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Quantifying Fossil Fuel CO_2 Component over Dakar from 1960 to 2010 by Radiocarbon Observation in Atmospheric CO_2 and Using Mauna Loa as Background

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Abstract: We investigated the atmospheric $\Delta^{14}C$ level and the fossil fuel CO_2 concentration in Dakar area from 1960 to 2010 by using the radiocarbon measurements obtained from tree leaves samples. We used the Carbon-14 dating method with a Liquid Scintillation Counter and an Accelerator Mass Spectrometer. The samples were subjected to physical and chemical pretreatments, then, they were transformed into benzene for the counting. The results show that the largest maxima of the ^{14}C concentration ($\Delta^{14}C$) are recorded at sites such as the SAR Factory (773‰ in 1964), Mbao Forest 2 (677‰ in 1966) and UCAD Botanic Garden (522‰ in 1970) and the smallest minima are the Airport Runway (45‰ in 2010), the Beach 2 (48‰ in 2009), the Mbao Forest 2 (59‰ in 2007), the SAR Factory (71‰ in 2005), Soumbedioune Market (80‰ in 2003) and Ucad Botanic Garden (91‰ in 2000). The Comparative curve of the minimum and the maximum values of $\Delta^{14}C_{bg}$ (background) and $\Delta^{14}C_{meas}$ (measured) show that ^{14}C concentration of the sites are lower than ^{14}C concentration in clean air. This can be correlated with the increase of the fossil fuel derived CO_2 caused by human activities such as population density, industrials emissions, and traffic. The evaluation of the fossil fuel concentration (CO_{2ff}) by mass balance equations, show, in most of the sites, an increase of the level of CO_{2ff}. Exceptional cases are obtained in Mbao Forest 1 and for UCAD Botanic Garden sites. One explanation of the values is that sites are much wooded these last years.

Keywords: Fossil Fuel CO_2, ^{14}C Concentration ($\Delta^{14}C$), Radiocarbon, Leaves, Clean Area

1. Introduction

With climate change and the degradation of air quality, the quantification of urban CO_2 emissions, the main greenhouse gas, is becoming a necessity in environmental management policy in all countries of the world. Fossil emissions of atmospheric CO_2 constitute one of the gases emitted during the combustion of fossil fuels such as oil, gas, coal and during the production of cement with clinker. These emissions are more pronouncing in highly urbanized and / or densely populated areas. To quantify this CO_2, commonly named fossil fuel CO_2, which is one of the components of the global CO_2 emitted, we used the radiocarbon dating method. Measurements of the carbon isotope 14C in atmospheric CO_2 are the only means of quantifying the component of fossil CO_2 [1-3] and give information on the local level of pollution. The fossil fuel CO_2 concentration (in ppm), cannot be found directly by measurement, but by using a mathematical model of the mass balance. Many similar approaches [2, 4-6] have already been made.

In order to better explain this phenomenon of contamination of the environment by this fossil CO_2, we have targeted the Dakar region as a study area, because this zone is the most populated and most industrialized area in Senegal. Since trees, leaves and short-lived plants assimilate carbon from photosynthetic air, they had better reflect any change in 14C concentration in the atmosphere [7]. For this reason, we selected deciduous and short-lived samples of herbaceous or

woody species collected by botanists from Cheikh Anta Diop University. These samplings took place between 1960 and 2010.

The radiocarbon isotopic ratio $\Delta^{14}C$ and the fossil carbon dioxide CO_2 concentration were determined for each sample. We have used sixteen (16) samples for this study.

After obtaining our results, first for ^{14}C isotopic ratios $\Delta^{14}C$, we made a comparison with ^{14}C isotopic ratios in an "unpolluted" zone (clean zone).

For this purpose, we used measurement data from a station located in the Northern Hemisphere, as well as Senegal, specifically at Mauna Loa in Hawaii, United States.

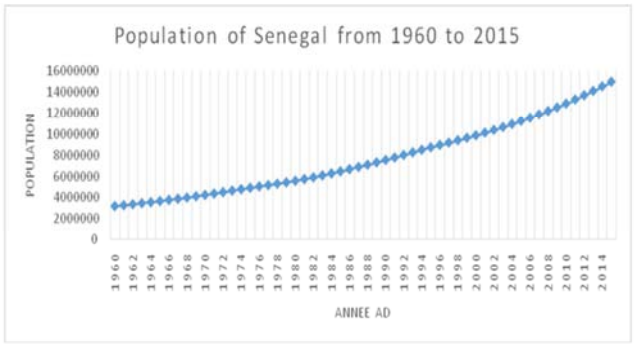

Figure 1. *Population of Senegal from 1960 to 2010 (Word data Bank 2017).*

2. Material and Methods

2.1. Material

Dakar is a peninsula of Cape Verde that covers a very small area of 550km^2 or only 0.3% ([27]) of the total area of Senegal. This region, despite its small size, is almost one quarter (23.2%) of the total national population. According to the general census of population and housing, agriculture and livestock published in 2014, the resident Senegalese population is estimated at 13 508 715 inhabitants in 2013 (ANDS, 2014). The growth rate of the population between 2002 and 2013 in urban and rural areas is estimating at 3.5% and 1.7% respectively. This population was estimated at 10 817 844 inhabitants in 2005 (reference year of the inventory of greenhouse gases in Senegal) of which 4 412 957 are urban and 6 404 887 are rural, representing an urbanization rate of 40%.

