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RESEARCH ARTICLE

ESTIMATION OF THE FOSSIL FUEL FRACTION COMPONENTS DUE TO THE SUESS EFFECT IN URBAN AREA

Matar Sène[1], Maurice Ndeye[2] and Abdou Diouf[3]

1. Department of Physics, University Cheikh Anta Diop, Dakar, Senegal.
2. Radiocarbon Laboratory, Institut Fondamentale d'Afrique Noire (IFAN), University Cheikh Anta Diop, Dakar, Senegal.
3. Department of Physics, Atoms Lasers Laboratory, University Cheikh Anta Diop, Dakar, Senegal.

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Abstract

Long used in the domain of archaeology, the C14 isotope has become an essential tracer in the evaluation of environmental fossil pollution. Since modern times, the combustion of fossil fuels such as coal, oil, natural gas, etc. in urban and/or industrialized areas releases a significant amount of fossil CO_2 into the environment. Thisincrease the concentration of CO_2, but also causes changes in the isotopic composition of carbon resulting in a deceased of the C14 concentration in the atmosphere and in other carbon reservoirs (terrestrial and marine biosphere).This phenomenon is the SUESS effect. The most favorable types of samples for such a study are leaves of trees or cernes. These reflect better the changes of the radiocarbon concentration in the atmosphere due to the biological assimilation of carbon from the air through photosynthesis. The evaluation of the Suess effect in polluted areas (Dakar region:UCAD Botanic Garden, Mbao Forest, SAR Factory, Beach)can be done using mass balance equations. From this model, we determined the fraction of fossil fuelsF_{foss}.The values we found vary between 0.25% in UCAD Botanic Garden and 4.19% in Mbao Forest, and they are all positive, which effectively proves the existence of the Suess effect in our sites.

Introduction:-

Carbon-14 is a radionuclide with a half-life equal to 5568 +/-30 years (conventional Libby half-life).It is produced naturally in the upper atmospheric layer from nuclear reactions between cosmic neutrons and air molecules (R E Taylor, 1987; G. Castagnoli and D. Lal, 1980; S A Korff and R B Mendell, 1980; M Molnàr et al.2010), particularly ^{14}N nitrogen.

In addition to this production, we have the artificial production that is of anthropic origin.

First there is the Bomb effect (Nydal et al.1983; D. E. Pataki et al. 2010, Hua et al.2013) which increased almost to double the concentration of ^{14}C during the nuclear tests (W Davis Jr et al.1977; I Levin et al.2003; J.C Turnbull.2007, 2006) and the Suess effect which led to a depletion of the concentration of ^{14}C in the atmosphere

Corresponding Author:-Matar Sène
Address:-Department of Physics, University Cheikh Anta Diop, Dakar, Senegal.

(Kuc and M. Zimnoc, 1998; A.Z. Rakowsky et al.2004.b, S Pawelczyk and A Pazdur. 2004; M. Molnàr et al.2010, Rakowski et al.2013; A Rakowski.2005, 2008, 2011 and 2013; R Baydoun.2015).

Once formed, together with other carbon isotopes (the ^{13}C and ^{12}C), ^{14}C enters the biological and geochemical carbon cycles and is assimilated by all living organisms in the form of carbon dioxide after oxidation of this radioisotope with air molecules such as oxygen mainly.

The concentration of $^{14}CO2$ in the atmosphere can no longer be taken as constant, because the current level of CO2 depends on the recent anthropogenic changes.

Atmospheric 14C is the ideal tracer for monitoring CO_2 derived from fossil fuels (Weijian Zhou et al.2014, I Levin et al.2003, 2008, J C Turnbull et al.2006, Andrzej Z Rakowski et al.2008, Diane E Pataki et al.2010, Scott J Lehman et al.2013, Tesfaye A. Berhanu et al.2017).

Due to the high demand of populations for energy, the burning of fossil fuels releases huge amounts of CO_2 into the atmosphere. This leads to a depletion of carbon-14 content and an increase in $^{14}CO_2$ concentration (A.Z. Rakowsky et al.2004.b, S Pawelczyk and A Pazdur. 2004; M. Molnàr et al.2010 Rakowski et al.2013; A Rakowski.2005, 2008, 2011 and 2013; R Baydoun.2015) in the different carbon reservoirs. Today this phenomenon is much more caused by industrial complexes, transportation sector, high human density in cities and other sources based on fossil fuel consumption.

