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Design and Construction of a Solar Powered Evaporative Air Cooler

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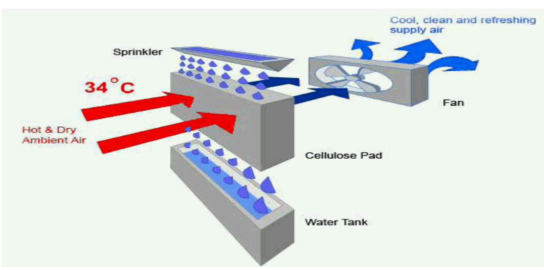
Abstract: Solar powered evaporative cooler using locally available materials such as galvanized iron, thin wooden strips, car radiator fan and submersible water pump of low power types was designed and constructed. The design and construction of this system are simplified in such a way that it can easily be reproduced by a lay man especially those living in hot and dry areas. In this work humidity and temperature control unit was integrated to control water supply there by regulating the humidity level of the room space while cooling. Energy consumption of this air cooler for 6hrs was 0.054kWh. This technology is cheaper and can efficiently improve indoor air quality and it is suitable for residential application especially for villages, schools and offices where there is a power outage problem or no grid extension.

Keywords; *Solar powered, evaporative cooler, design, construction and energy savings.*

I. INTRODUCTION

This research work is based on the evaporative cooling where hot dry air can be passed through evaporative pad, get cooled and then be blown to a building space as illustrated in Figure 1.1.



Basic evaporative cooling process [1]

Fossil fuels are being consumed significantly higher than the environmentally friendly renewable energy sources and this result in increase in greenhouse gas emissions and subsequent climate change. In this regard, massive and excess use of energy has raised people's concern on the limited energy resources, deterioration of the global climate as well as the disappearance of ozone layer [2].

Heating ventilation and air conditioning (HVAC) system takes nearly half the total energy supply to the buildings due to the fact that the mechanical compressor based air conditioning system are energy intensive i.e they consume a lot of energy during the working process [3]. Therefore, there is an urgent need to improve the energy efficiency of the HVAC system as well as promoting new technology to replace conventional [1] systems thereby decreasing the electrical energy consumption as well as the release of CO_2 into the atmosphere during the operation.

Another issue is the instability of power in Nigeria over decades and Nigeria is endowed with abundant solar radiation but yet the national energy supply is almost entirely dependent on conventional energy sources which are fast depleting [4]. So, there is need to design and construct a system which utilizes this abundant solar energy which does not impose any negative effects on eco-system while cooling our environment thus, the need for an alternative cooling system such as solar powered evaporative air cooler can never be overemphasized, letting solar photovoltaic powered evaporative air cooling system come into sight.

II. RELATED WORK

This section covers literature review from the basics extending to the developments and other investigations in evaporative cooling reported by different researchers. The basic methods or processes of achieving evaporative cooling and different types of evaporative cooling are discussed in this literature review. These are direct, indirect and combined direct and indirect types. Some historical backgrounds where applicable are also discussed to reflect the state of the art in the technological developments of the systems.

A. *Direct evaporative cooling system (DECS)*

Direct evaporative cooling system has been theoretically and experimentally studied by many scholars due to its easy fabrication and high efficiency in hot and dry districts [5]. Figure 1.2a describes a typical direct-type evaporative air

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cooler while; Figure 1.2b describes the cooling path for this type of cooling system. Its application is also worldwide and proven to be energy-saving and simple operation. **[6]** Presented a performance test of a direct evaporative cooler coupled with a ground circuit in Tehran. The investigation showed that the coupled system sufficiently provided the comfort condition with high cooling effectiveness and greatly reduce the electricity cost. **[7]** Initiated a performance investigation of a direct evaporative cooling system powered by solar energy with photovoltaic panels in Algerian. The monitor data indicated that the largest temperature drop of supply air could reach as low as 18.86℃ and almost two third of the country was installed with direct evaporative cooler due to the hot and arid climate, proving the direct evaporative cooler environmentally friendly and realistically feasible. **[8]** Presented an innovative model which utilizing solar assisted desiccant and direct evaporative cooling system to decrease the energy consumption of a building air conditioning system. The experimental results implied the capacity of this novel system for cooling supply air down to 21-22℃, which successfully eliminate the installation of cooling coils. Hence, the electrical energy associated with this auxiliary cooling device could be saved, resulting in increased electrical coefficient of performance (COP).

However, owing to the distinguished disadvantage of adding moisture to the supply air, the development of direct evaporative cooling is limited to some special conditions in [2]which the water vapor content in primary air does not strictly required and ambient air is hot and dry. On the other hand, the problem of bacterial proliferation and spread associated with high water vapor also hinders the massive extension of direct evaporative cooler. For example, **[9]** emphasized that the use of direct evaporative cooling system in humid places such as Maracaibo is not effective. In this way, indirect evaporative cooling system came to birth, gained its popularity and developed for more than a century.

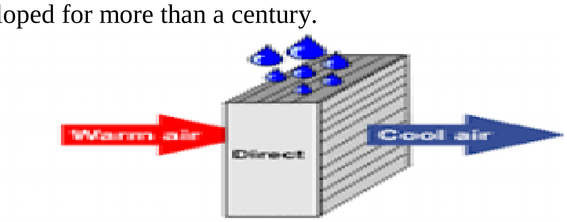

Figure 1.2a Typical direct- type evaporative air cooler **[1]**.

B. Indirect evaporative cooling system (IECS)

An indirect evaporative cooling system installed in Jordan which perfectly represents the climate of Mediterranean was analyzed by **[10]**. Figure 1.2b describes a typical indirect-type evaporative air cooler. With the operation of this system, the energy consumption and emission of carbon based gases were greatly reduced without influencing the comfort conditions. According to the data, if 500,000 Mediterranean buildings use indirect evaporative cooling system instead of conventional air conditioning, every year about 1084GWh/annum energy can be saved and 637,873 ton emission of CO_2 would be reduced. Still it took less than two years to get the payback. **[11]** Monitored an indirect evaporative cooling system in terms of cooling thermal heat of a building for a long time. It turns out that indirect evaporative cooling system adequately met the need of indoor temperature and could lower the temperature closer to wet bulb temperature. An indirect evaporative cooling system was installed in a dwelling by **[12]** to test its ability to eliminate the variable cold load of Iraqi. As a result, indirect evaporative cooling system provided residences with comfortable conditions for most of operation period with rather high efficiency owing to only fan and pump consuming power. Besides, indirect evaporative cooling system could act as an auxiliary part of the traditional air-conditioning system. For example, **[13]** utilized indirect evaporative cooler to pre-cool the supply air before it entered the mechanical cooling system. As it is reported, the indirect evaporative cooler served to cool nearly 75% load helped to save 55% consumption of electricity.

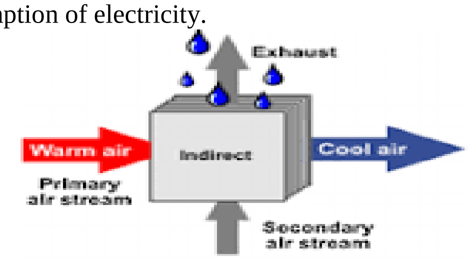

Figure 1.2b Typical indirect- type evaporative air cooler **[1]**.

This work falls under the category of direct type evaporative cooling system. Locally available material such as galvanize iron, thin wooden strips, etc were used for the construction, cover joint type was employed as welding may be expensive and hard to handle, the cost of pulleys and belt used in previous design for transmission were also eliminated making the system economical and ease of construction by local fabricators/artisans. The size of the water reservoir was also considered in this design.

III. MATERIALS AND METHODS

A. Materials

In the selection of the materials used for this construction, the following were taken into considerations; local availability of materials, low cost, easy handling during fabrication, lightness of materials, environmental effects such as non-toxicity, resistance to corrosion, low energy consumption, etc.

Thus, the materials used for this work include; 0.8mm galvanize iron (GI) sheet, glue, wire mesh, aluminum angle, thin wooden strips, bolts and nuts, 3.69W D.C fan/blower, 5W D.C water recirculation pump (submersible type), 6mm and 18mm rubber pipes, light indicators and power buttons, solar panel, charge controller and storage/backup battery. Table II discuss these materials in details.

B. Methods

From the study of existing ideas, new ideas were conceived keeping in mind their commercial success and given shapes and forms in the form of drawings as detailed in Figure 2.2a. Figure 2.2b described how solar energy is generated and supplied to the system while, Figure 2.2c shows how the system is assembled after the design and components selection based on design specifications and Figure 2.2d shows the principles of evaporative cooling. Figure 2.3a and 2.3b shows the dimensional drawings of the cooler and that of water grills respectively ready for implementation (construction) after the design and part selections.

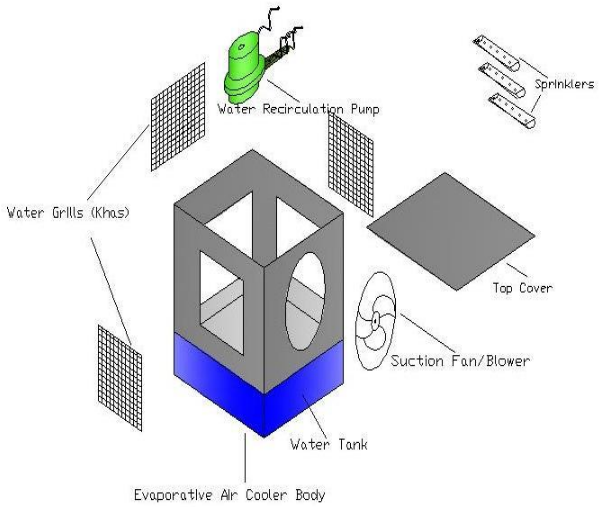

Figure 2.2a: Parts drawing of the solar powered evaporative air cooler

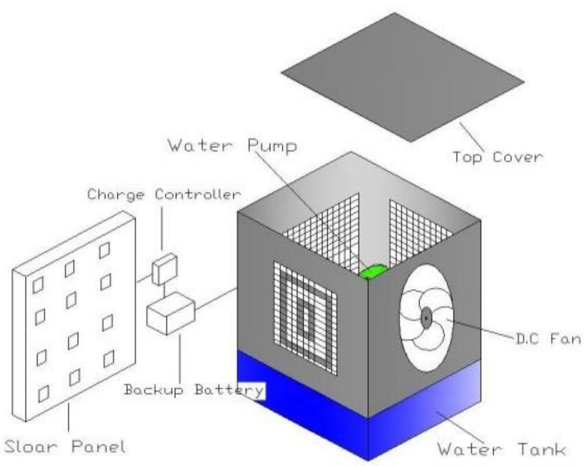

Figure 2.2b: Energy supply process of the solar powered evaporative air cooler

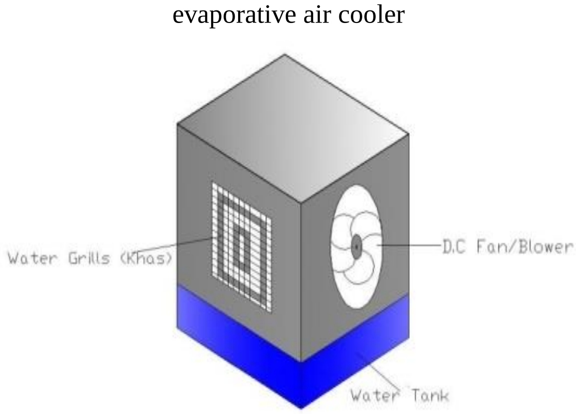

Figure 2.2c: Assembling drawing of the solar powered evaporative air cooler

This system is an enclosed system and air is allowed to pass only through the pads (water grills) and a suction fan is centrally located which draws in hot dry air through the grills as shown in figure 2.2c. Water drips into each of the pads through sprinklers at a constant rate of 22.22 x $10^{-6}m^3/s$ while the suction fan draws warm air through the wetted pads, lower the temperature of the air and then blown into the room space. This processes involved the conversion of sensible heat to latent heat causing a decrease in ambient temperature as water evaporation provides useful cooling.

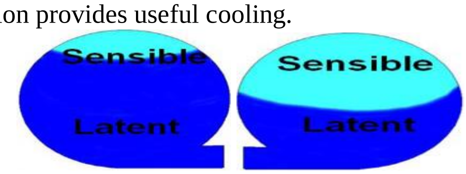

Figure 2.2d: Pictorial view representing principles of evaporative cooling

Design/Sizing of the evaporative air cooler

A rectangular type evaporative air cooler shown in figure 2.1a was designed and constructed in accordance with **[13]** to cool a room space of 4.75m x 3.16m floor area and a height of 2.90m that is approximately a volume of $43.5m^3$. The dimension of this cooler is 0.40m x 0.40m x 0.70m (l x b x h) with a diameter of 0.30mcentrally located in the front side for suction fan installation and three equal rectangular openings of 0.40m height x 0.30m width in the other three (3) sides for water grills (khas) installations as shown in figure 2.1a above. Here, only cover joint type was employed (no welding) in order to reduce cost. The size of this cooler is as designed below.

Air delivery or air displacement (V_1)

Under this heading, the calculations were done in BTU/hr and subsequently converted to standard unit which is in Watt (W).

$V_1 = \frac{\text{areaofroominsquare feet xheightofroom in feet}}{2}$ ---- (2.2a)

But 1 CMF=0.028 m^3/min------------------------ (2.2b)

The factor 2 in the denominator denotes that the air in the room is changed once in every two (2) minutes.

Heat load calculations: the following were taken into account while calculating the heat load and it was done in accordance with **[13].**

Let L be length of the room and B be width of the room in feet thus,

Heat of the room in Watt = L x B x 31.25 x 0.293W ---- (2.2c)

(Where 1 BTU/hr =0.293J/s=0.293W and 31.25 is a conversion factor for the room size)

For a room with North window without shading (BTU)- assuming a 0.61mx0.61mwindow= L_w x W_w x 1.4 x 0.293W -- (2.2d)

(Where 1.4 is a conversion factor for the window size)

Also, for a room with South window without shading (BTU) = L_w x W_w x 1.4 x 0.293W --------------------------------- (2.2e)

Occupant (BTU) = No. of people x 600 x 0.293W (assuming 3 people and 600 BTU per person) - (2.2f)

Heat gain through equipment: -

Equipment a: Color TV = $\frac{\text{Power rating (W)}}{\text{Hours of operation (hr)}}$

Equipment b: Computer = 6.25W/hr

Total heat gain through equipment (BTU) = Total equipment (W/hr) x 3.4x 0.293W (Where 3.4 is a conversion factor for heat gain through equipment) ------------------------------ (2.2g)
Assuming 2 light of 22W each in the room, lighting Equipment = (2 x power rating of each + 40)
Heat gain through lighting (BTU) = Total Lighting equipment x 4.25 x 0.293W; (Where 4.25 is a conversion factor for heat gain through lighting) -------------------------------------- (2.2h)
Total heat load (W) =equation (2.2c + 2.2d +2.2e + 2.2f + 2.2g + 2.2h) -- (2.2i)
Now, air delivery through air cooler = V_1 x 163.17 x 0.293W **[13].**
Air delivery through air cooler > Total heat load
Therefore, since the air delivery through air cooler is greater than the total heat load, the design is okay.

Water tank volume determination

A water tank volume is designed to accommodate high volume of water as well as water returning from the pad when the system is turned on. Since an optimal water tank size is considered in this research for longer time water supply without system breakdown, a tank size of 15cm height x 40cm width x 40cm length was designed and constructed with a total volume of 24000cm^3 (24Litres) for system effectiveness.

Design for cover joint

The type of joint employed in the construction of this air cooler was cover joint type, for easy fabrication as welding may be expensive and difficult to handle by mere artisans/fabricators.
The thickness of the cover straps was designed using equation 2.2r **[14], [20]**:
$t_1 = 3t$ -- (2.2r)
Where: t = 0.8mm-thickness of the galvanize iron and t_1= thickness of the cover joint.

Design for fasteners (bolts and nuts)

The determination of the diameter of bolts and nuts for fastening of components was adopted from **[14]** as given in equation 2.2s:
$W_t = \frac{\pi}{4}(d_c)^2\delta_t$ ------------------------------- (2.2s)
Where: W_t= total tensile load, d_c= diameter of the bolt and nut and δ_t= tensile stress.
Table 2 describes the types of bolts and nuts selected for each of the components.

Components Selections

Various components such as suction fan, water recirculation pump and cooling pad were selected based on the air delivery requirement through air cooler in order to overcome the total heat load. The criteria used in the selection of each of the components are as detailed below.

Selection of suction fan

The determination of fan capacity and selection was done in accordance with **[13], [19]** as shown in sub-headings below:

Room volume

First the volume of a room (V_R) to be cooled using evaporative air cooler was calculated by multiplying the length x width x height of growing area of a room and that gives a volume of 43.5m^3.

Air volume per minute required

The extraction fan should be able to adequately exchange the air in an indoor garden once every three minutes and the required air volume per minute was calculated using the formula below **[13]**:
Air volume per minute required =$\frac{room\ volume}{3\ minutes}$-- (2.2j)
This will be the absolute minimum air volume required to exchange the air in the room of 43.5m^{3}volume.
Thus, since a large volume of air is required, a 0.3m blade diameter car radiator fan with speed 62.84m/s (4000rpm), 0.33A and 3.69W (power rating) was selected for this design.

Selection of water recirculation pump

In order to determine the right size of the pump for an evaporative air cooler for a room cooling, there is need to find the total air delivery or displacement (i.e equation 2.2a) and divide by two **[21]**.
i.e,$\frac{V_1}{2}$thus, the maximum volume the size of the pump can handle based on this design is 10.75m^3 and at least water must be delivered to the top of a thick pad at the rate of 21.55 x 10^{-6}m^3/s per linear 0.025m of pad.
Therefore, a 66.67 x 10^{-6} m^3/s flow rate, 12V, 0.41A, 5W (power rating) and maximum head of 9m, D.C submersible pump was selected for this design.

Selection of pipes (water channels)

For a flow rate of 66.67 x 10^{-6} m^3/s, a distribution pipe with considerable diameter is required to deliver one-third of the total flow rate i.e 22.23x 10^{-6} m^3/s to a grill. Also, a distributor pipe required should also be at least 3 times the diameter of the distribution pipes. Therefore, 6mm diameter 'distribution' pipes and 18mm diameter 'distributor' pipe were selected for this design.

Selection of cooling pad

Plate 2.2e shows the photograph of the cooling pad used in this construction. As part of the general requirements, the efficiency of an active evaporative cooler depends on the rate and amount of evaporation of water from the cooling pad. This is dependent upon the air velocity through the fan, pad thickness and the degree of saturation of the pad, which is a function of the water flow rate wetting the cooling pad **[15].**
In this work, wooden strips type of cooling pad of 0.024m thickness was selected for an efficient performance of the evaporative cooling system as it has good water holding capacity, high moisture content, percentage dry basis, high bulk density, cheaper and locally available **[16].**

Plate 2.2e: A photograph of thin wooden strips for an evaporative air cooler (**Source:** Kogi State-Nigeria)

Selection of solar power supply system

Solar energy conversion was done by using solar panel, battery, and charge controller such that as sunlight falls on solar panel, it converts solar radiation into electrical energy by photoelectric effect. This electrical energy was stored in battery in the form of chemical energy. Charge controller was employed in between solar panel and battery which prevents overcharging and also protect against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk. The stored energy directly was used to power the system.
The selection of this solar power supply system was done in accordance with [17]. The selection depends greatly on the energy requirement of the system and hours of operation requirement by the user as shown below:
From the pump and fan selected above as the two (2) major components of this system, the Table 1 shows the detailed load analysis for the selection of solar power supply system for this air cooler.

TABLE I
LOAD ANALYSIS OF EVAPORATIVE AIR COOLER COMPONENTS

S/N	Items	No. of Unit	Power Rating (W)	Hours of Operation (h)	P (W)	E (Wh)
1.	Submersible Pump	1.00	5.00	12.00	5.00	60.00
2.	Suction Fan	1.00	3.69	12.00	3.69	44.28
Total					**8.69**	**104.28**

Determination of energy requirement

Energy requirement, E by the system can be calculated as follows:

$\mathbf{Energyrequirement, E\ (Whr)} =$
Load Power x hours of operation $+$
provision for Losses(Making provision of 25 % loss in the system)
System voltage, V = 12V,
The ampere hour requirement,

$$Ah = \frac{\text{Energy requirement,E}}{\text{System Voltage,V}} \text{------------------- (2.2k)}$$

Peak sunshine period of Sokoto-Nigeria is 6 hours per day thus, the charging current,

$$I_C = \frac{\text{Ampere}-\text{hour, Ah}}{\text{Peak sunshine hours, } S_p} \text{-------------------- (2.2l)}$$

Module sizing
No. of modules in parallel,

$$M_p = \frac{\text{Charging current,} I_c}{\text{Module current at max.power point, } I_{mp}} \text{------- (2.2m)}$$

No. of modules in series,

$$M_s = \frac{\text{1.25 X system voltage,V}}{\text{Module voltage at max.power point,} V_{mp}} \text{-------- (2.2n)}$$

Total No. of module, $M_T = M_p \text{ x } M_s = 1 \text{ x } 1 = 1$ No.
Therefore, 1 No., 12V, 80W module is recommended for the system.

Charge controller sizing

$I_{cc} = M_p \text{ x } I_{sc} +$ provision for safety $= 1 \text{ x } 11.20 \text{ x } 1.25 = 14A$,

Where shunt circuit current I_{sc} = 11.20A for the selected solar module. (The factor 1.25 is to make provision of 25% safety)
Therefore, 1 No., 12V, 20A charge controller is recommended for the system.

Determination of battery capacity
Assuming No. of storage days = 1day and DOD = 0.8 or 80%
Battery storage capacity,

$$B_{sc} = \frac{\text{Ampere hour x No.of storage days}}{\text{Depth of discharge (DOD) of the battery}} \text{------(2.2o)}$$

No. of battery in parallel,

$$B_p = \frac{\text{Battery storage capacity,} B_{sc}}{\text{Rated capacity per battery,} B_c} \text{--------------- (2.2p)}$$

No. of battery in series,

$$B_s = \frac{\text{System voltage,V}}{\text{Battery voltage,} V_B} \text{----------------------- (2.2q)}$$

Total No. of Battery, $B_T = B_p \text{ x } B_s = 1 \text{ x } 1 = 1$No.
Therefore, 1 No., 12V, 100Ah battery is recommended for the system.

System Construction Procedures and Testing

In the construction and testing of this solar powered evaporative air cooler, five (5) basic procedures were followed and these steps are as detailed below:

Construction of air cooler
A sheet (2.8m x 1.4m) of 0.8mm thickness of galvanized iron was bought and a dimension of 0.7m x 0.4m x 0.7m was cut from the sheet and folded into a rectangular 'U' shape which gives, front, bottom and back wall respectively. Two other side walls and top cover of the same dimension 0.7m x 0.40m x 0.7m were cut to fit in, in order to complete the rectangular box shape of the air cooler body as shown in the figure 2.3a. Then, a diameter of 0.3m was made at the centre of the front side for the installation of the fan. Also, a rectangular opening of 0.40m height x 0.30m width each were cut at a point on the other three sides of the cooler for the installation of water grills leaving a rectangular water tank with dimension 0.15m depth x 0.40m width x 0.40 length below the grills.
Here, only cover joint type was adopted instead of welding for easy fabrication. Car body filler was then used to prevent linkage(s).Now the body of evaporative air cooler is ready for other installations.