Dakar is one of the most industrialized capitals in Africa. It concentrates most of this sector (80% according to data from [8]). We must also add the transport sector, which has reached a number of cars, all kinds of categories combined.

This is why this densely populated, highly industrialized city, with accelerated growth in the land and air transport sector, is highly exposed to several types of pollution, such as particulate matter PM_5 and PM_{10}, VOCs (Volatile Organic Compound), methane CH_4, carbon monoxide CO and carbon dioxide CO_2. Road transport plays a leading role in the country's socio-economic development process. It also provides more than 90% ([9] of the travel needs of people and goods. Even with this high rate, we should note the strong presence of the informal in this sector. Thus, the number of cars of all kinds in Senegal is largely unequal. 73.3% (in 2005) of the national car fleet remain concentrated in Dakar.

The samples sites locations used are showing on this map below.

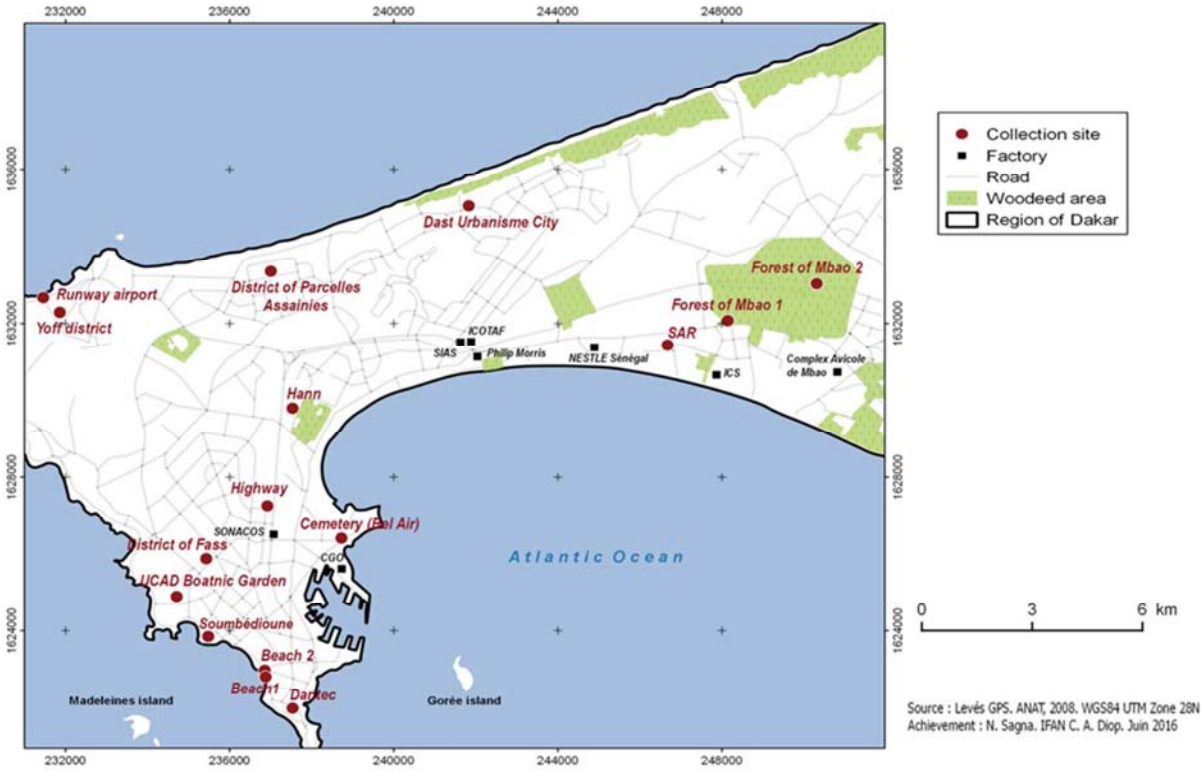

Figure 2. *Map of the Dakar region showing sample collection sites (circles) and industries (squares). [10].*

The sixteen (16) leaf samples used in this study are from ten (10) sites as shown in the table below.

