Review on the Uses of Appropriate Techniques for Arid Environment

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Abstract

In this paper, a review of the possible sources of water is presented. Paper concentrates on the drinking water needs, especially with respect to the remote / rural arid places. In the case of remote villages in developing countries, there is a need for systems, which produce clean potable water and development of effective methods to use water.

In the first part of the review, most common processes that can be used to produce water are discussed. Humidification and De-Humidification (H & DH) appears to be very popular to produce water in small quantities. The literature reviews cover different H & DH techniques in which air is used as a medium to carry water in the form of vapor. In this paper, appropriate techniques reviewed include the usage of passive and active systems, which are operated with or without the support of solar energy. Use of fog harvesting, and thermo-electric module are also discussed in brief. A concept of producing water from a SWRO plant with wind power is also discussed.

In the second part, techniques for conservation of natural resources and the effective methods to use water and energy are discussed. To conserve water, rainwater accumulation, pot in a pot system to store vegetables, solar powered absorption refrigeration units, drip irrigation and use of desert coolers are advocated. In order to save energy, ideas of using small wind powered ventilation systems, energy conserving designs of modern air-conditioned buildings conserve energy and provide good ventilation are proposed. Use of bags made of bio-degradable materials like paper or cloth is encouraged rather than the not bio-degradable plastics.

Introduction

Three essentials commodities for human beings to live are shelter, clothing and food. Of the three commodities, the third is consumed by people orally. So, prime importance is given to its clean and non-infecting nature. Water is one of the very important items, in every day's life, which is not only used to cook food but also to drink and clean. Claire [1] indicates, in accordance to one of the surveys of World Health Organization (WHO), that 97.5 percent of water on the earth is salty and the remaining 2.5 percent is fresh water. He also indicated that 70 percent of the fresh water is frozen in the polar icecaps and the other 30 percent is either as soil moisture or in underground aquifers. This leads to an estimate of less than 1 percent of the world's fresh water (or about 0.007 percent of all water on earth) is readily accessible for direct human use. Naturally, water scarcity is not a new problem.

Contaminated drinking water is dangerous to health. A recent study by Lorna of WHO [2] indicates that every eight second a child dies from a water related disease and that each year more than 5 million people die from illnesses linked to unsafe drinking water or inadequate sanitation. Household water filters cannot remove all the parasites, viruses, bacteria and heavy metals. These factors indicate the need of developing or identifying appropriate techniques suitable for an arid place especially situated at remote villages in developing countries in order to (1) produce good clean potable drinking water, and (2) to conserve water and energy.

Literature reviews and identifies all the different types of experimental H & DH procedures and test rigs that were used to produce water. Numerous technical papers can be sited in the literature in the fields of small and large scale desalination of water. So, only a few papers, specifically to identify the techniques are presented here.

1. Water Production

1.1 Solar Stills and Humidification & De-Humidification

Widely found small scale desalination units are solar stills with single or multiple effects arrangement. Arshad [3] reviewed the status of the solar distillers in brief. Solar stills operate with the principles of green house effect. Water is allowed to evaporate first and then the vapor is cooled to condense over an inclined surface. Water thus condensed would be collected in a trough as the product water. In most of the reports, it is found that the water production was in the order of 5 and 16 lit/m^2/d. The major limitations of solar stills are their small capacities, presence of non-condensing gases, entrapped volatile gases, limited evaporation / condensing areas and use of glass. Schematic diagram is provided in the fig.1.

To overcome the above mentioned limitations of solar stills, rugged pilot plants operating with the principles of H & DH of air, with / without the support of solar heaters, were designed and tested. Few reports are identified here and they are due to Dai *et al.*, [4], Said *et al.*, [5], Sousa *et al.*, [6] and Naser *et al.*, [7]. The maximum water production capacity was in the order of 1300 l/d.

