Increase in the Amount of Water in Nature from 1984 to 2010 due to the Combustion of Petroleum Derivatives

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Received april, 2016

Abstract: Most researches focus on the important issue of producing CO2 and its consequences such as the greenhouse effect and the increase of water acidity. During the burning of a fossil fuel oxygen sequestration from the atmosphere, water production and its ecological effects are not usually quantified. This data is crucial for the study of cycles: hydrologic, oxygen and carbon dioxide. The imbalances of these cycles drive global preservation policies. The present work aims to provide a quantifiable base from which technological and political decisions can be made. This reference will show the masses and volumes of water and CO2 and the reduction of oxygen from the atmosphere as the result of the burning of main fuels from 1984 to 2010.

Keywords: water, hydrologic cycle, combustion, greenhouse gases, petroleum.

Aumento da Quantidade de Água na Natureza, de 1984 a 2010 devido a Combustão de Derivados de Petróleo

Resumo: A maioria das pesquisas enfoca a importante questão da produção de CO2 e suas consequências, tais como o efeito estufa e o aumento da acidez da água. Durante a queima de um combustível fóssil sequestro de oxigênio da atmosfera, a produção de água e seus efeitos ecológicos não são normalmente quantificados. Estes dados são cruciais para o estudo dos ciclos: hidrológicas, oxigênio e dióxido de carbono. Os desequilíbrios desses ciclos direcionam políticas de preservação global. O presente trabalho tem como objetivo proporcionar uma base quantificável do qual decisões tecnológicas e políticas podem ser feitas. Esta referência mostrará as massas e volumes de água e CO2 e a redução do oxigênio da atmosfera, como resultado da queima de combustíveis principais de 1984 a 2010.

Palavras chave: água, ciclo hidrológico, combustão, gases de efeito estufa, petróleo.

1. Introduction

It is estimated that planet Earth has approximately 1360 quadrillion tons of water distributed as follows: 95% of salt water in the seas and oceans; about 2% is found in the polar caps and glaciers as fresh water ice; 0,04% is found in the atmosphere in liquid and gas phases; only 2,3% is freshwater in the liquid phase found on the ground and underground and nearly 130 trillion tons make up lakes, swamps and rivers[1, 2].

According to the Environmental Department[3] in 2013 the hydrologic cycle consists of the evaporation of liquid water caused by the sunrays, the rise of these vapors up the atmosphere until the right temperature enables their condensation thereby forming the clouds from which water precipitates in liquid state (or sometimes in solid state in the case of hail) and finally returning to the receiving bodies (oceans, rivers and lakes). In this cycle water goes through physical transformations only. There is no loss of the chemical substance called water. Thus, the amount of water in nature should remain the same.

As the human species evolved man increasingly needed more energy for innumerous purposes. Throughout history mankind used the most diverse kind of fuel until the advent of petroleum.

Based on petroleum the combustion processes were developed which optimized the use of these fuels, producing energy to feed from the simplest   to   the   most

complex systems to maintain the "status quo" of mankind[4].

In order to obtain the petroleum derivatives, the petroleum is submitted to the most diverse unit operations and chemical conversions in the industrial complex, namely the oil refinery[5]. According to Thomas[6] the most common petroleum derivatives are LPG (liquefied petroleum gas), naphtha, gasoline, kerosene, diesel, light and heavy crude oils, fuel oil and petrol coke. Among these derivatives, some are used as raw material at other refinery units (light and heavy oils), at petrochemical industries (naphtha and light oils), for the aluminum industry (part of the oil coke produced). Also, there are many derivatives that are used mainly as fuels (LPG, automotive and aviation gasoline, aviation and illuminating kerosene, diesel, fuel oil and petrol coke).

