INVENTION OF DESIGN METHODS FOR BIO-CLIMATIC HOUSES IN THE RURAL AREAS OF MIRPURKHAS, SINDH

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ABSTRACT

The domestic sector uses a significant portion of the world's energy resources. As a result, it's important to understand, evaluate, and apply bioclimatic architecture techniques that reduce energy usage while considering the potential passive and active building solutions. A sustainable technique known as "bioclimatic design" evaluates a design's viability while considering human relations and the climate. This Research investigates the bioclimatic features of architecture to make houses more comfortable and economical, it would not only resolve the energy crisis but also reduce environmental degradation. A variety of methods are used to recommend the design strategies for bioclimatic architecture such as case studies, surveys, interviews, questionnaires, computer programming, etc. Results conclude that the house system with the concept of bioclimatic architecture is the need of rural areas with the special context of Mirpurkhas, which has many valuable natural resources that previously were seriously ignored due to illiteracy and unawareness of people to use these resources for their benefit and comfort. Since the general review presented in this study proved to be an effective design strategy that produced significant energy savings, were able to achieve the goal of exporting some bioclimatic architecture strategies that have been implemented in particular regions to other regions with comparable climates.

Keywords: bioclimatic, Sun Light, biogas, Organic Matter and solar power

I. INTRODUCTION

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A house is a shelter in which people live for their protection against sun, wind, snow, different climatic conditions, and other living organisms (animals and insects) etc. here we can use the two words "shelter" and "house" interchangeably. The shelter can give you a feeling of well-being. It can help you maintain your will to survive [1]. People who are left out in the open for a long amount of time get tired and frequently lose hope in life. Thus, having a shelter raises one's standard of living. A shelter can be considered a place where families interact and children are raised healthily. [2]. Residents at shelters feel more secure and are Additionally able to concentrate more on other facets of their lives., shelters promote independence from the community and offer isolation. Like food, water, and clothes having shelter is also a basic necessity [3].

I. BACKGROUND

Mirpurkhas is a taluka city of the Mirpurkhas district Sindh Pakistan. It is the capital city of Mirpurkhas District the fourth largest city in the province of Sindh. The total area of Mirpurkhas district is 2925 km² with a total estimated population of 1,592,981, whereas the area of Mirpurkhas city is 1088 km² with a population of 198162 (estimated in 2014). Due to its rich soil, the city is well-known for its horticulture products, farming, and mango agriculture, which yields hundreds of different species of mangos annually. The entry point to the southeast of the province of Sindh is Mirpurkhas, which is located at 25°31′39.3°N 69°00′50.6°E on the Mirwah Canal. While Umerkot is exclusively connected by road, Hyderabad is 65 kilometers away by both road and rail. The town is located 220 kilometers southwest of Karachi. The Indian border is about 170 kilometers to the east. [4]. There are many bazaars and retail outlets in the city. The construction of the Jamrao Canal in the 1900s brought agriculture and irrigation back to life. The city was able to cultivate and repurpose crops, mostly providing grain, cotton goods like textiles, and sugar from sugarcane farms [5].

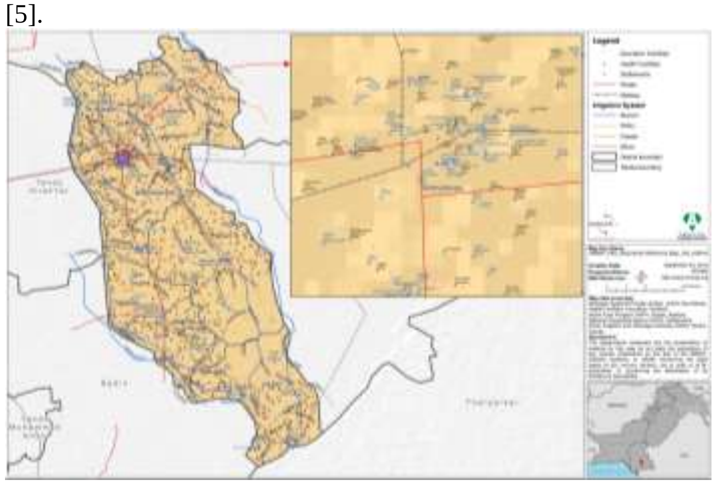

Figure 1. Taluka Division of Mirpurkhas District Sindh Pakistan

Source: Sindh-Mirpurkhas Population Density Map - September 2014 – Pakistan

The mostly middle and lower-class population lives in Mirpurkhas, especially in rural areas. These people follow the rural lifestyle. Houses are made up of brick masonry and roofs are Constructed with tiers and girders, verandahs, courtyards, etc. still used there [6-7].

Table 1: Estimated Population of Mirpurkhas District
Source: Sindh-Mirpurkhas Population Density Map – September 2014 – Pakistan

Taluka	Population	Male	Female	Pop Density	Average HH Size	Estimated HHs
Digri Taluka	294,321	153,050	141.271	488	5.9	49,885
Kot Ghulam Muhammad Taluka	387,778	201,649	186,129	491	5.6	69,246
Mirpurkhas Taluka	198,162	103,046	95,116	395	6.4	30,963
Sindhri	266,994	138,840	128,154	459	6.1	43,769
Jhudo	294,008	152,887	141,121	530	6.1	48,198
Hussain Bux Mari	151,718	78,895	72,823	488	6.1	24,872
Total	1,592,981	828,367	764,613	477	6	266,933

A lower-class population resided in some of the mud-built dwellings and some of the brick-and-mud houses. Despite having a tiny industrial park, Mirpurkhas has no operating industries. There are four sugar mills, though; the oldest is Mirpurkhas Sugar Mills, followed by Mirawah Sugar Mills, Digri Sugar Mills, and Najma Sugar Mills. The city of Mirpurkhas is renowned for encouraging sports in the province of Sindh. [8-9]

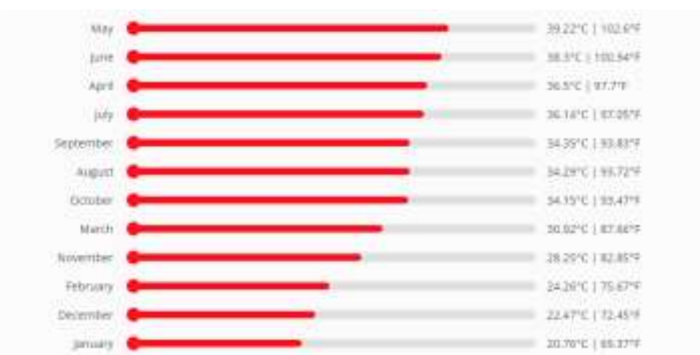

Figure 2. Mirpur Khas Temperature by Month
Source: Amur, A. et.al.,2022).

A. Literature

The term "bio-climate" describes architectural designs that include external factors and climate to help create the best possible internal thermal comfort. It addresses architectural and design components rather than entirely relying on mechanical systems, which are thought of as support. [10]. A good example of this is using natural ventilation or mixed-mode ventilation. And house is a building to provides shelter for human habitation, maybe for a single or many in one building [11]. It defines a residential structure that makes sure to preserve the environment by making effective use of locally sourced materials, greenery, and renewable energy sources. The Bioclimatic house also refers to an independent house that is fully run on natural precious resources and not dependent on mechanical systems [12].

B. Design Methods

In architecture, design policies are the way to comfort the building through the architectural design of buildings like planning, openings, height variations, etc. Some traditional and modern strategies or techniques used in buildings related to Cavity walls are used to stop heat loss through cavities by packing the air space with heat-blocking materials. A building's roof that has been planted over a waterproofing membrane with plants and a growing medium in part or full is known as a "green roof" or "living roof." [13]. A classic Persian architectural feature that allows for natural ventilation in buildings is the wind catcher. Wind catchers are still used in a lot of places, including Afghanistan, Pakistan, and the Middle East's traditional Persian-inspired buildings [14].

A surface that reflects the amount of heat flux sent into the building is significantly decreased if the building's exterior is painted in a color that reflects solar radiation to have minimum absorption but has strong emission in the long wave band. [15]. The balcony is a platform that extends from a building's wall, usually above the ground floor, and is supported by console brackets or columns. It is also covered by a balustrade. [16].

Arch. Cettimm Gallo (1994) researches the main techniques of bioclimatic architecture, to make it simple we must say that bioclimatic architecture is not an exclusive or new concept, it is very old indeed. This research paper portrays some of the techniques that are used in bioclimatic houses in different parts of the world [17].

Materials and construction of building fabrics are the factors that affect bioclimatic architecture. The use of local materials and the method of construction of these materials according to the atmospheric need of the building also makes the building [18]. B. Rivela and C. Bedoya focus on the significance of bioclimatic architecture related to the atmosphere affecting the building [19]. Edna Shaviv in 2011 defined the different design stages and the design tools used in them. The generative design tools are best in the early design stage and the evaluative tools are best in the advanced design stage though they can also be used in the former design [20]. Olgyay in 2015 researched bioclimatic orientation methods for buildings, he also pointed out that the effect of the daily temperature variance brought on by solar orientation was overlooked. [21]. The "Ten Book" by Vitruvius lists numerous advantages of passive building designs that can reduce occupant exposure to uncomfortable extreme weather [22].

Jaffe in 2016 guided the data on choosing and analyzing sites, such as latitude, sun angles, artificial and natural shade, meteorological conditions, and energy efficiency. The street layout, lot design planning of open areas, and sitting for single-family detached homes and high-rise dwellings are some of the design techniques to preserve sun access. Trees, landscaping, and vegetation utilization are referred to as secondary factors for building orientation. [23]. Dafton G. Njuguna (1997) defines the objective of energy efficiency is to minimize the quantity of energy needed to deliver goods and services. To reach and maintain a pleasant temperature, for instance, insulating a home enables a building to consume less energy for heating and cooling. By stopping heat input and loss through the building envelope, thermal insulation is a crucial technological advancement for lowering building energy usage. Low thermal conductivity building materials, frequently less than 0.1W/mK, are known as thermal insulation [24].

Artificial systems of cooling and heating have convinced architects to create glass boxes but it must not be done in this way, the facilities should not control the architecture. This was best proved by Le Corbusier who used to study the effect of climate before erecting a building. Some other examples of bioclimatic techniques used in houses are greenhouse verandahs, solar chimney walls, tomb walls, and sun ducts [25].

C. Summary

In the context of bioclimatic architecture and energy-efficient building design, a range of passive and active strategies are utilized to create comfortable and sustainable living spaces. These strategies include the use of underground wind catchers to regulate temperatures, especially in hot Mediterranean climates, as well as passive measures like ventilation, dehumidification, and shading in hot and humid areas [26]. Bioclimatic architecture incorporates elements such as green roofs, glazed surfaces, natural ventilation ducts, and strategic orientation of spaces to maximize natural light and minimize energy consumption [27]. Water recycling, the use of appropriate construction materials, and attention to outdoor thermal comfort are also integral aspects. By harnessing natural concepts and employing technologies like solar arrays and thermal collectors, bioclimatic architecture not only reduces pollution but also lowers costs and energy consumption [28]. Additionally, patio houses with light-insulating materials and natural features aim to combat excessive heat in hot and arid regions. Overall, these strategies collectively contribute to sustainable, cost-effective, and environmentally friendly building design [29].

This research aims to develop design strategies for Bioclimatic House by adopting passive design techniques, eco-friendly materials, solar systems, and organic waste.

II. RESEARCH METHODOLOGY

The first step in the research was to identify the several issues that the community of Mirpurkhas, Sindh, Pakistan was facing, including discomfort from the heat, unhygienic living conditions, high energy costs, etc. Thus, research covered a variety of Pakistani topics about the energy crisis and difficulties with thermal discomfort in residential buildings, particularly in rural areas. To improve thermal comfort in residential structures, this research addresses several strategies for varying seasons. A rural region of Pakistan's Mirpurkhas is chosen for this study. More information about the rural area's housing and living circumstances, energy crisis, etc., is investigated. A community-based questionnaire survey is used to investigate the issues facing rural communities. The study makes several recommendations for passive design strategies that are applied to building orientation. To increase comfort and decrease pollution, some energy-efficient measures are also recommended. These include wind catchers, which provide cold air to covered spaces, vegetation, which filters air, and windows and their shading devices that are measured properly in terms of size, shape, placement, and projections.

III. MATERIALS AND DISCUSSIONS

During a long time of investigation, investigations, and surveys, several issues were looked at regarding the rural Mirpurkhas area, including environmental pollution, lack of gas supply, discomfort from the heat, and energy shortages. This study offers several effective and feasible remedies, such as:

A. Sun Light for Electricity in the House

One of Earth's life support systems, the sun provides both light and heat. Every 50 minutes, solar energy, which is clean, abundant, and renewable provides enough energy to cover the world's annual consumption needs. Gathering even a tiny portion of this radiant energy and heat is the challenge.

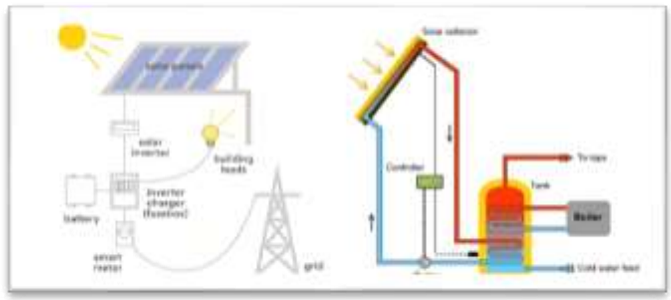

Figure 3: Solar System for Electricity
Source: www.leonics.com

Although off-grid domestic solar power systems are cut off from the typical electric power grid, grid-tied solar power systems are directly connected to both the home and the traditional electric utility grid. Batteries allow periods of surplus production and demand to be balanced when there is no connection to the electric grid [30].

B. Sun Light for Water Treatment in the House

Solar water heating is a technique that uses solar radiation to heat water in a panel that is often mounted on the roof. The heated water can then be used as hot water or to power a central heating system.

Solar panels can be installed on a flat roof or an angled frame on the ground. They should be positioned on a south-facing pitched roof that is free of shadow and has a pitch of between 20 and 50 degrees. A roof area of two to five square meters is needed for a normal domestic installation. If an additional water cylinder is needed, you may also need space for it [31].

C. Solar System for Water Heating

Using a solar thermal collector, solar water heating (SWH) is the process of converting solar radiation into renewable energy for water heating. Systems for solar water heating include a variety of methods that are being used more and more globally. The storage tank of a "close-coupled" SWH system is positioned horizontally, directly above the roof's solar collectors. Since the hot water climbs into the tank naturally due to thermosiphon flow, no pumping is necessary [32]. A circulating pump transfers water or heat transfer fluid between the storage tank and the collectors in a "pump-circulated" system, which has a ground- or floor-mounted storage tank below the level of the collectors (see Figure 4).

D. Solar System for Water Purification

A solar water purification system is a home water purification system that uses solar heating in addition to water distillation and treatment of solar radiation. In situations where low turbidity water is not accessible, non-volatile solid contaminants such as salts, silt, heavy metals, and microbes will be eliminated from polluted water by distilling it using a solar-heated still to produce potable water. Even if the water in some wells and rivulets appears pure, it might not be safe to drink [33]. The polluted water would be contained in clean to address this issue. The solar energy collector, the solar distillation system, and the solar water disinfection system are the three primary parts of the system. A device called a solar energy collector gathers solar radiation and transforms it into thermal energy for use in the solar distillation process and the SODIS As seen in Figure 4, the solar distillation system is comparable to the traditional water distillation system. Using sun radiation, a solar water disinfection system purifies low turbidity, microbiologically polluted water into potable water. All three systems are connected by an insulated or thermally resistant piping system, which should be as short as feasible to reduce heat losses [34].

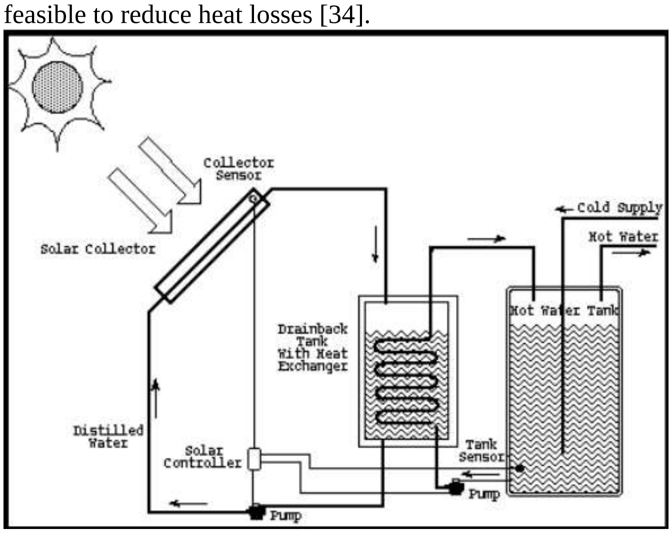

Figure 4: Solar Water Heating System and Water Purification

Source: energy.gov

E. Organic Matter

Farm animal waste comes from livestock, poultry, and dairy production. It can be manure from farm animals or the byproducts of meat processing. It has been used as fertilizer in the old times but now its utilization become more evaluated, now a day it is widely used in the biomass process for biogas. Primarily talk about biogas, refers to a mixture of several gases (Table 2) that are created when organic matter breaks down in the absence of oxygen. Biogas can be generated from a variety of raw sources, including green waste, food waste, sewage, plant material, manure, and agricultural waste [35].

Table 2: Typical composition of biogas

Compound	Formula	%
Methane	CH_4	50-75
Carbon Dioxide	CO_2	25-50
Nitrogen	N_2	0-10
Hydrogen	H_2	0-1
Hydrogen sulfide	H_2S	0-3
Oxygen	O_2	0-0.5

Since it generates no net carbon dioxide and has a continuous cycle of production and use, biogas is regarded as a renewable resource. The cycle of organic material growth, conversion, and consumption, followed by regeneration, is continuously repeated (Figure 5). In terms of carbon, the primary bioresource grows with the absorption of as much atmospheric carbon dioxide as it releases during the final conversion of the material into energy [36].

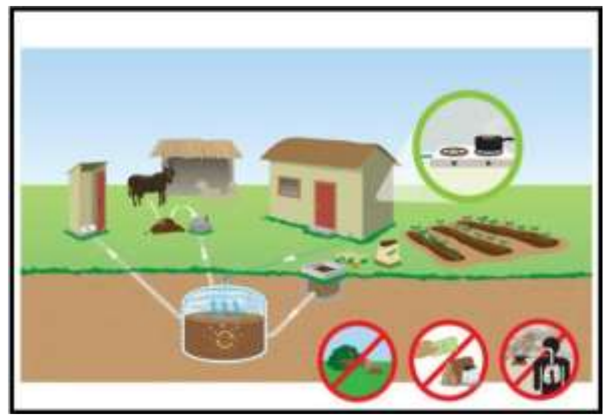

Figure 5: Biogas process

Source: practicalaction.org

F. Use of biogas in-house

Once the biogas is made, we can use it in two ways in a single house (shown in Figure 6). Biogas is mainly used for cooking gas (methane gas) and another use is to run generators for electricity. But its pressure is not high that is why only light electric appliances can run on this generator.

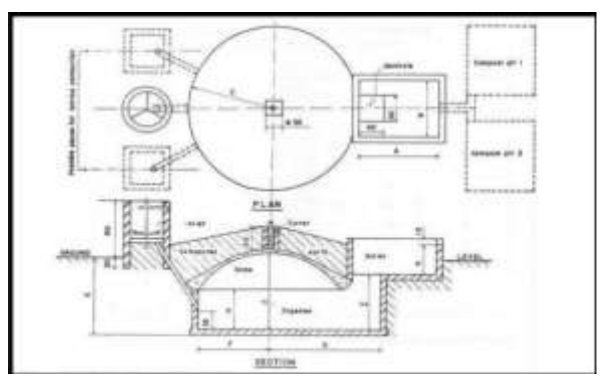

Figure 6: Plan and Section of Biogas Plant

Source: www.nathmotors.com

G. Architectural Factors of Bioclimatic Building Orientation of Building

Orientation is the main and basic factor of any building. It is the art of placing any building concerning some particular direction. As a result of avoiding the cost of heating and cooling, a properly oriented structure can save you a significant amount of money because it keeps you comfortable without incurring many extra expenses. There are two main points for orienting any building [37].

Orienting the building to make use of the Sun Figure 7 illustrates how we may design and build structures that reject heat in the summer and capture free heat in the winter since the sun is lower in the sky in the winter than it is in the summer.

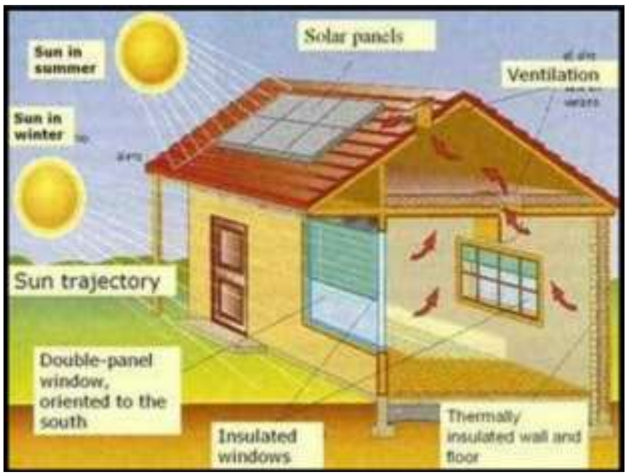

Figure 7: Orientation W.R.T Sun
Source: blog.smartgardener.com

Using the wind to your advantage when you orientate your building, the maximum advantage of wind we can get by ventilation or cross ventilation. When placing ventilation openings, you are placing inlets and outlets to optimize the path air follows through the building. Windows or vents placed on opposite sides of the building give natural breezes a pathway through the structure [38].

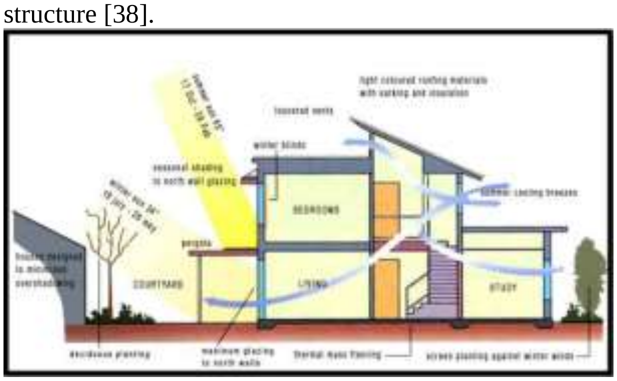

Figure 8: Orientation W.R.T Wind
Source: wordpress.com

SHADING DEVICE

Devices designed specifically to shield from sunshine, and natural light, or to block views are known as shading devices. Horizontal shading devices, which are positioned in front of windows in a variety of ways, and vertical shading devices, which are located inside buildings and can be either fixed or movable, are the two main categories of shading devices. Additionally, vertical shade devices can be made with different angles depending on where the sun is [39].

In devices that naturally shade as seen in Figure 9, shade can be provided periodically when trees and other plants are present. In addition to providing shade, vegetation can also reduce wind, precipitation, and solar radiation. Well-planted trees can reduce a building's energy use by up to 30% (see Figure 10) [40].

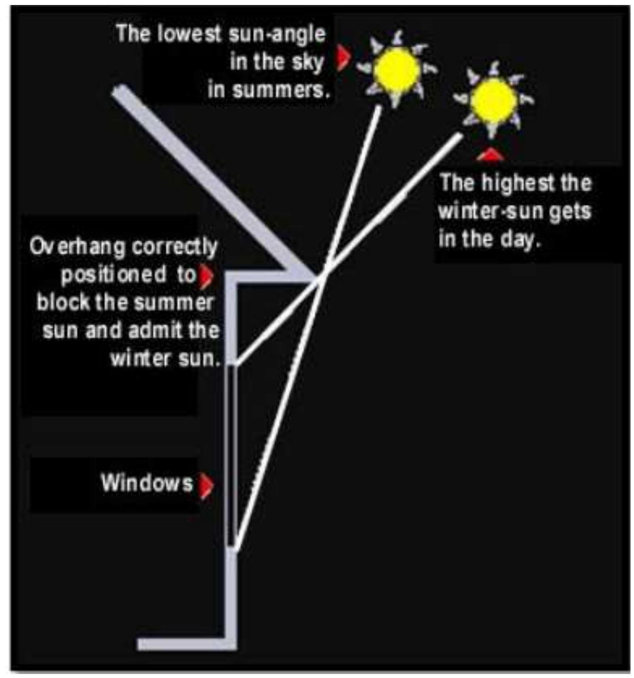

Figure 9: Horizontal Shading
Source: www.revitcity.com

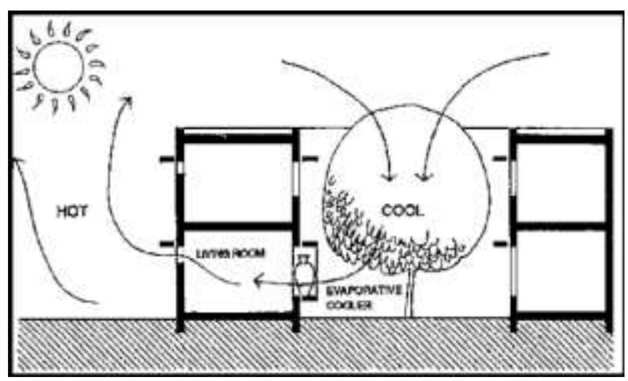

Figure 10: Air Filtration Though Natural Shading Device
Source: Home exchange.in

IV. CONCLUSION

In conclusion, adopting bio-climatic design techniques for rural homes in the Mirpurkhas is a potential strategy for resolving the particular difficulties faced by the area. It provides an economical, environmentally friendly, and culturally aware solution that has the potential to greatly improve rural populations' quality of life.

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