design that properly manages moisture sources from outside and inside the building, and with heating, ventilating, air-conditioning (HVAC) system designs that are effective at controlling indoor humidity;
- Use materials that do not emit pollutants, or are at least low-emitting;
- Assure acoustic privacy and comfort by employing sound-absorbing material and equipment isolation;
- Control disturbing odours through contaminant isolation and removal, and by careful selection of cleaning products. Pursue energy efficient strategies to remove harmful odours and recover energy used in conditioning the interior environment;
- Create a high-performance luminous environment through the careful integration of natural and artificial light sources; and
- Provide high quality potable water.

Value Aesthetic Concerns

- Ensure that windows have proper solar glare control, and encourage occupants to adjust to align with outdoor environmental conditions.
- Design spaces around basic human needs, proven preferences, and connections to the patterns of nature and the mind.
- Design circulation spaces with natural light and views that encourage interaction among building occupants. Where possible, use open stairways conveniently located which encourage people to use them instead of elevators both for health and energy savings.
- Require that individual buildings or facilities be consciously integrated into their natural and man-made context.

Provide Thermal Comfort

- Use ASHRAE Standard 55 *Thermal Environmental Conditions for Human Occupancy* as the basis for thermal comfort.
- Evaluate the use of access floors with displacement ventilation for flexibility, personal comfort control, and energy savings.
- Understand moisture dynamics as a key criterion in the selection of wall and roof assemblies.
- Evaluate the benefit of specifying high-performance windows to increase mean radiant temperature (MRT).
- Consider external conditions impacting thermal comfort.
- Provide easily maintained window treatments that occupants can individually control for both thermal comfort and light exposures from the sun.

Provide Ventilation and Maintain Acceptable Indoor Air Quality

- Design the ventilation system to meet or exceed ASHRAE Standard 62.1 *Ventilation for Acceptable Indoor Air Quality*. Work closely with the Mechanical Engineering team to strike a balance between optimal fresh air and energy efficiency using either the ventilation rate procedure (VRP) or the indoor air quality procedure (IAQP). Also, consider surveying building occupants to determine their satisfaction with the interior air quality.
- Implement a construction management program that ensures key ventilation components are protected from contamination during construction. Ensure that construction filters placed in ductwork and mechanical equipment are routinely inspected and replaced as needed. Do not install carbon filters until all construction work, including dry wall and painting, has ceased.
- During operation, either develop a plan for identifying needed filter media replacement or replace filter media on a regular schedule.

- Provide Energy Recovery Ventilation systems for needed ventilation air as a standard feature in new construction which is typically highly insulated and extremely airtight.

Prevent Radon Entry, Airborne Bacteria, Mold and other Fungi

Prevention of mold and fungi is dependent upon effective HVAC and building envelope design and construction. The HVAC system must be able to control interior humidity throughout a wide range of outdoor conditions. The system must be designed to have the capacity to dehumidify at the 1% Humidity Ratio and mean coincident dry bulb temperature, and control interior humidity at both extreme and low load conditions. The building envelope must be carefully designed to prevent intrusion of water and to dry if intrusion should occur. It must also incorporate barriers that control vapour and air infiltration.

- Carefully consider the envelope of the building to prevent moisture infiltration.
- Investigate and remediate immediately when there is a mold or moisture problem, either from high humidity, a leak, or flood.
- Ensure the number of spores in the indoor air is less than the outdoor air. It is recommended that there should be less than 700 spores in a cubic meter of air.
- In areas where it is prevalent, include measures to test for radon and control and mitigate radon build-up.

Limit the Spread of Pathogens

For health care facilities:

- Implement proper maintenance procedures to prevent nosocomial infections.
- Consider removing restroom doors to reduce the chance of acquiring infections.

Use Safer Materials That Have Less Hazardous Ingredients and are Low-Emitting

- Look to EPA's Recommendations for environmental performance standards and Eco labels
- Limit the use of volatile organic compounds (VOCs) in such products as cleaners, paints, sealants, coatings, and adhesives. See also WBDG Evaluating and Selecting Green Products.
- Avoid products containing formaldehyde (i.e., carpet, wall panels, or prefabricated cabinetry).
- Remove asbestos-containing material, or contain it in a manner that precludes the possibility of future exposure.
- Carefully follow lead-safe work practices during renovations by enforcing thorough clean-up. Follow EPA's Renovation, Repair, and Painting regulatory requirements, using certified contractors and lead-safe work practices.
- Create safe, convenient, and secure storage spaces for housekeeping chemicals.
- If an area in an occupied building is being renovated, then consider isolating and negatively pressurizing the construction area whenever work is being performed that would produce dust, fumes, or odours. If conditioned air is required due to high end finishing work, then air should be directly exhausted to the exterior environment and not returned to the fan.
- Ensure that office equipment emits minimal odours or pollutants and is contained in an unoccupied, enclosed space.

Assure Acoustic Privacy and Comfort

- Minimize noise through the use of sound-absorbing materials, high sound transmission loss walls, floors, and ceilings, and equipment sound isolation.
- Minimize noise distractions by shared proximities (grouping similar functions together) and through controlled circulation patterns.

- Consider sound masking systems, where feasible. These systems introduce an unobtrusive background sound that reduces interference from distracting office noise. Note that some level of HVAC "noise" can serve as a background white noise source, eliminating the need for sound masking systems.
- Avoid the use of small diameter ducts with high velocity airflow.

Control Disturbing Odours through Contaminant Isolation and Product Selection

- Directly exhaust copying and housekeeping areas, and provide added return air grills in these areas. This will help limit lower atmosphere ozone generation, commonly associated with duplicating and printing processes. Ozone acts as a power oxidant. It can attack surfaces of certain elastomers, plastics, paints, and pigments; and aid in sulphide and chloride corrosion of metals. Possible health hazards caused by ozone include eye and mucous membrane irritation as well as chronic respiratory disease.
- Minimize disturbing odours through contaminant isolation and careful selection of cleaning products.
- Ensure maintenance procedures are in place to remove all trash and recyclables from the building on a regular basis rather than storing them within the building for prolonged periods of time.
- Prohibit smoking in all areas of the building. Environmental Tobacco Smoke (ETS) is a known carcinogen.
- In special cases where smoking is permitted, e.g., federal judge's private chambers, ensure that the spaces:
    - Have lower pressure than adjacent areas;
    - Comply with ASHRAE Standard 62.1 for proper ventilation;
    - Are isolated from the return air system of surrounding areas to prevent pollutants from spreading to other areas.
- Use and effectiveness of Air Cleaners.

Create A High—Performance Luminous Environment

- Provide day lighting for ambient lighting wherever feasible.
- Supplement natural light with integrated, high-performance ballasts, lamps, fixtures, and controls.
- Replace magnetic fluorescent lamps with high-frequency electronic ballasts to reduce flickering.
- Reduce direct glare from both natural and man-made sources in the field of view—particularly in spaces with highly reflective surfaces, such as visual display terminals (VDTs).
- Use ambient lighting systems that provide reduced levels of diffuse, general illumination, and supplement with task lighting. Most people do not need lighting in excess of 300 lux.
- Avoid dark colors on walls. Locate windows to maximize benefits of natural light and minimize glare.
- Provide dimmable fixtures where possible, combined with task lighting for occupant control. Dimming light levels will conserve electricity and reduce heating loads which lighting imposes on the building's HVAC system. Lighting levels are often designed for the most demanding user, and all other occupants are forced to adapt to light levels that are brighter than desired.
- Create a safer and more accommodating environment for the growing population of people with low vision (defined as a chronic visual impairment that causes functional limitations or disability) and other disease- or other age-related vision challenges.

Provide Quality Water

- Comply with EPA Safe Drinking Water Act (SDWA) for the levels of various metals and bacteria in potable water systems.
- For newly installed or temporarily suspended domestic water systems, follow "start-up" procedures by flushing all downstream outlets.

- Conduct periodic 'maintenance flushing' to proactively control drinking water issues.
- Control domestic water temperature to avoid temperature ranges where legionellae grow: keep domestic water temperatures above 140°F (60°C) in tanks and 122°F (50°C) at all taps (faucets and showers).
- Design cooling tower and building air intake placement so air discharged from the cooling tower or evaporative condenser is not directly brought into the facility's air intake.
- Consider a closed loop system instead of an open system to reduce the potential of exposure at the cooling tower.

Be Aware of Exposure to Electromagnetic Fields (EMF)

Electromagnetic fields (EMF) are generated by forces associated with electric charges in motion, and by microwaves, radio waves, electrical currents, and transformers. EMF are thought to cause cancer, however there is currently insufficient evidence to prove this. There are no federal standards limiting occupational or residential exposure to EMF at this time, only various U.S. and International voluntary occupational exposure guidelines. Nevertheless, facility designers and managers should consult the following resources to find out the latest scientific research and recommendations on dealing with EMF exposure:

- National Institute of Environmental Health Sciences, Electric and Magnetic Fields
- World Health Organization (WHO), Electromagnetic fields (EMF)

Balance IEQ Strategies with Security Requirements

Since the terrorist attacks of 9/11, building owners and occupants have placed greater emphasis on facility security and safety. However, security and safety measures must be considered within a total project context, including the project's environmental goals. Several indoor environmental quality strategies, such as

dedicated ventilation systems and tight building envelopes, can be employed to help designers achieve an integrated, high-performance facility.

Secure facilities and spaces are not inherently exempt from day lighting. As required by the applicable security criteria, consider the following fenestration design features: non-opening; acoustical protections; visual protection, via elimination of line of sight into secure areas with angles or translucent or semi-opaque glazing, curtain walls, clerestories, skylights, glass unit masonry, fiberglass panels and other lightweight plastics; minimum required elevation from the ground or platforms; and access to daylight in break rooms and other common spaces (5).

2.2.4 Negative effects of Poor indoor Environment

A poor indoor environment quality (in terms of exposure to chemicals) is not often noticed by the occupants, making it one of the many health concerns that still remains a silent threat. As a result, residents are continuously exposed to a combination of endocrine disruptors and carcinogens (benzene, formaldehyde, PM/PAHs) (phthalates, PCBs).

A poor indoor experience can stifle productivity, waste money, and affect occupant health. So, whether you're an architect, designer, business owner, or employee, you should be aware of these 10 ways the indoors can affect you.

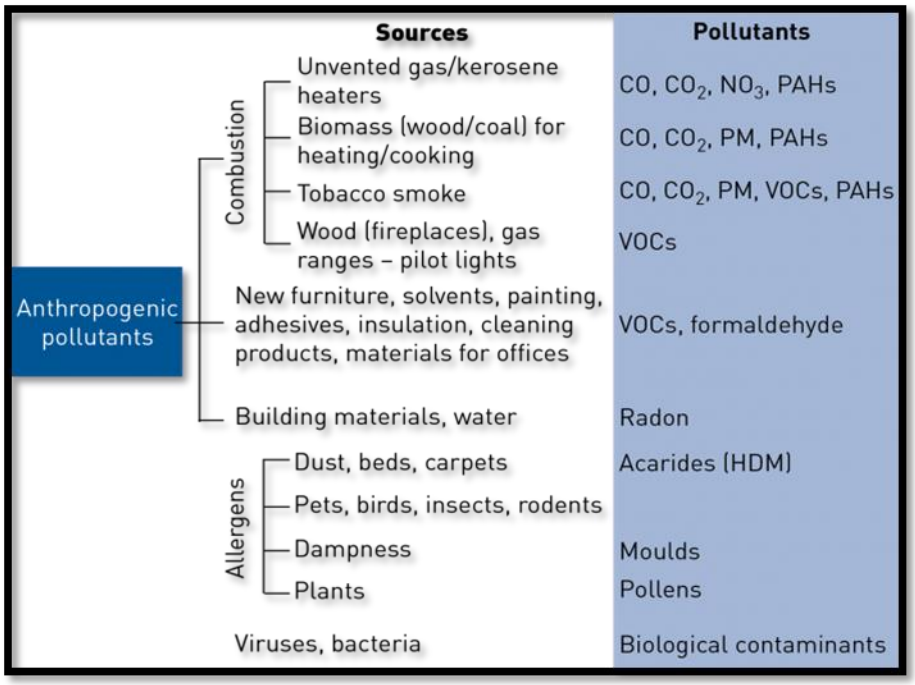

Figure (1): Different types of air pollutants

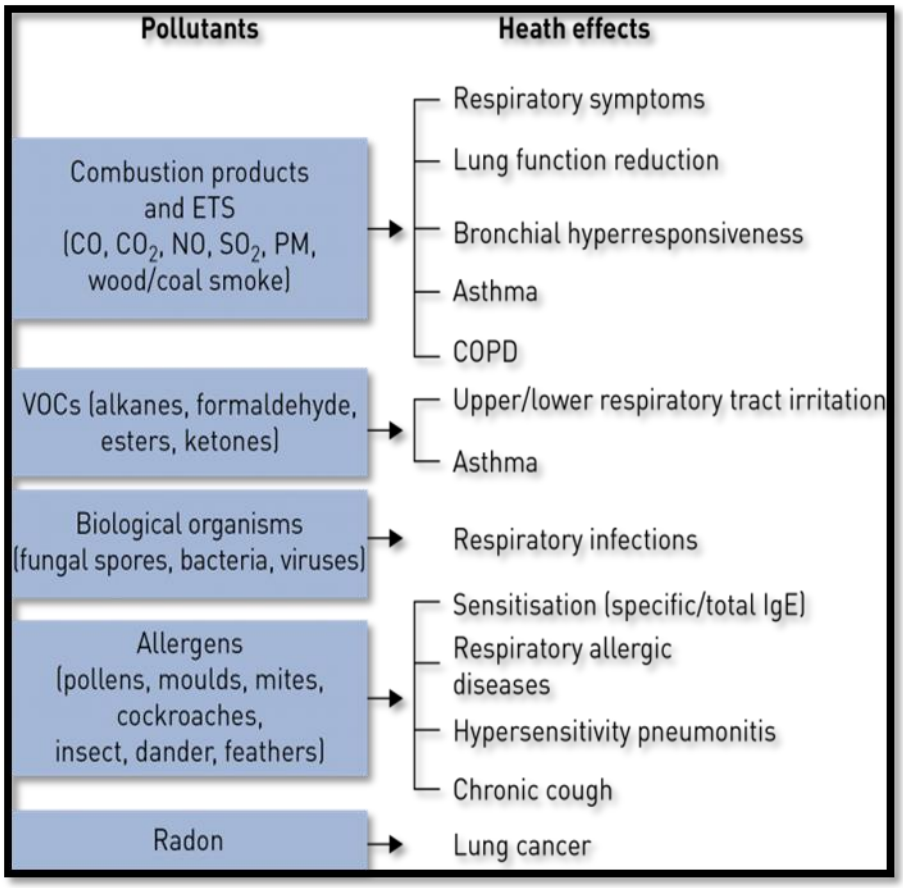

Figure (2): Air pollutants and their health effects

Source 1: https://www.erswhitebook.org/chapters/indoor-environment/

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1. **Indoor elements are often surprisingly toxic**

   The first questions that arise when discussing indoor environments are how the indoors affect us and how far-reaching those effects are. Those questions are multifaceted because the average indoor environment is complex, with many factors potentially affecting occupant well-being. The CDC's definition of indoor environmental quality (IEQ) notes that building dampness and contaminant exposure are typically responsible for occupant health issues. Recently, materials with high levels of volatile organic compounds (VOCs) have been spotlighted as particularly harmful to air quality; the EPA points out that concentrations of VOCs are noticeably higher indoors (as much as ten times higher than outdoor environments). Since VOCs are so common in paints, varnishes, wood preservatives, and other building materials, people who spend lots of time indoors are likely being exposed to particularly high levels of these damaging compounds.

2. **Indoor elements affect how you work, interact, and even sleep**

   An indoor environment doesn't have to be toxic to significantly affect its occupants. That's what the Well Living Lab, collaboration between Delos and the Mayo Clinic, found in its first study. Researchers attached biometric wearables to office workers and monitored their biological response to various changing elements in the environment, including changes in acoustic, lighting, and thermal conditions. The Lab concluded that such changes affected how the

workers performed, interacted, and slept. We're more sensitive than we might think to even more subtle environmental changes, and as a result, if indoor elements aren't carefully optimized, people won't feel or perform their best.