1.2. H & DH Units with Special Designs

Böhner, [8] tested a set of solar powered desalination units. Area of the collector surface was 800 m^2. The two special flow arrangements used were open water cycle with closed air cycle and open & air cycle. Closed loop with a seawater spray was used for humidification. Water producing capacity of the plant was in the range of 2 to 20m^3/day. Figure 2 shows a schematic diagram of this arrangement.

Madani and Zaki [9] used a pair of heat pipes to produce water in the dehumidification column to produce water. The water production was in the range of 630 ml/h to 1250 ml/h. They performed tests on solar distillation also.

Abualhamayel and Gandhidasan [10] constructed a solar distiller, which makes use of a liquid desiccant to extract fresh water from the humid atmosphere. The experiments with solar stills gave raise to a yield of about 1.92 kg/m^2. They also explain a system suitable for any arid places, called 'Earth-Water Collector'. It was constructed on the ground and moist sand little below the surface was used to humidify air inside the distiller. Moisture in the humid air was then made to condense at the bottom of the glazed roof. It was reported that the yield in the arid areas was about 1.0 l/m^3. Figure 3 is a schematic diagram explaining the principle of earth-water collector arrangement.

Mattheus *et al*., [11] used a green house with an area of 10,000m^2 and seawater spray of 0.1m^3/s for humidification. With seawater as the cooling fluid in a condenser (de-humidifier), product water obtained per day was in the range of 57.8 to 125.5 m^3. Figure 4 shows a schematic diagram of this arrangement.

1.3. New Concepts of Water Production

In certain places of the Kingdom of Saudi Arabia, during the months of June to August, the environmental air is found to be very humid and foggy while other places it is dry and cold. Based on the environmental data from the year 1971 to 1980, [12], the range of atmospheric temperature and relative humidity, have been published by the Ministry of Agriculture and Water. Data published covered different seasons, especially during the summer (June, July & August) and winter (December, January and February) months. Three different regions in the survey are the Arabian Gulf, inland stations and Red sea region. Maximum and minimum values of the reported humidity and temperature are in the ranges of 13 to 78 percent RH and 4.5 to 36.8^{o}C. The mean air velocity in the mountainous area is reported to be 12 to 15 km/hrs and in the escarpment mountainous area it is in the range of 7 to 13 km/hrs. Based on the above mentioned facts on fog and wind speed, following concepts of obtaining water are presented.

a) Fog Harvesting

At Chile, Philip [13] used an ingenious water-supply 'fog harvesting' system. Fifty 'fog catchers' were installed. At the top of a hill, huge nets were installed with the support of 12 eucalyptus pillars. Water containers were placed at the bottom. Water collected was in the order of about 1,900 gallons every day. It was reported that the water from the small-scale system to be clean, cheap and it was also said that the supply was steady.

In the 'Source Book on Alternate Techniques (OUS)' [14] a report has been identified that water droplets in fog are collected in the net and run off into a conveyance system that carries the water to storage area. Technique is said to be the most effective of all water augmentation technologies for arid and mountainous areas. It was said that 30 percent of the mist contained in fog could be harvested. System is under developmental stage. The cost of water produced by this method is estimated to be $ 3 / 1000 lit.

b)Thermoelectric Refrigeration

A thermoelectric module [15] is a solid-state device used to transfer heat primarily through the use of dissimilar semiconductor materials. Thermoelectric cooler is a heat pump. The cold junction becomes cold through absorption of energy by the electrons as they pass from one semiconductor to another. A heat sink discharges the accumulated heat energy from the system. A DC power source pumps the electrons from one semiconductor to another. T.E. module and its heat sink can be used to dehumidify the humid air. The concept of using thermoelectric module as a producer of water cum heater / cooler, in a remote place, is depicted in the fig.5.

c) Another concept, ideal for the arid environment, is to make use of the wind power. A standalone wind mill can supply electrical energy sufficient enough to operate a standalone SWRO plant. Concept of standalone wind mill and SWRO is depicted in fig.6.

d) Milk and juice manufacturing industry make use of heat to obtain the concentrates of the raw materials. The raw materials are milk or juice and certain preservatives; which vary depending on the manufacturing process. There are many byproducts like skimmed milk, butter, ghee, curd, butter milk, cheese, milk powder, pulp, essence etc. In the process large quantities of water, nearly 30 to 60 percent of the raw material by weight would be evaporated and driven away into the environment. By having a heat exchanger in the exhaust, water can be recovered. A conceptual diagram is provided in the fig.7.