In this paper, we show the existence of the local Suess effect in the urban areas of Dakar, by calculating the fraction Fraction F_{foss} of Fossil fuel.

Sampling Sites And Methods:-

Sampling sites

All our samples come from the Dakar region. We chose this locality, the capital of Senegal, because it is by far the most populated (23.2% of the total population of the country and a density of about 5,739 inhabitants per square kilometer) and the most industrialized (80% of the national sector) according to data from www.ands.sn.

The transport sector contributes significantly to air pollution in Senegal. Its gas emissions undoubtedly have a serious impact on urban air quality, particularly in Dakar, and consequently on the health of the population. The poor condition and/or age of vehicles are also sources of CO_2 pollution. The car fleet in Dakar is aging and constantly increasing.

Located on the Cape Verde peninsula, Dakar is bordered to the east by the Thies region and the Atlantic Ocean surrounds it to the north, south and west.

This locality, with a high human density, very industrialized also and with an accelerated growth of the sector of terrestrial or air transport, is strongly exposed to several forms of pollution like PM5 and PM10, VOC, methane, carbon monoxide (CO) and carbon dioxide CO_2....

Our study focuses mainly on the contamination of atmospheric air by CO_2 of anthropogenic origins.

Methods:-

At first, we do physical pre-treatments. Physical pre-treatments were carrying out, whose role is to eliminate all the physical impurities present in the sample, before proceeding to the chemical treatments. Physical pretreatment is usually a manual job that is often less complicated.

The chemical pretreatments we performed for our last samples are identical to the same pretreatment as we did the previous work. Each sample was washed in distilled water and treated with a 0.5M hydrochloric acid solution for about thirty minutes, and then these samples were further rinsed with distilled water. Then we make an attack with sodium hydroxide solution NaOH at 0.1M.

After around one hour, we rinse with samples with distilled water. Then, the samples were washed and dried in a drier with a temperature of about 30 ° C.

Now let us look at the stage of benzene synthesis. First, carbon dioxide CO_2 is synthesized by burning the carbon of the sample with phosphoric acid H_3PO_4.

Sample (Carbone C) + H_3PO_4 CO_2 ⟶

Then we synthetize acetylene from carbon dioxide and with an excess of lithium at 600°C.

$2CO_2$+ 10Li (600°) ⟶ $4LiO+Li_2C_2$

After cooling the reactor, the synthesized products, lithium hydroxide Li $(OH)_2$ and Li_2C_2 lithium carbide were hydrolyzed to produce C_2H_2 acetylene which was finally converted to C_6H_6 benzene by a 50 °C catalytic reaction of trimerization.

$Li_2C_2+2H_2O$ ⟶ $C_2H_2+2LiOH$

$3C_2H_2$ + (Chrome Cr^{3+}; Vanadium V) ⟶ C_6H_6

For radiocarbon measurements, we use a conventional method with the liquid scintillation counter (Tricarb 3170TR / SL) with a super low-level option. In order to minimize background interference and discriminate true beta events (β), the Tricarb 3170TR / SL are equipped with a bismuth and germanium detector ($Bi_4Ge_3O_{12}$) as well as a peak analyzer.

Normalization is done routinely to see the electronic stability of the counting system. The optimization of the counting area was done to maximize the merit factor (E_2 / B) where E is the return and B the count rate of the background.This type of meter is equipped with a SNC (Self Normalization and Calibration) cassette.

Results and Discussion:-

Fraction F of Fossil Fuel Calculation

By mass balance equation, we have established in our previous articles:

$$\left[CO_2\right]_{foss} = \left[CO_2\right]_{bio} \frac{\Delta^{14}C_{bio} - \Delta^{14}C_{total}}{\Delta^{14}C_{total} - \Delta^{14}C_{foss}} + \left[CO_2\right]_{bg} \frac{\Delta^{14}C_{bg} - \Delta^{14}C_{total}}{\Delta^{14}C_{total} - \Delta^{14}C_{foss}} \quad \textbf{(1)}$$

To establish the mass balance equation we will consider these approximations used by several authors and available in the literature:

(a) Fossil carbon dioxide CO2 is radiocarbon free, which results in $\Delta^{14}C_{foss} = -1000‰$ **(2)**