The combustion process aims at obtaining the energy in a controlled manner, to be used in industrial processes and for the use in home equipment or for social purposes. The petroleum derivatives are made up mainly of carbon (C) and hydrogen (H), forming the so called hydrocarbons which can be represented by the generic chemical formula C_nH_m. Considering that in a complete combustion the entire carbon converts into carbon gas (CO_2 and hydrogen into water (H_2O), one can write Equation (1),

in which oxygen (O_2) is supplied by an atmosphere having a composition of 21% oxygen and 79% nitrogen (N_2) in moles or in volume[7].

$$C_nH_m + (n+(n/4))O_2 \rightarrow nCO_2 + (m/2) H_2 \quad (1)$$
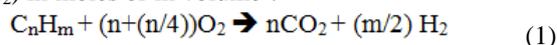
Petroleum fractions are not substances, but are actually mixtures of substances in which hydrocarbons predominate. It is for this reason that these fractions can be represented by an average hydrocarbon found in each of these fractions[8]. This is a very useful procedure because it enables a stoichiometric calculation of the various fuel fractions of petroleum. In order to execute this work, the main fractions and usually the most consumed fuels were LPG (liquefied petroleum gas), gasoline, illuminating kerosene, aviation kerosene and diesel.

According to Szklo[8] if we take an average saturated hydrocarbon of a typical range from each fraction, the LPG can be represented by 50% of C_3H_8 (propane) and 50% of C_4H_{10} (butane); gasoline by C_8H_{18} (octane); illuminating and aviation kerosene by $C_{14}H_{30}$ (tetradecane) and diesel by $C_{16}H_{34}$ (hexadecane).

Table 1 presents global consumption of LPG, gasoline, illuminating kerosene (IK), aviation kerosene (AK-1) and diesel in billion barrels of fuel fractions per day (bbl/d)[9]. The specific LPG, gasoline, kerosene and diesel masses were obtained as follows in Table 2.

Table 1. Global consumption of LPG, gasoline, kerosene (IK – AK) and diesel.

Year	bbl LPG/day	bbl gasoline/day	bbl IK/day	bbl AK-1/day	bbl diesel/day
1984	3188220	10586280	717270	1836900	7769960
1985	3281790	10755570	696180	1909240	7926390
1986	4180690	15385350	2124080	2651370	13599120
1987	4472340	15766430	1741230	3202430	14058400
1988	4583990	16355120	1702430	3500660	14420000
1989	5205290	16349000	1588790	3678700	15065230
1990	5392300	16537810	1624060	3673750	15284070
1991	5822690	17293660	1590160	3648310	16664110
1992	5673720	17227920	1717240	3650480	16870100
1993	5708220	17532280	1728670	3713360	17596450
1994	5949020	17751230	1755800	3832190	17826850
1995	6160770	18071230	1820250	3952080	18160260
1996	6474950	18335700	1866830	4082530	18502770
1997	6638820	18667970	1839340	4146050	19248300
1998	6476390	19099470	1823210	4257420	19054860
1999	6748550	19404920	1820350	4372380	19713940
2000	7240860	19882330	1890850	4545940	20379690
2001	7242900	20077720	1874980	4503900	21340080
2002	7567810	20188500	1767490	4494530	20946300
2003	7607960	20407940	1712600	4534770	21609630
2004	7876320	20869190	1629330	4830430	22560920
2005	7717520	21169240	1702660	5041960	23156820
2006	7796900	21471270	1561090	5188850	23772610
2007	8499850	21642860	1272800	5249270	24294740
2008	8332650	21325920	1278570	5267830	24723530
2009	8238240	21755210	1203250	4979510	24266550
2010	8961400	22065600	1230580	5219510	24986350

Unisanta Science and Technology **(71-77) p.p. ISSN 2317-1316**

Table 2. Specific mass of LPG, gasoline, kerosene (IQ and QAV-1) and diesel.

Fuel Fraction	Specific Mass (kg/m^3)	Reference
LPG	550	ANP # 18 [10]
Gasoline	739	ANP # 21 [11]
Illuminating Kerosene	791	ANP # 04 [12]
Aviation Kerosene	791	ANP # 03 [13]
Diesel	856	ANP # 65 [14]

The main objective of this paper was to estimate the increase in the amount of water in nature in a specific period of time based on the stoichiometric calculations of Equation (1), on the above mentioned main fraction consumption and on the adoption of a hydrocarbon representative of each fuel fraction. The secondary objective of this work is to estimate the quantity of carbon gas produced and the amount of oxygen taken from the atmosphere.

No reference to other papers that addressed the issue in the present work directly was found in the researched literature.

2. Materials and methods

Inasmuch as this is a theoretic study there have been no laboratory practices. Consequently, no glassware, test tubes, reagents or equipment were used.