2. Conservation of Water

2.1. Domestic Water Conservation

It is well known that 'Water saved is water produced'. Trees and rain fall are somehow connected by nature. In order to improve the number of trees and plantations, another slogan which gains popularity in India, is 'One Family - One Tree'. Drinking water conservation by rainwater accumulation is becoming popular at various parts of India. Collected rain water can be used for irrigation thereby the requirement on good water is reduced. Drip irrigation is suggested for the purpose. To store rain water, tanks are suggested. A schematic arrangement to accumulate is shown in the fig.8. To improve the ground water level, soak pit type of arrangements are suggested in order to allow water to percolate in to the ground. Plastic bags thrown in open, over a long period of few decades, would form an impermeable layer in sand or soil. Damages caused by the layer would be totally non-recoverable. As plastics are not bio-degradable, use of bags made of bio-degradable materials like paper or cloth is encouraged.

One of the main rural needs is preservation of vegetables. To preserve vegetables in their good conditions many methods of used in the rural places. They are drying (with hot air, fire or solar), pickling (in salt or sugar) and refrigeration [16]. By adopting the first two methods, taste of the commodities would suffer slight loss of aroma and taste. To use refrigeration systems, electricity is essential, which possibly may not be available in abundant at rural sites. Ravindran *et al*., [17] noticed that the vegetables kept in a pot in pot arrangements were maintained in fresh conditions for 3 weeks, while the vegetables which were kept in open got spoiled with in one week. A schematic diagram of the pot in pot arrangement is shown in the fig.9. Main advantage of the arrangement would be for preservation without Refrigeration and Electricity, which is a typical application for rural area.

2.2. Conservation of Water in Existing Industries

Ismail and Matrawy [18] performed experiments with an air washer to conserve water. Recovery of water was from a dehumidifier placed in a duct. They used heat exchangers of finned type. Yield of the dehumidifier was found to be in the order of 10 kg/ hr.

Aly [19] collected water from humid air from a Li Br – H_2O absorption A/C system. The absorption refrigeration unit was operating with generator temperature of 300^{o}C. Waste heat from a nearby facility was used to run the system. The comfort air condition system produced a supply of fresh water of 29 l/d as a by-product. Vapor absorption units are nowadays available with capacities of 30 tons and the maximum capacity would be in the order of 1000 tons. Solar powered vapor absorption systems are readily available in the market. Schematic arrangement of solar powered unit is shown in the fig.10.

3. Conservation Of Energy

Energy conservation through building construction designs.

1. Energy efficiency of vapor absorption refrigeration or an air-conditioning unit is expected to be very high. It is said that the vapor absorption refrigeration unit consumes only about ten percent energy as that of a vapor compression refrigeration system of the same capacity. If the waste heat of a modern power plant is used in an absorption refrigeration plant, probably the entire air conditioning load of its offices can be taken up.

2. Wind – driven turbine ventilators are readily available [20]. Turbine of the unit spins freely with the slightest breeze. Extra long fins catch the air more efficiently than any other ventilators. They suck air from the buildings, ventilating systems and fumes or gasses from chimney flues by creating partial vacuum. They are designed with self lubricating bearings and require minimum maintenance. The schematic arrangement of the wind-driven ventilators is shown in fig.11.

3. Locus of sun with respect to earth is in the direction from East to West. In the normal planes to this direction, more solar radiation and heat would be experienced. In order to reduce energy requirements for summer air conditioning, it is advisable to orient the largest outer surface of any building in the North – South direction (a conceptual diagram is shown in the fig.12) and projections like sun shades can be provided [21].