Table 1. *Related information for each type of samples.*

Dakar Sites	Species	Year of collection	Sample code	Code labo	Geographic coordinates
Forest of Mbao 1	*Cyperus Esculentus*	1960	29922	AA92997	14°45N, 17°18′W
	Cyperus Esculentus	2007	FST2	DK44	14°45N, 17°18′W
Forest of Mbao 2	*Crotalaria Retusa*	1966	03414	AA93000	14°46′N, 17°18′W
SAR Factory	*Lactuca Aspera*	1964	53992	AA92999	14°44′N, 17°20′W
	Lactuca Intybacea	2005	FST1	DK43	14°44′N, 17°20′W
Highway	*Indigofera Aspera*	1961	04501	AA92998	14°42′N, 17°26′W
District of Fass	*Terminalia Catapa*	1976	20340	AA933001	14°41′N, 17°27′W
UCAD Boatanic Garden	*Indigifera Costata*	1970	04738	DK39	14°41′N, 17°27′W
	Indigifera Costata	1979	20340	DK40	14°41′N, 17°28′W
	Nérium Oleandee	1990	04664	DK41	14°41′N, 17°30′W
	Nérium Oleander	2000	28114	DK42	14°41′N, 17°32′W
Market Soubédioune	*Ficus Umbellata*	2003	54163	AA9004	14°40′N, 17°27′W
Beach 1	*Indigofera Captica*	1981	04739	AA9002	14°46′N, 17°23′W
Beach 2	*Ipomoca Coptica*	1998	54162	AA9003	14°46′N, 17°23′W
	Ipomoca Coptica	2009	FST3	DK45	14°46′N, 17°23′W
Runway airport	*Pentatropis Spiralis*	2010	FST5	DK46	14°44′N, 17°29′W

2.2. Methods

In general, before any measurement, any organic or mineral sample undergoes a series of physicochemical pretreatments before passing to the last step of counting.

Firstly, for the samples measured at the radiocarbon dating laboratory in Dakar, the 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 concentration of hydrochloric acid solution for about thirty minutes, and then these samples were further washed with sodium hydroxide solution NaOH at 0.1M.

The purpose of this second wash is to ensure that the character of the solution containing the sample is not influenced by acidity or basicity. Then, the samples were washed and dried in a drier with a temperature of about 30 ° C. To prepare the liquid scintillation spectrometry, dry samples were then directly added to the lithium in the synthesis bench reactor and the reaction is triggered from 800 ° C and lasts for us for 04 hours, set with a timer.

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° catalytic reaction. Then the counting is done using the liquid scintillation counter available at Cheikh Anta Diop laboratory.

This penultimate stage before the interpretation of the counting results is a more complex phase and therefore more difficult than the first stages.

Eight (8) herbaceous dry leaf samples (> 10 g per sample) were processed in the ^{14}C laboratory of IFAN Ch. A. Diop using the conventional liquid scintillation counting method.

For radiocarbon measurements, the liquid scintillation counter (Tricarb 3170TR / SL) with a super low-level option was used. 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 [1]. This type of meter is equipped with a SNC (Self Normalization and Calibration) cassette. These samples carry the codes DKxx.

Parts of our samples were measured by mass spectrometry by the NSF-Arizona Physics Laboratory in the United States. These samples carry the codes AA-xx (Arizona AMS).

3. Results and Discussion

The results we obtained are recorded in the table.

Table 2. *$\delta^{13}C$, Fraction of Modern Carbon F and $\Delta^{14}C_{site}$ corresponding samples.*

Year	Sample code	Code Labo	$\delta^{13}C\left(‰\right)$	Fraction of Modern Carbon F	$\Delta^{14}C_{site}\left(‰\right)$
1960	29922	AA92997	-11,8	1,182±0,005	184±5
2007	FST2	DK44	-25	1,052±0,006	60±5
1966	03414	AA93000	-28,2	1,674±0,006	677±6
1964	53992	AA92999	-29,1	1,770±0,008	773±8
2005	FST1	DK43	-25	1,064±0,006	71±5
1961	04501	AA92998	-29,4	1,202±0,005	204±5

Year	Sample code	Code Labo	$\delta^{13}C(‰)$	Fraction of Modern Carbon F	$\Delta^{14}C_{site}(‰)$
1976	20340	AA933001	-26,6	1,337±0,005	342±5
1970	04738	DK39	-25	1,518±0,006	522±6
1979	20340	DK40	-25	1,301±0,005	306±5
1990	04664	DK41	-25	1,181±0,005	187±5
2000	28114	DK42	-25	1,084±0,006	91±5
2003	54163	AA9004	-23,7	1,073±0,005	80±5
1981	04739	AA9002	-25,5	1,272±0,051	277±5
1988	54162	AA9003	-29,8	1,103±0,006	110±6
2009	FST3	DK45	-25	1,041±0,006	48±5
2010	FST5	DK46	-25	1,050±0,006	58±5

The next table show the $\Delta^{14}C_{bg}(‰)$ and $\Delta^{14}C_{site}(‰)$ values for the samples.

