

## DETERMINATION OF THE SULFUR CONTENT OF GASOLINE FROM FOUR MAJOR FUEL DISTRIBUTORS IN DAKAR

### Abstract

Sulphur dioxide (SO<sub>x</sub>) emissions are closely linked to the use of fuels containing sulphur, and the maximum permitted sulphur content is one of the most closely monitored fuel parameters. In this article, we determined the sulfur content of gasoline samples taken from four gasoline stations in the most representative groups in terms of distribution of light petroleum products. The aim is to assess the environmental impact of sulfur dioxide emissions resulting from the use of gasoline by vehicles, and to reduce the sulfur content upstream.

**Key words:** sulfur, SO<sub>x</sub>, energy, gasoline, station

### I. Introduction

Industrial development, leading to a proliferation of gasoline-powered vehicles, is encouraging the use of gasoline containing impurities such as sulfur and metals, of which sulfur content remains an important parameter.

Sulfur oxide emissions are known to have adverse effects on vegetation, forests and agricultural crops. Sulfur dioxide emissions can also affect building stone and ferrous and non-ferrous metals. Sulfurous acid, produced by the hydration of sulfur dioxide, is harmful because it accelerates the corrosion of iron, steel and zinc, reducing the strength and longevity of certain structures. SO<sub>x</sub> can also concentrate near ground level, causing smog. Humans can be exposed to SO<sub>x</sub> by breathing, drinking or eating the substance, as well as through skin contact. The adverse health effects of SO<sub>x</sub>, as with most air pollutants, depend on factors such as the duration and quantity of exposure[1-4]. The impact of sulfur dioxide is harmful to health, as it causes irritation of the nose and throat. Exposure to high levels can cause nausea, vomiting, stomach pains and corrosive damage to the respiratory tract and lungs, with long-term inhalation exposure leading to chronic respiratory difficulties. SO<sub>x</sub> also contribute to the formation of particulate matter (PM) pollution by reacting with other compounds in the air. The elderly, children and people with pre-existing respiratory disorders such as asthma are particularly vulnerable to the effects of SO<sub>x</sub> exposure [4-8].

Sulfur pollution of hydrocarbons represents a major public health risk due to the various pathologies that can be caused by this element. As part of this study, we are interested in studying the quality of gasoline in Senegal by checking the sulfur content of four major fuel distributors.

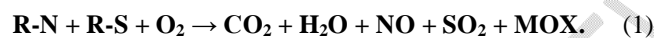
**Comment [a1]:** Incorporate into the abstract of the article all methodologically recommended elements for the presentation of a text of this nature. The abstract should encompass the justification of the study, the raised issue with appropriate evidence, the methodology and procedures adopted, criteria for sample selection, findings, and study recommendations

**Comment [a2]:** For better contextualization and to enhance the study's relevance, we recommend providing an overview of the gasoline distribution market at the study location, including the origin of the gasoline sold, storage conditions, and distribution mechanisms. Additionally, it would be beneficial to discuss the quality standards established, either technically or legally, for gasoline consumption, and to present evidence of the problem regarding the poor sulfur content in the distributed gasoline.

## II. Materials and methods

### II.1 Determination of sulfur content

The operating principle for sulfur 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 1050°C. Oxidation products include CO<sub>2</sub>, H<sub>2</sub>O, NO, SO<sub>2</sub> and various other oxides (designated MOX below). Flue gases are passed through a membrane drying system to remove all water, then to the sulfur detector module for quantification. [8-10].



Sulfur calibration standards were analyzed to produce calibration curves. When samples of unknown sulfur content are analyzed, the ElemeNtS software compares the raw sample data with the calibration curve to generate and report sulfur concentrations.

The SO<sub>2</sub> contained in the flue gases is exposed to ultraviolet radiation of a specific wavelength, as shown in equation (2). This radiation is re-emitted in the form of sulfur fluorescence. This fluorescence is detected by a photomultiplier tube (PMT) and is proportional to the amount of sulfur in the original sample [10-12].



### II.2 Selection of samples

We chose four gas stations in Dakar corresponding to the most representative groups in gasoline distribution in Senegal to determine sulfur content. These sampling points are confidential Dakar gas stations: 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.

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### II.3. Sulfur and nitrogen analyzer reader called ElemeNtS

The carrier gas used for flow control is helium. In this study, the gas is helium (He), a rare, inert gas (figure 1).

**Comment [a3]:** The indication of this value depends on the analysis technique. What is it based on? Let me rephrase the sentence to provide a more specific context.

**Comment [a4]:** ChatGPT  
It is necessary to present, even if fictitiously, the sampling conditions (collection and preservation for testing, time, quantity, etc.), as they directly influence the quality outcome to be analyzed.



**Figure 1.** ANTEK sulfur analyzer called ElemeNTS

Oven temperatures range from 950 to 1050°C, and calibration is performed using a blank between 0 and 50 ppm. The instrument has two detection channels for determining the sulfur content of the gasoline sample to be analyzed. Detection takes place over the same time period.

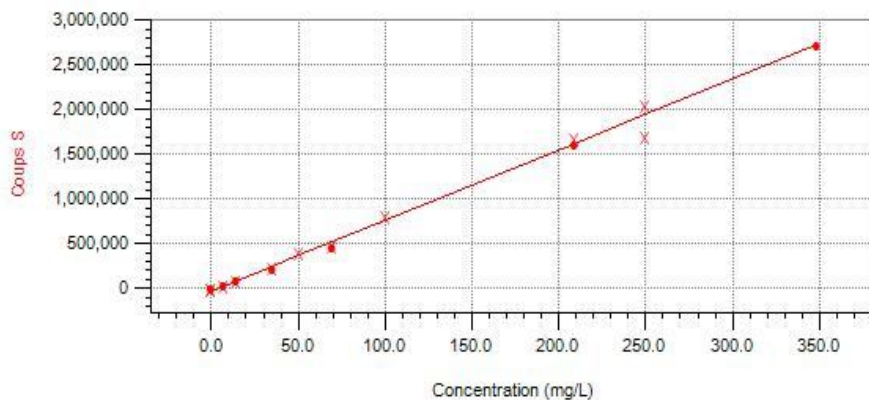
### III. Results and discussion

#### III.1 Results

##### III.1.2. Determination of sulfur content in samples

During the reading or detection phase, the device waits for the signal to drop before reading the mass concentration value 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 to determine sulfur content. The sulfur content measurements taken by the unit are mass concentrations, expressed in mg/L; the unit then converts to mg/kg (ppm) using density.

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



**Comment [a5]:** We suggest providing a rationale for the number of samples, as they may not appear to be significant enough to justify a study of this nature. Gasoline is a product obtained in refineries under predetermined operational conditions to meet consumption specifications. However, its daily logistics for distribution points, involving storage, transportation, and actions affecting its daily preservation, can introduce various factors influencing its properties based on production time, storage duration, and gasoline type (whether it's additive or not). Hence, a justification regarding this sampling element for testing is necessary.

**Figure 2.** Calibration curve

The measurement method is called NAPHTA G201 0-300 ppm. Each signal gives a certain number of strokes to determine the sulfur concentration according to the detection channel contained in the gasoline. The excitation of the signal generates the number of hits

### II.1.2. Results of sulphur content measurements on samples

#### Sample A: density 0,7400 kg/L

**Table 1:** Average sulfur content of sample A

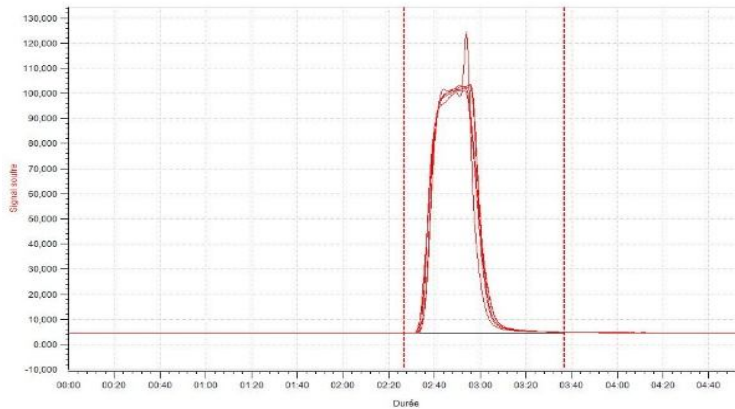
Eléments	Hits	Concentration in mg/L	Concentration in ppm	Standard deviation(%)	Calibration range
Sulfur	2140887	274,450	370,878	2,7	OK

For this sample A, the concentration of sulphur in ppm is  $274,450 / 0,740 = 370,878$  mg/kg or ppm, which is in line with the value given by the instrument. The instrument displays OK for the calibration range for the measurement of sulphur content in gasoline sample A, indicating that we are within the correct range.

**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	2045871	317735,83	262,430	354,635	OK
2	2132710	319326,46	273,415	369,480	OK
3	2152142	319861,49	275,873	372,802	OK
4	2182504	320398,53	279,714	377,992	OK
5	2191207	320899,48	280,815	379,480	OK

The results show that all five measurements obtained for the sulfur content of gasoline sample A are within the selected range, because the instrument displays OK for the calibration range.



**Figure 3.**Sulfur content of sample A

This curve is made up of three parts, the latency phase lasting approx. 2 minutes 30 seconds, the reading or detection phase lasting approx. 70 seconds, and the post-reading phase lasting approx. 60 seconds. The higher the signal, the higher the sulfur content.

**Sample B: density 0,7540 kg/L**

**Table 3:** Average sulfur content of sample B

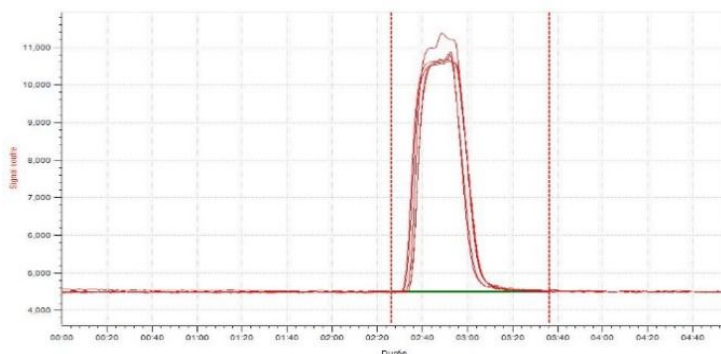
Eléments	Hits	Concentration in mg/L	Concentration in ppm	Standard deviation(%)	Calibration range
Sulfur	5123	2,095	2,77	0,7	OK

For this sample B, the concentration of sulphur in ppm is  $2,095 / 0,7540 = 2,77$  mg/kg or ppm, which is in line with the value given by the instrument. The instrument displays OK for the calibration range for the measurement of sulphur content in petrol sample B, showing that we are within the correct range.

**Tableau 4 :**Injection details and results of the five measurements on sample B

Injection number	Hits N	Surface signal N	Conc N (mg/L)	Conc. N mass (mg/kg)	Calibration range N
1	5691	10586,66	2,351	3,118	OK
2	5130	10505,50	2,051	2,721	OK
3	5137	10492,68	2,055	2,725	OK
4	5044	10503,38	2,005	2,659	OK
5	5064	10473,91	2,016	2,673	OK

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



**Figure 4.**Sulfur content of sample B

From Table 3, for the sulfur content of sample B, the number of strokes is 141199 and ranges from 1000000 to 1500000.

**Sample C: density 0,7520 kg/L**

**Table 5:** Average sulfur content of sample C

Eléments	Hits	Concentration in mg/L	Concentration in ppm	Standard deviation (%)	Calibration range
Soufre :	833451	109,060	145,026	0,8	OK

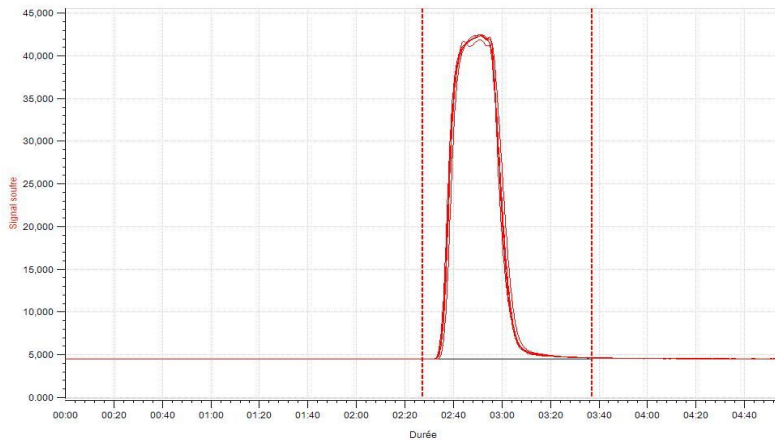
For this sample C, the concentration of sulfur in ppm is  $109,060 / 0,7520 = 145,026$  mg/kg or ppm; this is in line with the value given by the instrument. The instrument displays OK for the calibration range for the measurement of the sulfur content of gasoline sample C; this shows that we are within the correct interval.

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

Injection number	Hits N	Surface signal N	Conc (mg/L)	N	Conc. N (mg/kg)	mass	Calibration range N
1	823171	315894,42	107,759		143,297		OK
2	831380	316759,74	108,798		144,678		OK
3	834925	316720,15	109,246		145,274		OK
4	838180	317057,93	109,658		145,822		OK

5	839597	317036,35	109,837	146,060	OK
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The results show that all five measurements obtained for the sulfur content of gasoline sample C are within the selected range.



**Figure 5.**Sulfur content of sample C

From Table 1, for the sulfur content of sample C, the number of strokes is 833451 and ranges from 500000 to 1000000.

**Sample D: density 0,7380 kg/L**

**Table 7:** Average sulphur and nitrogen content of sample D

Eléments	Hits	Concentration in mg/L	Concentration in ppm	Standard deviation (%)	Calibration range
Sulfur	811084	106,230	143,943	1,1	OK

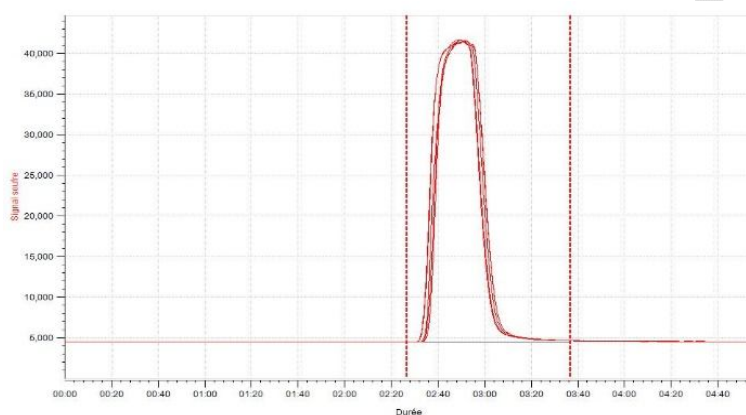
For this sample D, the sulfur concentration in ppm is  $106,230 / 0,7380 = 143,943$  mg/kg or ppm, which is in line with the value given by the instrument. The instrument displays OK for the calibration range for the sulphur content measurement of gasoline sample D, indicating that the calibration range is correct.

**Table 8:** Injection details and results of the five measurements on sample D

Injection number	Hits N	Surface signal N	Conc (mg/L)	N	Conc. N (mg/kg)	mass	Calibration range N
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1	802276	316748,38	105,116	142,434	OK
2	800110	317101,73	104,842	142,062	OK
3	814787	316904,27	106,699	144,578	OK
4	818767	316746,92	107,202	145,260	OK
5	819479	316824,71	107,292	145,382	OK

The results show that the five measurements obtained for the sulfur content of gasoline sample D are within the selected range.



**Figure 6.**Sulfur content of sample D

From Table 7, for the sulfur content of sample D, the number of strokes is 811084 and ranges from 500000 to 1000000.

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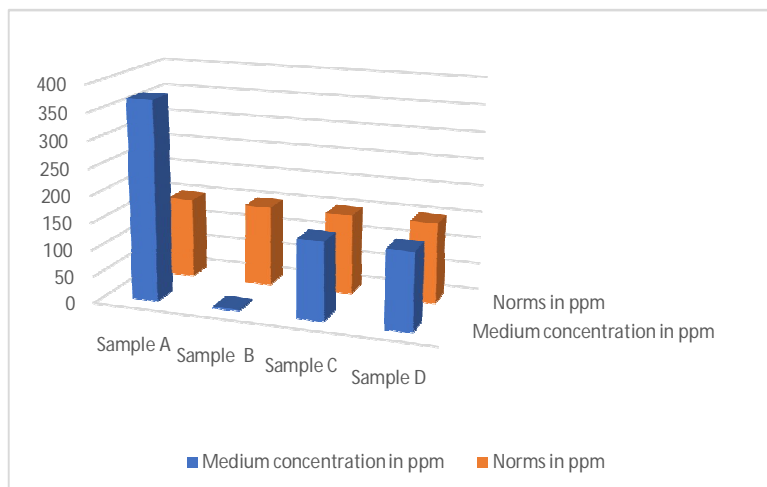
### III.2 Discussion

The results of the average sulfur content of the four samples shown in Table 9 show that station B has the best gasoline quality, followed by stations D and C respectively, with sulfur contents below the standard set at 150 ppm (European Directive 98/70/EC). The wisest choice is to refuel at petrol stations B, D and C, in order to preserve the condition of the various vehicle equipment and reduce SOx pollution.

**Table 9:** Summary of average sulfur measurements for the four samples

Measures	Sample A	Sample B	Sample C	Sample D
Medium concentration in ppm	370,878	2,778	145,026	143,943
Norms in ppm	150			

**Comment [a6]:** The treatment of experimental data does not align with the standards expected for a work of the magnitude of a scientific article. I suggest employing methods for the analysis of experimental data, such as ANOVA, t-Student tests, Chi-square tests, Linear and Logistic Regression, Wilcoxon-Mann-Whitney test, Correlation tests, or Friedman and Kruskal-Wallis tests, depending on the nature of the data, to better assess the significance of the results. From there, appropriate conclusions can be drawn for the discussion section.



**Graphe 1.** Average sample concentrations relative to standards

Sample A, with an average content of 370,878 ppm, is far from the norm, which is a source of SOX air pollution, with all the environmental consequences and pathologies that this entails. From Table 1, for the sulphur content of sample A, the number of hits is 2140887, ranging from 2000000 to 2500000. Figure 1 shows a graph of approximately 274,450 mg/L, representing the mean value of the sulfur mass concentration measurement for the five measurements carried out on sample A. Figure 2 shows a peak that exceeds the average signal, due to sources of contamination caused by the presence of additives, reagents and other elements with impurities.

Gasoline sample B, with a sulfur content of 2,778 ppm, complies with the 150 ppm standard and is the fuel with the lowest sulfur content. The risk of pollution through the formation of SOx sulfur oxides is too low to create acid rain and sulfuric corrosion in the vehicle's engine systems. Figure 1 shows a graph of approximately 2,09 mg/L, which represents the average value of the sulfur concentration measured over the five measurements carried out on sample B. Figure 3 shows a peak that exceeds the average signal, due to sources of contamination such as additives, previously analyzed samples, repetitive injections, reagents or other elements with impurities.

Gasoline sample C, with a sulfur content of 145,026 mg/kg or ppm, complies with the standard set at 150 ppm, so there's little risk of pollution. Figure 1 shows a graph of approximately 109,060 mg/L, representing the average sulfur concentration of the five

measurements carried out on sample C. In Figure 4, no peaks above the mean signal are observed for sample C, which explains the absence of contamination sources.

Gasoline sample D, with a sulfur content of 143,943 ppm, complies with the standard set at 150 ppm. The risk of pollution through the formation of sulfur oxides SO<sub>x</sub> is low. Figure 1 shows the approximate mass concentration of 106,230 mg/L, which represents the mean value of the sulfur concentration measurement from the five measurements carried out on sample D. In Figure 5, there are no peaks above the mean signal for sample D, which can be explained by the absence of contamination sources.

#### IV. Conclusion

For public authorities and the general public, pollution remains a matter of common interest. The consequences of environmental degradation caused by sulphur pollution are economically and socially costly for the environment and the people affected.

The results of our physicochemical analyses have given us an overall view of the quality of the fuels distributed by our stations. This work has enabled us to qualitatively verify the levels of possible SO<sub>x</sub> pollution by cars, in order to alert producers and decision-makers to the quality of the hydrocarbons distributed in Senegal.

#### COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

#### V. References

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**Comment [a7]:** The discussion is quite lacking. In addition to determining whether the results fall within or outside the regulated range, in a study of this nature, it is necessary to substantiate findings based on literature data from similar studies. It's essential to assess if the obtained results make sense not only from a quality standpoint but also from an environmental perspective, especially considering why certain issues were raised in this study. A thorough discussion of the results should include comparisons with scientifically relevant similar studies, providing a comprehensive analysis.

**Comment [a8]:** Enhance the conclusions after addressing the recommendations presented here. