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Study of Air Pollution by NOx from Petrol Fuels at Four Stations in Dakar–Senegal by Determining Nitrogen Content

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

NO_X emissions are a health hazard, and are increasingly regulated in cars. NOx also contributes to the formation of acid rain and the eutrophication of ecosystems. Nitrogen oxides are a family of molecules including nitrogen monoxide (NO) and nitrogen dioxide (NO_2). These gases are formed

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in the engine during high-temperature fuel combustion, and play a role in the formation of fine particles in ambient air. In this article, the aim is to determine the nitrogen content of gasoline samples taken at four gasoline stations of the most representative groups in terms of distribution of light petroleum products in order to assess the environmental impact due to greenhouse gas emissions resulting from the use of gasoline by vehicles and to reduce the nitrogen content in the form of nitrogen oxides NOx. After an introduction, we presented the material and the method used, followed by the results of our analyses and a discussion of the results obtained before concluding.

Keywords: Content; nitrogen; nitrogen oxide (NOx); energy; gasoline; station.

1. INTRODUCTION

Crude oil contains nitrogenous hydrocarbons in basic (quinoline, isoquinoline, pyridine) or neutral forms. These compounds may be malodorous or have a pleasant odor. It decomposes under the action of heat to give organic bases or ammonia, which reduce the acidity of catalysts in transformation units [1-3]. Nitrogen, odorless, colorless and tasteless, is a greenhouse gas and contributes to the depletion of the stratospheric ozone layer. It contributes to the eutrophication of terrestrial and aquatic environments, i.e., to their imbalance. Nitrogen is neither flammable, toxic nor irritating.

Industrial development, leading to a proliferation of gasoline-powered vehicles, encourages the use of gasoline containing impurities such as sulphur, nitrogen and metals, among others, whose sulphur and nitrogen content remain important parameters.

NOx, also known as nitrogen oxides, are pollutant gases emitted mainly by combustion engine vehicles, and are very harmful to the respiratory system. NOX contribute to the acidification and eutrophication of the environment. These emissions disrupt the composition of air, surface water and soil. They also indirectly reinforce the greenhouse effect [4-6].

At a time when environmental sciences and the concept of sustainable development are becoming important benchmarks in our societies, it seems necessary to have the means to combat pollution. Nitrogen pollution of hydrocarbons represents a major public health risk, due to the various pathologies that can be caused by this element. In this study, we focus on the quality of gasoline in Senegal, by checking nitrogen levels.

2. MATERIALS AND METHODS

2.1 Determination of Nitrogen Content

The operating principle for nitrogen analysis begins with the complete high-temperature oxidation of the entire sample matrix illustrated in equation (1). The sample is burnt with oxygen at a temperature of 1050ºC. Oxidation products include CO_2, H_2O, NO, SO_2 and various other oxides (designated MOX below) [5-9]. Flue gases are passed through a membrane drying system to remove all water, then to the nitrogen detector module for quantification (MultiTek® Analysis of Sulfur in Diesel Engine Fuel and by Ultraviolet Fluorescence (1)).

$$\mathbf{R\text{-}N + R\text{-}S + O_2 \rightarrow CO_2 + H_2O + NO + SO_2 + MO_X} \quad (1)$$

Nitrogen calibration standards are analyzed to produce calibration curves. When samples of unknown nitrogen content are analyzed, the Elements software compares the raw sample data with the calibration curve to generate and report nitrogen concentrations.

In equation (2), NO reacts with O_3 (ozone), produced by an on-board ozone generator, to form NO2* [9-13]. (excited nitrogen dioxide). As the metastable species decays, a photon of light is emitted at specific wavelengths and detected by a photomultiplier tube (PMT). This chemiluminescence emission is specific to nitrogen and is proportional to the amount of nitrogen in the original sample. Only chemically bound nitrogen is detected, diatomic atmospheric nitrogen (N_2) is not.

$$\mathbf{NO + O_3 \rightarrow NO_2^* + O_2 \rightarrow NO_2 + hv + O_2} \quad (2)$$

2.2 Choice of Samples

We chose four gas stations in Dakar corresponding to the most representative groups

Image 1. ANTEK nitrogen analyzer

in gasoline distribution in Senegal to determine nitrogen content. These sampling points are confidentially: Sample A from station A, Sample B from station B, Sample C from station C and Sample D from station D.