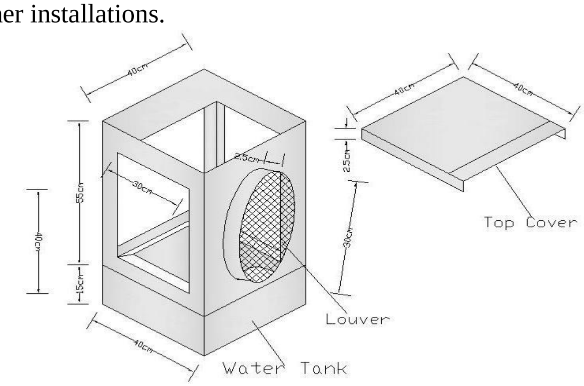

Figure 2.3a: Evaporative air cooler body with various dimensions

Construction of water grills (khas)

A 2.4cm x 2.4cm aluminum angle of 3.30m length, 1.3cm wire mesh of 0.61m x 1.83m, and a bag of wooden strips were used in the construction of water grills (khas).

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This length of aluminum angle was divided into three equal lengths of 1.1m and each length was folded to form a rectangular 'U' shape of 0.4m x 0.3m x 0.4m. A galvanize iron was then cut into three of 0.30m length x 0.05m each and also folded in to normal 'U' shape with 10 holes under each to form sprinklers. Each of these sprinklers was then used to complete the rectangular shape of the aluminum angle at the top through which water drops on the cooling pad. The two sides of these rectangular shapes were then covered with 1.3cmwire mesh and with wooden strips inside them to form grills (khas) as shown in Figure 2.3b.

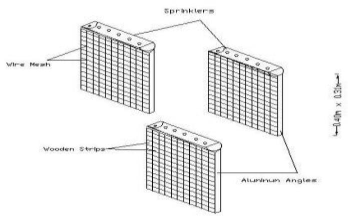

Figure 2.3b: Rectangular water grills (khas)

Installation of water pump and fan

A 2.40m x 6mm internal diameter of flexible plastic pipe was cut into three equal lengths of 0.8m to form water distribution channels. These water channels were then attached to water pump through a 0.05m length of 18mm pipe to form a pump unit as shown in Plate 2.3c.

The 12V D.C submersible pump unit and suction fan were finally installed to the air cooler using clips, bolts and nuts respectively as shown in the Plate 2.3d.

Plate 2.3c: Water distribution channel and a submersible pump (pump unit)

Plate 2.3d: Installation of suction fan, water grills, pump unit and humidity sensor

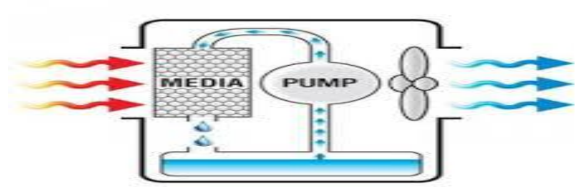

Figure 2.3e: Operation process of the installed fan and pump

Installation of indicator lights and power buttons

One yellow, one green and one red light indicators of 10 milliamps attached to a 1kilo-ohmseach were installed on the cooler to indicate ON/OFF of fan, pump and power supply respectively. Also, two power buttons of different color (one red and one black) were also installed for switching ON/OFF the system.

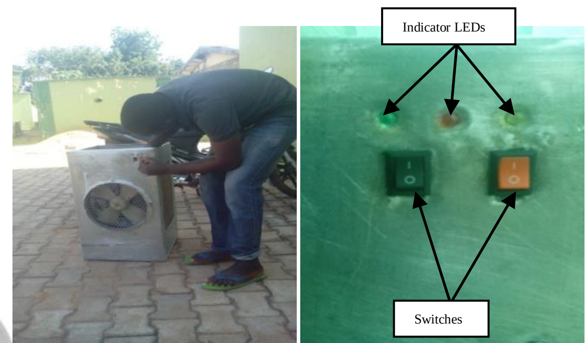

Plate 2.3f: Installation of indicator lights and power buttons

Wiring

All the designed components were properly connected for effective running using appropriate wires as shown in Figure 2.3g. Here, the flexible DTH11 humidity and temperature sensor/controller was installed as shown in Figure 2.3g to control the pump in such a way that, when the humidity level rises above the comfort zone the sensor/controller will put off the pump and vice-versa. Thus, the evaporative air cooler was tested okay and now ready for use/performance evaluation.

