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THE IMPACT OF GREENHOUSE GASES DURING DISTILLATION PROCESS: A CASE STUDY OF A WICK TILTED TYPE SOLAR STILL

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Abstract

This study investigate the heating effect of greenhouse gases during distillation in a wick type solar still where the evaporator serve as solar energy collector/ blackbody. The wick tilted solar still has a chamber/evaporator as part of it's component where the wet –wick inside the evaporator is placed on mesh wire which will be able to absorb the sunlight energy during the distillation process, and in the process the temperature within the evaporator will continue to rise up and likewise, the molecules of water inside the wet -wick, the available air within, would be heated and can lead to evaporation. This paper will emphasizes the importance of greenhouse gases in distillation process as it caused heating effect. Hence, before and during the evaporation enough gases, water vapor appeared and are transported by air from region of higher temperature to region of comparatively low temperature through the process of displacement method. These gases are greenhouse gases, and they help a lot in the distillation process. Thus, the greenhouse gases provide an impact in the distillation process.

***Keyword*:** greenhouse gases, evaporation, wick, and distill water.

1. INTRODUCTION

In Nigeria clean water is a problem especially, in the northern part of Nigeria. Thus, by using an equipment wick tilted solar still to make purification possible by separating clean water from solid dissolved material. Solar still like the wick type solar still can be used in the north-east part of Nigeria. So, whenever the wick solar still is kept in an open place it has the availability of feeling the sun effect. As such, in this study there is the need for the investigation of the impact of greenhouse gases in form of heating effect to the molecules of water inside the wet- wick .Hence, the ultraviolet solar energy is able to pass through the cover glass which is transparent and as it pass through the cover it changes to infrared solar energy which fall on the wet-wick where already the wick must have absorbed some water inside it[1]. So, as time goes the evaporator will get heated, the wet wick now get heated, likewise the water inside the wick. As the temperature increase with time then evaporation will take place. Water chemically consist of hydrogen and oxygen which are gases.

2. INTERACTION OF INFRA RED LIGHT BY EVAPORATOR AND IT'S CONTENTS

To create or absorb infra red light, the molecule must be electrically lopsided, at least in passing. The reason , is this , if the symmetry is broken by having different types of atoms on each side, like carbon monoxide (Co) or nitrogen oxide (NO) , the molecules begin to have some greenhouse properties. Both these types of molecules are very reactive and are not found in enough abundance within the evaporator /chamber of the solar still which can lead to much greenhouse effect, but these are good stepping –stone molecules to think about before moving to more complicated atoms like Co_2 . However, two modes of vibration do generate an asymmetry in the electric field. The most important Co_2 gas is involved in vibration mode which is the bending vibration. When the Co_2 molecule is bent, the oxygen , carrying slight negative charges, swing from one side of the molecule so the other. The Co_2 bending vibration absorbs and emits infra red light, it is said to be infra red active. Water, H_2o, is a molecule that is bent in its lowest energy state. This is because the oxygen has two pairs of electrons hanging off it, which push the hydrogen toward the other side .Hydrogen atoms hold their electrons more loosely that oxygen atoms in chemical bonds, so each hydrogen has a slightly positive charge. The oxygen of the molecule has a slight negative charge. In contrast to Co_2, water has a dipole moment built into its resting structure. Just as for the NO molecule, rotating an H_2o molecule would oscillate the electric field and generate light. Because the arrangement of the nuclei in H_2o is more complex than for NO , there are many modes of vibration of the water molecule, including a symmetric stretch and a bend, these modes are also infra red active[3]. Thus, water vapor is very electrically lopsided and can absorb and emit lots of frequencies of infra red light . Inside , the evaporator/chamber of the solar still the influence of an light energy to water molecules increase the temperature of the evaporator , wick and water molecules inside it. Next, evaporation will take place and the water molecules at comparatively low temperature place which is the inner side of the glass cover , precipitation will take place in form of droplets and trickles down a channel out to a collection point for distill water[6].

3. INTERACTION OF INFRA RED LIGHT ANG GREENHOUSE GASES

Radiation is energy transmitted by electromagnetic waves. All objects emit radiation . As a simple model to explain this phenomena. Consider an arbitrary object made up an ensemble of particles continuously moving about their mean position within the object. A charged particle in the object oscillating with a frequency n induces an oscillating electric field propagating outside of the object at the speed of light c . The oscillating electric field, together with the associated oscillating magnetic field, is an electro magnetic wave of wavelength l=c/n emitted by the object . The electromagnetic wave carries energy; it induces oscillations in a charged particle placed in its path. One refers to electromagnetic waves equivalently as photons, representing quantized packets of energy with zero mass travelling at the speed of light. We will use the terminology "electromagnetic waves" when we wish to stress the wave nature of radiation, and "photons" when we wish to emphasize its quantized nature.

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A typical object will emits radiation over a continuous spectrum of frequencies. By using a spectrometer one can measure the radiation flux DF (wm^{-2}) emitted by a unit surface area of the object in a wavelength bin [I,I + DI]. This radiation flux represents the photon energy flowing perpendicularly to the surface. By covering the entire spectrum of wavelengths one obtains the emission spectrum of the object. Since DF depends on the width DI of the bins and this width is defined by the resolution of the spectrometer, it makes sense to plot even the radiation spectrum as DF/DI Vs I, normalizing for DI. Ideally one would like to have a spectrometer with infinitely high resolution in order to capture the full detail of the emission spectrum [1]. This ideal defines the flux distribution function

$$\Phi_\lambda = \lim_{\Delta\lambda\to 0}\left(\frac{\Delta\Phi}{\Delta\lambda}\right) \quad (1)$$

Which is the derivative of the function, φ representing the total radiation flux FT emitted by a unit surface area of the object, integrated over all wavelength is given as

$$\Phi_T = \int_0^\infty \Phi_\lambda d\lambda \quad (2)$$

Because of the quantized nature of radiation, an object can emit radiation at a certain wavelength only if it absorbs radiation at that same wavelength.

A particle can emit at a certain oscillation frequency only if it can be excited at that oscillating frequency. In the wick solar still we have an evaporator which serves like a blackbody where the radiation fall on it's glass cover and then radiation penetrates through the evaporator inform of the wave ultraviolet and later change to long wave inform of infrared light. A blackbody is an idealized object absorbing radiation of all wavelengths with 100% efficiency. The German physicist Max. Planck showed in 1900 that the flux distribution function (In) for a blackbody is dependent only on wavelength and on the temperature T of the blackbody [1]:

$$\Phi_\lambda = \frac{2\pi hc^2}{\lambda^5\left(\exp\left(\frac{hc}{KT\lambda}\right)-1\right)} \quad (3)$$

f(In) = Constant (4)

In equation(3) where $h=6.63 \times 10^{-34} Js^{-1}$ is the planck constant and $K=1.38 \times 10^{-23} Jk^{-1}$ is the Boltzmann constant and in equation (4) the function (In), where I= wavelength and n =frequency has three important properties with regard to blackbody which are :

1. Blackbody emit radiation at all wavelengths
2. Blackbody emission peaks at a wavelength I Max. inversely proportional to temperature, T. By solving function(In)=0 , we obtain $I_{\max} = \frac{a}{T}$ where $a = \frac{hc}{5k}$ =2897mmk (Wien's Law) . This result makes sense in terms of our simple model particles in a warmer object oscillate at higher frequencies
3. The total radiation flux emitted by a blackbody, obtained by integrating fnB over all wavelengths is FT=ST, where S =285kt/15c2h3=$5.67\times10^{-8} wm^{-2}k^{-4}$ is the Stefan-Boltzmann constant.

An alternative definition of flux distribution function is relative to the frequency $n = \frac{c}{I}$:

$$\Phi_v = hm_{\Delta v\to 0}\left(\frac{\Delta\Phi}{\Delta v}\right) \quad (5)$$

Where DF is now the radiation in the frequency bin [n, n +Dn]. Yet another definition of the flux distribution function is relative to the wave number $n = \frac{1}{I} = \frac{n}{c}$. The functions fn and fn are simply related by fn= c fn. The functions f(n)and f(I) are related by

$$\Phi_v = \left(\frac{d\lambda}{dv}\right)(-\Phi_\lambda) = \frac{\lambda^2}{c}\Phi_\lambda \quad (6)$$

For a blackbody,

$$\Phi_\gamma = \frac{2\pi h\gamma^3}{c^2\left(\exp\left(\frac{h\gamma}{KT}\right)-1\right)} \quad (7)$$