These petrol stations are the most appropriate sampling points because they are the most frequented by users. The environmental study is more interesting given the large number of vehicles. The majority of vehicle users buy petrol at these stations, particularly in Dakar. These petrol stations belong to the largest fuel distribution groups in Senegal.

2.3 Sulfur and Nitrogen Analyzer Reader Called Elements

The ANTEK nitrogen analyzer was used (MultiTek® Analysis of Sulfur in Diesel Engine Fuel and by Ultraviolet Fluorescence). The carrier gas used for flow control is helium. In our case, the gas is helium (He), a rare, inert gas. Furnace temperatures range from 950 to 1050°C.

The instrument has two detection channels for determining the sulfur or nitrogen content of the gasoline sample being analyzed. Detection takes place over the same time period. For calibration, the blank is used between 0 and 50 ppm, and the name of the measurement method is NAPHTA G201 0-300 ppm.

The two detections are carried out simultaneously for an identical time equal to 2 minutes 30 seconds for each of the elements - sulfur and nitrogen - whose content we want to determine. During the reading or detection phase, the device waits for the signal to drop before reading the value of the mass concentration expressed in mg/L, represented by the number of counts.

The unit takes five readings and averages them for each of the four gasoline samples taken for nitrogen determination.

3. RESULTS

3.1 Determination of Nitrogen Content of Samples

Measurements of nitrogen content taken by the instrument are mass concentrations, expressed in mg/L ; the instrument then converts to mg/kg or ppm using density.

$$C\ (ppm) = \frac{C(\frac{mg}{l})}{\rho(\frac{kg}{l})} \quad (3)$$

Each signal gives a certain number of strokes, which determines the nitrogen concentration according to the detection channel contained in the gasoline. The excitation of the signal generates the number of strokes.

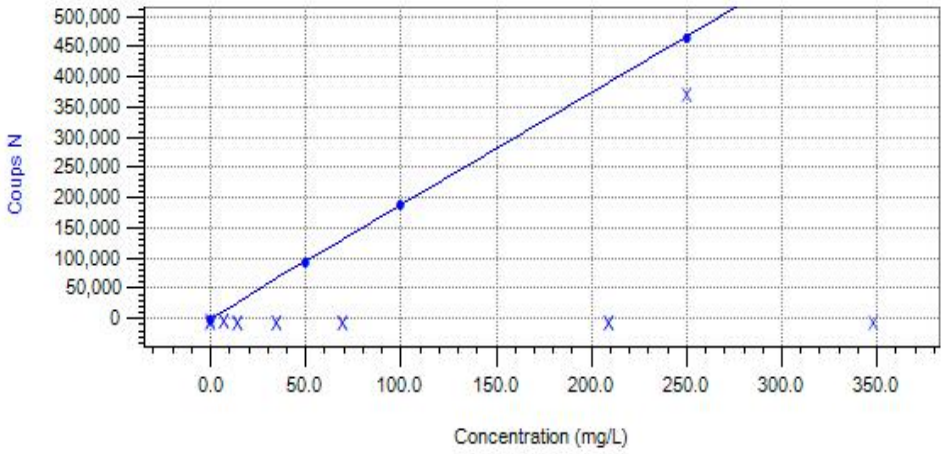


Fig. 1. Calibration curve

3.2 Results of Four Samples Nitrogen Content Measurements

3.2.1 Sample A: density 0.7400 kg/L

For sample A, whose measurements are recorded in Table 1, we find the mass concentration C (ppm) in nitrogen = 46,921 / 0,740 = 63,407 mg/kg.

The instrument indicates Min for nitrogen content, meaning that we are close to the minimum threshold of the range.

The results show (Table 2) that all five measurements obtained for the nitrogen content of gasoline sample A are below the concentration because the instrument displays MIN for the calibration range; gasoline sample A, with an average nitrogen content of 63,407 ppm, does not meet the standard set at 60 ppm.