4. By arranging the rooms and walls in a building in a specific way, natural draft be initiated in a building. The natural draft would assist in improving the ventilation. A conceptual diagram is shown in the fig.13.

Conclusion

As numerous technical papers can be sited in the literature, only a few literatures, specifically to identify the techniques are presented here.

Surveys of the appropriate techniques are reviewed in two categories, firstly to produce water and secondly the conservation of water. To be more relevant to the topic, only the experimental reports have been reported.

The techniques covered do cover many appropriate technologies developed at different parts of the world. They can be used according to the local conditions of the arid environment and needs.

It is worth mentioning that the technique of humidification and dehumidification will find its applications in the other fields like (i) Development of a small mobile water chiller / heater (ii) Off-road land-transport vehicles (iii) Land survey camps; (iv) Ships (v) Off Shore platforms, (vi) Emergency situations, (vii) Special military operations etc.

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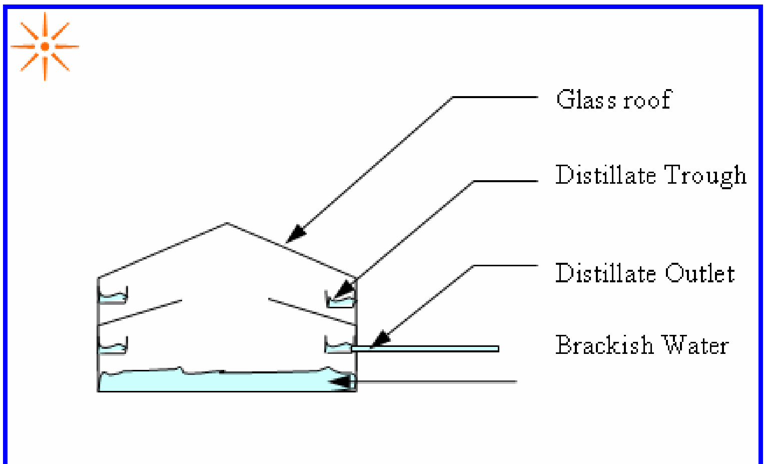