The method applied was based on the information on the global consumption of LPG, gasoline, kerosene (illuminating and aviation) and diesel according to Table 1. The data of this table was changed into tons/day to be used in the equations of each fraction studied representing the hydrocarbon combustion.

The schedule of sequence of these changes was the following:

a) the production in barrels/d (bbl/d) was transformed into m^3/d, using the conversion factor of 1 bbl/0,159 m^3;

b) the production in m^3/d was transformed into tons/day (t/d), using the specific mass value of each fuel fraction; the resulting value was considered to be the production of the respective average hydrocarbon;

c) the stoichiometric calculations of the combustion equations provided the total amount of water and carbon gas produced[15];

d) Once the values were calculated, Figures 1 thru 7 show the amounts of consumption and production per day – not per year – to reduce the number of digits used.

The following calculation will illustrate the sequence for the LPG in 1984:

1) Consumption of LPG: 3.188.220 bbl/d;

2) Converted into m^3/d: (3.188.220 bbl/d). (0,159 m^3/1 bbl) = 506.927 m^3/d;

3) Converted into t/d: (506.927 m^3/d). (0,55 t/m^3) = 278.810 t/d;

4) Granted the LPG is formed by 50% of C_3H_8 and 50% of C_4H_{10} the resulting consumption is 139.405 t/d of C_3H_8 (propane) and 139.405 t/d of C_4H_{10} (butane); Equations 2 and 3 represent the full combustion of propane and butane.

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O \qquad (2)$$

$$C_4H_{10} + 6,5O_2 \rightarrow 4CO_2 + 5H_2O \qquad (3)$$
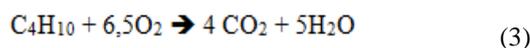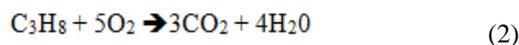
Equation 2 shows that for the combustion of 1 mole of C_3H_8 3 moles of CO_2 and 4 moles of H_2O are produced; By applying the fundamentals of stoichiometric calculation to Equation 2 and observing that the data is in tons per day, we arrive at Equation 2a in which mH_2O is the water production (t/d), mC_3H_8 is the propane consumption (t/d) and (72/44) is the molar proportion between the production of water to the consumption of propane.

$$MH_2O = (72/44)MC_3H_8 \qquad (2a)$$

By applying the same rationale again to Equation 2, we arrive at Equation 2b in which mCO_2 is the production of carbon gas (t/d) and (132/44) is the molar proportion/ratio between the production of carbon gas to the consumption of propane.

$$MCO_2 = (132/44)MC_3H_8 \qquad (2b)$$

By applying the same procedures to Equation 3, we obtain Equations 3a and 3b which measure the production of water and carbon gas in respect to the production of butane.

$$MH_2O = (90/58)MC_4H_{10} \qquad (3a)$$

$$MCO_2 = (176/58)MC_4H_{10} \qquad (3b)$$

By rearranging Equations 2a, 2b, 3a and 3b, we obtain Equations 4 and 5.

$$MH_2O=((72/44)+(90/58))x139.405=444.435\,t/d \quad (4)$$

$$MCO_2=((132/44)+(176/58))x139.405=841.237\,t/d \quad (5)$$
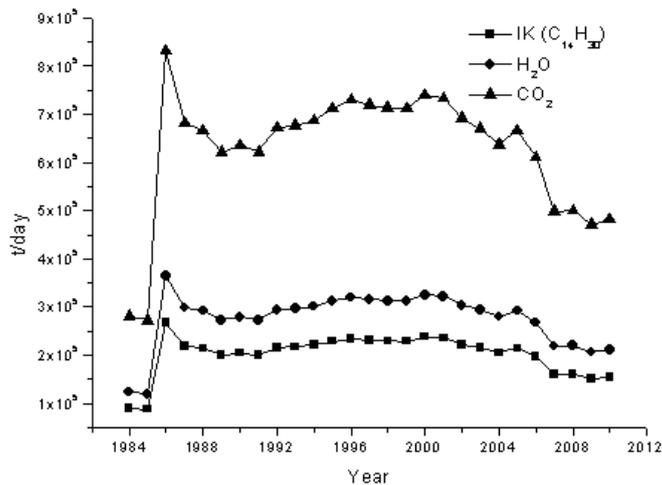
3. Results and discussion