There is a risk of pollution with the formation of NOx nitrogen oxides, which can create five key threats from nitrogen pollution: water quality, air quality, greenhouse gas balance, ecosystems and biodiversity [1-4].

Fig. 2 consists of three parts:

- The latency phase lasts approximately 2 minutes 30 seconds.
- The reading or detection phase lasts approximately 70 seconds.
- The post-reading phase lasts 60 seconds.

The higher the signal, the higher the nitrogen content. For nitrogen content, from Table 1, the average number of strokes for sample A is 89009. Fig. 1 shows that it is between 80000 and 100000.

3.2.2 Sample B: density 0.7540 kg/L

For sample B, whose measurements are given in Table 3, we find the mass concentration C (ppm) in nitrogen = 2,032/ 0,7540 = 2,695 mg/kg. The instrument mentions OK for nitrogen content, which means we're within range.

The results in Table 4 show that all five measurements obtained for the nitrogen content of gasoline sample B are within the selected range.

For nitrogen content, from Table 3, the average number of hits for sample B is 5094 . It ranges from 0 to 50000 according to Fig. 1. The mean value for the mass concentration of sample B is approximately 2,032 mg/L, as shown graphically in Fig. 1.

Table 1. Average nitrogen content of sample A

Elements	Hits	Concentration (mg/L)	Concentration mass (mg/kg)	Standard deviation (%)	Calibration range
Nitrogen	89 009	46,921	63,407	2,4	Min

Table 2. Injection details and results of the five measurements on sample A

Injection number	Hits N	Surface signal N	Conc N (mg/L)	Conc. N mass (mg/kg)	Calibration range N
1	85 600	10 698,81	45,106	60,955	Min
2	89 050	10 665,96	46,941	63,434	Min
3	88 900	10 618,53	46,864	63,330	Min
4	90 530	10 611,84	47,733	64,505	Min
5	90 950	10 624,39	47,960	64,810	Min

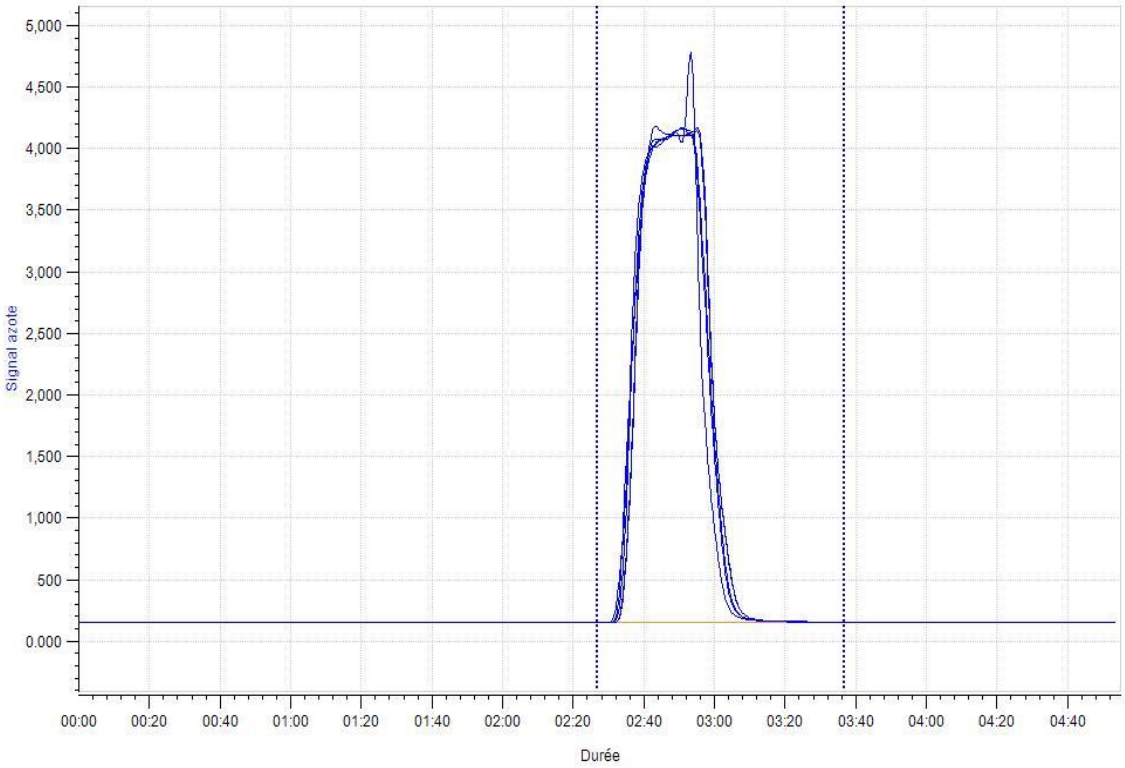


Fig. 2. Nitrogen content of sample A

Table 3. Average nitrogen content of sample B

Elements	Hits	Concentration (mg/L)	Concentration mass (mg/kg)	Standard deviation (%)	Calibration range
Nitrogen	5 094	2,032	2,695	0,9	OK

Table 4. Details of injection and results of five measurements of sample B

Injection number	Hits N	Surface signal N	Conc N (mg/L)	Conc. N mass (mg/kg)	Calibration range N
1	5 691	10 586,66	2,351	3,118	OK
2	5 130	10 505,50	2,051	2,721	OK
3	5 137	10 492,68	2,055	2,725	OK
4	5 044	10 503,38	2,005	2,659	OK
5	5 064	10 473,91	2,016	2,673	OK

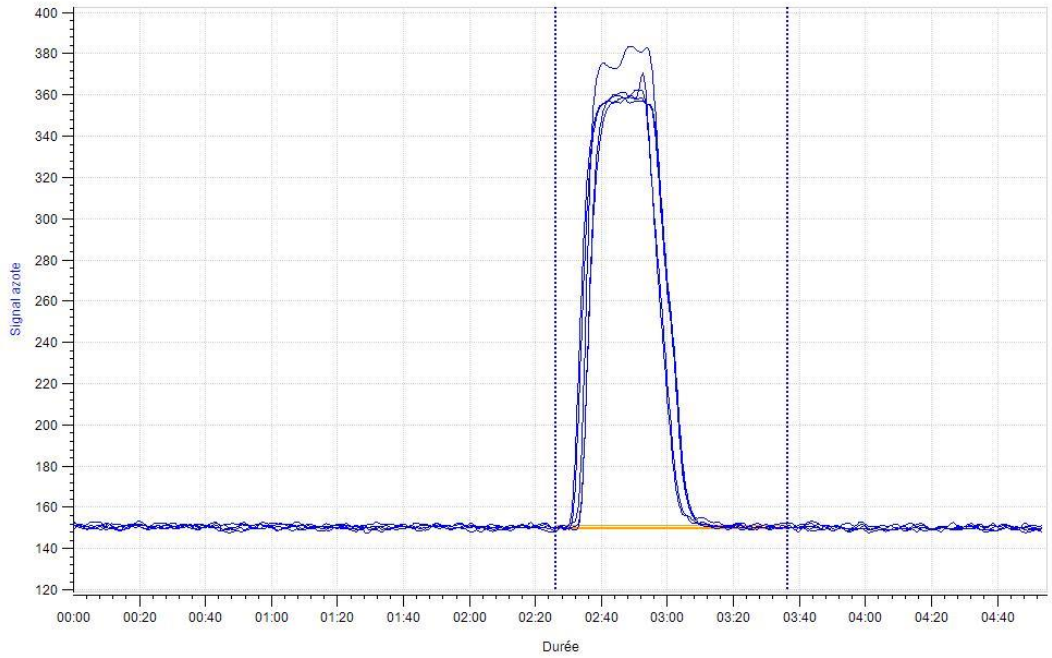


Fig. 3. Nitrogen content of sample B

3.2.3 Sample C: density 0.7520 kg/L

For this sample C, the results of which are given in Table 5, we find the average mass concentration C (ppm) of nitrogen = 14,459/ 0,7520 = 19,227 mg/kg. The instrument indicates Min for the nitrogen content of the gasoline sample C . This means that we are close to the minimum threshold value of the range.