Fig. 1. Passive Solar Still

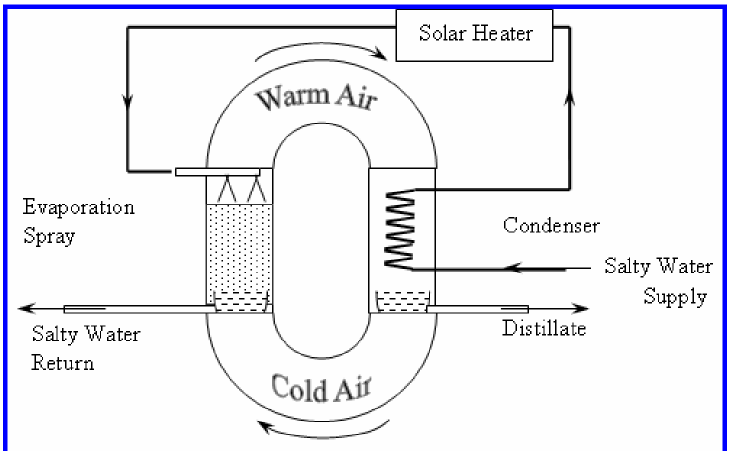

Fig.2. Humidification and De-humidification Unit

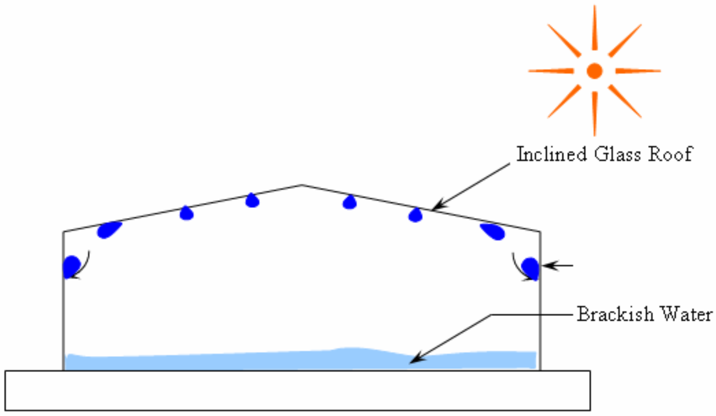

Fig.3. Principle of Earth-Water Collector

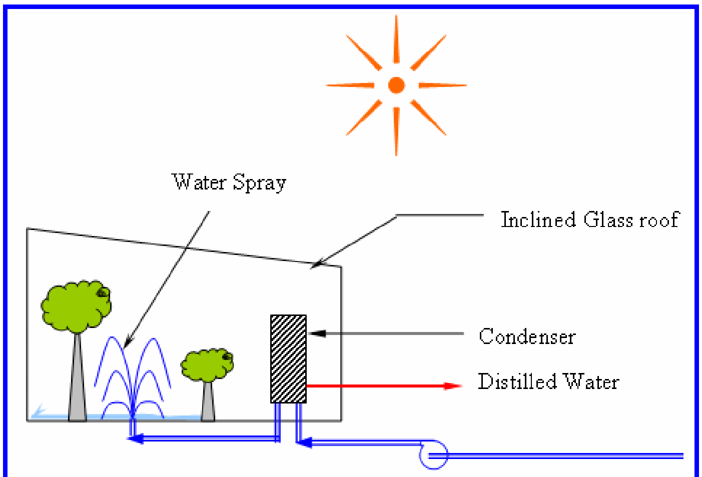

Fig.4. Active arrangements of Green house

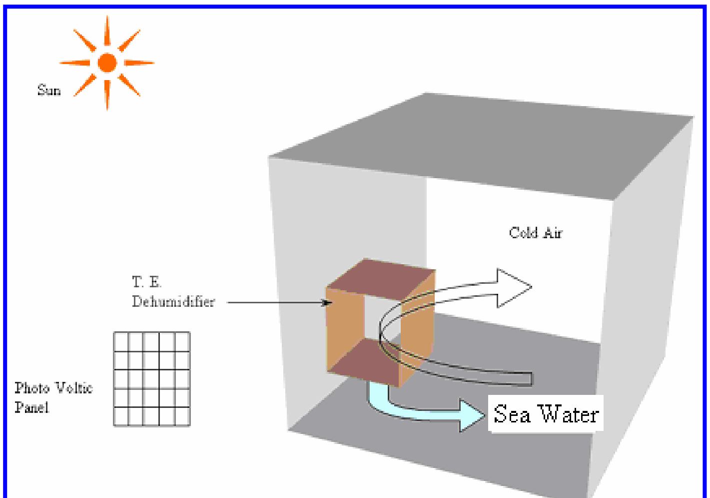

Fig.5. Concept of using TE System at a Remote Site

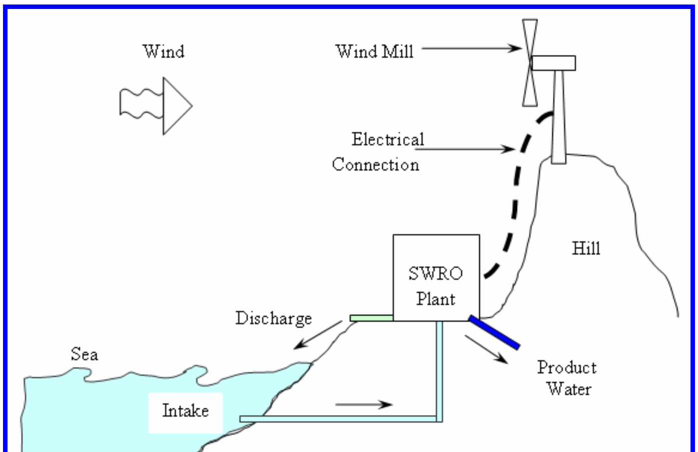

Fig.6. Concept of Standalone Wind Mill and SWRO

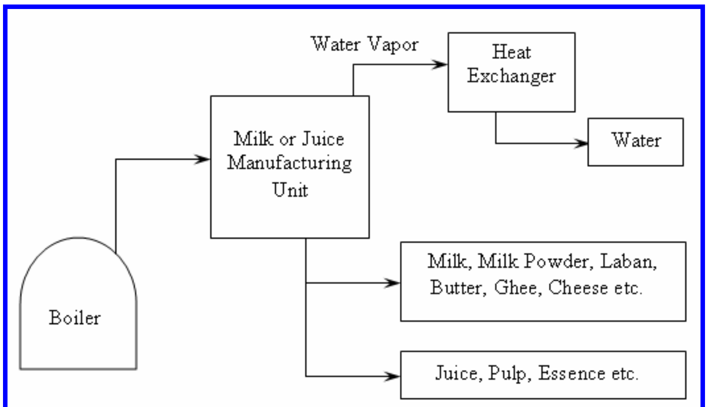

Fig.7. Recovery of Water in a Process Industry

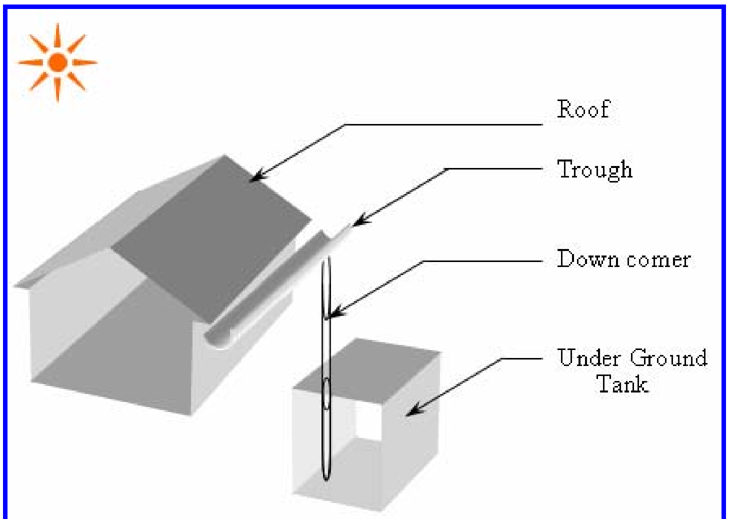

Fig.8. Rainwater Accumulation

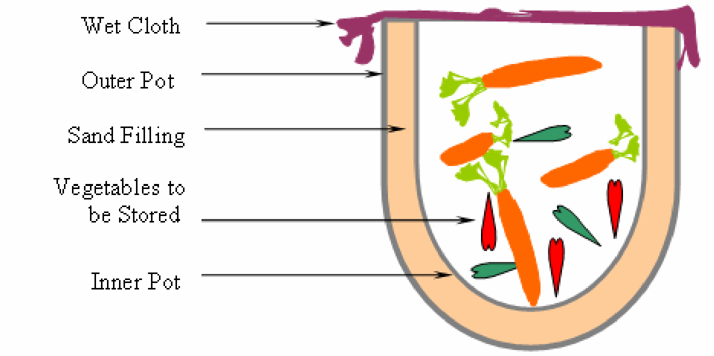

Fig.9. Pot in a pot system to store Vegetables in a desert

