Experimental Study on Atmospheric Water Extraction

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Abstract- In present work we proposed an experimental study on atmospheric water extraction with application of solar energy and desiccants. The study also aimed at evaluating the different parameters such as climate, region, humidity, temperature, area etc. Water percentage for drinking purpose on our earth is much lesser as compare to population. For distillation process we have to spend lots of money to get pure water though we unable to get highly pure water. So, to overcome this we proposed an effective and less expensive project to get pure water. Atmosphere is itself a large source of water so to extract it from atmosphere we apply absorption and regeneration process by using desiccants and solar energy. From this we get highly pure water than RO UV water purifiers. In present work we use two varying area basin of $0.3m^2$ and $0.45m^2$ which have a glass surface over its upper face which is tilt by an angle of 30^0 . Which follows a day-night cycle for absorption and regeneration. We found that the water extracted from this two area is 0.5liters in $0.45m^2$ area and 0.32liters in $0.3m^2$ area for finding the water extraction rate theoretically we proposed a simple equation related with density.
Keywords- Acrylic sheet, plywood, silica gel, thermocole, thick black film etc

1. INTRODUCTION

Water is basically necessary for life. The amount of fresh water on the earth is only 2.53 percent (35 million km^3) of the total amount (1.384 billion km^3). A large fraction of fresh water (24 million km^3) is ice and permanent snow in the Antarctic and Arctic regions. The main source of water for human consumption (fresh water lakes and rivers) contains about 0.26 percent of the total global fresh water reserves (90,000 km^3).

Atmospheric air contains about 14,000 km^3 of water in vapor form, and hence it can be used as a new and renewable water resource. Extraction of water form atmospheric air can be accomplished by two different methods. The first method is by cooling moist air to a temperature lower than the air dew point. The second one is by absorbing water vapor from moist air using a solid or liquid desiccant, with subsequent recovery of the extracted water by heating the desiccant and condensing the evaporated water.

Moreover, solar energy can be used as a renewable source of heat in extraction processes of water from atmospheric air. In present work an analytical study is done for calculation of mass of absorbed water from atmospheric air. Calcium chloride and silica gel are used as desiccant for absorbing the moisture and tilted surface wooden box with glass covering is used for evaporating and condensing absorbed water vapors. The study which is carried out theoretically, aims to evaluate the effect of different parameters on the system performance. These parameters include driving parameters which are radiation intensity and ambient temperature and other auxiliary parameters such as climate, region, day, time and surface area.

Naturally, water scarcity is not a new problem. Contaminated drinking water is dangerous to health. A recent study by Lorna of WHO 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 produce good clean potable drinking water, and to conserve water and energy.

2. LITERATURE REVIEW

The first project was proposed by V. V. Tygarinov named as "An Equipment for Collecting Water from Air," in Russia, 1947 [2]. An apparatus consisting of a system of vertical and inclined channels in the earth to collect water from atmospheric air by cooling moist air to a temperature lower than its dew point has been proposed.

A. M. Hamed, "Absorption-Regeneration Cycle for Production of Water from Air-theoretical Approach"[1]. Description and analysis of the theoretical cycle for absorption of water vapour from air with subsequent regeneration, by heating is presented in first model. A theoretical limit for the maximum possible amount of water which can be collected from air using the desiccant through the absorption regeneration cycle at certain operating conditions of ambient parameters, heat to be added to the desiccant during regeneration and maximum available heating temperature could be evaluated through the analysis of this cycle. The absorption regeneration cycle, which can be applied for the production of water from atmospheric air, is shown in Fig1. The theoretical cycle is plotted on the vapour pressure-concentration diagram for the operating absorbent and consists of four thermal processes which are:

- Process 1-2: isothermal absorption of water vapour from air.
- Process 2-3: constant concentration heating of the absorbent.
- Process 3-4: constant pressure regeneration of absorbent.
- Process 4-1: constant concentration cooling of absorbent.

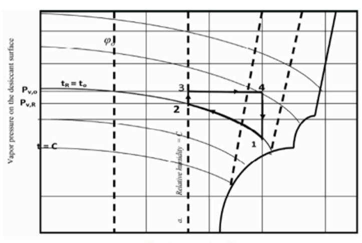

Fig. 1 Absorption regeneration cycle

This cycle can be applied in desiccant systems with different configurations and different heat sources. As the purpose of this cycle is to produce water from air and the input energy to the system is the heat added during the regeneration process, then the efficiency of the cycle can be defined as the ratio of heat added to regenerated vapour to the total heat added. Theoretical analysis showed that, strong and weak solution concentration limits play a decisive role in the value of cycle efficiency. However, a modified cycle is described and analyzed by Sultan. In this modified cycle, the practical considerations were taken into account.

R.C.Hall proposed a system for the production of water from atmospheric air by absorption using ethylene glycol as a liquid desiccant with subsequent recovery in a solar still [3]. The effects of temperature and humidity on the recovered water were studied and the results presented in the form of a composition-psychometric chart, but the paper does not provide any information about the mass of recovered water. Sofrata constructed a non-conventional system to collect water from air based on an adsorption-desorption process using a solid desiccant. The study also discussed the feasibility of the application of air conditioning systems for collecting water from moist air by cooling it to a temperature lower than the dew point. Alayli used a typical S-shaped composite material for absorption of moisture from atmospheric air with subsequent regeneration using solar energy [4].

A. M. Hamed tested two methods to extract water from atmospheric air using solar energy. The first method was based on cooling moist air to a temperature lower than the air dew point using solar absorption cooling system [6]. The second method was based on the absorption of moisture from atmospheric air during the night using calcium chloride solution as a liquid desiccant, with sub-sequent recovery of absorbed water during the day. As a result of this study, the second method was recommended as a most suitable application of solar energy for water recovery from air. I. H. Abualhamayel, and P. Gandhidasan proposed the system shown in Figure 2 for water recovery from air [5]. The system consists of a flat, blackened, tilted surface and is covered by a single glazing with an air gap of about 45 cm. The bottom of the unit is well insulated. At night, the strong absorbent flows down as a thin film over the glass cover in contact with the ambient air. If the vapour pressure of the strong desiccant is less than the vapour pressure of water in the atmospheric air, mass transfer takes place from the atmosphere to the absorbent. Due to absorption of moisture from the ambient air during the night, the absorbent becomes diluted. The water-rich absorbent must be heated during the day to recover the water from the weak absorbent. Therefore, during the day, the weak desiccant flows down as a thin film over the absorber surface. The weak absorbent is heated by solar energy, and the water that evaporates from the solution rises to the glass cover by convection where it is condensed on the underside of the glass cover and the absorbent leaving the unit becomes strong. The performance of the unit at night depends on the potential for mass transfer, which is the difference in water vapour pressure between the ambient air and desiccant.

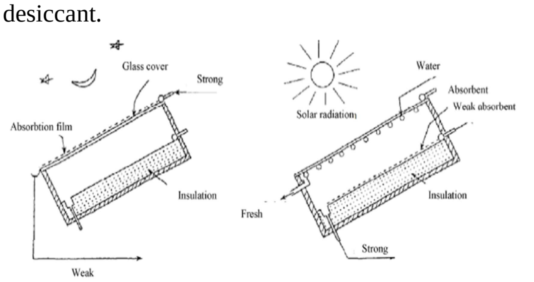

Fig. 2 Working cycle at day and night

3. CLIMATIC CONDITION OF BULDANA FIELD

3.1 Climate and Rainfall

The Climate of the district is characterized by a hot summer and general dryness throughout the year except during the south-west monsoon season, i.e., June to September. The mean minimum temperature is 13°C and means maximum temperature is 42.3°C. The normal annual rainfall over the district ranges from 711 mm to 911 mm. It is the minimum in the northern parts of the district around Malkapur (711 mm) and Jalgaon (Jamod) (719 mm). The average annual rainfall of last ten years (1996-2005) in the district varied from 539 mm (Nandura) to 845 mm (Sindkhed Raja).

3.2 Ground Water Resources

Central Ground Water Board and Ground Water Survey and Development Agency (GSDA) have jointly estimated the ground water resources of Buldhana district based on GEC-97 methodology. Ground Water Resources assessment was done for 7709.11 sq. km. area of which 481.09 sq. km. is under command and 6671.01 sq. km. is non-command. About 557 sq. km. area comes under poor ground water quality. As per the estimation, the total annual ground water recharge is 732.57 MCM with the natural discharge of 36.62 MCM, thus the net annual ground water availability comes to be 695.95 MCM. The gross draft for all uses is estimated at 416.44 MCM with irrigation sector being the major consumer having a draft of 387.58 MCM. The domestic and industrial water requirements for the next 25 years are worked out at 49.69 MCM. The net ground water availability for future irrigation is estimated at 248.54 MCM. The stage of ground water development varies from 38.45% (Mehkar) to 121.65% (Jalgaon-Jamod). The overall stage of ground water development for the district is 59.84%. As per estimation, Jalgaon (Jamod) taluka falls in "Over-Exploited" category, Buldhana in "Semi-Critical" category whereas remaining 11 talukas fall in "Safe" category. Out of the total 57 watersheds, 2 watersheds (PT-10 and PT-11) fall under "Over-Exploited" category; 1 watershed (GP-1) falls under "Critical" category; 11 watersheds (PT-8, PT-12, PT-16, PTB-1, PTV-2, GP-1, GPD-1, GPD-2, PG-1, PG-2, PG-4) fall under "Semi-Critical" category while remaining 43 watersheds fall under "Safe" Category.

3.3 Suitability of Ground Water for Drinking Purpose

The suitability of ground water for drinking purpose is determined keeping in view the effects of various chemical constituents in water on the biological system of human being. Though many ions are very essential for the growth of human, but when present in excess, have an adverse effect on human body. The standards proposed by the Bureau of Indian Standards (BIS) for drinking water (IS-10500-91, Revised 2003) were used to decide the suitability of ground water. The classification of ground water samples was carried out based on the desirable and maximum permissible limits for the parameters viz., TDS, TH, Ca, Mg, Cl, SO_4 and NO_3 prescribed in the standards. The portability of groundwater in 94% of wells monitored has been affected by the high concentration of NO_3 present in ground water. The TH and concentration of Mg in some of the ground water samples have also crossed the maximum permissible limits. Overall, the ground water quality scenario of the wells monitored in the district is not bright.

3.4 Ground Water Related Issues and Problems

The rainfall data analyses for the period 1901-2003 indicates that the northern part of the district comprising of Jalgaon (Jamod) and the southern part of the district comprising of Chikhli, Mehkar Donegaon and Deolgaon Raja where the occurrence of droughts was more than 20% of the years, comes under the category of "Drought Area". Deeper water levels of more than 20 m bgl are observed in restricted northwestern part of the district in parts of Malkapur, Nandura and Jalgaon (Jamod) talukas. Thus future water conservation and artificial recharge structures in the district may be prioritised in these parts of the district. Ground water quality is adversely affected by nitrate contamination in 94% of the samples collected in May 2006. Continues intake of high nitrate concentration water causes infant methaemoglobinamea, popularly known as Blue Babies. Thus all the wells used for water supply should be first analysed for nitrate contents and if the nitrate content is found beyond permissible limit the ground water may be used for other purposes than drinking. Adequate sanitary protection to the wells may be provided to control the nitrate contamination. The special study carried out by CGWB in Purna River Alluvial basin indicates that in small north eastern part of Shegaon taluka brackish to saline ground water has been observed with EC ranging from 2000 to µ mhos/cm at 25°C. Thus it is inferred that these areas of Purna River Alluvium are affected by inland salinity problem due to diagenetically altered meteoric water having longer residence time, high rate of evapotranspiration and it is restricted to the sandy aquifers inter-layered with clayey beds due to which less recharge of ground water is taking place.

4. Experimental setup

The aim behind this experimental work is to evaluate the mass flow rate of atmospheric water extracted in climatic condition of Buldhana city of Maharashtra. With the help of silica gel,which is the most available as marking desiccant. In the experimental part of this study, a desiccant solar collector system with varying area i.e. we made the set up of 0.45 m^2 and 0.3 m^2 boxes. Which consist of a glass surface tilt at an angle of 35^0 both the setup which is made from wood and has insulation of thermocole. The solution of 500 gm of silica gel is used as desiccants which have the high absorbitivity. As, the solution absorb water from atmospheric air at night period, we kept the desiccant in air at night. The moisture content of air is mainly depends upon temperature and humidity of air thus, we measure the temperature and humidity of ambient air in zone of Buldana city.

In general view of the experimental apparatus as shown in figure. It consist of a box having cross section of (48/45) and height 47and second one is consist of cross section (33/32) and height of 31cm. A glass cover which has thickness of 5 mm and 4mm respectively. The glasses tilt on the surface of box having an angle of 35^0.Back side of the box has a door to kept the desiccant trays in and out. The box is insulated by 10mm thickness of thermacole strip. At the time bed absorb the incident solar radiant and consequently bed temperature increases as result the vapour pressure of the solution on the bed surface increases and this vapour pressure difference between bed and glass cover leads to vapour formation at this moment evaporation of moisture from the bed is carried out with subsequent condensation on the glass surface. The drops of condensate are collected at the bottom of glass surface and leads to storage with the arrangement of channel and funnel. Evaporation and condensation continues until the vapour pressure on the bed surface is equal to the glass surface. At the end of the day the removable door is opened and the bed is allowed to cool until the vapour pressure of the surface lower than the ambient air. Temperature at different time interval is recorded in day time of bed surface and ambient air during operation period. And that might relative humidity is calculated at a time interval of 2hrs by measuring wet bulb and dry bulb temperature. The above procedure is followed over 3 nights and 3 days in a season of summer and rainy.