Les résultats du tableau 6 montrent que les cinq mesures obtenues pour la teneur en azote de l'échantillon d'essence C sont proches de la valeur du seuil minimal de la gamme car l'appareil affiche MIN. L'échantillon d'essence C dont la teneur moyenne en azote est de 19,227 mg/kg ou ppm respecte la norme fixée à 60 ppm. Il y a peu de risque de pollution avec la formation des oxydes d'azote NOx pouvant créer cinq menaces clés de la pollution par l'azote qui sont la qualité de l'eau, la qualité de l'air, le bilan gaz à effet de serre, les écosystèmes et la biodiversité.

From Table 5, for the nitrogen content of sample C, the average number of strokes is 28,325. Fig. 1 shows that it ranges from 0 to 50,000.

Table 5. Average nitrogen content of sample C

Elements	Hits	Concentration (mg/L)	Concentration mass (mg/kg)	Standard deviation (%)	Calibration range
Nitrogen	28 325	14,459	19,227	0,2	Min

Table 6: Injection details and results of five measurements on sample C

Injection number	Hits N	Surface signal N	Conc N (mg/L)	Conc. N mass (mg/kg)	Calibration range N
1	28 400	10 156,16	14,499	19,281	Min
2	28 221	10 152,30	14,403	19,153	Min
3	28 353	10 148,95	14,474	19,247	Min
4	28 310	10 144,42	14,451	19,217	Min
5	28 342	10 126,00	14,468	19,239	Min

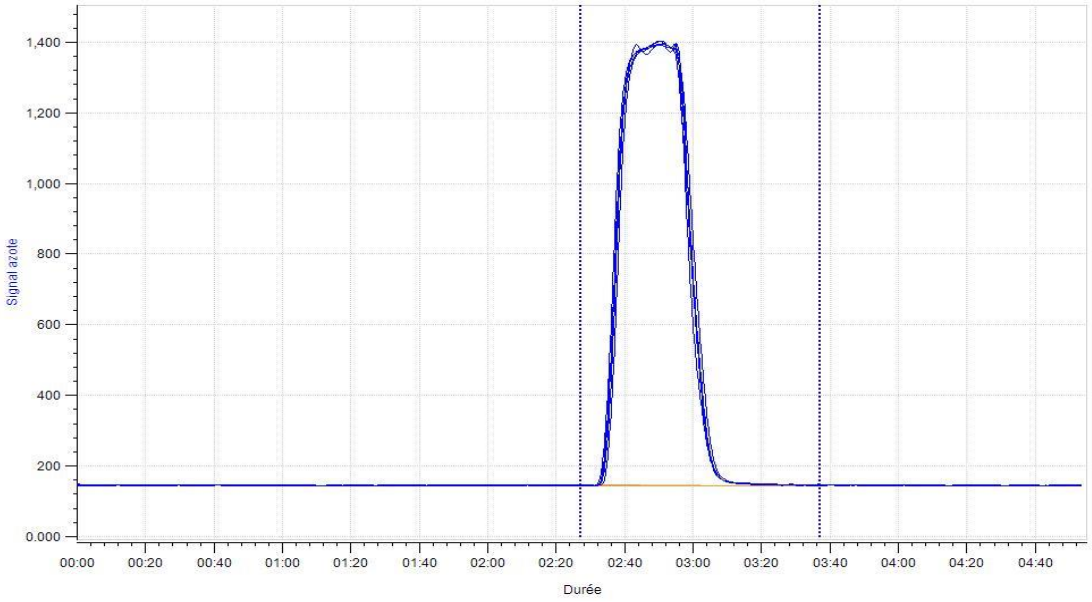


Fig. 4. Nitrogen content of sample C

Table 7. Average sulfur and nitrogen content of sample D

Elements	Hits	Concentration (mg/L)	Concentration mass (mg/kg)	Standard deviation (%)	Calibration range
Nitrogen	27 343	13,934	18,880	1,3	Min