Table 3. *$\Delta^{14}C_{bg}$ and $\Delta^{14}C_{site}$ (‰) corresponding for samples.*

Dakar Sites	Species	Year of collection	$\Delta^{14}C_{bg}(‰)$	$\Delta^{14}C_{site}(‰)$
Forest of Mbao 1	*Cyperus Esculentus*	1960	235	184
		2007	60,3	59
Forest of Mbao 2	*Crotalaria Retusa*	1966	735	677
SAR Factory	*Lactuca Aspera*	1964	804	773
	Lactuca Intybacea	2005	77	71
Highway	*Indigofera Aspera*	1961	223	204
District of Fass	*Terminalia Catapa*	1976	387	342
UCAD Boatanic Garden	*Indigifera Costata*	1970	556	522
		1979	326	306
	Nérium Oleander	1990	190	187
		2000	100	91
Market Soubédioune	*Ficus Umbellata*	2003	92	80
Beach 1	*Indigofera Captica*	1981	277	277
Beach 2	*Ipomoca Coptica*	1998	115	110
		2009	57,1	49
Runway airport	*Pentatropis Spiralis*	2010	51,4	58

Through, Table 3, we have plotted the maximum and the minimum values of $\Delta^{14}C_{site}$ ($\Delta^{14}C_{mes}$) respectivement in figure 4 and in figure 5 and the corresponding $\Delta^{14}C_{bg}$.

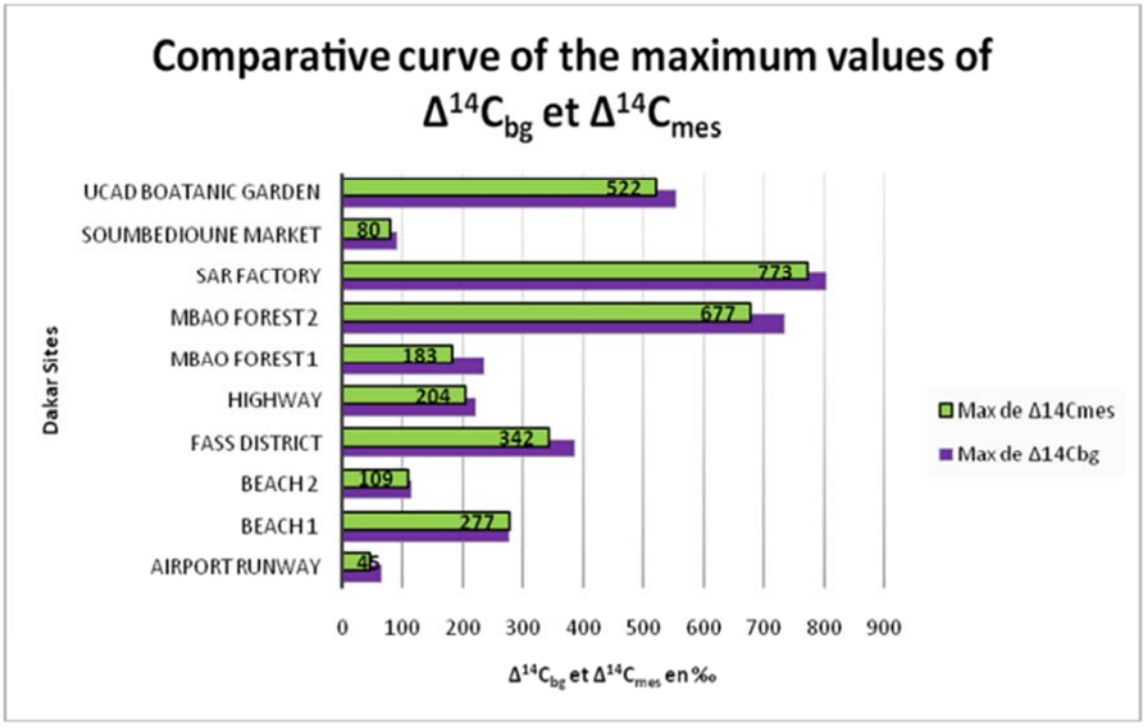

Figure 3. *Comparative curve of the maximum values of $\Delta^{14}C_{bg}$ and $\Delta^{14}C_{mes}$.*