Solution to $\frac{fnb}{n} = 0$ yields a maximum emission at frequency $n\max = \frac{3KT}{h}$, corresponding to $\mathrm{Im}\,ax = \frac{hc}{3KT}$. The function fn peaks at a wavelength 5/3 larger than the function fi. The Planck blackbody formulation for the emission of radiation is generalizable to all objects using Kirchoff's Law . This law states that if an object absorbs radiation of wavelength I with an efficiency ei , then it emits radiation of that wavelength at a fraction ei of the corresponding blackbody emission at the same temperature. Using Kirchoff's law and equation (3), one can derive the emission spectrum of any object simply by knowing it's absorption spectrum and it's temperature.

$$\Phi_\lambda(T) = \in_\lambda(T)\Phi_\lambda^b(T) \quad (8)$$

$\Phi_\lambda^b(T)$ =absorption spectrum

HEAT AND MASS TRANSFER MODES INSIDE THE WET-WICK

The modes of heat exchange inside the wet-wick layed on a mesh wire in a wick type solar still between the absorber /evaporator and the cover surfaces are heat radiation and convection accompanied by evaporative heat and mass transfer (in the form of water vapor)[1].

CONVECTIVE HEAT TRANSFER MODE INSIDE THE TILTED WICK TYPE SOLAR STILL

This type of mode of heat exchange occurs between the absorber/evaporator and cover surfaces. It is entirely dependent on the temperature difference and the value of h_c . This is a function of the air vapor mixture properties. It must be obtained from emphirical data, which is usually correlated using dimensionless equations of the Nusselt - Grashof type [2].

An appropriate relationship for estimating h_c which is the height value between the wick and cover glass for the tilted wick type solar still (as rectangular inclined cavity). Is the Nusselt number correlation as a function of Rayleigh number $(R\alpha_H)$ and inclination angle (θ) which is reported by [3]. It is expressed as:

$$NU_H = 1 + 1.44\left[1-\frac{1708}{R\alpha_H\cos\theta}\right]\left[1-\frac{1708(\sin 1.8\theta)^{1.6}}{R\alpha_H\cos\theta}\right] + \left[\left(\frac{R\alpha_H\cos\theta}{5830}\right)^{\frac{1}{3}}-1\right] \qquad (9)$$

Where (0<$R\alpha_H$<10^5) and (0 < 60).

NU_H has a maximum error (with respect to practical values) of about 15% for $\theta \le 60^{\theta}$ and up to $\pm$ 10% for θ in the range 60^{θ} to 75^{θ}. Also, the convection heat transfer coefficient between two parallel plates (inner surface of the glass and the upper surface of the wick which is layed on the mesh wire) separated by a distance H, is related to the Nusselt number which is defined in the usual form as[4] :

$$NU_H = \frac{h_c H}{K_a} \qquad (10)$$

Where the Rayleigh number is expressed as:

$$R\alpha_H = \frac{\theta\beta H^3\Delta T}{\alpha_a v_a} \qquad (11)$$

and the diffusivity (α_a) is expressed as:

$$\alpha_a = \frac{k_a}{\rho_a c_p, a} \qquad (12)$$

Here, θ is the inclination angle (degree), ρ_a is the air density (kg/m^3), v_a is the kinematic viscosity (m^2/s), $c_{\rho,a}$ is the air specific heat (J/kg.k) and k_a is the air thermal conductivity (w/m.k)The notation [] implies that, if the quantity in brackets is negative, it must be set equal to zero[5,6].

In solar still (ΔT) is the effective temperature difference between the evaporation and condensation surfaces[7,8]. This has been expressed as:

$$\Delta T = T_{abs} - T_{\text{cov}} + \frac{(p_{abs}-p_{\text{cov}})(T_{abs}+273.15)}{268900-p_{abs}} \qquad (13)$$

Where the water vapor pressure at the absorber temperature is

$$p_{abs} = 10^{\left[(0.622+7.5(T_{abs}-273.15)/T_{abs}-35.0)\right]} \text{ (here in mmHg)} \qquad (14)$$

$$p_{\text{cov}} = 10^{\left[0.622+7.5(T_{abs}-273.15)/T_{abs}-35.0\right]}\,(hereinmmHg) \qquad (15)$$