3. **A poor indoor environment can cause productivity (and profit) to plummet**

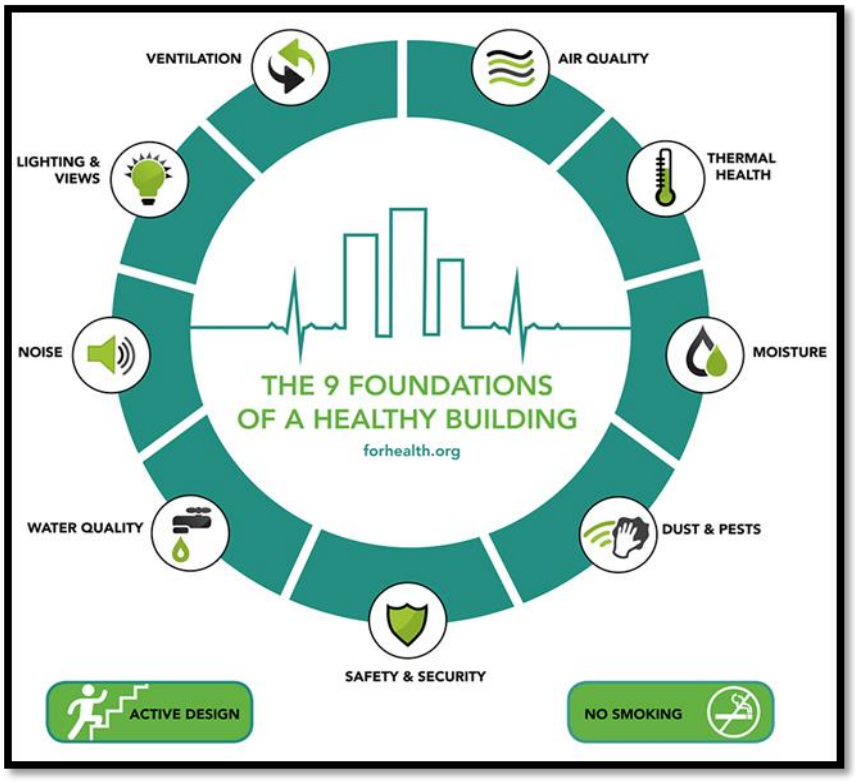
   Unfortunately, the stereotype of the stuffy office is still true today. It's not uncommon to see workplaces without windows, adequate ventilation, fitness solutions, or places of rest. These conditions can cause a poorer quality of life, and occupants in spaces like these may suffer from major sleep issues. Perhaps most noticeably, productivity rapidly declines and may even hit an all-time low.

   This may not seem obvious until you take a look at how employees in optimized workspaces are performing. For instance, an increase in ventilation from 20 cubic feet per minute of outdoor air to 40 boosts annual productivity per worker by $6,500. Even the smallest of changes can create a ripple effect; the simple inclusion of one plant per square meter increases productivity by 15%. For business owners and employees alike, these statistics underscore the importance of creating a work environment conducive to health and well-being.

   There are also countless worker health benefits that a better workplace brings with it. A 2000 study published in the Annual Review of Energy and the Environment observed that millions of dollars and countless work hours are lost yearly due to a poor indoor environment. The study estimated that better environments could reduce problems related to respiratory diseases, allergies, asthma, and other building-caused health issues, saving an estimated total of $31 billion annually. (And that's not even counting the estimated $140 billion savings from improved employee performance in general.) All in all, a human-first indoor workspace isn't a design accommodation but rather a fundamental necessity.

4. Be aware of the 9 foundations of a healthy building

At Harvard University's T.H. Chan School of Public Health, the Healthy Buildings project is examining exactly what a "healthy building" looks like and how the A&D industry can set new standards for indoor health. The initiative is the brainchild of Environmental Design professor Joseph Allen and his team, who have synthesized a wide range of environmental research into a condensed approach they call the 9 foundations of a healthy building. These foundations are the elements that make up the indoor built environment: air quality, thermal health, moisture, dust and pests, safety and security, water quality, noise, lighting and views, and ventilation. These 9 foundations require the right balance to foster the best possible indoor environment. This list is perhaps best used as a springboard to identify problem areas within an indoor environment and establish a set of criteria by which indoor spaces can be evaluated and explored.



Figure(3): Different aspects of good indoor environment

Source 2: From for health.org: The 9 foundations of a healthy building review the most essential components of the indoor built environment

5. Air quality is one of the most important indoor elements

While all of the 9 foundations for a healthy building is essential to an optimized indoor environment, many designers and businesses are focusing heavily on-air quality. This makes sense, as the EPA states that poor indoor air quality (IAQ) can have long-term health effects, possibly including respiratory diseases, cancer, and heart disease. Less severe but nonetheless damaging effects include irritation, headaches, dizziness, and fatigue. It's well documented that inadequate ventilation (and therefore lower IAQ) can lead to a loss of productivity and satisfaction. The EPA suggests several methods of improving IAQ, such as eliminating or reducing air pollution, improving ventilation, and utilizing air cleaners. Since air quality impacts all occupants and can have lasting effects, it needs to be a top priority for anyone in A&D.

6. Climate change may impact IEQ

The relationship between outdoor and indoor environments is more interconnected than it may at first appear. That's what a 2011 report by the Institute of Medicine indicated, noting that climate change may worsen already poor indoor environments. The abstract states, "As the world's climate changes, buildings that were designed to operate under the 'old' climatic conditions may not function well under the 'new'—affecting the health of those who live, work, study, or play in them." Indoor elements like air quality, building dampness, thermal stress, and ventilation could all be adversely affected by climate change. If left unchecked, these elements can create detrimental indoor spaces, so it's critical to monitor these in both old and new buildings.

7. Integrating biophilic design is better for everyone involved

The typical indoor environment today isn't exactly what I'd describe as "connected to nature." Indoor spaces tend to be rather shut off from the natural world, and many don't even have windows. Yet a connection to nature is exactly what biophilic design aims to create in order to foster a healthier environment for humans. Biophilic design can help improve behavioural health as well as social interaction and work performance. Many other aspects of biophilic design are naturally healthy—the presence of plants can enhance IAQ, for example—and it's also a highly sustainable design philosophy, making it an attractive option for both human occupants and the indoor environment.

8. Studies prove that comfort matters

Most indoor spaces are built to be comfortable, but few builders and designers qualify comfort during the planning and building processes. Comfort can be correlated with the indoor elements that affect occupants. A study in the International Journal of Sustainable Built Environment looked at thermal comfort, acoustic comfort, and visual comfort. Each element is essential to overall IEQ and needs to be regulated to maximize occupant comfort. Furthermore, these elements can be manipulated to create various indoor environments. For example, natural ventilation causes people to feel closer to nature than mechanical ventilation. Thus, the particular levels of comfort can be adjusted with occupant needs and the local environment in mind.

9. Watch out for Sick Building Syndrome and Building Related Illness

The range of negative health effects that an indoor space can have on occupants is often categorized under the Sick Building Syndrome term. As defined by the EPA, Sick Building Syndrome (SBS) is "used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified." While the culprits are often easy to identify (e.g., high-VOC materials, inadequate ventilation, etc.), if left untreated SBS can

significantly impact occupant health. SBS can affect more than physical health; workers can experience a loss of energy and productivity, while visitors and guests may experience dissatisfaction with the space. The best prevention against SBS is continuous surveillance of indoor elements and ongoing maintenance to ensure that IEQ is at its best.

Similar to SBS, Building Related Illness (BRI) refers to health issues that “can be attributed directly to airborne building contaminants.” A 1994 study in the Journal of Allergy and Clinical Immunology categorized the mechanisms by which agents cause BRI into four categories: immunologic, infectious, toxic, and irritant. It’s also possible for more than one of these mechanisms to cause BRI. However, the problems of SBS and BRI are preventable and manageable through vigilance and proactive measures.

10. Circadian-based light exposure can improve productivity and mood

Human circadian rhythms are responsible for the regulation of our energy cycles, but many artificially lit commercial settings disrupt these natural rhythms. In an office setting, this often causes workers to underperform and feel drowsy throughout the day, and in a general commercial setting, this can cause mood drops in occupants. Considering circadian rhythms in the built environment ultimately aids in performance increases and generates more positive emotions. Specifically, circadian-based lighting is greatly beneficial. Unfortunately, many indoor environments don’t have enough light to biologically stimulate occupants and satisfy circadian cycles. When light is sufficiently able to stimulate a biological response, IEQ increases. In one study, occupants who received more circadian stimuli became less depressed and got more sleep. Modifying lighting to the human circadian cycle is a simple yet dramatically effective change that any indoor space can easily make.

2.2.5 Advantages of good Indoor Environment

1. **Health and well-being:**

   Many people have health issues related to poor environments or living situations. A significant way this can be improved is through clear air and exposure to fewer toxins and pollutants. By adding air purifying systems to buildings, companies are prioritizing the quality of the air their workforce breathes. Many offices are built in older buildings with subpar ventilation, and a high-quality air purifying system can significantly improve the indoor air quality. Air filtration systems will eliminate odours, VOCs, pathogens, and particles from the air. Your workers deserve to breathe in fresh air and enjoy the many health benefits this will bring.

2. **Global Environment:**

   Through modern building designs that incorporate ventilation systems, energy-efficient lighting, and effective temperature control, more eco-friendly buildings, known as green buildings, are being established. According to the most recent IPCC report, buildings contribute to almost 40% of global energy-related CO_2 emissions. Therefore, green buildings play a positive role in benefitting the global environment.

3. **Work Productivity:**

   These essential health benefits coincide with improvements to work productivity levels. Improving indoor air quality can reduce absences and work hours being affected and reduced by asthma, respiratory allergies, depression, and stress. A happier and healthier workforce is certain to be more productive and innovative.

4. **Financial Sustainability:**

   Alongside higher productivity, which increases the value of a company, green buildings are an investment that'll pay off quickly. They are built using durable material and are energy efficient, often with onside renewable generators. Therefore, they cost less in upkeep, bills, and waste.

Source 3: https://enviroklenzairpurifiers.com/what-are-the-benefits-of-indoor-environmental-quality-ieq/

2.2 Empirical Studies

2.2.1. Researchers Conducted Abroad

Yasemin Afacan (2016) carried out study on “The influence of sustainable design features on indoor environmental quality satisfaction in Turkish dwellings”. The aim of this paper is to explore the influence of sustainable design features on occupants’ satisfaction levels with indoor environmental quality (IEQ) aspects in three types of dwellings. Satisfaction level was investigated through a field survey with 240 participants, in apartments, row and detached houses in Turkey. Satisfaction level was explored in terms of overall satisfaction with IEQ, with the efficiency of daily living activities and with sleeping quality. Satisfaction level was also investigated regarding the dwellings’ thermal, ventilation, lighting, sound level and moisture qualities. The findings indicate that the existence of exterior insulation, a thermostat, light dimmers and control of daylighting systems through operable windows have high impacts on the satisfaction level of occupants living in all three types of dwellings.

Zhao Dong et al., (2022) undertook research on “The impact of space design on occupants' satisfaction with indoor environment in university dormitories”. This study aims to better understand the influence of space design on occupants' satisfaction with indoor environmental quality. It conducted a questionnaire survey among occupants of five types of spaces in seven university dormitories. In total, 921 valid responses were collected. Using multiple linear regression, it was found that space design was the most influential factor on the occupants' overall satisfaction with indoor environmental quality. A correlation analysis indicated that there was an overestimation of the correlation between space design and other indoor environmental quality factors. The results of the Mann-Whitney test demonstrated that space design had a halo effect on these factors, and its pros and cons were analyzed. Furthermore, we compared five types of

spaces to identify the most satisfactory space type. Single and twin rooms with balconies provided more satisfaction. The occupants' satisfaction increased with an increase in the area per capita, whereas the increase was limited when the value reached 13.5 m2. This study revealed the importance of space design on occupants' satisfaction which deserves more attention, and offered a new dimension to indoor environmental quality research**.**

Xi Meng et al., (2022) conducted research on **"**A new method to improve indoor environment: Combining the living wall with air-conditioning**".** Indoor plants can improve indoor thermal environment, relieve the anxiety, and reduce the CO_2 concentration especially in enclosed rooms with air-conditioning and heating. However, owing to the space limitation and the light requirement, it is very difficult to maintain traditional large-scale plantings indoors. To improve indoor planting efficiency and thermal environment, the living wall was introduced to be combined with air-conditioning. Two identical rooms were built to analyze the efficiency of combining a living wall with air-conditioning. One room contained a living wall and air-conditioning, while the other room only with air-conditioning was served as a reference. The indoor thermal environment and CO_2 concentration were monitored, while the 64 participants were questioned to display their subjective feelings in two rooms. The results showed that combining the living wall lowered the relative humidity by 2.6%, maintained the indoor air speed at 0.20 m/s~0.30 m/s and reduced the CO_2 concentration by approximately 10%, while it increased the uniformity of these environmental parameters. The average skin temperature in the room with the living wall was 0.2 °C higher than that in the referred room and closer to the neutral mean skin temperature. The living wall significantly improved the subjective evaluation on indoor environment especially in air movement and air freshness, with the thermal comfort level from 0.13 (Slightly higher than "Neutral (0)") to 0.73 (Slightly lower than "Comfortable

(+1)").

Amzad Nasser et al., (2017) Carried out a study on **"**Comparative Study of Conventional and Green Residential Building**".** The purposes of the study were to select and study the energy consumption of an existing residential building and adopting techniques to convert the selected building into green building by proposing a 3D model structure showing the green concept to be adopted and to compare the conventional and green residential building in terms of passive design, material, energy, water use and energy simulation. The results of the study were coped with production of bio waste which can be converted to bio gas, thus reducing the burning of other fossil fuels. Effective treatment of grey water that can be used for gardening, flushing etc. Harvesting rain water in order to reduce deal with water scarcity in dry period. Effective cooling system that provides air conditioning similar to that provided by an electric air conditioner. Passive design which increases internal air flow and provides sufficient ambient light. Solar panels help to produce necessary amount of electricity for household purposes. Thermal variation is represented using energy-2D simulation software. A model representing all elements of green building were made. LEED point increased after converting the selected residential building into green building.

Dian Rizkiaditama et al., (2019) Carried out study on "Evaluation of ecosystem quality, comfort, and services of eco-friendly residences in Lowokwaru District, Malang". This research aimed to evaluate the quality of residential ecosystem at Lowokwaru District, Malang. The research was conducted in five different densities residences namely BCT (Bukit Cemara Tujuh), BHPH (Bukit Hijau & Permata Hijau), BP (Bumi Palapa), GJM (Graha Jati Mulya, and PJ (Permata Jingga) and a traditional residence TW (Tunggul Wulung) as a reference, using a purposive sampling method. In each sampling sites, we observed the quality of vegetation of Green Open Space

(GOS), microclimate, geography, comfortable index, and ecosystem services. Data was analyzed by PCA and clustered by using PAST 3.0 software. The results showed GOS coverage in all locations met the government standard of Malang City and showed similar performance in comfort, although each residence having varied GOS distribution. House density affected the GOS coverage dominating by non-native trees with C and D stratification. Furthermore, GOS vegetation in BP effectively reduced dust deposition, noise and attracted wild bird visitors such as Pycononotus aurigaster. Besides BP, PJ and GJM became potential eco-friendly residences by planting more native trees species.

A research was conducted by **Soheil Roumi et al., (2022)** on “Global Research Trends on Building Indoor Environmental Quality Modelling and Indexing Systems—A Scient metric Review”. The purpose of this study is to provide a holistic review of two decades of research advancement in the indoor environmental quality modelling and indexing field (IEQMI) using bibliometric analysis methods. The explicit objectives of the present study are: (1) identifying researchers, institutions, countries (territories), and journals with the most influence in the IEQMI topic; (2) investigating the hot topics in the IEQMI field; and (3) thematically analyzing the keyword evolution in the IEQMI field. A scientometric review was conducted using the bibliometric data of 456 IEQMI research articles published in the past two decades. VOSviewer software was employed for bibliometric analysis, and the SciMAT tool was used to investigate the keywords’ thematic evolution in three sub-periods (2004–2009; 2010–2015; 2016–2021). Results show that there is a continuous increment in the number of published papers in the field of IEQMI, and 60 out of 193 countries in the world have been involved in IEQMI studies. The IEQMI research mainly focuses on: (a) thermal comfort and energy efficiency; (b) occupant satisfaction and comfort; (c) IAQ and health issues; (d) methods and procedures. This field has undergone significant evolution. While ‘indoor environmental quality was initially the

only theme in the first period', 'occupant satisfaction', 'buildings', 'impact', 'building information modelling', and 'health' were added as the main thematic areas in the second period; 'occupant behavior' and 'energy' were novel themes in IEQMI studies receiving much attention in the third period.

Oluwaseun S. Dosumu and Clinton O. Aigbavboa (2019) "An Investigation of the Factors Influencing Indoor Environmental Quality (IEQ) of Residential Buildings in Gauteng, South Africa". The study aims to examine the factors affecting the IEQ of buildings with respect to type of building unit, gender, age, ethnicity and directions that the windows of occupants' building units are facing. The study was conducted in Ekurhuleni Metropolitan Municipality (EMM) of South Africa. The descriptive (questionnaire) survey research design (quantitative method) was adopted in the study. The convenience sampling technique was used to collect data for the study. The method of data analysis includes percentages, mean scores, t-test statistic and one-way analysis of variance. The results of the study indicate that the factors investigated in the study were significantly optimum for the IEQ of buildings. However, inferential statistics show that the respondents differed on some factors of IEQ based on age, gender, ethnicity and building unit. Based on the findings, the study concludes that, the factors affecting IEQ of buildings vary according to age, gender and type of building units occupied. Hence, the factors need to be given dedicated consideration whenever design of buildings are to be done. Despite the existence of standards/assessment tools for determining the IEQ of proposed buildings, gender, age and type of units to be provided for occupants should be put into consideration when building projects are to be designed for IEQ.

1.2.2 Researchers Conducted in India

A research study was conducted by **Nishant Raj Kapoor et al., (2021)** on "A review on Indoor Environment Quality of Indian School Classrooms". This article systematically discussed IEQ parameters related to studies conducted in Indian school classrooms during the last fifteen years. Real-time research studies conducted on Indoor Air Quality (IAQ), Thermal Comfort (TC), Acoustic Comfort (AcC), and Visual Comfort (VC) in Indian school classrooms from July 2006 to March 2021 are considered to gain insight into the existing research methodologies. This review article indicates that IEQ parameter studies in Indian school buildings are tortuous, strewn, inadequate, and unorganized. There is no literature review available on studies conducted on IEQ parameters in Indian school classrooms. The results infer that in India. There is no well-established method to assess the indoor environmental condition of classrooms in school buildings to date. Indian school classrooms are bleak and in dire need of energy-efficient modifications that maintain good IEQ for better teaching and learning outcomes. The prevailingCOVID-19 Pandemic, Artificial Intelligence (AI), National Education Policy (NEP), Sick Building Syndrome (SBS), Internet of Things (IoT), and Green Schools (GS) are also discussed to effectively link existing conditions with the future of IEQ research in Indian school classroom.

Arindam Datta et al., (2017) Carried out study on "Indoor air quality of non-residential urban buildings in Delhi, India". The main objective of the study was to observe the indoor environment of existing selected buildings and redesigning them with enhanced Indoor Environment. The study was conducted in two office buildings and one educational building in Delhi during pre-monsoon. CO2, PM2.5 and VOCs were measured inside each building at every 5 min interval between 9:30 AM and 5:30 PM for 5 days every week. The average CO2 concentration in both office buildings (1513 ppm and 1338 ppm) was recorded much higher than the ASHRAE standard.

Ductless air-conditioning system couple with poor air-circulation and active air-filtration could be attributed to significantly higher concentration of PM2.5 in one of the office buildings (43.8 lg m 3). However, there was significant variation in the concentration of different pollutants at different locations in a building. Among different non-residential buildings, significantly lower concentration of all pollutants was recorded in the educational building (CO2: 672 ppm; PM2.5: 22.8 lg m 3 and VOC: 0.08 ppm). Total hazard ratio analysis ranks one of the office buildings as most hazardous to workers health compared to others. Ó 2017 The Gulf Organization for Research and Development. Production and hosting by Elsevier B.V.

A review study was conducted by **Yosef Al Horr et al., (2016)** on "Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature**".** The paper presents a study through extensive review of the literature, by establishing links between IEQs and occupant well-being and comfort. A range of issues such as sick building syndrome, indoor air quality thermal comfort, visual comfort and acoustic comfort are considered in this paper. The literature included refereed journals, refereed conference proceedings, some reports available on the internet, and books. The study was conducted in a four-stage cycle of identify, collect, classify and analyze. The complexity of the relationship between occupant comfort and well-being parameters with IEQ are further exacerbated due to relationships that these parameters have with each other as well. Based on the review of literature in these areas it is established that design of buildings needs to consider occupant well-being parameters right at the beginning.

Swanya Prabha Maharana et al., (2018) conducted a study on **"**Exposure to indoor air pollution and its perceived impact on health of women and their children: A household survey in a slum of Kolkata, India". The objective of this study is to study the presence of IAP, its associated factors and impact on health of women residing in an urban slum of Kolkata, West Bengal,

India. It was a cross-sectional study done from January 2017 to March 2017 among 120 households of a slum. Data were collected using a pre-designed pre-tested schedule from the homemaker of the households. All analyses were conducted with R: A Language and Environment for Statistical Computing. About 60% households used kerosene as cooking fuel predominantly. Smoke from the neighboring houses troubled 57.5% respondents. More than 60% houses were overcrowded and more than 70% houses were poorly ventilated. IAP-related symptoms such as irritation in the eye, suffocation, dry cough significantly correlated with the presence of IAP sources and its contributory factors. Of 120, 78 (65%) perceived the presence of IAP in their houses. Lower per capita income (PCI), ground floor, and joint family were found to have higher odds of sources of IAP. Younger age, lower PCI, and ground floor were found to be strongly associated with higher contributory factors of IAP. The study found that the majority of the households were exposed to IAP due to kerosene, neighborhood smoke while overcrowding and ill-ventilation accentuated it. Effective intervention with intersectoral coordination is the need of the hour.

Alfred J. Lawrence and Ajay Taneja (2005) conducted a study on “An Investigation of Indoor Air Quality in Rural Residential Houses in India - A Case Study”. This study attempts to provide information about the present IAQ of rural residential homes in Agra (the city of the Taj Mahal), India, during 3 months of the rainy season from July to September 2003. Measurements were made in the living rooms of the homes and included CO, NO, NO2, SO2 and particulate matter (PM10). The results were analysed statistically and indoor concentrations were correlated with outdoor concentrations for all the houses. It was found that the average indoor concentration of CO was 1.8±0.4ppm, for NO it was 0.12±0.06ppm, for NO2 it was 0.09±0.02ppm, and for SO2 it was 0.06±0.01ppm whereas PM10 was found to be 0.0287ppm. It was seen that the indoor concentrations at all the houses of the 5 villages studied had a positive correlation with the outdoor

concentrations but little of the variation indoors was due to outdoor sources. An activity schedule of inside and outside these homes was also prepared to see its influence on the concentrations of pollutants. As standards for indoor air were not available for the Indian conditions the results were compared with standards of other countries, which showed that they lay below permissible limits.

Arup Jana et al., (2022) conducted a study on “Household air pollution and cognitive health among Indian older adults: Evidence from LASI”. The objectives of the study was to aim at negative effects of air pollution on cognitive health among older adults, but whether indoor air pollutants such as cooking fuel, tobacco smoke, and incense burning exposure affect the cognitive score was unknown, especially in limited-resource areas. The study has utilized the recently released data from the Longitudinal Ageing Study of India (LASI), Wave 1, conducted from 2017 to 2018. A total of 63,883 (≥45 years) older adults were considered for the analysis. Descriptive statistics, bivariate analysis and ordinary least squares regression were employed in the study. After adjusting socioeconomic and demographic characteristics, indoor air pollution was found to be a significant determinant of cognitive health. The study has identified exposure to indoor air pollution as a risk factor for cognitive impairment among older adults.

Conclusion on Review of Literature

After going through the various available literature, the investigator came across various researches in India which focused on impact of Indoor Environment of Commercial buildings. The research conducted outside India focused on satisfaction level of residents regarding Indoor Environment and ways of improving Indoor Environment status. The investigator did not come across any research promoting designing of a residence to enhance the Indoor Environment. This motivated the researcher to develop a residence design with enhanced Indoor Environment. Hence, the present research was undertaken.

CHAPTER – III
METHODOLOGY

Research methodology is a science to study how research is done systematically and scientifically (Kothari, 2014). The research design and operational definitions of the terms used in the study are explained briefly in this chapter. Construction of the tool for the data collection of the study is also reported in this chapter. The sampling technique, data collection and scheme for analysis of data are also described. The methodological procedure carried out is described here under the following heads:

3.1. Research Design

3.2. Operational Definitions

3.3. Locale of the Study

3.4. Unit of Inquiry

3.5. Sample Size and Sampling Procedure

3.6. Selection and Construction of the Tool

3.7. Establishment of Content Validity

3.8. Data Collection

3.9. Data Analysis

3.10. Development of working drawings

3.1 Research Design

A research design is arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedures (Kothari, 2014). Descriptive research includes surveys and fact-finding enquires of different kinds (Kothari, 2014). The present study

was descriptive and aimed to design a Residential Unit with enhanced indoor environment. It was fulfilled by a systematic approach by observing existing residences organizing design ideas, materials and drafting 2D and 3D designs.

3.2 Operational Definitions

Certain terms were operationally defined for the present study. They were as follows:

3.2.1 Eco-friendly ways to control air pollution

For the present study eco -friendly ways to control air pollution was defined as any activity intended to have little or no adverse effect on the environment.

3.2.2. Air Pollution

For the present study air pollution was defined as the contamination of air by harmful gases, dust and smoke which affects plants, animals and humans drastically.

3.2.3 Indoor environment

Indoor environmental quality (IEQ) was referred to indoor conditions in a building related to the health of those who occupy it. IEQ included factors such as lighting, air quality, and damp conditions.

3.3 Locale of the study

The study was conducted in Vadodara city, Gujarat, India. The samples of the present study were selected from Amit Nagar Society of Vadodara city. This residential area was located in North Zone of Vadodara city.

3.4 Unit of Inquiry

The unit of inquiry were the selected residences of Vadodara City.

3.5 Sample Size and Sampling Procedure

3.5.1 Sample Size

The sample of the present study comprised of 90 residences of Amit Nagar Society in Vadodara city.

3.5.2 Sampling Procedure

Purposive convenience sampling method was adopted for selecting the sample which was collected from Amit Nagar Society in Vadodara city. Only those residences were selected who meet the following criteria:

1. Residences which were situated in Amit Nagar Society.
2. Houses were constructed by the builders or by themselves.
3. Who willingly agreed to provide the data for the present study.
4. Those homemakers who were the decision makers.

3.6 Selection and Construction of Tool

a) **Questionnaire:** Questionnaire was selected as a tool to gather the data because the personal information could be obtained easily taking the respondents in confidence and it ensured complete data.

3.6.1 Construction of the Tool

Questionnaire was selected as tool for the present study. On the basis of objectives framed for the study and literature reviewed the tool was constructed. Various sources such as books, journals and electronic media were used to make the tool for the present research. The feedback from the professionals like interior designers, architects and academicians of related field from the Department of Family and Community Resource Management also helped in making the tool for the present study.

Tool 1 – Questionnaire

The questionnaire was comprised of the following two sections:

Section I – Background Information

This section included the background information of the respondents and their family such as age, employment status, and educational level.

Section II – Observation sheet

The observation sheet was used to collect the detailed information regarding the existing status of residences in Vadodara city, with a purpose

to assess the existing residences of the respondents in a relation to different aspects like design of the residence, materials, furniture, storage, lighting, ventilation, and plantation.

3.7 Establishment of content Validity of the Tool

3.7.1 Establishment of Content Validity

Validity indicates the degree to which a tool measures what it is supposed to measure (Kothari, 2012). The tool of the present research was subjected to establishment of content validity. To establish the content validity, the tool was given to a panel of eleven judges comprising of experts from Faculty of Family and Community Sciences and practicing Architects and Interior Designers of Vadodara City. The judges were requested to judge the clarity and relevance of the content for each aspect, whether the content was relevant, irrelevant, clear and ambiguous and was fulfilling the objectives of the research. The tool included a cover letter for requesting the expert to be the judge. It also contained the objectives of the study. Judges were requested to give the suggestion for the tool. The suggestions were incorporated in the final tool for data collection.

3.7.2 Pretesting

A pilot study was conducted to check the feasibility and clarity of the observation sheet. Pretesting of the scale was done on 30 non sampled residences selected from Vadodara city.

3.8 Data Collection

The data was gathered by the researcher. The observation sheet was used for data collection. The purpose of the research was explained and rapport was built so as to get the true responses.

3.9 Data Analysis

The procedure of analysis of the data comprised of categorization, tabulation and statistical analysis.

3.10 Development of Working Drawing

The design development mainly focused on proposing a small residence design with following supportive working drawing.

Table 1: List of drawings

Sr. No.	TITLE
1.	Existing floor plans of ground and first floor
2.	Proposed working drawings of selected areas of the residence

The drawings of the ideal residence were developed using **"Auto CAD 2018"** software. The Architectural scale was used as default scale for the present study.

CHAPTER – IV

FINDINGS AND DISCUSSIONS

The aim of the present study was to design a residence for enhancing the indoor environment. The data was collected through questionnaire and observation sheet to obtain the finding of the present study which is presented in this chapter. The finding is supported by relevant discussion and interpretations. This z is divided into three sections.

SECTION – I Background information of the respondents

SECTION – II Observation of the selected existing residences

SECTION – III Proposed Drawings of a Residence for Enhancing the Indoor Environment

SECTION – IV Developing a booklet for the homemakers to enhance their knowledge regarding ways to improve the indoor environment in residences.

SECTION – I

4.1 Background Information of the Respondents

This section dealt with the background information of the respondents and their family. It included background information like age, employment status, educational level, type of family, size of family and total family income.

4.1.1 Personal information

This contained information regarding age (in years), employment status and educational level.

Table 1: Frequency and percentage distribution of the respondents according to their personal information

Sr. No	Personal Information of the Respondents	Respondents (n=90)	
		f	%
1.	**Age (in years)**		
i.	25-40 years	41	**45.6**
ii.	41-56 years	32	35.6
iii.	57-73 years	17	18.8
	Mean	**45.76 years**	
	S.D	**12.05**	
2.	**Employment Status**		
i.	Not employed (Homemaker)	28	31.2
ii.	Self employed	36	**40**
iii.	Service	26	28.8
3.	**Educational Level**		
i.	Up to 12^{th} class	27	30
ii.	Graduate	43	**47.8**
iii.	Post Graduate	20	22.2

Age (in Years): The total age of the respondents ranged from 25 years to 73 years with the mean age 45.76 years (Table 1, Fig. 1). A little less than one half of the respondents (45.6%) was in the age group of 25 to 40 years. More than

one-third of the respondents (35.6%) were in the age group 41 to 56 years and very few of the respondents (18.8%) were in the age group of 57 to 73 years.

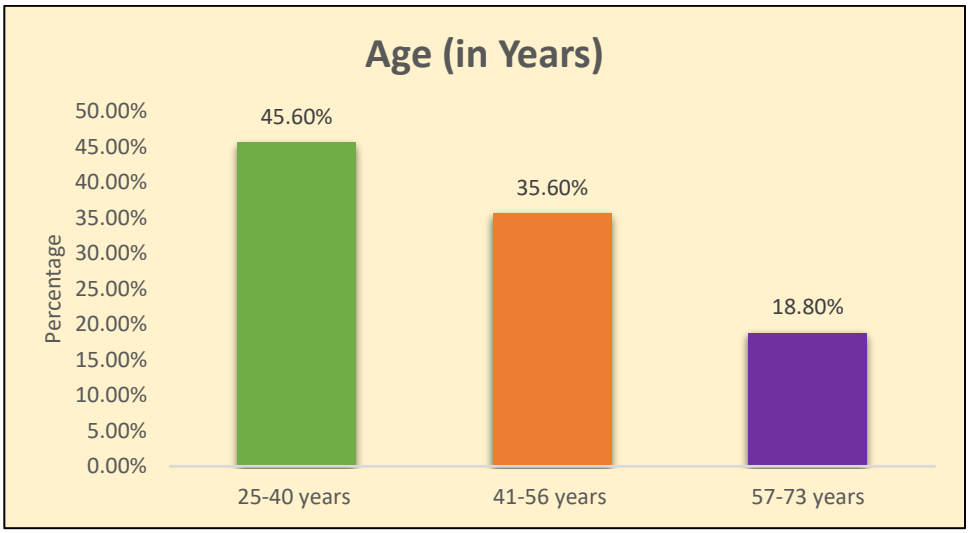


Figure (4): Graphical representation of the respondents according to their age.

Employment Status: A little less than one half of the respondents (40%) were self-employed such as some of them were small scale business owners, doctors, freelancers etc. (Table 1, Fig. 2). A little less than one-third of the respondents (31.2%) were not employed (homemaker). Little more than one-fourth of the respondents (28.8%) were doing job or service.

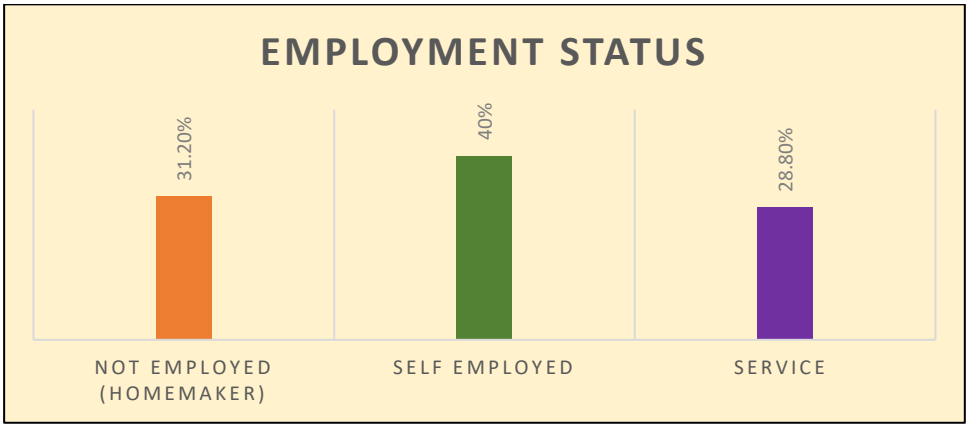


Figure (5): Graphical representation of the respondents according to their employment status.

Educational Level: The data revealed that (Table 1, Fig. 5**)** little less than one half of the respondents (47.8%) were educated up to 12th class. Nearly one-

third of the respondents (30%) were graduate and few of the respondents (22.2%) were post graduate.

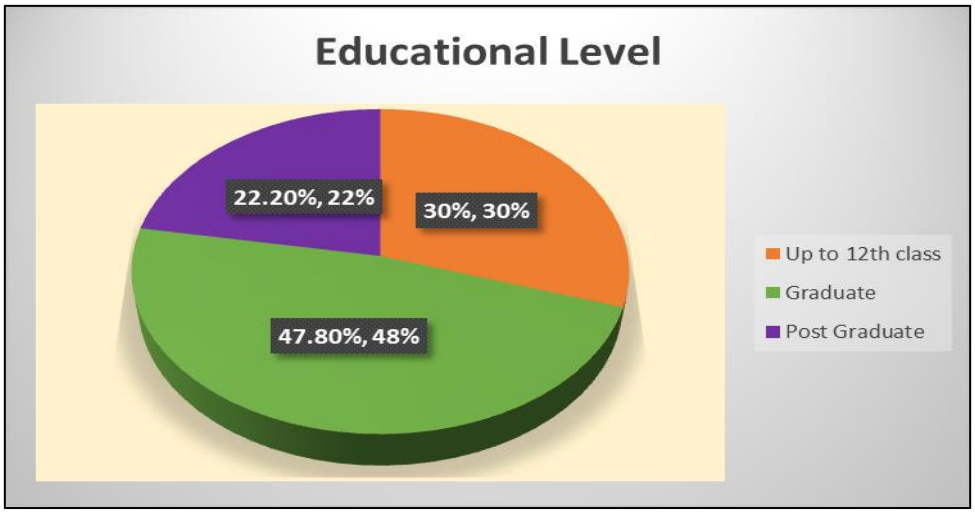


Figure (6): Graphical representation of the respondents according to their educational level.

Table 2: Frequency and percentage distribution of the respondents according to their family information

Sr. No	Family Information	Respondents (n=90)	
		f	%
1.	**Type of family**		
i.	Nuclear family	70	**77.7**
ii.	Joint family	20	22.3
2.	**Size of the Family**		
i.	Small (1 to 3 members)	42	**46.7**
ii.	Medium (4 to 6 members)	31	34.5
iii.	Large (above 6 members)	17	18.8
3.	**Total Family Income (in rupees)**		
i.	₹ 6,000 - ₹ 15,000	19	21.1
ii.	₹ 15,001 - ₹ 25,000	15	16.6
iii.	₹ 25,001 - ₹ 35,000	10	11.2
iv.	₹ 35,001- ₹ 45,000	46	**51.1**
	Mean	**38678.3**	

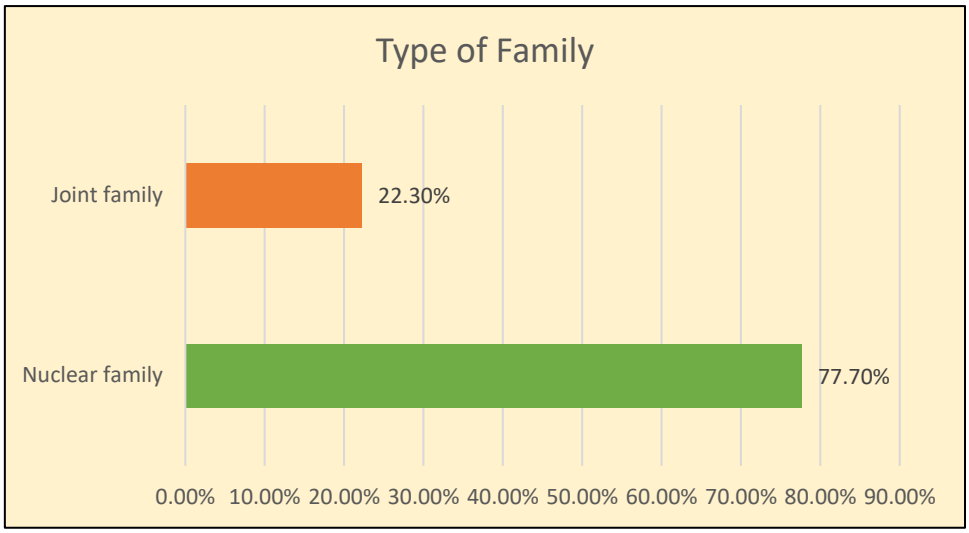


Figure (7): Graphical representation of the respondents according to their type of family.

Type of family: It was found that a little more than three-fourth of the respondents (77.7%) belonged to nuclear family and one-third of the respondents (22.3%) lived in joint family (Table 2, Fig. 6).

Size of the family: It was found that little less than one half the respondents (46.7%) lived in small sized family, little more than one-third of the respondents (34.5%) lived in medium sized family and less than one-fifth of the respondents (18.8%) lived in large sized family (Table 2, Fig. 7).

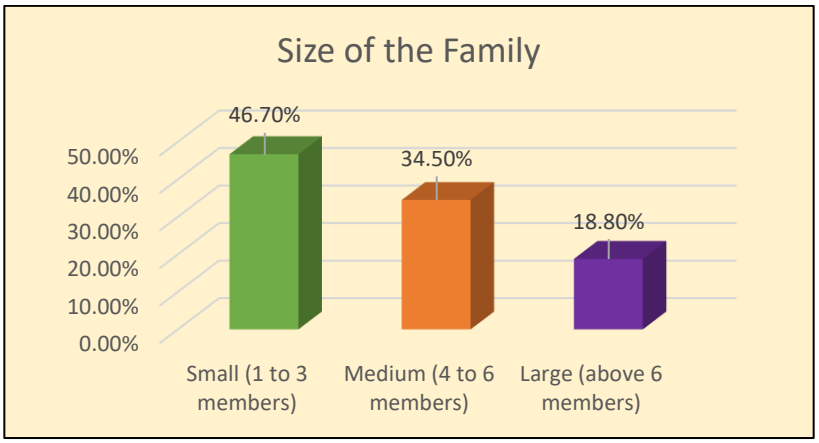


Figure (8): Graphical representation of the respondents according to their size of the family.

Total Family Income: The total family income of the respondents ranged from ₹6000 to ₹45000 with the mean of ₹ 38678.3 (Table 2, Fig. 8). It was found that more than half of the respondents (51.1%) had total family income between ₹35,001 to ₹45,000, a little more than one-fifth of the respondents (21.1%) had total family income between ₹6,000 to ₹15,000, little less than one-fifth of the respondents (16.6%) had total family income between ₹15,001 to ₹25,000 and little more than one-tenth of the respondents (11.2%) had total family income between ₹25,001 to ₹35,000.

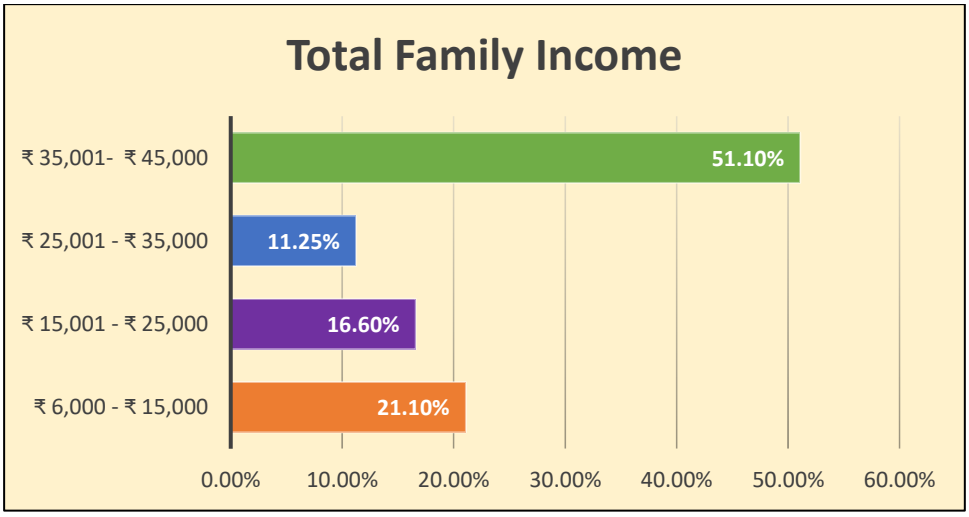


Figure (9): Graphical representation of the respondents according to their total family income.

SECTION – II

4.2 Observation of the selected existing residences

This section contains the description of the existing interior spaces based on the observations.

4.2.1 Kitchen

4.2.1.1 Description of Existing Kitchen Space

Design of the Kitchen: U-shaped, one wall and L-shaped kitchen were observed in majority of the residences. The placement of doors and windows in many residences was found to be on adjacent walls with windows placed above cooking centre. The height of the counter top was observed to be around 2’-9” and depth of the countertop was observed around 1’-7” for majority of the residences.

Materials: Granite was used as a countertop material for majority of the residences, while a majority of digital and textured laminates were used for cabinet finishes.

Windows: Majority of the respondents had small wooden windows at the height of 1’-3” from the floor level, wooden external framing of 3” and metal grilling on the outer face of the window.

Storage: Majority of the respondents had storage facility below the countertop to store heavy and large utensils while it was observed that storage facility above the counter top was less provided. Some respondents had a separate microwave unit and crockery unit beside the main counter area.

Lighting and Ventilation: It was observed that majority of the respondents had only 1 window above the cooking centre, while 2 doors were provided on either adjacent walls or opposite face for wash area and connecting room. Very a smaller number of task light and artificial lights were provided in large kitchens. Provision of chimney was observed for a smaller number of residences whereas exhaust fans were provided in all the respondents kitchens.

Plants and Placement: It was observed that no plants were placed in any of the respondent's kitchen area.

Plate(1): Researcher observing the interiors of kitchen

Plate(2): Researcher observing the interiors of kitchen

4.2.2 Bathroom

4.2.2.1 Description of Existing Bathroom Space

Flooring: Vitrified Tiles were used in majority of the bathroom spaces for flooring while some of the respondents had Kota stone in their bathroom spaces.

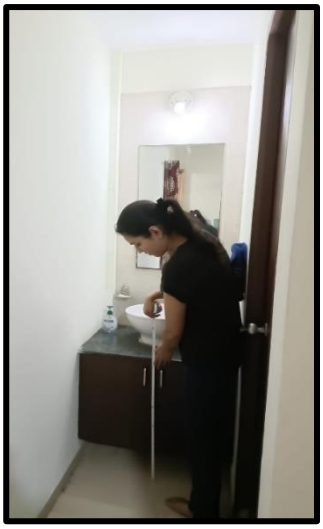
Walls: Wall tiles of ceramic material were placed till lintel level in majority of the bathroom area. The texture of the tiles was observed to be wavy, stone finish and rough in some of the respondent's bathroom.

Ceiling: It was observed that majority of the respondent's had low ceiling of around 7' in height from the finished floor level. Some of the respondents had raw ceiling whereas some of the respondents had gypsum ceiling in their bathrooms.

Lighting and Ventilation: Sufficient natural light was incorporated through ventilation windows provided in the bathrooms.

Placement of Plants: It was observed that none of the respondents had plants placed inside their bathroom areas

Plate(3): Researcher observing the interiors of bathroom



Plate(4): Researcher observing the interiors of bathroom

4.2.3 Living Room

4.2.3.1 Description of Existing Living Room Space

Materials: For majority of the living room spaces, textured veneers and laminates were used as some furniture finish materials. Majority of the respondents had corduroy and velvet materials used for sofa covering and cushioning.

Storage: For the provision of storage majority of the respondents used storage facility below sofa or within the provided TV unit.

Flooring: It was observed that majority of the respondents had vitrified tiles for their flooring whereas some of the respondents had soft furnishing used in their flooring such as carpets and galichas. It was also observed that wooden finish vinyl flooring was a preferred choice for some of the respondents.

Walls: Neutral paints and highlighting textures were used for majority of the wall finishes of living room, whereas some of the respondents had wallpapers hung up on the walls as a wall finish material. Rough and medium textures were widely preferred among the respondents.

Plants and Placements: It was observed that areca palm and snake plants were widely used by majority of the respondents. These plants were placed either on one side of the sofa or beside the connecting staircase area. The size and quantity of the plants were less in comparison to the size and shape of the rooms.

Plate(5): Researcher observing the interiors of living room

Plate(6): Researcher observing the interiors of living room

4.2.4 Bed Room

4.2.4.1 Description of Existing Bed Room Space

Materials: Textured and glossy laminates were used by majority of the respondents for cabinets, wardrobes, bed and side tables. Metal and wooden knobs were widely used to create openings in various areas.

Storage: It was observed that majority of the respondents had adequate storage facility in the bedroom in place such as below the bed, overhead cabinets/extended wardrobe, side tables and dressing table. Some of the respondents lacked storage facility which resulted in cluttered bedroom and placement of temporary storage baskets around the room.

Flooring: Vitrified flooring was found to be most common in the bedrooms whereas some of the old aged respondent's bedroom had vinyl flooring or carpet (galicha) flooring. It was observed that some of the respondents had matt finished vitrified flooring in their bedrooms for aesthetic purpose.

Walls: Wall paints were found in majority of the respondent's bedroom as wall finish material, some of the respondents had application of wallpaper on one of the walls to create a highlighting feature whereas very few of the respondents had MDF sheet application on their walls for grooving and to create an emphasizing feature.

Plants and Placement: It was observed that very less of the respondents had placed snake plants, money plants, Aloe Vera and succulent varieties in their bedroom on TV console unit, bed side table and on study tables.

Light and Ventilation: It was found that the placement of doors and windows in some of the respondent's residences were on opposite walls and very few of the respondents had doors and windows placed on adjacent walls as per the structure and architectural design. Adequate amount of natural light was incorporated in the bedrooms through windows which also created natural ventilation.

Plate(7): Researcher observing the interiors of bedroom

Plate(8): Researcher observing the interiors of bedroom

Plate(9): Researcher observing the interiors of bedroom

SECTION – III

4.3 Proposed Drawings of a Residence for Enhancing the Indoor Environment

The development of these designs was based on the information gathered by the researcher. The designer found that various components of controlling indoor air pollution were not incorporated in the respondents houses such as placement of plants, material selection, direction of sunlight etc.

The proposed designs of various areas of a residential unit with regards to enhancing the indoor environment followed by discussion on each component of design are discussed here.

4.3.1 Proposed design of Foyer unit

On the basis of the findings of the study the designer proposed a design of foyer unit of 34.16 sq. ft.

Wall AB

On wall AB a shoe rack of 5’-6” was designed. The shoe rack and siting unit was made up of Ply and laminate, 0.75” stone is placed on the top of the unit which makes it easy to clean and maintain from dust and bacteria coming from the front door. The shutters of the shoe cabinet and sitting unit has 0.5” of hollow spacing each with 1” of gap between the other for proper air circulation and ventilation within the unit. Having ventilation will help circulate the air inside the cabinet and would also help eliminate stale odours as well as will allow the foul smell to dissipate. The legs of the shoe cabinet and sitting unit was designed of stainless steel which is easy to clean and sanitize.

MgO board (Magnesium Oxide board) was used to pack the area between the column behind the shoe rack and sitting unit because it is a non-insulating board traditionally used for general construction and partition as it is highly resistant to mould, mildew, moisture and weather. 2’x2’ glossy finish vitrified tiles were used for the foyer area which helps

in easy cleaning of the area as it faces maximum amount of footfall throughout the day. Non – VOCs (Volatile Organic Compound) wall paint and finishes were used as wall covering on the rest of the wall of the foyer unit. Proposed design of Living/ Dining unit.

4.3.2 On the basis of the findings of the study the designer proposed a design of Living/Dining **unit of 170.75sq. ft.**

Wall AB

The Living/Dining room was designed using various eco-friendly materials. Wall AB of the Living/Dining room displays a wall attached TV unit. The TV Cabinet has 3 frameless shutter and 1 glass shutter for placing setup box. The cabinet is made up of ply and glossy finish laminate which makes it easy to clean and maintain from dust and bacteria. A 0.75” of stone was placed on the top of the TV cabinet for maintaining a clutter free and clean environment. Half bamboo wall panelling with varnish finish was designed behind on the wall beside the TV unit. Since bamboo is considered as an eco-friendly material it helps in reducing indoor air pollution and is also easy to clean and maintain. A door for bedroom entrance and one for kitchen entrance was designed on this wall.

Wall CD

A window of 6’-0”x 4’-6” was designed on this wall. Roman blinds were suggested as window covering material with regards to its sustainability and eco-friendly qualities. L-Shaped sofa was designed on wall CD and wall DA. The material used for sofa construction was Ply and upholstery. Waxed canvas was used as a sofa covering material which is durable and waterproof as compared to most of the fabrics and is also a useful alternative for leather and is considered as an eco-friendly material which is easy to clean the make it dusts free. Mild Steel fabrication was used for designing sofa foot as it is easy to maintain.

Wall DA

Half Cut bamboo panelling of 3’-4” of height from ceiling drop was designed on wall DA for placement of dining unit. A collapsible dinning unit with 4-seater space was designed with ply and glossy finish laminate. The collapsible dining unit works on hydraulic channels placed behind the unit. A seating bench was designed as well which provides seating for both living and dining area. The bench was designed with the same material as the sofa to avoid excess usage and wastage of materials. Vertical gardening was designed in terracotta pots attached to wall with water dripping plate to remove excess water.

Apart from this, a centre table was designed using recycled rubber and recycled plastic bottles. Various indoor oxygen generating plants were placed on TV unit, dining table and centre table such as Snake plant, peace lily, aloe Vera, Chinese evergreen, fiddle leaf fig plant and areca palm. These plants were selected purposively because they require less amount of care and maintenance. For window and door coverings microfiber synthetic fabric was used as has longer longevity and is low maintenance. Non – VOCs (Volatile Organic Compound) wall paint and finishes were used as wall covering on the rest of the wall of the living/dining room.

An 8” level drop flush gypsum ceiling was designed for living room without grooves which does not catch dust and cobwebs easily giving an environment friendly atmosphere. Placement of doors and windows were designed in such a way that it helps in maintaining cross-ventilation throughout the public open space. 2’x2’ Glossy finish Vitrified tiles were used for flooring.

4.3.3 Proposed design of Kitchen

On the basis of the findings of the study the designer proposed a design of Kitchen unit was of 114.4 sq. ft.

Wall AB

U-shaped kitchen was designed where placement of sink stove and refrigerator was provided on adjacent walls. An east facing window of 3'-3"x 4'-0" was designed for cross ventilation in kitchen which brings the morning sunlight in the kitchen making the environment clean, dry and also lights up the area. Placement of sink was designed under the window to allow the dirty smell from the dishes to be replaced by fresh and clean air, it also allows proper air filtration throughout the kitchen. It also helps in keeping the area dry and also helps in killing the bacteria and stops the formation of algae. A hollow cabinet was designed above the lintel level for the chimney duct to pass through. The cabinet was designed in such a way that it also fulfils the purpose and at the same time looks appealing as it matches with the overall kitchen design.

Wall BC

Base cabinets and overhead cabinets were designed on wall BC having 2'-8" of distance between them which allows the cooking fumes and smell to pass through the chimney. A 2'-0" chimney ducting was designed above the placement of cooking stove to absorb heat, smoke, oil and grease generated through cooking and also helps in keeping the kitchen clean and odour-free. Having a chimney also helps in keeping the wall tiles clean and free from oil and grease and also helps in recycling the air which keeps surroundings fresh and free from cooking smoke. Two niche each of 1'-2" deep were designed on one corner of the overhead cabinet for placing daily and regular use items such as tea, sugar, salt etc.

Wall CD

A wall attached tall microwave and oven unit was designed on wall CD with placement of refrigerator towards the end of the platform. Glass shutters were designed for overhead cabinets for placing crockery and artefacts fulfilling the purpose of a crockery unit. Two ledges of 1’-9” deep were designed for placement of microwave and oven.

Glossy laminates were used for cabinet and shutter coverings which helps in easy cleaning keeping the laminates free from grease, oil and dust. A 3” otli was designed under the base cabinets which restricts the dust and waste from entering the cabinets keepings it clean. Plain flushed gypsum ceiling was designed on kitchen ceiling which maintains a uniformity and also provides a clean, formal and non-distracting look. Vitrified tiles selected for kitchen flooring with glossy finish as this category of tiles are easy to clean and maintain. Two doors on opposite facing walls were designed purposively to provide cross-ventilation in kitchen which helps in keeping the area clean, dry, dust and smoke free and also helps in maintaining a germ-free environment. Non – VOCs (Volatile Organic Compound) wall paint and finishes were used as wall covering on the rest of the walls of kitchen.

Wall DA

Horizontal metal planters were attached to wall using clamps for planting herbs and medicinal plants which helps in detoxifying the air and reduction in pollution. Herbs such as basil, rosemary, oregano, mint etc. are considered as best choices for kitchen plants.

4.3.4 Proposed design of Bedroom-1

On the basis of the findings of the study the designer proposed a design of Bedroom-1 of 104 sq. ft.

Wall BC

On wall BC a multipurpose wall unit of mandir unit, storage unit and side table with seating was constructed. MDF (Medium Density Fibre board) was used to construct the mandir head covering. CNC cutting of a traditional motif of 0.25” deep was done on mandir head covering for aesthetic look, oil-based varnish was used as mdf finishing paint to enhance its natural appearance. MgO (Magnesium Oxide Board) was used as wall panelling for the mandir area and was finished with wax paint for glossy and royal look.

A connecting side table and seating unit was also constructed with the mandir area. A cnc sutting mdf board partition was also deigned between mandir area and side table unit to divide the space according to its purpose yet keeping it functional and appealing. Glass table top was designed for the unit as it helps in easy cleaning and maintenance from the droppings of the agarbatti (incense stick), kumkum (red colored powder used for performing rituals) etc. An upholstered puffy seating was designed for the unit with wooden and polish finished legs and leather upholstery which is easy to clean and does not retain dust. Glass /stone of 9.5” in height was designed and placed on the back side of the unit and also as backrest to maintain an even and connecting look for the bedroom. A window of 4’-0”x 4’-3” was designed on the wall as well. 3 wall frames of equal size and shape were placed one above the another to create an informal balance on the wall.

Horizontal metal planters were attached to wall for plantation. For excess water outlet a drainage pipe was designed in such a way that it carries the water outside through the window.

Wooden finish body with natural polish and highlighting laminate was used in designing the bed. A groove of 0.25” was designed all around the bed for aesthetic purpose.

Wall DA

A wardrobe of 6’-9” was designed on wall DA having wooden finished concealed door opening, a skirting of 3” and satin finish laminate. The choice of laminate was such that it is easy to clean and maintain as it does not retain any dust particles on the surface giving a clean and tidy appearance.

The placement of the door and window was designed in such a way that it helps in creating air-circulation in the room throughout the day. White wash ceiling was provided for the ceiling and 2’x2’ glossy finish vitrified tiles were selected for the flooring as it is easy to clean and maintain. Non – VOCs (Volatile Organic Compound) wall paint and finishes were used as wall covering on the rest of the walls of bedroom.

4.3.5 Proposed design of Bedroom-2

On the basis of the findings of the study the designer proposed a design of Bedroom-1 of 189 sq. ft.

Wall AB

On wall AB a full heighted six shutter openable wardrobe was designed with a dressing unit on one side. The wardrobe was designed using full sheet bamboo plywood for framing. Bamboo plywood is considered as FSC-certified plywood which is made of fine layers of bamboo strips laid in parallel order and kiln dried, sanded smooth and then laminated edge to edge to create a single-ply panel. These panels are then laminated again to each other to create multi-ply bamboo plywood making it as eco-friendly material for furniture construction. Glossy finish laminate was suggested for wardrobe covering as it is easy to clean and maintain. 0.25” grooves were designed on the shutters for aesthetic purpose and 1” vertical groove was designed between two consequent shutters for opening.

A dressing table of bamboo plywood and raw wooden patti was designed beside wardrobe with arc shaped mirror and drawer for storage. Leather finished upholstered puffy stool was provided with the dressing unit for seating.

Recycled wool fibre wall paper was suggested for wall finish application above dressing unit.

Wall BC

A king-sized bed made from bamboo plywood and veneer finish laminate was designed on this wall. A textured pattern made from cork sheet base and leather upholstered stitches with 0.25” grooves was designed for bed back wall. 1” all round wooden Patti with varnish finish for framing was suggested. The pattern was designed till lintel level to match the rhythm created by two adjacent doors placed on the wall.

Vertical gardening was designed on the adjacent wall using metal as the base material for plantation. It was designed in such a way that the excess water from the plants caused due to watering would be carried outside through the balcony door keeping the flooring clean and dry.

Wall DA

On wall DA, a study unit cum TV unit was designed. The material used for the study unit was natural wood for frame and legs and recycled acrylic glass for shutters. Oil based varnish was used as finishing material for the study unit. The placement of TV was designed above glass shutters for easy operation of TV router. A solar operated ceiling suspended light was placed above study unit for adequate lighting in the area.

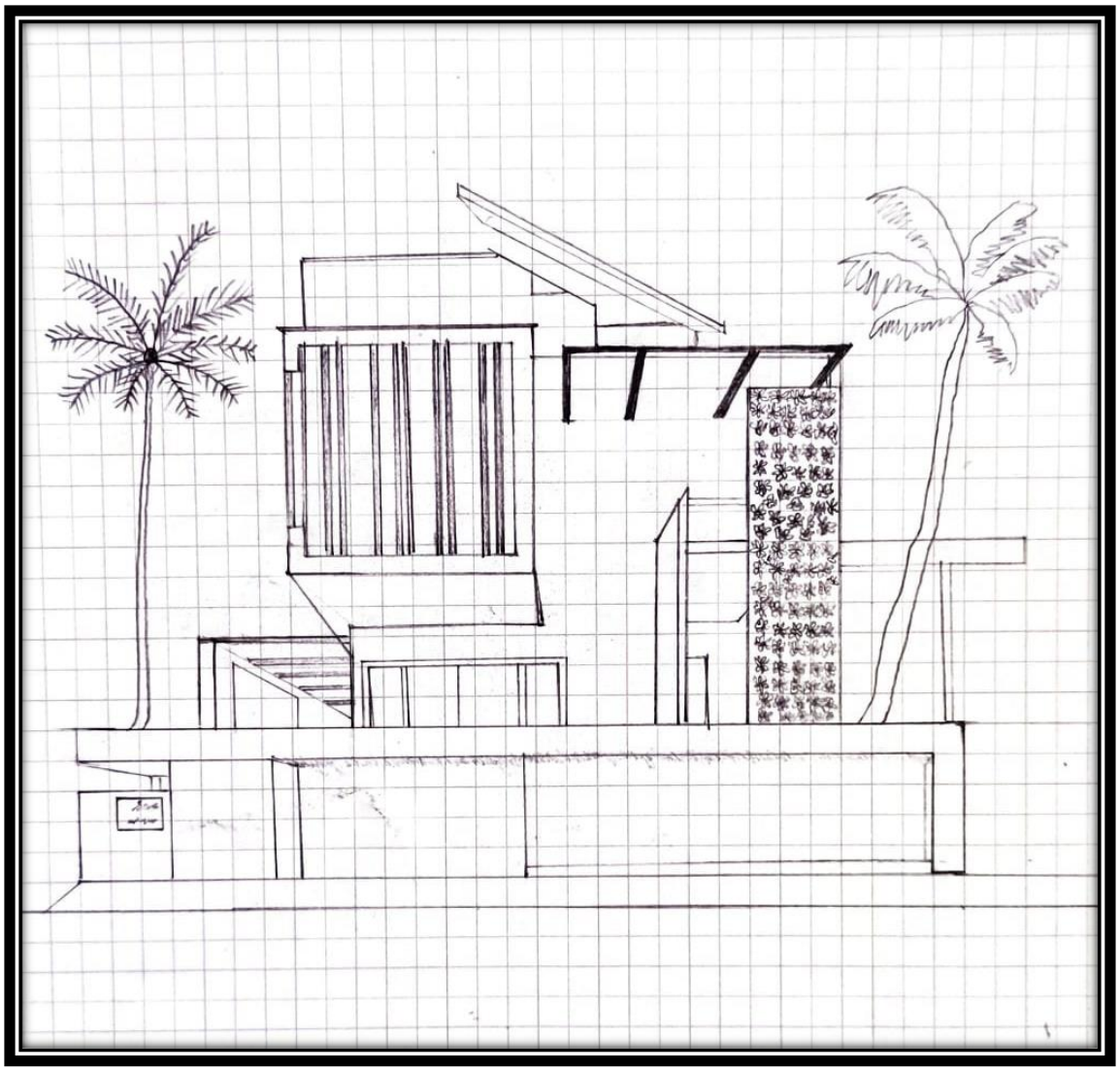
2'x2' Gypsum sheet with satin finish paint was used for the ceiling finish and 2'x2' glossy finish vitrified tiles were selected for the flooring as it is easy to clean and maintain. Non – VOCs (Volatile Organic Compound) wall paint and finishes were used as wall covering on the rest of the walls of bedroom.

4.3.6 Design description for Bathrooms

For bathrooms, ventilators were provided for air-circulation and air-purification. Water limit control water closet and water supply flushes were provided which uses less amount of water as compared to traditional water supply hardware. Matt finish floor tiles was suggested for every bathroom as it makes it easy for cleaning and keeps the bathroom dry and free from moist and dew. Porcelain stoneware tiles were used for bathroom wall covering as these tiles are also eco-friendly, durable and are made with closed-cycle technologies that recover and reuse energy, water, raw materials and waste materials. Variety of indoor plants were also placed in the bathroom for creating a lively atmosphere.

4.3.7 Design description for exterior area

- The structure of the residence was planned according to passive design consideration in taking advantage of the climate to maintain a comfortable temperature and keeping in mind the orientation, size and placement of doors and windows.
- The placement of doors and windows were planned in such a way that it prevails air circulation and cross ventilation within rooms through inlets and outlets provided to optimize the path air flows in the building. Cross ventilation is considered as a common technique to remove pollutants, reducing the accumulation of moisture, odours and other gases and to generate passive cooling in an indoor environment.
- Vertical garden was planned on the exterior wall of the residential area as it acts as an extra insulation containing a layer of air between the wall and the plants which indirectly reduces external noise levels by absorbing the sound as well as it keeps the building cool in summer and warm in winter, improves the health and air quality, reduces mental stress, saves land space, is aesthetically appealing, helps to reduce and reuse waste bottles and accessories, provides privacy and thus enabling one to save electricity.
- Solar panels were designed on the terrace with a fake elevated surface created facing the direction which observes maximum amount of sunlight during the day. Solar panels help in maintaining the indoor air quality as it mitigates air pollution by reducing carbon emissions of the surroundings. By generating electricity from solar panels, less electricity is consumed which helps in controlling the indoor air pollution.
- Large ornamental trees were planned on north side as it helps in controlling winter winds, opening from south side was provided with placement of large windows as it helps in keeping the house cool from summer breeze.



Plate(17): Proposed front elevation (residential exterior)

- Deciduous plants and annual evergreen trees were planted on either side of the residence to keep the surrounding clean, reduces external noise and as well as generates fresh and clean air for the residents.
- Architectural films were applied on the windows observing maximum amount of sunlight as it deflects UV rays and keeps the indoor environment cool.
- Apart from structural consideration, indoor oxygen generating plants were also planned in various areas of the residence such as snake plant, Aloe Vera, peace lily, Chinese evergreen, fiddle leaf-fig plant, areca palm etc., these plants provide a natural surrounding as well as provides abundant oxygen and helps to keep the indoor air

environment clean. It also improves the building's sustainability by reflecting solar radiation, absorbing rainwater and improving air quality (plants absorb CO2 and release oxygen).

SECTION IV

4.3 Developing a booklet for the homemakers to enhance their knowledge regarding ways to improve the indoor environment in residences.

The designer with the help of review of literature had developed an informative booklet. The booklet included introduction, common indoor air pollutants, indoor air quality (IAQ), factors that contribute to indoor air quality (IAQ), strategies to control indoor air quality (IAQ) in residential buildings and ways to control indoor air pollution were incorporated in the booklet. A panel of experts from the field of interior designing and architecture were requested to validate the importance of topic, content and language clarity of the text. The suggestions given by the experts were incorporated and the booklet was developed accordingly.

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATIONS

The pandemic has been an alarming situation worldwide and left us being more alert about our health and air borne diseases. According to studies, there are larger health concerns associated with exposure to indoor air pollution than there are with exposure to outside pollution. Particularly vulnerable populations, such as children, young people, the elderly, or those with chronic respiratory and/or cardiovascular disorders, can be harmed by poor indoor air quality. Although air pollution can come from a variety of places, including the street and the home, its effects can be just as deadly: Injurious health impacts of contaminated air include heart disease, asthma, and other respiratory disorders. This indicates the importance of conducting more studies on eco-friendly ways to control air pollution at residence level in order to enhance our understanding on the cause of problems and associated remedial measures. The Department of Family and Community Resource Management, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, offers course on "Residential Space Designing" as well as “Ecology and Environment” at Bachelors level, “Interior Space Designing- Residential and Commercial” and “Green Interiors” at Master's level. Hence, the information gathered through the present research will widen the database and will help in strengthening the curriculum. The study will be helpful for the Owners and residents of the residences, as the researcher prepared a booklet to enhance the knowledge on eco-friendly ways to improve the air quality in interior spaces of Residences. The eco-friendly design of a residence developed by the researcher will be helpful for Interior designer, Architects and Civil Engineer as a reference while designing new residences in creating a healthier atmosphere indoors as the research findings would provide strong data base reflecting various eco-friendly materials which can be used to reduce air pollution inside the residences.

Objectives of the study

1. To observe the indoor air environment of the existing residences.
2. To design an ideal residence for enhancing indoor air environment.
3. To design a booklet for the homemakers to enhance their knowledge regarding ways to enhance indoor air environment in residences.

Delimitations

1. The study was limited to 90 residences of Vadodara city.
2. The study was limited to designing a residence with enhanced indoor air environment.