(b) ^{14}C biogenic concentration $\Delta^{14}C_{bio}$ is equal to the ^{14}C concentration in the background $\Delta^{14}C_{bg}$ because the main flow of the biosphere comes from autotrophic respiration ($\Delta^{14}C_{bio} = \Delta^{14}C_{bg}$). **(3)**

Taking into account, of these two approximations we obtain:

$$F_{foss} = \frac{\Delta^{14}C_{bg} - \Delta^{14}C_{total}}{\Delta^{14}C_{bg} + 1000} \text{ (Fraction of Fossil fuel)} \quad \textbf{(4)}$$

We will use this formula; in our results to find estimate the local Suess effect in our study sites.

According to the relation (4) of the previous section: $F_{foss} = \frac{\Delta^{14}C_{bg} - \Delta^{14}C_{total}}{\Delta^{14}C_{bg} + 1000}$

For the ^{14}C concentration in clean air $\Delta^{14}C_{bg}$, we chose the measurement data from the Mauna Loa station in Hawaii (Globalview-CO_2-2010) because this site according to (Q Hua et al.2004)is in the same hemisphere as

Senegal (NH Zone 2). Countries in the same hemisphere have approximately the same level of background CO_2 (Q Hua et al.2013).

These $\Delta^{14}C_{bg}$ values are recorded in the following table (**Table 1**).

For $\Delta^{14}C_{mes}$ values we have use the formula (3). Fraction of modern carbon $F^{14}C$of sample are obtained according to

$$F^{14}C = \frac{A_{SN}}{A_{STD}}$$

Table 1:- $\Delta^{14}C_{mes}$ (sites) and $\Delta^{14}C_{bg}$ (clean area)according on the sites.

Sites	$F^{14}C$	$\Delta^{14}C_{mes}$	$\Delta^{14}C_{bg}$
UCAD Botanic Garden	1,518±0,006	522±6	556
	1,301±0,005	306±5	326
	1,181±0,005	187±5	190
	1,084±0,006	91±6	100
Mbao Forest	1,182±0,005	186±5	235
	1,674±0,006	677±6	735
	1,052±0,006	60±5	75
SAR Factory	1,770±0,008	773±8	804
	1,064±0,006	71±5	90
Beach	1,272±0,051	272±5	277
	1,103±0,006	110±6	115
	1,041±0,006	49±5	70

We have plotted in the following figure (Tableau 1) the Δ^{14}Cmes and Δ^{14}Cbg values of the different samples used.

Discussion:-

We chose the measurement data from the Mauna Loa station in Hawaii (United States of America) (Globalview-CO_2-2010) because this site according to (Q Hua et al.2004)is in the same hemisphere as Senegal (NH Zone 2). Countries in the same hemisphere have approximately the same level of background CO_2as shown in the following map (Q Hua et al.2013).

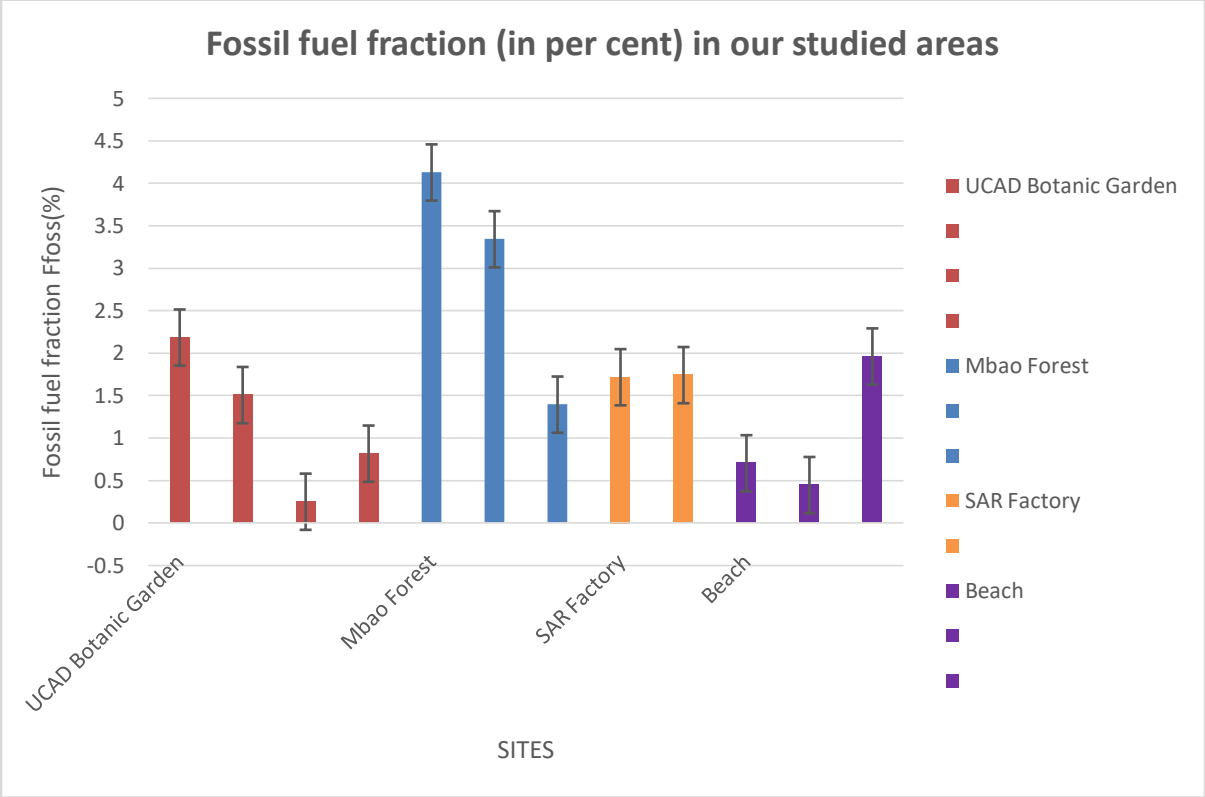
The values of the fossil fuel fractionF_{foss} calculatedin the table below show the degree of the Suess effect at each location due to fossil fuel use.

Tableau 2:- Fossil fuel fraction Ffoss in studied area.

SITES	$\Delta^{14}C_{bg}$	$\Delta^{14}C_{total}$	f_{foss}	$f_{foss}(‰)$
UCAD Botanic Garden	556	522	0,0218509	2,18508997
	326	306	0,01508296	1,50829563
	190	187	0,00252101	0,25210084
	100	91	0,00818182	0,81818182
Mbao Forest	235	186	0,04129555	4,12955466
	735	677	0,03342939	3,34293948
	75	60	0,01395349	1,39534884
SAR Factory	804	773	0,01718404	1,71840355
	90	71	0,01743119	1,74311927
Beach	277	272	0,00704777	0,70477682
	115	110	0,0044843	0,44843049
	70	49	0,01962617	1,96261682

The depletion of 14C in the studied areas could be attributed to emissions of all varieties in urban areas that release a large amount of pollutants, mainly CO_2, which could reach the selected sampling sites.

Graphe 1:- Fossil fuel fraction (in per cent) in our studied areas.



The spatial repartion of CO_2 fossil in Dakar region prove the positive values of the fraction of fossil fuel that we found. Values that vary between 4.19% in Mbao forest sites and 0.25% in UCAD botanic garden since modern times.

The samples coming from the botanical garden of UCAD are susceptible to be polluted by the many different kinds of cars that use this avenue every day.But also this same phenomenon can affect the sites around the beach located on the same district.

The SAR factory, which is an industrial cement manufacturing industry, also releases a large amount of fossil CO2, which also affects the samples coming from this site.

The same phenomenon is observed at the level of the forest of Mbao, which, despite containing many trees capable of sequestering part of the fossil carbon is subject to this form of pollution because located near an avenue (national road No. 1) and only a few kilometers from the factory SAR.

Even if it exists for the moment in small quantities, there is a dilution of natural atmospheric CO_2 by fossil CO_2 in our urban areas.

Conclusion:-

Plant samples (plants and trees) are often used to prove excess CO_2 in the atmosphere from modern anthropogenic disturbances. There is a decrease in ^{14}C concentration in the urban areas we studied. This is confirmed by the calculation of the fossil fuel fraction Ffoss that we have calculated in this paper.

We plan to do further spatial and temporal studies to determine the fossil fuel fraction in other areas following various periods.

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