Therefore, the convection heat transfer rate from the absorber wet-wick to the inner surface of the glass cover can be expressed as:

$$q_c = h_c\left(T_{abs}-T_{\text{cov}}\right) \qquad (16)$$

EVAPORATIVE MASS TRANSFER MODE INSIDE THE TILTED WET-WICK-TYPE SOLAR STILL

Evaporative mass transfer accompanies the heat convection in the form of water vapor. The amount of water transferred from the wet-wick surface to the condensate film on the cover can be estimated in terms of the analogy between heat and mass transfer. Accordingly, the mass flow rate is proportional to the heat transfer coefficient and the driving potential. The latter is the difference in partial pressures of the material being transferred[9,10,11]. The algebraic formulation of the corresponding rate of heat flux is:

$$q_c = 0.016h_c\left(p_{abs}-p_{\text{cov}}\right) \qquad (17)$$

Where

$$q_c = h_c\left(T_{abs}-T_{\text{cov}}\right) \qquad (18)$$

and

$$h_c = 0.016h_c\frac{p_{abs}-p_{\text{cov}}}{T_{abs}-T_{\text{cov}}} \qquad (19)$$

This is related to the amount of the condensation on the inner surface of the cover glass by the expression:

$$q_c = \frac{Dh_{\text{lg}}}{3600} \qquad (20)$$

Where h_{lg} is the latent heat of evaporation of the water and D is the distillate production rate, h_{lg} is expressed as a function of water temperature as:

$$h_{\text{lg}} = 10^3\left(2501.67-2.389T_{abs}\right) \qquad (21)$$

RADIATIVE HEAT TRANSFER MODE

The radiative heat transfer inside of the wet wick type solar still, between the cover glass and the absorber/evaporator surfaces is considered as that between two infinite parallel plates. With assumptions of diffuse and gray surfaces and that the aspect ratio is sufficiently large to neglect edge effects, It is given per unit area as[9]:

$$q_r = \frac{\sigma\left(T_{abs}^4 - T_{cov}^4\right)}{\frac{1}{\in_{abs}} + \frac{1}{\in_{cov}} - 1} \quad (22)$$

Where σ is Stefan-Boltzman's constant (5.6697 x 10^{-8} w/m^{2}k^4). The measured value of the wick is equal to 0.98. For simplicity it can be approximated to unity. Hence equation (22)

$$q_r = \in_{cov} \sigma\left(T_{abs}^4 - T_{cov}^4\right) \quad (23)$$

And hence the radiation heat transfer coefficient from absorber/evaporator to the cover glass can be expressed as:

$$q_r = \in_{cov} \sigma\left(T_{abs}^2 + T_{cov}^2\right)\left(T_{abs} + T_{cov}\right) \quad (24)$$

The amount of energy utilized in vaporizing water in the wet-wick (J/m^2)	The amount of incident solar energy falling on the passive single slope wick tilted type solar still (J/kg)
0.272	1.096
0.64	2.56
0.912	3.648
0.8	3.2
0.552	2.208
0.504	2.016

Table 1: The table above showed values of the amount of energy utilized in vaporizing water in the wet –wick and the amount of incident solar energy on the passive single slope wick tilted type solar still.

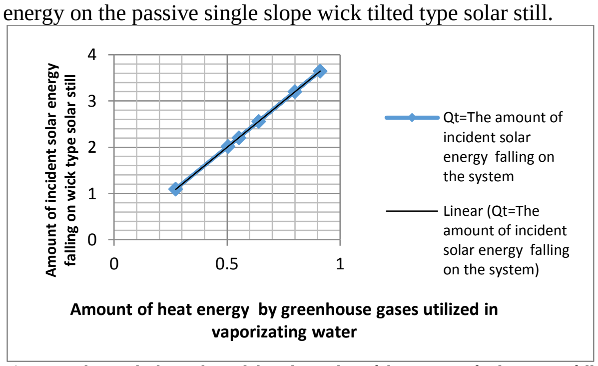

Figure 1: The graph above showed the relationship of the amount of solar energy falling on the system and the impact of the heat generated/produced by greenhouse gases.

CONCLUSION

With this study/research, one can realized the impact of greenhouse gases (carbon dioxide, water vapor) during the distillation process where the mass-heat transfer play a vital role as the gas increase the heating effect of the entire evaporator as a blackbody itself and hence, increasing the condensation level. By having a linear graph it showed that there is high impact of the green house gases (GHG) to the molecules of water inside the wet-wick in the evaporator.

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