Table 8. Details of injection and results of five measurements of sample D

Injection number	Hits N	Surface signal N	Conc N (mg/L)	Conc. N mass (mg/kg)	Calibration range N
1	26 957	10 143,63	13,727	18,601	Min
2	26 978	10 182,42	13,739	18,616	Min
3	27 524	10 223,15	14,031	19,012	Min
4	27 629	10 312,22	14,087	19,088	Min
5	27 625	10 364,96	14,085	19,085	Min

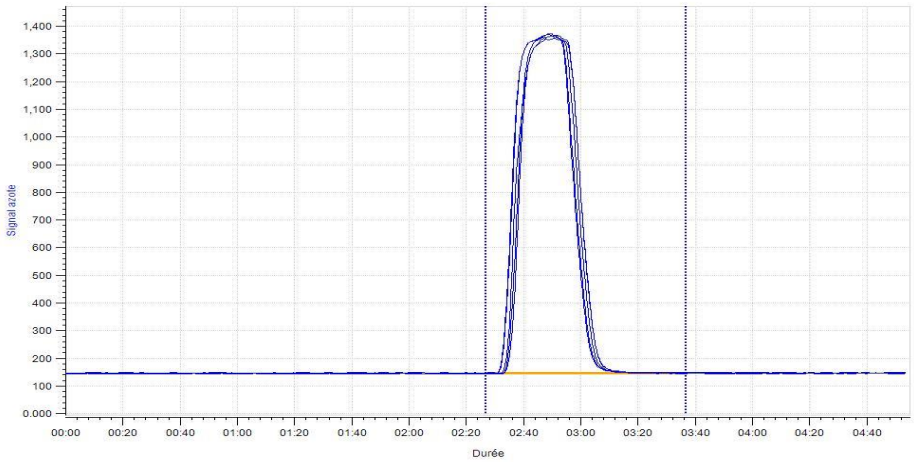


Fig. 5. Nitrogen content of sample D

3.2.4 Sample D: density 0.7380 kg/L

For sample D, the results of which are recorded in Table 7, we find the nitrogen concentration C (ppm) = 13,934/ 0,7380 = 18,880 mg/kg; this is in line with the value given by the instrument recorded in Table 7. The instrument indicates Min for nitrogen content, meaning that we are below the range.

The results confined in Table 8 show that the five measurements obtained for the nitrogen content of petrol sample D are not within the chosen range because the instrument indicates MIN for the calibration range. This means that we are close to the minimum threshold value of the range. Gasoline sample D, with an average nitrogen content of 18,880 ppm, complies with the 60 ppm standard. The risk of pollution with the formation of nitrogen oxides NOx is low for creating five key threats of nitrogen pollution which are water quality, air quality, greenhouse gas balance, ecosystems and biodiversity.

The number of strokes is 27,343, and in Fig. 1 it ranges from 0 to 50 000. In Fig. 1, the mass concentration is approximately 13,934.