Methodology

Descriptive research design was used for the present study. The sample of the present study comprised of 90 residences selected through purposive convenience sampling technique from the Amit Nagar Society, Vadodara city, Gujarat state. The observation was conducted from 19th December to 15th January 2023 in the Amit Nagar Society, Vadodara city, Gujarat state. The observation sheet was used as data collection tool. It was divided into two sections. Where, section 1 included the background information of the respondents and section 2 included the observation sheet for the existing residences. To establish the content validity of the data collection tool, it was given to a panel of 11 judges comprising the experts from Family and Community Resource Management of Vadodara city. The judges were requested to judge whether the listed statements under each aspect were clear or ambiguous and relevant or irrelevant. Based on the valuable suggestions given by the experts, minor changes were done and all the statements were retained. The data collected from the survey was then used to identify the factors affecting indoor environment of a residence, which became the base for selecting correct material and technique while designing the ideal residence with enhanced indoor environment.

The major findings of the study

The major findings of the study are presented here.

Section I: Background information of the respondents

- It was found that less than one half of the respondents (45.6%) were in the age group of 25 to 40 years with the mean age of 45.76 years.
- 40 per cent of the respondents were self-employed such as some of them were small scale business owners, doctors, freelancers etc.
- The data revealed that little less than one half of the respondents (47.8%) were educated up to 12^{th} class.
- It was found that a little more than three-fourth of the respondents (77.7%) belonged to nuclear family.
- The findings revealed that little less than one half the respondents (46.7%) lived in small sized family.
- It was found that more than half of the respondents (51.1%) had total family income between ₹35,001 to ₹45,000 with the mean income of ₹38678.3.

Section II: Observation of the selected existing residences

1. Description of Existing Kitchen Space

U-shaped, one wall and L-shaped kitchen with the countertop finished in granite material were observed in majority of the residences with storage facility below the countertop to store heavy and large utensils. Window height was 1'-3" from the FFL with external wooden framing of 3" and metal grilling on the outer face of the window. Majority of the respondents had only 1 window above the cooking centre, while 2 doors were provided on either adjacent walls or opposite face for wash area and connecting room and no plants were placed in the kitchen area.

2. Description of Existing Bathroom

Vitrified tiles were used for flooring and ceramic tiles were used for wall backsplash in majority of the bathroom spaces. Majority of the residences had

low ceiling height from the FFL and sufficient natural light was incorporated through ventilation window. None of the respondents had plants placed in the bathroom area.

3. Description of Existing Living room

Majority of the living rooms had textured veneer and laminates for furniture finish and corduroy and velvet finishes were used for sofa covering and cushioning with the provision of storage below sofa and within the TV unit. Majority of residences had vitrified used in flooring and neutral-colored paints and highlighting textures were used for wall finish. Areca palm and snake plants were widely used by majority of the respondents in the living area.

4. Description of Existing Bed room

Textured and glossy laminates were used by majority of the respondents for cabinets, wardrobes, bed and side tables with adequate storage facility. Majority of residences had vitrified used in flooring and wall paint was used for wall finish. Very less respondents had placed plants in their bed room area. Adequate amount of natural light was incorporated in the bedrooms through windows which also created natural ventilation.

Section III: Proposed Drawings of a Residence for Enhancing the Indoor Environment

The development of these designs was based on the information gathered by the researcher. The designer found that various components of controlling indoor air pollution were not incorporated in the respondents houses such as placement of plants, material selection, direction of sunlight etc.

The proposed designs of various areas of a residential unit with regards to enhancing the indoor environment followed by discussion on each component of design were discussed here.

1. Proposed design of foyer unit

A shoe rack of 5’-6” was designed. The shoe rack and siting unit was made up of Ply and laminate, 0.75”. Circulation of air was incorporated to eliminate stale

odours. The legs of the shoe cabinet and sitting unit was designed of stainless steel which is easy to clean and sanitize. MgO board (Magnesium Oxide board) was used to pack the area between the column behind the shoe rack, as it is highly resistant to mould, mildew, moisture and weather. 2'x2' glossy finish vitrified tiles were used for the foyer area which helps in easy cleaning.

2. Proposed design of Living/Dining unit

The TV unit is made up of ply and glossy finish laminate which makes it easy to clean and maintain from dust and bacteria. Bamboo is considered as an eco-friendly material it helps in reducing indoor air pollution and is also easy to clean and maintain. A window of 6'-0"x 4'-6" was designed. Roman blinds were suggested as window covering material with regards to its sustainability and eco-friendly qualities. Waxed canvas was used as a sofa covering material which is durable and waterproof as compared to most of the fabrics and is also a useful alternative for leather and is considered as an eco-friendly material which is easy to clean the make it dusts free. Half Cut bamboo panelling of 3'-4" of height from ceiling drop was designed on wall for placement of collapsible dining unit. A collapsible dinning unit with 4-seater space was designed with ply and glossy finish laminate.

3. Proposed design of Kitchen

The designer proposed a design of U-shaped Kitchen unit was of 114.4 sq. ft. An east facing window of 3'-3"x 4'-0" was designed for cross ventilation in kitchen which brings the morning sunlight. Placement of sink was designed under the window to allow the dirty smell from the dishes to be replaced by fresh and clean air. Glossy laminates were used for cabinet and shutter coverings which helps in easy cleaning keeping the laminates free from grease, oil and dust. A 3" otli was designed under the base cabinets which restricts the dust and waste from entering the cabinets keepings it clean. Two doors on opposite facing walls were designed purposively to provide cross-ventilation in kitchen which helps in keeping the area clean, dry, dust and smoke free and also helps in maintaining a germ-free environment.

4. Proposed design of Bedroom-1

A multipurpose wall unit of mandir unit, storage unit and side table with seating was constructed. MDF (Medium Density Fibre board) was used to construct the mandir head covering. CNC cutting of a traditional motif of 0.25” deep was done on mandir head covering for aesthetic look. Glass table top was designed for the unit as it helps in easy cleaning and maintenance from the droppings of the agarbatti (incense stick), kumkum (red colored powder used for performing rituals) etc. Horizontal metal planters were attached to wall for plantation. For excess water outlet a drainage pipe was designed in such a way that it carries the water outside through the window. An upholstered puffy seating was designed for the unit with wooden and polish finished legs and leather upholstery which is easy to clean and does not retain dust.

5. Proposed design of Bedroom-2

A full heighted six shutter openable wardrobe was designed with a dressing unit on one side. The wardrobe was designed using full sheet bamboo plywood for framing. Bamboo plywood is considered as FSC-certified plywood. Glossy finish laminate was suggested for wardrobe covering as it is easy to clean and maintain. A dressing table of bamboo plywood and raw wooden patti was designed beside wardrobe with arc shaped mirror and drawer for storage. Leather finished upholstered puffy stool was provided with the dressing unit for seating. A study unit cum TV unit was designed. The material used was natural wood for frame and legs and recycled acrylic glass for shutters. Oil based varnish was used as finishing material. The placement of TV was designed above glass shutters for easy operation of TV router. A solar operated ceiling suspended light was placed above study unit for adequate lighting in the area. 2’x2’ Gypsum sheet with satin finish paint was used for the ceiling finish and 2’x2’ glossy finish vitrified tiles were selected for the flooring as it is easy to clean and maintain.

6. Proposed design for Bathrooms

For bathrooms, ventilators were provided for air-circulation and air-purification. Water limit control water closet and water supply flushes were provided which uses less amount of water as compared to traditional water supply hardware.

Matt finish floor tiles was suggested for every bathroom as it makes it easy for cleaning and keeps the bathroom dry and free from moist and dew. Porcelain stoneware tiles were used for bathroom wall covering as these tiles are also eco-friendly, durable and are made with closed-cycle technologies that recover and reuse energy, water, raw materials and waste materials. Variety of indoor plants were also placed in the bathroom for creating a lively atmosphere.

7. Proposed design for Exterior Area

The structure of the residence was planned according to passive design. The placement of doors and windows were planned in such a way that it prevails air circulation and cross ventilation within rooms through inlets and outlets provided to optimize the path air flows in the building. Vertical garden was planned on the exterior wall of the residential area. Solar panels were designed on the terrace with a fake elevated surface created facing the direction which observes maximum amount of sunlight during the day. Large ornamental trees were planned on north side as it helps in controlling winter winds, opening from south side was provided with placement of large windows. Deciduous plants and annual evergreen trees were planted on either side of the residence to keep the surrounding clean. Architectural films were applied on the windows observing maximum amount of sunlight. Apart from structural consideration, indoor oxygen generating plants were also planned in various areas of the residence such as snake plant, Aloe Vera, peace lily, Chinese evergreen, fiddle leaf-fig plant, areca palm etc. Non-VOC emitting paint was used at the interiors as well as the exterior of the residence.

Section IV: Developing a booklet for the homemakers to enhance their knowledge regarding ways to improve the indoor environment in residences.

The designer with the help of review of literature had developed an informative booklet. The booklet included introduction, common indoor air pollutants, indoor air quality (IAQ), factors that contribute to indoor air quality (IAQ), strategies to control indoor air quality (IAQ) in residential buildings and ways to control indoor air pollution were incorporated in the booklet. A panel of experts from the field of interior designing and architecture were requested to validate the importance of topic, content and language clarity of the text. The suggestions given by the experts were incorporated and the booklet was developed accordingly.

Implications

The findings of the present study had the following implications:

For the Field of Family and Community Resource Management:

The Department of Family and Community Resource Management, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, offers course on "Residential Space Designing" as well as “Ecology and Environment” at Bachelors level, “Interior Space Designing- Residential and Commercial” and “Green Interiors” at Master's level. Hence, the information gathered through the present research will widen the database and will help in strengthening the curriculum.

For Residence owners

The study will be helpful for the Owners and residents of the residences, as the researcher prepared a booklet to enhance the knowledge on eco-friendly ways to improve the air quality in interior spaces of Residences

For Interior Designers

The findings of the study will help interior designers as the researcher has proposed an ideal design for residence with enhanced indoor environment. These designs can be used for future reference and changed according to resources as well as client's preferences.

For libraries and documentation centers

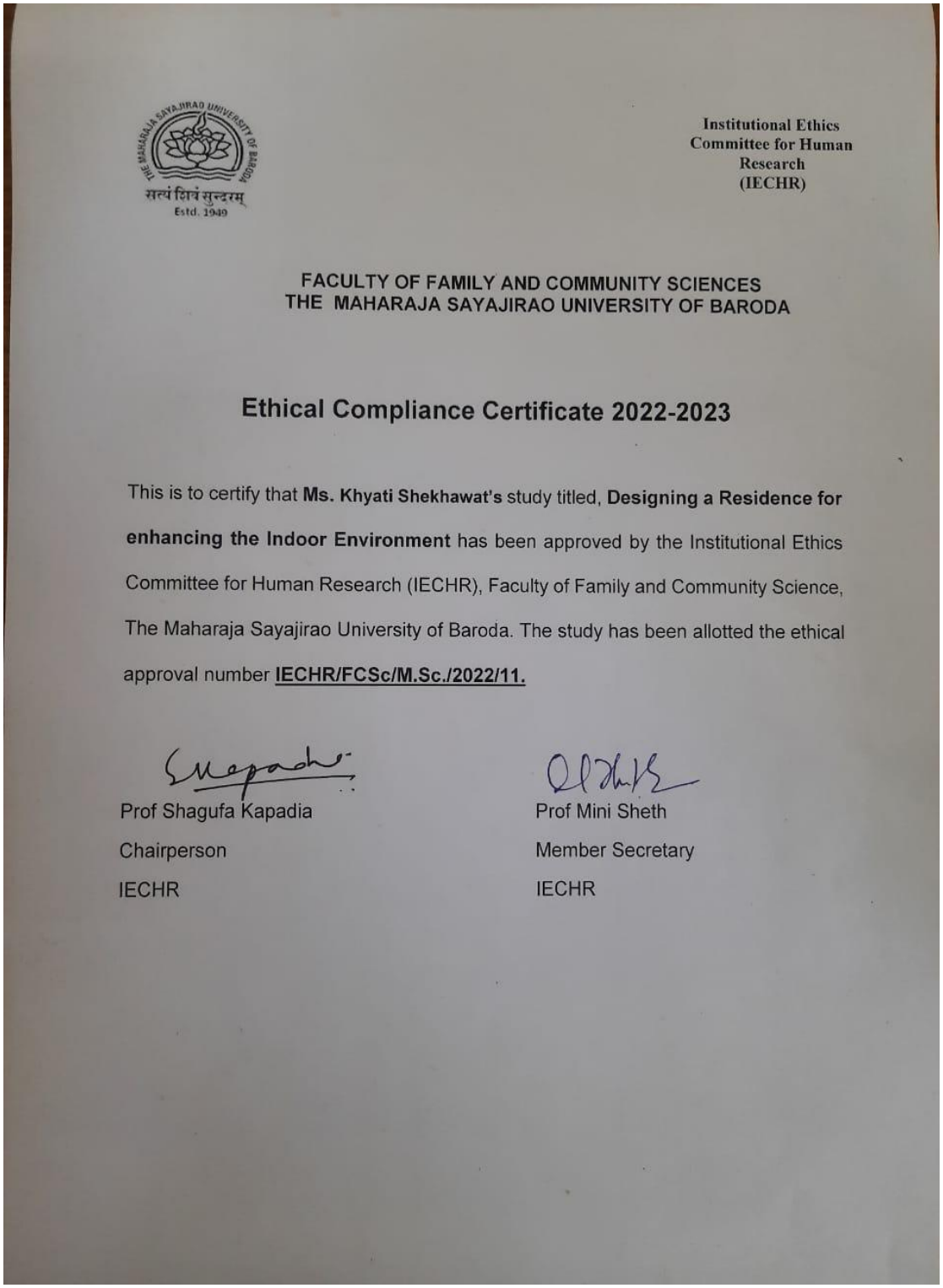
The findings of the present research would be a ready reference for documentation on the related subject.

Recommendations

1. Similar research can be conducted in flats and commercial spaces.
2. Researches can be conducted on the same topic in other cities.

APENDIX 1

Ethical Compliance Certificate



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Estd. 1949

Institutional Ethics
Committee for Human
Research
(IECHR)

FACULTY OF FAMILY AND COMMUNITY SCIENCES
THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA

Ethical Compliance Certificate 2022-2023

This is to certify that **Ms. Khyati Shekhawat's** study titled, **Designing a Residence for enhancing the Indoor Environment** has been approved by the Institutional Ethics Committee for Human Research (IECHR), Faculty of Family and Community Science, The Maharaja Sayajirao University of Baroda. The study has been allotted the ethical approval number **IECHR/FCSc/M.Sc./2022/11.**

Prof Shagufa Kapadia
Chairperson
IECHR

Prof Mini Sheth
Member Secretary
IECHR

APENDIX 2

Data Collection Tool

BACKGROUND INFORMATION

No. of respondent:_____

Kindly finish the following information.

1. Name of respondent: _____
2. Address:_____
   _____
3. Age of respondent (in completed years):_____
4. Mobile no.: _____
5. Employment status of the respondent:
   - Homemaker ☐
   - Business ☐
   - Service ☐
   - Self employed ☐
   - Any Other _____
6. Educational level
   - Illiterate ☐
   - Primary School ☐
   - High school ☐
   - Graduate ☐
   - Any Other _____
7. Types of family:
   - Joint ☐
   - Nuclear ☐
8. Size of family:
   - Small (1 to 3 members) ☐
   - Medium (4 to 6 members) ☐
   - Large (above 6 members) ☐
9. Total family Income:_____

OBSERVATION SHEET

No. of Respondent: _____

Location of house: _____

Dimension of house: length _____breadth _____height _____

No. of rooms: _____

No. of levels/floors: _____

Year of construction: _____

1) KITCHEN

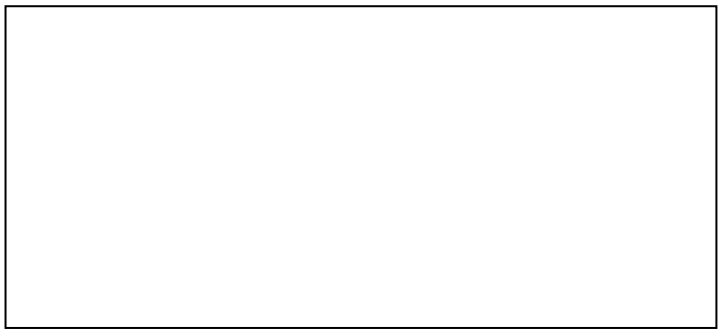
Dimension of kitchen: Length_____ breadth_____ Height_____

A. Design of the Kitchen

1. Type of kitchen
   - One wall
   - Gallery
   - L-shaped
   - G-shaped
   - U-shaped
   - L-shaped island
   - G-shaped island
   - Peninsula

2. Size of the kitchen (in sq. Ft.):
   _____

3. Placement of Windows and Doors :-



4. Dimension in inches:
   - Height of counter top from floor level: _____
   - Depth of counter top (from front to back): _____
   - Height of base cabinets from floor level: _____

- Depth of base cabinets: _____
- Height of wall cabinets (from top of countertop to the base of wall cabinets): _____
- Total height of wall cabinets (from base of the wall cabinets to top of wall cabinets): _____
- Depth of wall cabinets: _____
- Dimension of storage cabinets other than base and wall cabinets (LXBXH)_____
- Work triangle (in ft.): _____
- Dimension of doors: _____
- Dimension of windows: _____
- Height of windowsill from floor level: _____
- Height of artificial light from floor level: _____