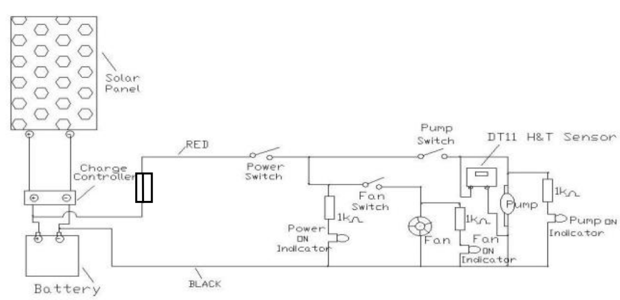

Figure 2.3g: Electrical wiring/circuit diagram of the constructed system

System Cost of Constructions Analysis

In the construction of this system, a total sum of **N49, 820.00** was spent in producing one unit of the air cooler. However, Table 2 discusses this cost of construction in details.

TABLE II
SYSTEM COST OF CONSTRUCTIONS ANALYSIS

S/N	Items	No. of Unit	Cost (N)
1.	12V car radiator fan	1	4,000
2.	12V submersible pump	1	7,950
3.	0.8mm sheet of G.I	1	8,000
4.	Bag of wooden strips	1	2,000
5.	80cm of 6mm rubber pipe	3	600
6.	10cm of 18mm rubber pipe	1	100
7.	M6 x 50 JF screw for fan	4	80
8.	M6 x 12 JF screw for rollers	16	160
9.	M5 x 15 JP screw for grills	12	120
10.	Length of aluminum angle	1	2,400
11.	1.3cm/hole mesh wire for grills	2	1,400
12.	1.9cm/hole mesh wire for louver	1	700
13.	Set of roller	1	700
14.	Painting	-	5,000
15.	Labour	-	3,500
16.	Body filler	-	1,000
17.	Wire and wiring	-	2,000
18.	H&T sensor	1	10,000
19.	Indicator lights	3	30
20.	Power buttons	2	20
21.	1kΩ Resistor	3	60
Total			**49,820.00**

IV. RESULTS AND CONCLUSION

A. Results

After a successful construction of the solar powered evaporative air cooler, an experimental performance test was conducted at Sokoto Energy Research Centre (SERC) in Usmanu Danfodiyo University, Sokoto (UDUS), Sokoto State-Nigeria in an office of 4.75m (length) x 3.16m (width) x 2.90m (height), so as to obtain the test results and analyze. Thermal comfort condition was achieved while the temperature was reduced significantly from 48℃ to 26.8℃ and relative humidity was increased from 10.2% to 36.1% on average which is still within the comfort zone [22].

B. Conclusion

So as to compare the cost of this product with the existing products in the market, solar products appeals better and affordable by common people. This solar product perfectly suits for villages, schools and offices and thus prevention from the power outage problems because of its low energy consumption (9W). It comprises of many attractive features such as 24,000 cm3 of water tank capacity which can serve water for almost 24 hours before refilling, high capacity of suction fan, water recirculation pump and usage of solar energy at lower cost. The system is eco-friendly and natural, electricity savers. Durability of this product is more thus minimizing the cost. No fossil fuels used in the electricity generation so, this product saves environment from getting polluted. The cost of power consumption within 6 hours of operation based on per unit charge of electricity in Nigeria for the solar air cooler calculated ₦1.50 while the projected annual cost of power consumption for the system will be ₦540.00 making this air cooler more economical to use than the conventional AC in terms of energy and cost saving. The flexible DTH11 humidity and temperature sensor/controller installed as shown in Figure 2.3g was able to perfectly control the water supply by the pump in such a way that, when the humidity level rises above the comfort zone the sensor/controller will put off the pump and vice-versa.

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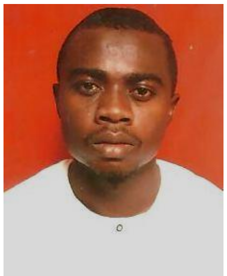

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