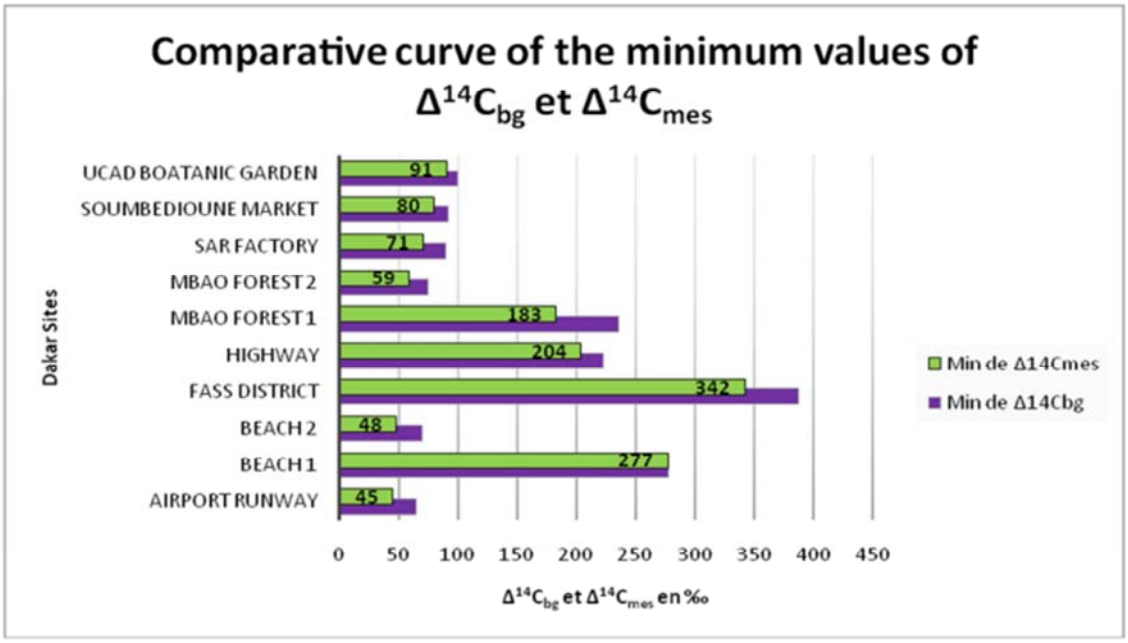

Figure 4. *Comparative curve of the minimum values of $\Delta^{14}C_{bg}$ and $\Delta^{14}C_{mes}$.*

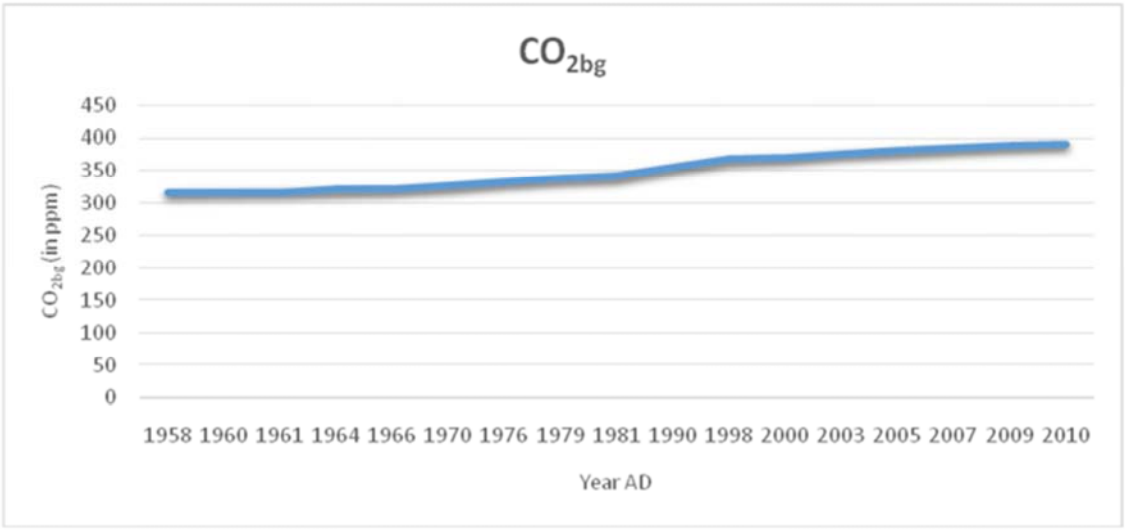

Figure 5. *Concentration of CO_2 in ppm in the troposphere at Mauna Lao (NOAA ESRL data from 07 August 2018).*

The diagrams in Figures 3 and 4 compare the concentration levels $\Delta^{14}C$ of a few sites in the Dakar region with $\Delta^{14}C$ concentrations of supposedly unpolluted areas (Clean Zone).

In the diagram of figure 3, the most important maxima for the sites such as:

The SAR factory ($\Delta^{14}C$ = 773 in 1964 ‰), Mbao Forest 2 ($\Delta^{14}C$ = 677 ‰ in 1966) and UCAD Botanic Garden ($\Delta^{14}C$ = 522 ‰ in 1970).

In the diagram of figure 4, the less important minima are the site such as:

Airport runway ($\Delta^{14}C$ = 45 ‰ in 2010), Beach 2 ($\Delta^{14}C$ = 109 ‰ in 1998 versus 48 ‰ in 2009), SAR Factory ($\Delta^{14}C$ = 71 ‰ in 2005), Soumbedioune Market ($\Delta^{14}C$ = 80 ‰ in 2003) and UCAD Boatanic Garden ($\Delta^{14}C$ = 91 ‰ in 2000).

The two diagrams show that the minima are associated with recent dates, because anthropogenic pollution and the use of fossil fuels. This phenomenon is happening more and more thanks to the urbanization and industrialization of cities with the modern era.

These curves also show that the level of our sites always remains below the level of in supposed unpolluted areas (Clean zone)

This difference is explained by the fact fossil CO_2 emitted into the atmosphere is very poor in 14C and rich in ^{12}C and ^{13}C. This phenomenon is known as the Suess effect.