Figures 1 thru 5 refer to the production of water and carbon gas in relation to the data provided by Table 1 in accordance with the illustration of the calculation schedule.
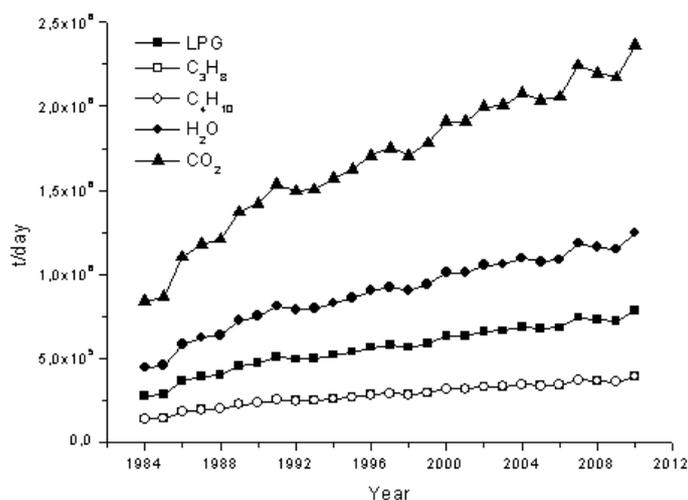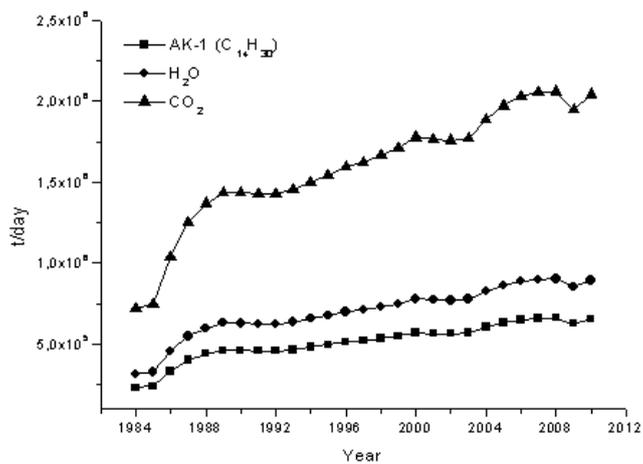

Figure 1. LPG consumption (C_3H_8 e C_4H_{10}), water production (H_2O) and carbon gas (CO_2).
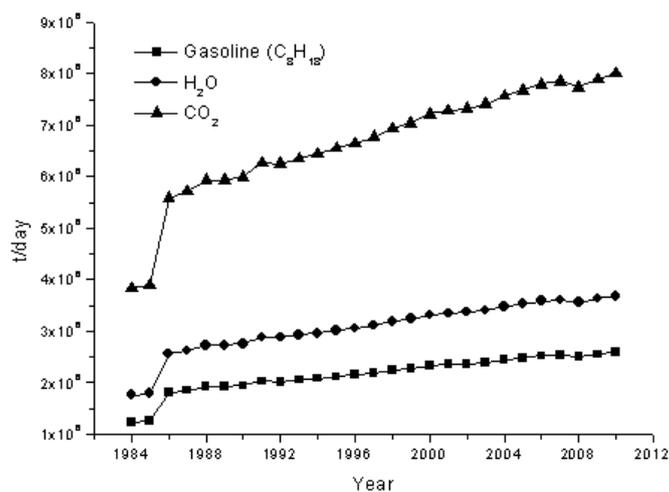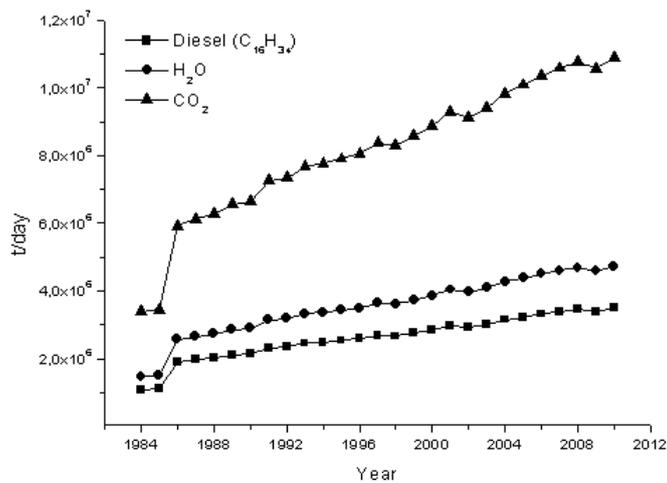

Figure 2. Consumption of gasoline, water production (H_2O) and carbon gas (CO_2).