Fig.3 Actual experimental setup

5. CALCULATION

1. Water vapour density is defined as

$$\boldsymbol{D_v = \frac{M_w}{V} \quad \frac{kg}{m^3}} \quad \textbf{.....................(1)}$$

Where,

M_w is mass of water vapour (kg) and

V is total volume of a moist air sample (m^3).

The value of water vapour density is find from following expression

$$\mathbf{D_v = RH\ \rho_a\ \ kg\ m^{-3}} \quad \textbf{..................(2)}$$

Where,

RH = relative humidity at given temperature

ρ_a = Air density given in below table

The value of relative humidity is find from psychrometric chart as shown in figure no. 4 for a DBT 25^0C and WBT 24^0C for volume $1m^3$

Put value of ρ_a and RH in equation (2) at DBT 27^0 C and WBT 20^0C

1. $D_v = 0.92 \times 1.17$
   $D_v = 1.0764$ kg/m^3
   $M_{L1} = D_v \times V$
   $M_{L1} = 0.10764$ kg

Similarly for other reading

2. $M_{L2} = 0.1062$ kg
3. $M_{L3} = 0.1076$ kg
4. $M_{S1} = 0.0344$ kg
5. $M_{S2} = 0.0340$ kg
6. $M_{S3} = 0.0344$ kg

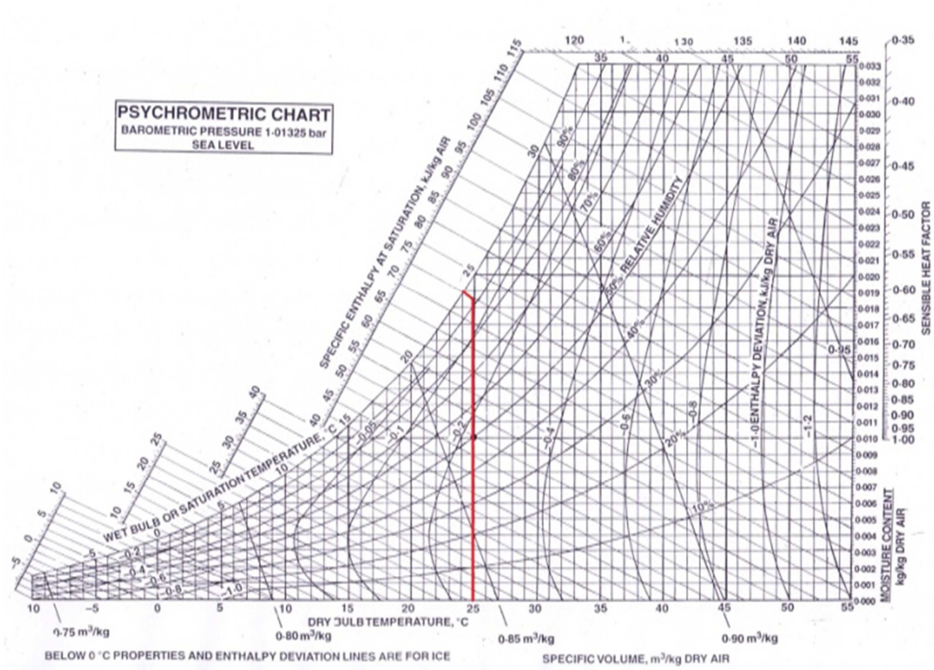

Fig 5 Psychrometric Chart

6. Result

Temperature, t_a (°C)	Density, r_a (kg/m^3)
0	1.28
10	1.23
20	1.19
30	1.15
40	1.11

Days	Temperature ^0C		Volume		Air Density kg/m^3	Relative Humidity %	Water vapour density kg/m^3	Mass of water vapour Kg	
	WBT	DBT	V_1 (L)	V_2 (S)				(L)	(S)
1	24	25	0.1	0.032	1.17	92	1.0764	0.1076	0.00344
2	23	24	0.1	0.032	1.18	90	1.062	0.1062	0.00398
3	24	25	0.1	0.032	1.17	92	1.0764	0.1076	0.00344

Table 2 Result

7. CONCLUSION

From the above experiment we conclude that theoretically we get the mass of water at 24 wet bulb temperature and 25 dry bulb temperature is around 0.1076kg at an area of $0.45m^2$ and 0.00344kg at an area of $0.3m^2$ but in actual we found the 0.52 litres of water at an area of$0.45m^2$ and 0.32 litres at an area of $0.3m^2$.

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