3.1. Mauna Loa Observations

In Senegal no measure of carbon dioxide CO_2 at the

troposphere level is available yet. [12, 13] (in the site of Mauna Loa) and [14] (in the sites of Schauinsland and Jungfraujoch) have made CO_{2bg} data available to the scientific community for research on the carbon cycle and radiocarbon dating.

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 [12] is in the same hemisphere as Senegal (NH Zone 2). Countries in the same hemisphere have approximately the same level of background CO_2 as shown in the following map [13].

The concentration varies, but weakly (between 300ppm and 350ppm) because this level of the atmosphere that is the troposphere is not affected by the anthropic disturbances. It represents the primary (background) CO_2 content in the atmosphere without local sources, i.e. the level of CO_2 that is homogeneous in the lower atmosphere.

To determine the CO_{2ff} it is first useful to determine the $\Delta^{14}C_{bg}$ of a given level. $\Delta^{14}C_{bg}$ represents the values of carbon isotopic mixing ratios in the free troposphere.

Station Name	Station Code	Latitude	Longitude	Elevation
(Mauna Loa Observatory)	MLO	19,5°N	155,6°N	3397m

3.2. Estimation of the Fossil Fuel CO_2 Component

To evaluate the fossil CO_2 concentration expressed in ppm (Part per Million) we used approaches similar to those of previous studies ([2, 4-6]). The method is based on a study of the isotopic composition of carbon. Among these isotopes, there is carbon 14, which is an excellent tracer ideal for studying these emissions of fossil origin [2, 7-15, 16] and [17, 18-19].

Carbon 14 is a basic element, present in all known forms of life. Solar rays of cosmic and galactic origin generate the natural production of carbon 14. The latter contain protons that react, with the molecules of the air release thermal neutrons [20] having a very high energy.

These neutrons formed in the upper atmosphere collide with the molecules of the air, such as nitrogen and oxygen. They are slowed because of the numerous shocks between neutrons-molecules and reach the thermal energy of gases. It follows reactions with the nuclei of air atoms, present in the atmosphere and the troposphere to give the carbon 14.

The formed radionuclide reacts in turn with the oxygen to form carbon dioxide molecules ($^{12}CO_2$, $^{13}CO_2$ and $^{14}CO_2$).

For anthropogenic carbon dioxide (CO_2), it cannot be directly estimated from radiocarbon measurements but can be quantified using a mathematical model of mass conservation for the global carbon cycle and described by the following equations:

$$CO_{2sites} = CO_{2bg} + CO_{2ff} + CO_{2bio} \quad (1)$$

CO_{2sites}, CO_{2bg}, CO_{2ff} and CO_{2bio} are respectively the concentration of CO_2 in the site, background, fossil and biogenic. They are expressed (ppm)

$$CO_{2sites}\left({}^{14}F_{sites}\right) = CO_{2bg}({}^{14}F_{bg}) + CO_{2ff}({}^{14}F_{ff}) + CO_{2bio}({}^{14}F_{bio}) \quad (2)$$

F_{site}, F_{bg}, F_{ff} and F_{bio} are respectively the modern fractionation of site, background, fossil and biogenic CO_2.

Or using, modern fractionation

$$F = \frac{A_{SN}}{A_{abs}} = \frac{\Delta^{14}C}{1000} + 1 \quad (3)$$

$$CO_{2sites}(\Delta^{14}C_{sites} + 10^3) = CO_{2bg}(\Delta^{14}C_{bg} + 10^3) + CO_{2ff}(\Delta^{14}C_{ff} + 10^3) + CO_{2bio}(\Delta^{14}C_{bio} + 10^3) \quad (4)$$

$\Delta^{14}C_{site}$, $\Delta^{14}C_{bg}$, $\Delta^{14}C_{ff}$ and $\Delta^{14}C_{bio}$ respectively represent the 14C concentration of the site, background, fossil and biogenic.

If we take into account the relationship:

$$\Delta^{14}CO_2 = \left[\frac{\left({}^{14}C/C\right)_{éch}}{\left({}^{14}C/C\right)_{std}} - 1\right] 1000 \quad (5)$$

(according to [21]) and the fact that CO_2 emitted by fossil fuels does not contain 2 (or almost) 14C, then we can write: $\Delta^{14}C_{foss} = -1000‰$?.

Thus, the relation (4) becomes:

$$CO_{2ff} = CO_{2bio}\frac{\left(\Delta^{14}C_{bio} - \Delta^{14}C_{mes}\right)}{\Delta^{14}C_{mes} - \Delta^{14}C_{ff}} + CO_{2bg}\frac{\left(\Delta^{14}C_{bg} - \Delta^{14}C_{mes}\right)}{\Delta^{14}C_{mes} - \Delta^{14}C_{ff}} \quad (6)$$

Taking into account these two following approximations, namely, fossil emissions do not contain ^{14}C and that the ^{14}C biogenic concentration is equal to the ^{14}C concentration in the background because the main flow of the biosphere comes from autotrophic respiration, find the relationship:

$$CO2_{foss} = CO_{2mes}\frac{(\Delta^{14}C_{bg} - \Delta^{14}C_{mes})}{\Delta^{14}C_{bg} + 10^3} \quad (7)$$

The value of $\Delta^{14}C$ (Ratio ^{14}C / C) will be used to estimate the radiocarbon concentration [17, 21-22].