Figure 3. Consumption of illuminating kerosene (IK), water production (H_2O) and carbon gas (CO_2).

Figure 4. Consumption of aviation kerosene (AK- 1), water production (H_2O) and carbon gas (CO_2).

Figure 5. Consumption of diesel, water production (H_2O) and carbon gas (CO_2).

In Figures 1 thru 5 one can clearly observe the increase of global consumption of liquefied petroleum gas, gasoline, illuminating kerosene, aviation kerosene and diesel. Consequently, there is an increase in the production of water and carbon gas due to the combustion of these petroleum fractions.

With the data of Figures 1 thru 5 one can build Table 3 which presents the production of water in cubic meters (as one considered the specific mass of water to be 1000 kg/m^3 and carbon gas in tons.

Taking the year to be 365 days, the amounts of water and carbon gas can be calculated through Equations 6 and 7, using the data in Figures 1 thru 5.

$$V_{H_2O}=365 \times 228663306 = 83462106584 \, m^3 \tag{6}$$

$$M_{CO_2}=365 \times 505148601 = 184379239237 \, t \tag{7}$$

In order to produce (H_2O) and carbon gas (CO_2) oxygen was removed from the atmosphere. The oxygen in the water did not return to the atmosphere whereas part of the oxygen contained in the carbon gas returned to the atmosphere through plant photosynthesis and algae chlorophyll.

The calculation of the quantity of oxygen in the form of carbon gas was not taken up in the present study due to the complications caused by the photosynthesis mechanisms. However, the amount of oxygen in the form of water was calculated given that 1 mole of water equals 18g of which 16g are oxygen and 2g are hydrogen. Thus, knowing the proportion between oxygen and hydrogen in 1 mole of water, the mass of oxygen removed from the atmosphere was calculated in Equation 8, where mH_2O is the mass of water produced from 1984 to 2010.

$$M_{O_2}=(16/18)mH2O=74188539186 \, t \tag{8}$$

Therefore, in the period from 1984 to 2010 for the sole purpose of burning hydrogen from the fuel fractions concerned in the present study, seventy four billion, one hundred and eight-eight million, five hundred and thirty-nine thousand, one hundred and eighty-six tons of oxygen were removed from the atmosphere.

In order to have an idea of the effect this quantity of water may have in the environment, the diameter (D) of a hypothetical circular lake was devised with a 50 m depth (P) to hold the water produced between 1984 and 2010. Equation 9 calculates the volume of this lake which has a cylindrical shape.

$$V=(\pi D^2 P)/4 \tag{9}$$

Rearranging Equation 9 we obtain Equation 10.

$$D=((4V)/(\pi P))^{0,5} \tag{10}$$

It is a gigantic lake with 50m deep and 46 km in diameter.

4. Conclusions

Although calculations were conservative because only five fuel fractions of petroleum derivatives were taken into account, they gave us an estimate of the increase in the amount of water in nature. The increase in the carbon gas content in the atmosphere also became evident as did the removal of oxygen from the atmosphere and changing it into water.

For a more realistic estimate of the amounts produced of water and carbon gas and the removal of oxygen from the atmosphere it would be interesting to obtain the data of the use of petroleum derivatives ever since the discovery of this source of energy and raw materials by the colonel Edwin Drake in Titusville, Pennsylvania, in 1859. The experimental obtainment of the masses of water and carbon gas through combustion of the fractions in question would make the calculations more accurate.

Table 3. Production of water and carbon gas per day between 1984 and 2010.

Fuel Fraction	H$_2$O (m^3/day)	CO$_2$ (t/day)
LPG	2,41E+07	4,57E+07
Gasoline	8,28E+07	1,80E+08
IQ	7,42E+06	1,69E+07
QAV-1	1,89E+07	4,30E+07
Diesel	9,54E+07	2,20E+08
Total	2,29E+08	5,05E+08

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