B. **Materials**

1. Materials used for countertop: _____
2. Materials used for cabinets: _____
3. Materials used on cabinets shutters: _____
4. Materials used for flooring: _____
5. Materials used on walls: _____
6. Materials used in ceiling: _____
7. Materials used for drawers: _____
8. Materials used for doors: _____
9. Materials used for windows/doors: _____

C. Storage

1. Storage facility below the counter top
    - Yes
    - No
2. What is stored in base cabinets? _____
3. Storage facility above the counter top
    - Yes
    - No
4. What is stored in wall cabinets? _____
5. Storage facility other than base and wall cabinets
    - Yes
    - No
6. What is stored in cabinets other than base and wall cabinets?
    _____
    _____

D. Lighting and Ventilation

1. Number of windows: _____
2. Number of doors: _____
3. Placement of windows and doors: _____
4. Number of artificial lights: _____
5. Number of task lights: _____
6. Provision of exhaust fan if natural ventilation is not there: _____

E. Plants and placement

- Not available_____
- Name _____ Placement _____
- Name _____ Placement _____
- Name _____ Placement _____
- Name _____ Placement _____

2) BATHROOM

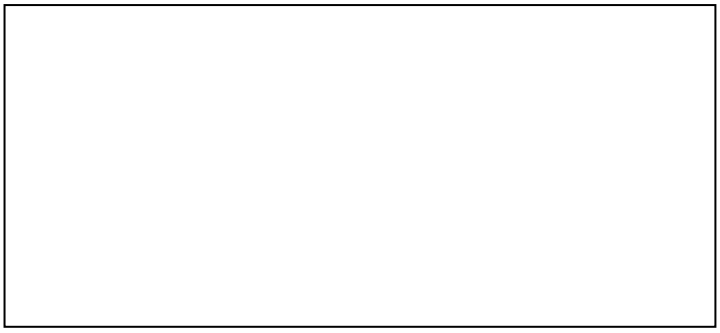
Do you have separate bath room or attached bathroom? _____

Dimension of bathroom: Length_____ Breadth_____ Height_____

A. Dimension in inches:

- Dimension of doors: _____
- Dimension of windows: _____
- Height of windowsill from floor level: _____
- Height of artificial light from floor level: _____

5. Placement of Windows and Doors :-



B. Floor

1. Floor material
    - Vinyl
    - Rubber
    - Rough ceramic
    - Linoleum
    - Any other _____

2. Intensity of colour
    - Light
    - Medium
    - Dark

3. Condition of flooring
    - Even
    - Uneven
    - Damage

C. Wall

1. Type of finish applied on wall
    - Tiles
    - Paints
    - Wallpapers
    - Any other _____

2. Materials of tiles
    - Ceramic
    - Vinyl
    - Marble
    - Any other _____

3. Wall texture
    - Smooth
    - Medium
    - Rough

D. Ceiling

1. Height of ceiling
    - High (7’ and above)
    - Medium (6’ – 9’)
    - Low (6’ and below)

2. Condition of ceiling

- Good
- Damp
- Leaking

3. Materials of ceiling
   - Plaster of Paris
   - Gypsum
   - MDF
   - PVC
   - Any other _____

4. Colour of the ceiling: _____

E. Lighting and Ventilation

1. Natural lighting
   - Sufficient
   - Moderate
   - Insufficient

2. Artificial lighting
   - Sufficient
   - Moderate
   - Insufficient

3. Height of ventilation
   - Very high
   - Moderate
   - Low

4. Types of materials used
   - Fiberglas
   - UPVC
   - Vinyl
   - Any other _____

F. Door

1. Opening of door
   - Inside
   - Slider
   - Outside

2. Material used
   - Wood
   - PVC Sheet

- Laminate
- Glass
- Any other _____

3. Condition of door
   - Good
   - Uneven
   - Broken

G. Water closet (WC)

1. Style of water closets
   - Western
   - Semi Indian
   - Indian

2. Space around water closet
   - Sufficient
   - Moderate
   - Insufficient

H. Storage

1. Storage facility in the bathroom
   - Yes
   - No

2. Storage facility other than wall cabinets
   - Yes
   - No

I. Plants and placement

- Not available_____
- Name _____ Placement _____
- Name _____ Placement _____
- Name _____ Placement _____
- Name _____ Placement _____

3) LIVING ROOM

Dimension of living room: Length_____ Breadth_____ Height_____

1. Placement of Windows and Doors :-

A. Dimension in inches:

- Dimension of centre table (LXBXH): _____

- Dimension of sofa (LXBXH): _____
- Dimension of storage (LXBXH): _____
- Dimension of TV unit (LXBXH): _____
- Space between sofa and TV unit (in ft.): _____
- Space between sofa and centre table (in ft.): _____
- Dimension of doors:_____
- Dimension of windows:_____
- Height of windowsill from floor level: _____
- Height of artificial light from floor level: _____

B. Materials

1. Materials used for cabinets:_____
2. Materials used for flooring:_____
3. Materials used on walls:_____
4. Materials used in ceiling:_____
5. Materials used for drawers:_____
6. Materials used for doors:_____
7. Materials used for windows/doors:_____

C. lighting and ventilation

1. Number of windows: _____
2. Number of doors: _____
3. Placement of windows and doors: _____
4. Number of artificial lights: _____
5. Number of task lights: _____
6. Provision of exhaust fan if natural ventilation is not there: _____

D. Storage

1. Storage facility below the centre table
    - Yes
    - No
2. Storage facility above the TV unit
    - Yes
    - No
3. Storage facility below sofa
    - Yes
    - No

4. Storage facility available in the living room
    - Yes
    - No

E. Ceiling

1. Height of ceiling
    - High (7’ and above)
    - Medium (6’ – 9’)
    - Low (6’ and below)

2. Condition of ceiling
    - Good
    - Damp
    - Leaking

3. Materials of ceiling
    - Plaster of Paris
    - Gypsum
    - MDF
    - PVC
    - Any other _____

4. Colour of the ceiling: _____

F. Wall

1. Type of finish applied on wall
    - Tiles
    - Paints
    - Wallpapers
    - Any other _____

2. Materials of tiles
    - Ceramic
    - Vinyl
    - Marble
    - Any other _____

3. Wall texture
    - Smooth
    - Medium
    - Rough

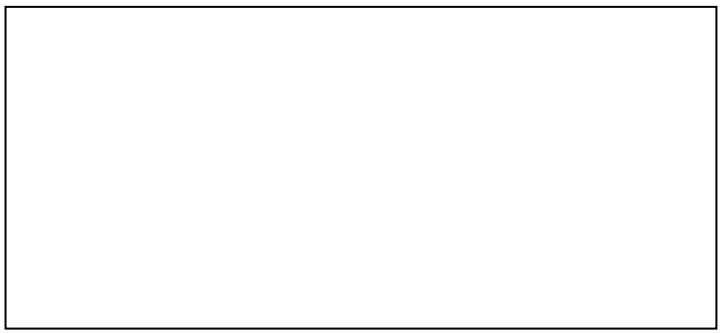
E. Plants and placement

- Not available_____
- Name _____ Placement _____
- Name _____ Placement _____
- Name _____ Placement _____
- Name _____ Placement _____

4) BEDROOM

Dimension of bed room: Length_____ Breadth_____ Height_____

1. Placement of Windows and Doors :-



A. Dimension in inches:

- Dimension of bed (LXBXH): _____
- Dimension of storage (LXBXH): _____

- Dimension of wardrobe (LXBXH): _____
- Space between bed and wardrobe (in ft.): _____
- Space between wardrobe and dressing unit (in ft.): _____
- Dimension of doors:_____
- Dimension of windows:_____
- Height of windowsill from floor level:_____
- Height of artificial light from floor level:_____

B. **Materials**

1. Materials used for cabinets:_____
2. Materials used for flooring:_____
3. Materials used on walls: _____
4. Materials used in ceiling:_____
5. Materials used for drawers:_____
6. Materials used for doors:_____
7. Materials used for windows/doors:_____

C. lighting and ventilation

1. Number of windows:_____
2. Number of doors:_____

3. Placement of windows and doors:_____
4. Number of artificial lights:_____
5. Number of task lights:_____
6. Provision of exhaust fan if natural ventilation is not there: _____

D. Storage

1. Storage facility below the bed
   - Yes
   - No
2. Storage facility available in the Bedroom
   - Yes
   - No

E. Ceiling

1. Condition of ceiling

   - Good
   - Damp
   - Leaking

2. Materials of ceiling

   - Plaster of Paris

- Gypsum
- MDF
- PVC
- Any other _____

3. Colour of the ceiling: _____

F. Wall

1. Type of finish applied on wall
   - Tiles
   - Paints
   - Wallpapers
   - Any other _____
2. Materials of tiles
   - Ceramic
   - Vinyl
   - Marble
   - Any other _____

3. Wall texture
   - Smooth
   - Medium
   - Rough

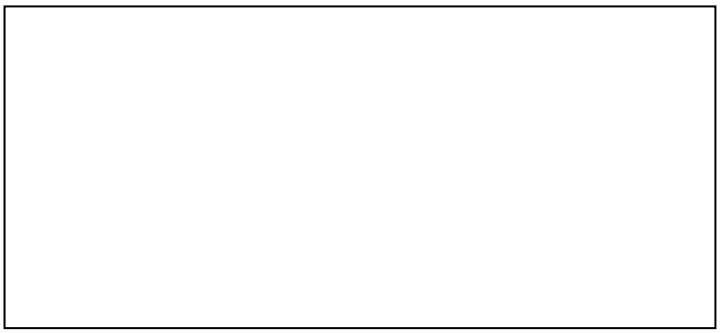
E. Plants and placement

- Not available_____
- Name _____ Placement _____
- Name _____ Placement _____
- Name _____ Placement _____
- Name _____ Placement _____

5) POOJA ROOM

Dimension of pooja room: Length_____ Breadth_____ Height_____

1. Placement of Windows and Doors :-



A. Dimension in inches:

- Dimension of cabinets (LXBXH): _____
- Dimension of storage (LXBXH): _____
- Space between cabinet and door (in ft.): _____
- Dimension of doors:_____
- Dimension of windows:_____
- Height of windowsill from floor level:_____
- Height of artificial light from floor level:_____

B. Materials

8. Materials used for cabinets:_____
9. Materials used for flooring:_____
10. Materials used on walls: _____
11. Materials used in ceiling:_____
12. Materials used for drawers:_____
13. Materials used for doors:_____
14. Materials used for windows/doors:_____

C. lighting and ventilation

7. Number of windows:_____
8. Number of doors:_____
9. Placement of windows and doors:_____
10. Number of artificial lights:_____
11. Number of task lights:_____
12. Provision of exhaust fan if natural ventilation is not there: _____

D. Storage

Storage facility available

- Yes
- No

E. Ceiling

4. Condition of ceiling

    - Good
    - Damp
    - Leaking

5. Materials of ceiling

    - Plaster of Paris
    - Gypsum
    - MDF
    - PVC
    - Any other _____

6. Colour of the ceiling: _____

F. Wall

4. Type of finish applied on wall
    - Tiles
    - Paints
    - Wallpapers
    - Any other _____
5. Materials of tiles
    - Ceramic
    - Vinyl
    - Marble
    - Any other _____

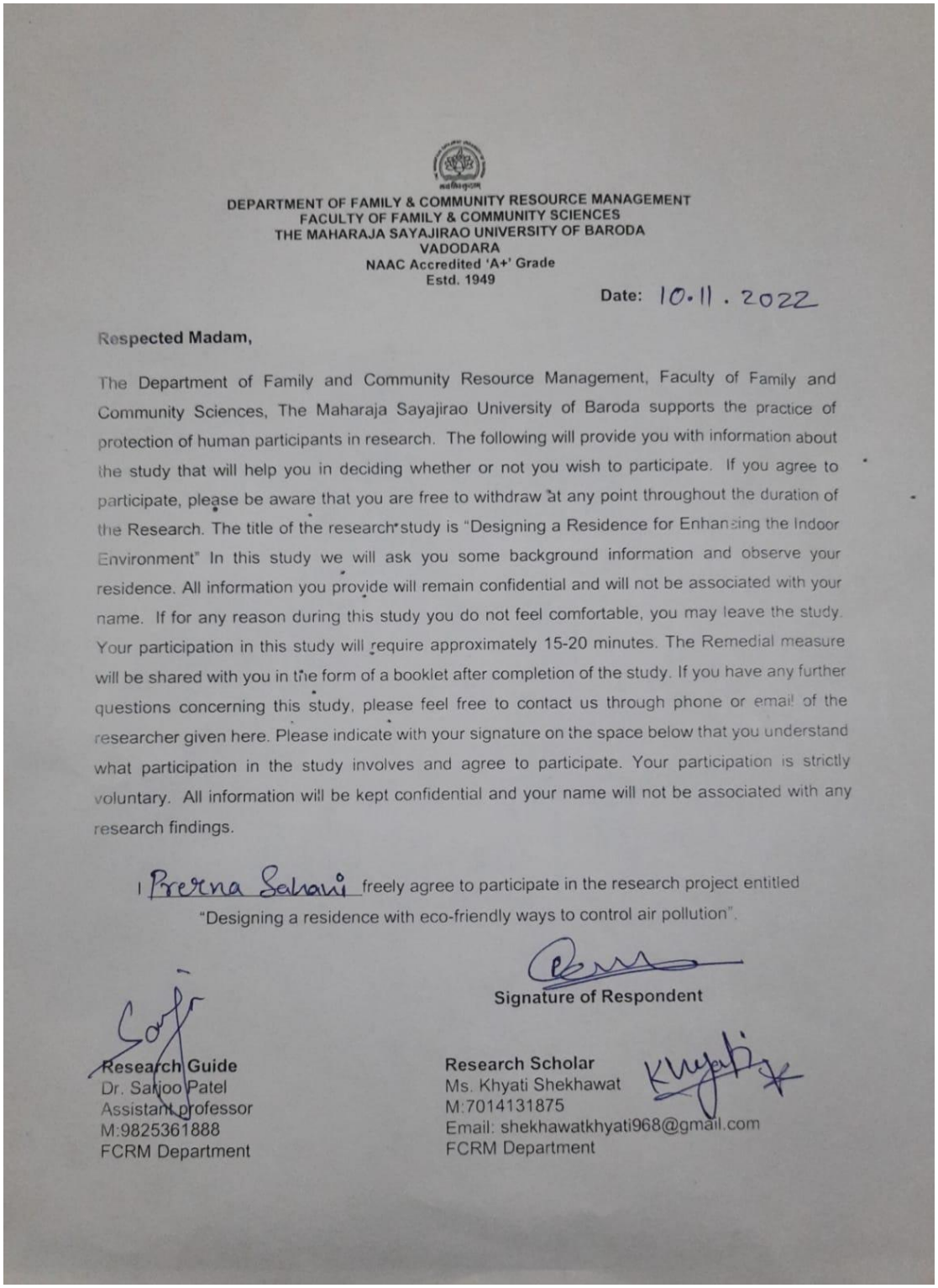
6. Wall texture
    - Smooth
    - Medium
    - Rough

E. Plants and placement

- Not available_____
  _____
- Name _____ Placement
  _____

APENDIX 3

Consent letter for respondents



DEPARTMENT OF FAMILY & COMMUNITY RESOURCE MANAGEMENT
FACULTY OF FAMILY & COMMUNITY SCIENCES
THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA
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Date: 10.11.2022

Respected Madam,

The Department of Family and Community Resource Management, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda supports the practice of protection of human participants in research. The following will provide you with information about the study that will help you in deciding whether or not you wish to participate. If you agree to participate, please be aware that you are free to withdraw at any point throughout the duration of the Research. The title of the research study is "Designing a Residence for Enhancing the Indoor Environment" In this study we will ask you some background information and observe your residence. All information you provide will remain confidential and will not be associated with your name. If for any reason during this study you do not feel comfortable, you may leave the study. Your participation in this study will require approximately 15-20 minutes. The Remedial measure will be shared with you in the form of a booklet after completion of the study. If you have any further questions concerning this study, please feel free to contact us through phone or email of the researcher given here. Please indicate with your signature on the space below that you understand what participation in the study involves and agree to participate. Your participation is strictly voluntary. All information will be kept confidential and your name will not be associated with any research findings.

I Prerna Sahani freely agree to participate in the research project entitled "Designing a residence with eco-friendly ways to control air pollution".

Signature of Respondent

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ABSTRACT

Climate change, pollution, environmental deterioration, and resource depletion are some of the most pressing environmental problems today. Interestingly, even in urban areas, interior air is five to 10 times worse than outdoor air, according to multiple WHO studies. Fortunately, it is largely a preventable risk. Understanding and controlling common pollutants indoors can help reduce risk of indoor health concerns. Buildings with improved environment quality can reduce the risk of any physical or psychological discomfort and disease to the residents. A poor indoor environment quality (in terms of exposure to chemicals) is not often noticed by the occupants, making it one of the many health concerns that still remains a silent threat. This indicates the importance of conducting more studies on eco-friendly ways to control air pollution at residence level in order to enhance our understanding on the cause of problems and associated remedial measures. The sample of the present study comprised of 90 residences from Amit Nagar society, Vadodara city, Gujarat state. The designer found that various components of controlling indoor air pollution were not incorporated in the respondent's houses such as placement of plants, material selection, direction of sunlight etc. After observation the researcher proposed an ideal design for the residence with improved indoor environment. The eco-friendly design of a residence developed by the researcher will be helpful for Interior designer, Architects and Civil Engineer as a reference while designing new residences in creating a healthier atmosphere indoors as the research findings would provide strong data base reflecting various eco-friendly materials which can be used to reduce air pollution inside the residences. The development of these designs was based on the information gathered by the researcher.