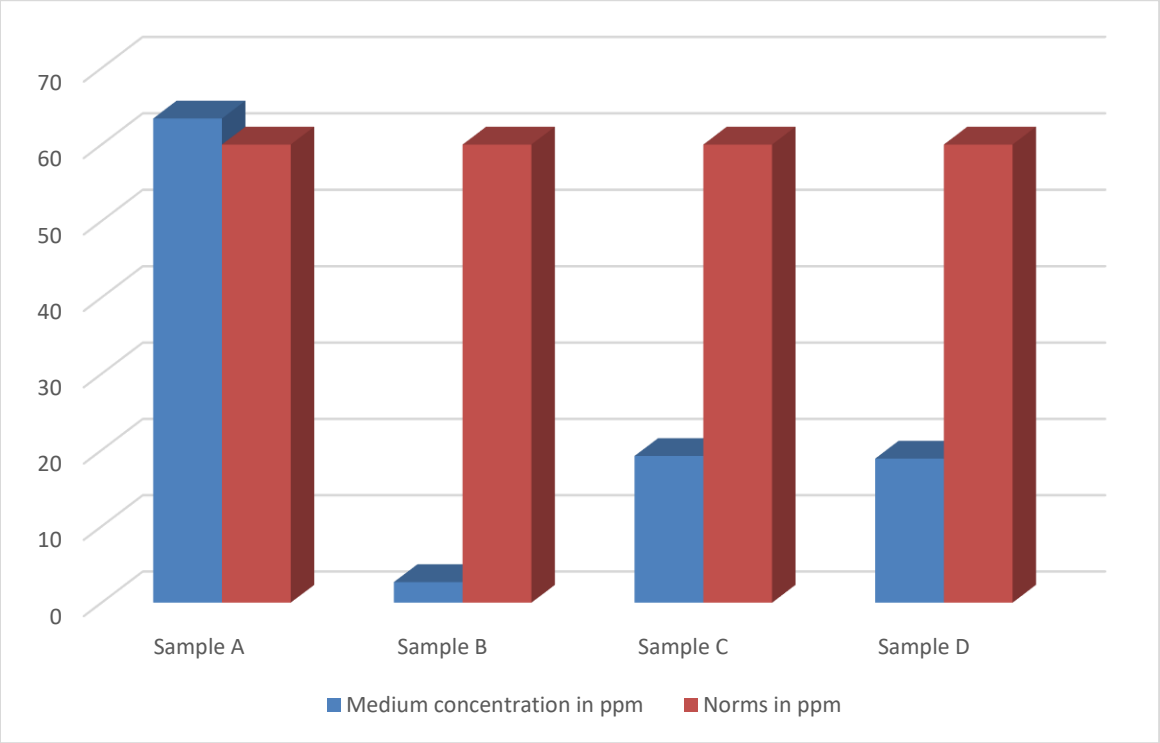
4. DISCUSSION

The results of the average nitrogen contents of the four confined samples in Table 9 show that station B has the best gasoline quality, followed respectively by station D and C with nitrogen contents below the standard set at 60 ppm. Sample A's nitrogen content of 63.407 ppm slightly exceeds the 60 ppm standard.

The wisest choice is to refuel at petrol stations B, D and C to preserve the condition of the various vehicle equipment and reduce NOx pollution.

Table 9. Summary of average nitrogen measurements for the four samples

Measures	Sample A	Sample B	Sample C	Sample D
Medium concentration in ppm	63,407	2,695	19,227	18,880
Norms in ppm	60	60	60	60



Graph 1. Average sample concentrations relative to standards

The mean value of the mass concentration of nitrogen in sample A is approximately 46.921 mg/L, which is shown graphically in Fig. 1. In Fig. 2, a peak is noted which exceeds the mean signal, and is explained by sources of contamination due to the presence of additives, previously analyzed samples, the same sample following repeated injections, reagents, standards and other elements with impurities.

Gasoline sample B, with an average nitrogen content of 2.695 ppm, complies with the 60 ppm standard. The risk of pollution with the formation of nitrogen oxides NOx is too low to create five key threats of nitrogen pollution which are water quality, air quality, greenhouse gas balance, ecosystems and biodiversity.

For sample C, the number of counts is 28,325, ranging from 0 to 50,000, and the mean value of the nitrogen mass concentration of the five measurements carried out for sample C is approximately 14.459 mg/L, as shown graphically in Fig. 1. In Fig. 4, there are no peaks above the mean signal, which explains the absence of sources of contamination.

From Table 7, we obtain a mass concentration value of 13.934 mg/L. For sample D, in Fig. 5, there are no peaks above the signal mean, due to the absence of contamination sources.

5. CONCLUSION

We have carried out several measurements of nitrogen concentration determinations on samples from four service stations of the four major fuel distributors in Senegal. This work enabled us to qualitatively verify the levels of possible NOx pollution from cars, in order to alert producers and decision-makers to the quality of the hydrocarbons distributed in Senegal. In view of the results obtained and the urgent need to improve the quality of hydrocarbons to combat NOx and SOx pollution, our research prospects include determining the sulfur content of distributed fuels.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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