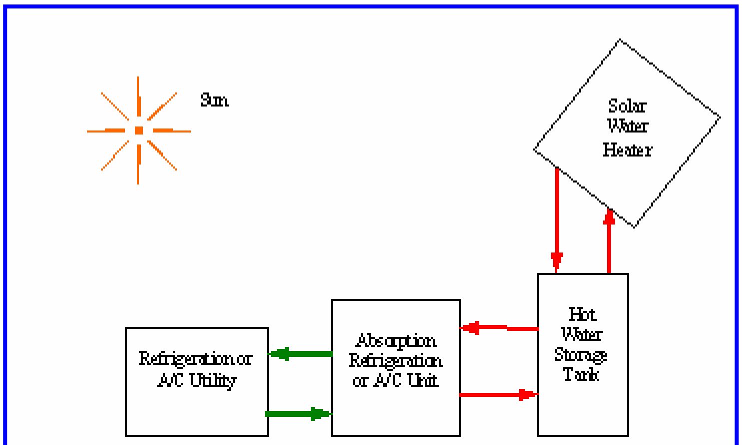

Fig.10. Vapor Absorption A/C or Refrigeration

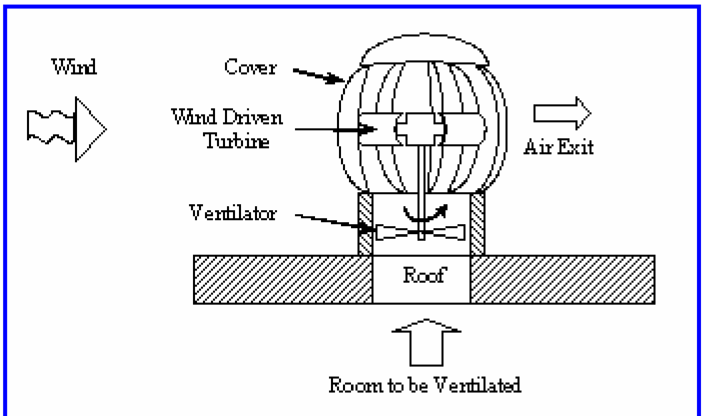

Fig.11. Wind-Driven Ventilators

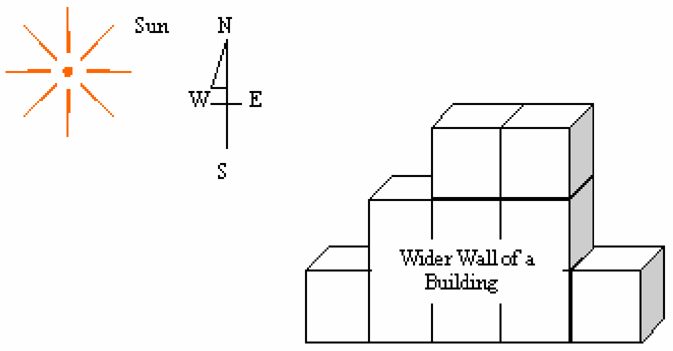

Fig.12. Energy Conserving Design of a Modern Building

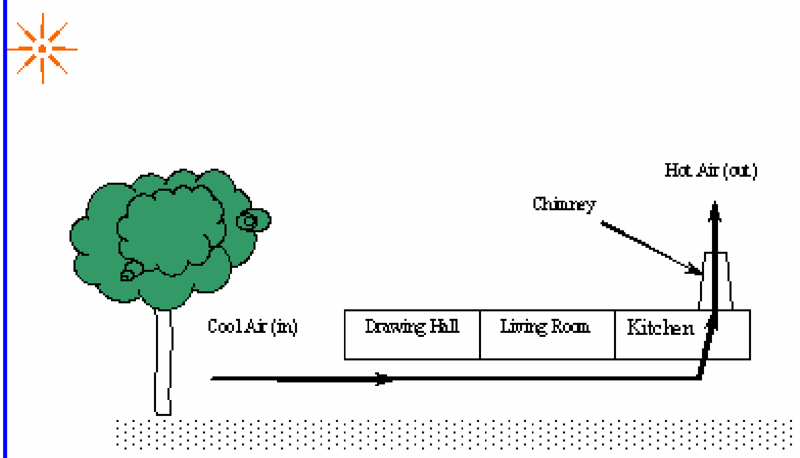

Fig.13. Schematic Diagram of Natural Circulation for Ventilation