WAYS TO IMPROVE THE INDOOR ENVIRONMENT

A Guide to simple changes in construction and practices to follow to Enhance Indoor Environment of the Residences

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Guided by: Dr. Sarjoo Patel

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2022-2023

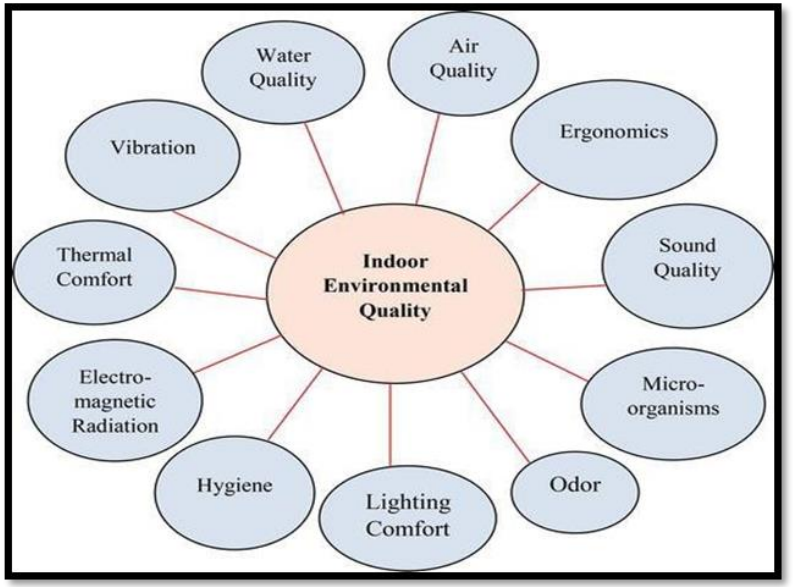
PREFACE

A homemaker is a person who maintains the upkeep of his or her residence. A homemaker's, job is to provide care for a family and household. Their responsibilities include cooking, cleaning, organizing, and making plans for the entire household. In the present scenario of increasing risk of health due to pollution and new diseases most of our time goes in staying at home. So, the responsibility of enhancing the Indoor environment of the residence for better health and productivity of the whole family also comes on the shoulders of homemakers. As the homemakers perform a crucial role in taking decisions for their residences, it is important to enhance their knowledge regarding indoor environment of their home. This booklet is the outcome of the research undertaken under the title" Designing a Residence for Enhancing the Indoor environment". This booklet includes constructional as well as easy changes along with day-to- day practices necessary to get an enhanced indoor environment for healthier life.

CONTENTS

INTRODUCTION

Indoor Air Quality (IAQ) refers to the quality within and around buildings and structures which affects the health and comfort of the building occupants. Understanding and controlling common pollutants indoors and outdoors can help reduce the risk of occupants. There are larger health concerns associated with exposure to outside pollution. Injurious health impacts of contaminated air include heart disease, asthma and other respiratory disorders.

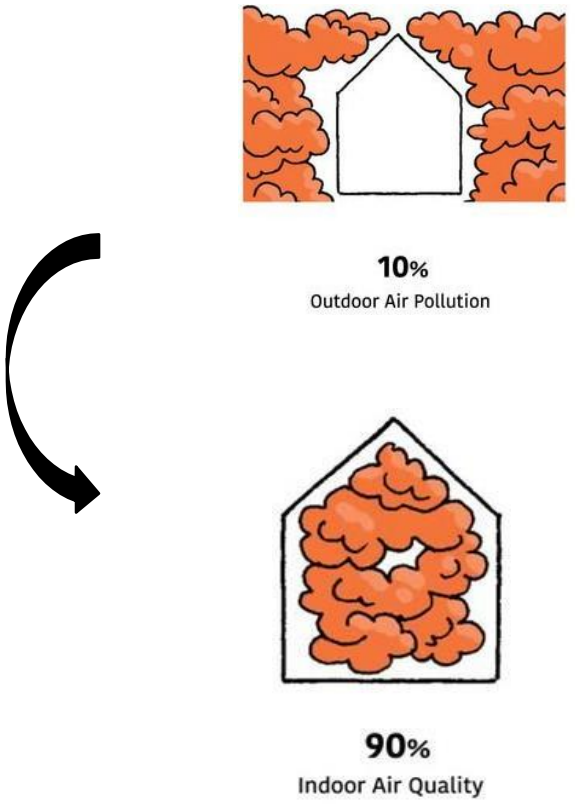


SOME OF THE COMMON INDOOR AIR POLLUTANTS

AIRBORNE PARTICLES	• Generated through diesel, exhaust fan, dust, smoke and other sources
INDOOR FORMALDEHYDE	• Generated from building materials, furniture, cooking and smoking
HOUSEHOLD ODORS & GASES	• Generated from activities such as painting, cooking and smoking
OZONE	• Comes from outdoor air
CARBON DIOXIDE	• Generated from people exhaling and cooking

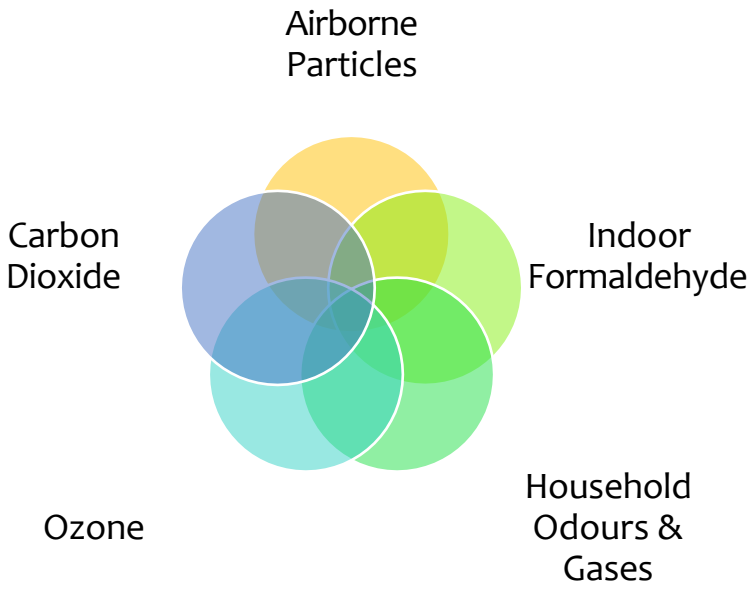
INDOOR AIR QUALITY (IAQ)

- **Indoor air quality (IAQ) is a term which refers to the air quality within and around buildings and structures.**
- **And especially as it relates to the health and comfort of buildings occupants.**



FACTORS THAT CONTRIBUTE TO INDOOR AIR QUALITY (IAQ)

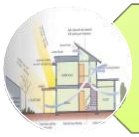
- Indoor air quality is not a simple, easily defined concept like a desk or a leaky faucet. It is a constantly changing interaction of complex factors that affect the types, levels and importance of pollutants in indoor environments majorly in commercial buildings.
- These factors include: **sources of** pollutants or odours; design, maintenance and operation of building ventilation systems; moisture and humidity.
- In addition, there are many other factors that affect comfort or perception of indoor air quality of several commercial buildings.



CONTROLLING INDOOR AIR QUALITY (IAQ) IN RESIDENTIAL BUILDINGS: THREE MAIN STRATEGIES

WAYS TO CONTROL INDOOR AIR POLLUTION

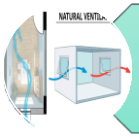

Use of Innovative materials


Employment of passive design


Application of architectural firms


Transition to renewable energy


Inclusion of green roofs and walls


Natural Ventilation

Low-Non-VOC Paints


Inclusion of Plants

USE OF INNOVATIVE MATERIALS

Architects and Engineers have to adopt natural and sustainable materials that reduce the level of Indoor Air Pollution.

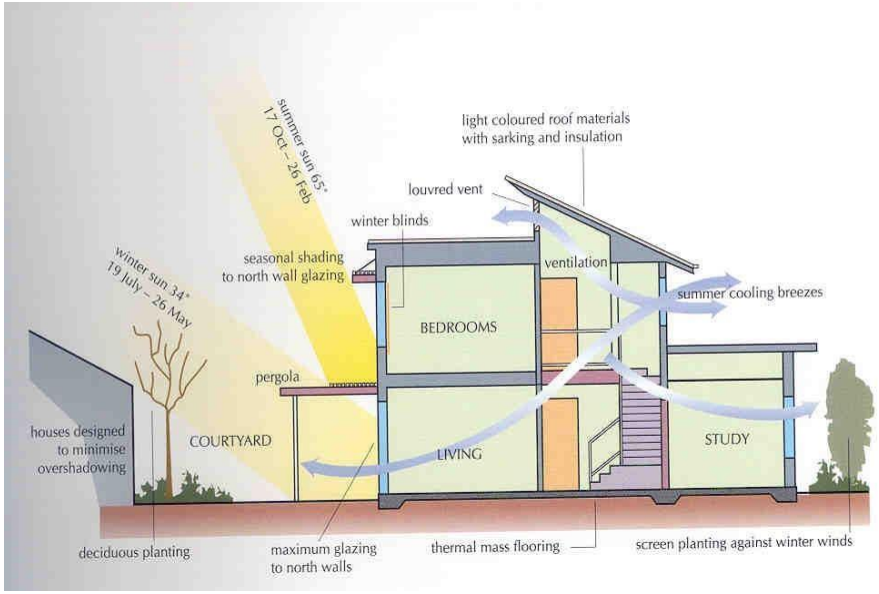
- Bamboo
- Cane
- Waxed Canvas
- Recycled rubber
- Recycled Plastic
- Glass
- Microfiber synthetic fabrics
- Non-VOC Paints
- MDF & HDF
- Magnesium Oxide Board (MgO)
- Bamboo Plywood
- Recycled Wool Fiber
- Cork
- Concrete
- Linoleum
- Vinyl

EMPLOYMENT OF PASSIVE DESIGN

- Passive design "takes advantage of the climate to maintain a comfortable temperature range in the building".

- Passive solar building design uses the energy of sun and wind as important elements in the building's functionality, including heating, cooling and lighting.

- Special attention needs to be given to the building's location, orientation, size, windows and walls that surround the building.



APPLICATION OF ARCHITECTURAL FILMS

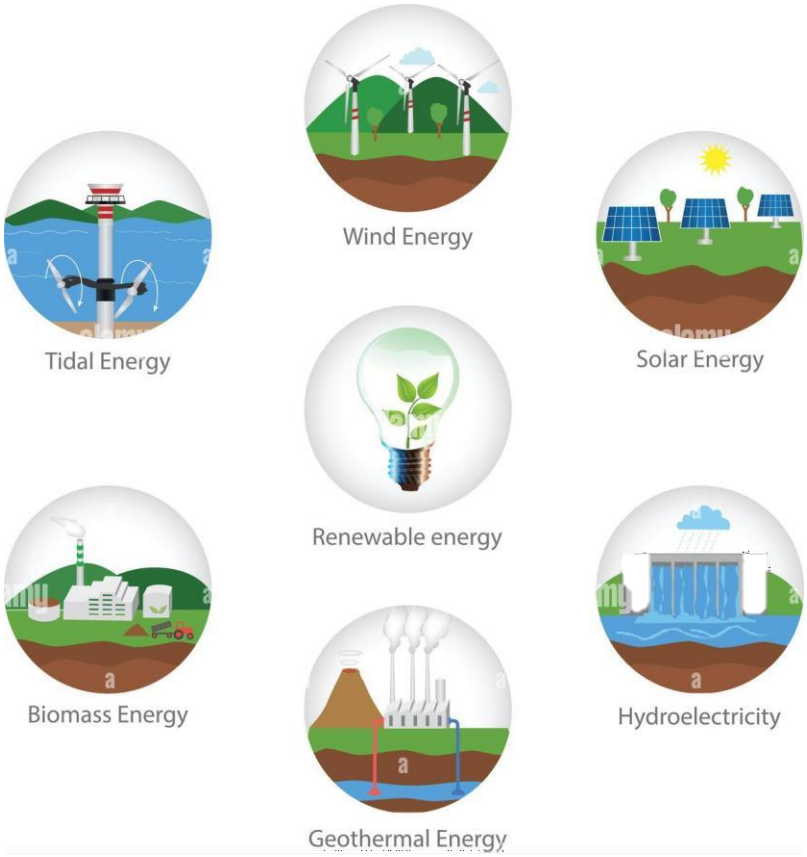
- By applying a thin architectural film, one can reduce an area heating and cooling needs accordingly.

- There are other benefits of architectural film are such that it can also deflect UV rays, which damage the furniture and flooring in an environment, and reduce the building's need to invest in new materials that contribute to CO2 emissions.

TRANSITION TO RENEWABLE ENERGY

- Solar energy is green and cost-effective, and it can reduce a company's CO2 emission and energy costs.

- In some countries, if a building collects enough energy, it can even sell it back to the provider and make a profit.

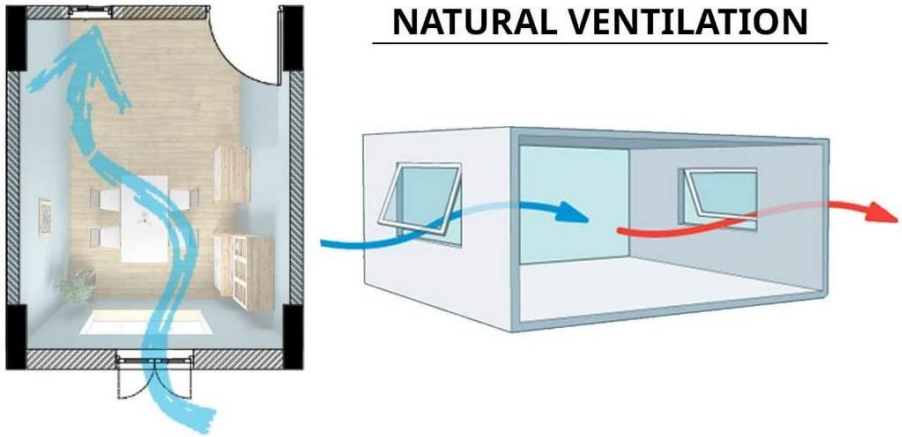


INCLUSION OF GREEN ROOFS AND WALLS

- "Vertical gardens" and "green roofs" are considered as new concepts.
- Vertical gardens allow a building to boost its positive environmental impact.
- These gardens are installed on the outside as well as inside to provide insulation as well as reduce heating and cooling costs.
- It improves the building's sustainability by reflecting solar radiation, absorbing rainwater and improving air quality (plants absorb CO2 and release oxygen).

NATURAL VENTILATION

- Natural ventilation methods, such as solar heating or thermal mass cooling, use passive systems, rather than mechanical, to supply outdoor air to a building's interior for ventilation and cooling.
- They provide the most comfortable and energy-efficient environment for employees and other building occupants.



LOW OR NO-VOC PAINT

- VOC stands for volatile organic compounds.
- VOCs are toxic to humans, animals in your home, and the environment.
- By choosing low or no-VOC paints, you're making a healthier choice for everyone.
- Another benefit to low or no-VOC paints is that they aren't considered hazardous waste.
- It's a great way to do a refresh in your home that's a better choice for your family and the planet.

INCLUSION OF PLANTS

- incorporating numerous amounts of plants in indoor and outdoor areas of buildings reduces the amount of air pollution very effectively.
- Plants plays an important role in any interior and exterior spaces.
- We all know that plants give nice natural surroundings.
- it also provides abundant oxygen to the surroundings.
- Some common variety of indoor easy to maintain plants are discussed further:

a) Snake Plant

Snake Plant (Sansevieria trifasciata) which is also commonly known as "Mother-in-law's tongue".

It is widely used in indoors as it has superior air purification quality and also removes carbon dioxide at night

b) Peace Lily

Peace Lily (Spathiphyllum) is considered as a lively plant which is filled with peace and contentment.

It helps in overcoming pollen allergies as it cleanses the air of the surrounding

c) Aloe Vera

Aloe Vera (Barbadensis) also known as the “Miracle Plant”

Because it has various medical properties that rejuvenate, soothe and also heals the human body.

It has thick and fleshy leaves with toothed margins.

d) Chinese Evergreen

Chinese Evergreen (Aglaonema Commutatum) popular across Asia as not only it brings prosperity into the house but are the most durable plants as they tolerate poor light, dry air and drought very well.

e) Fiddle leaf-fig plant

Fiddle leaf-fig plant have big leaves and thin trunk.

They require amount of care and can live in just partial indirect light.

f) Areca palm

Areca palm (Dypsis lutescens) is also known as “butterfly palm” which also fulfils the work as an air humidifier.

This plant can grow anywhere between 3 feet to 8 feet in height

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