The values of $\Delta^{14}C_{bg}$ and $\Delta 14C_{mes}$ are expressed in per thousand (‰). That is, the value of the result is multiplied by 1000. The values of CO_{2mes} and CO_{2ff} are in parts per million (ppm).

Thus with the help of our measurements and the relation (7) we have calculated the concentration of fossil CO_2 of the sites. The results obtained for our different samples are recorded in the following table:

Table 4. *Sites, year of sample, and fossil CO_2 value of the sites.*

Samples	Year	CO_{2mes}	$\Delta^{14}C_{bg\ (‰)}$	$\Delta^{14}C_{site\ (‰)}$	CO_{2ff} (ppm)
Mbao Forest 1	1960	316,91	235	184	13,3
	2007	383,79	75	60	5,7
Mbao Forest2	1966	321,28	735	677	10,7
SAR Factory	1964	319,62	804	773	5,5
	2005	379,8	90	71	6,6
Highway	1961	317,64	223	204	4,9
District of Fass	1976	332,04	387	342	10,7
UCAD Boatanic Garden	1970	325,68	556	522	7,1
	1979	336,84	326	306	5
	1990	354,39	190	187	12,5
	2000	369,55	100	91	3
Soubédioune Market	2003	375,8	92	80	4,1
Beach1	1981	340,11	277	277	0
Beach2	1998	366,7	115	110	1,9
	2009	387,43	70	49	7,9
Runway Airport	2010	389,9	68	45	8,4

These values allowed us to draw the CO_{2ff} diagram of the site according to the sampling years. We first made a study on the spatial distribution of fossil CO_2.

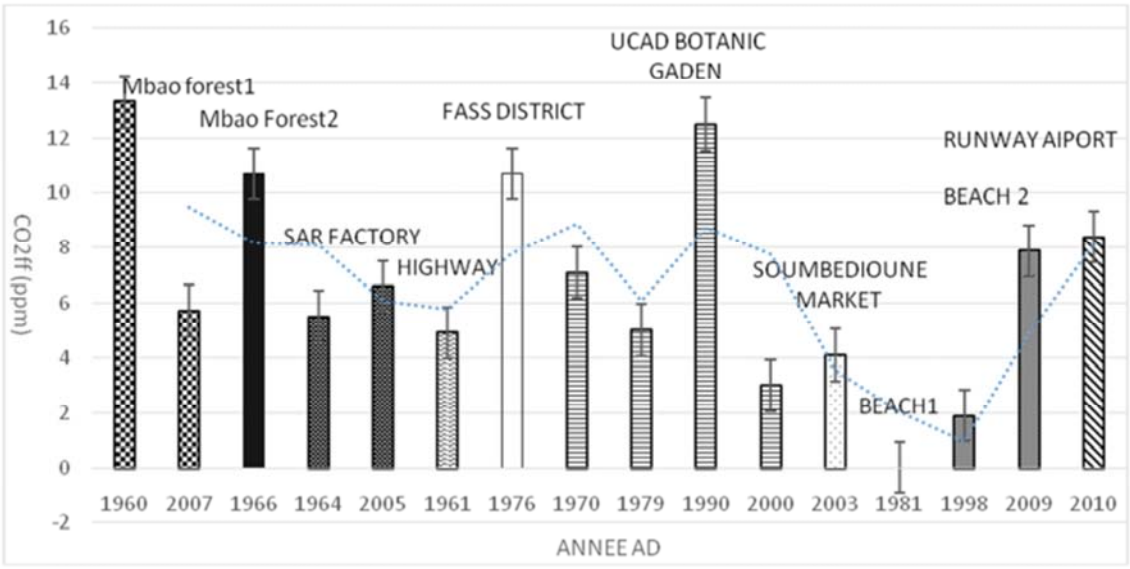

Figure 6. *Values of the fossil component CO_{2ff} (in ppm).*

The ideal for us was to have at least two samples per site for different years to better see the progression of fossil carbon dioxide concentration in the global environment of Dakar. We will focus on it for further studies. Nevertheless, our results can allow us to have an interesting idea on the level and level of progression of fossil CO_2 in Dakar.

There is an overall increase in fossil CO_2 concentration according to the trend curve on the moving average of the CO_{2ff} values of our samples.

This increase is noted in the following sites:

1. At the SAR Factory where the value of the fossil CO_2 concentration is from 5.5ppm in 1964 to 6.6ppm in 2005. This can be explained by the fact that the SAR Factory, which is an oil refining industry, is dumping a huge amount of carbon dioxide into the atmosphere. This is not without consequence on the CO_2 level of the sites that is close to the SAR Factory. In the future, the SAR Factory sites will have a fossil CO_2 that increases over the years.
2. At Beach 2 where the CO_{2ff} value goes from 1.9ppm in 1998 to 7.9ppm in 2009. This site is located at the intersection of the ocean and the western corniche which is a very large highway very frequently used by thousand of cars of all kinds. In addition there is the effect of the ocean which a large carbon reservoir.
3. Then at the Runway Airport with a CO_{2ff} of 8.4% in 2010 and at the level of the Fass District with a CO_{2ff} of 10.7ppm in 1976.

They ranged from 13.3ppm in 1960 to 5.7ppm in 2007, a drop in fossil CO_2 content of -57.1% for the Mbao Forest1. Moreover, for the Mbao Forest 2, we have a fossil CO_2 of 10.7ppm. These values remain high but decrease, instead of increasing, thanks to the Mbao forest, composed of trees, shrubs and plants and which releases biogenic CO_2 into the atmosphere.

Secondly, we made a curve of the variation of the value of

fossil CO_2 according to the years to see its nature of progression. We notice that it increases with time. This is normal because the industrialization and urbanization of the city of Dakar, vector of the development of the combustion of fossil fuels, is increasing day by day. The population of Dakar is growing very fast. Industry, as well as transportation of all kinds, is increasing. The latter remains mined, largely by means of transport used and which reject more CO_2 than new cars. Occasional cars reject more CO_2 than new cars.

On the other hand, in Dakar 72,8% of cars are occasion against 27, 2% formed by new cars [8].

The following table gives the fossil CO_2 values of our sites and fossil CO_2 per inhabitants (Data taken at: [23] depending of the year.

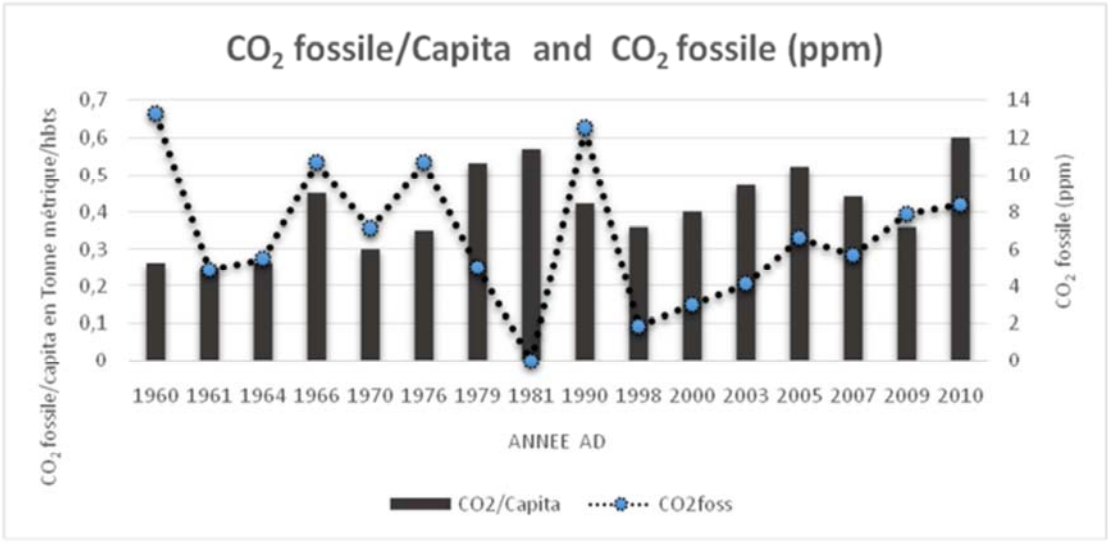

Figure 7. *Values of the fossil component CO_{2ff} (in ppm) and fossil fuel CO2 (in metric tons).*

By analyzing the variations in CO_2 emissions from 1960 to 2010, it can be stated that CO_2 fossil is increasing. In conclusion, we can note a depletion of the content (mixing ratio) of carbon 14 and an increase for CO_2. [6-29] have shown this phenomenon through different studies at different times. Today, this phenomenon is caused, most often, by industrial complexes, the transport sector, the high human density in the cities and other sources based on the consumption of fossil fuel.

4. Conclusion

Our result show that radiocarbon concentration of ^{14}C ($\Delta^{14}C$ or $\Delta^{14}CO_2$ for some authors) of our samples is lower than those of clean areas for the same periods because of the Suess effect. This is most evident in lager agglomerations.

The fossil fuel CO_2 (CO_{2ff}) concentrations found in our samples increases and are consistent with those available at the Word Bank data (datawordbank.org) for Senegal.

In view of our results, compared to the global trend, Dakar is a polluted city and trends related to the exponential growth of the population and its activities require a policy of monitoring and limiting polluting activities.

In perspective, we intend to make a more detailed study by using several sites distributed in time and space in Dakar region again and the other regions of Senegal.

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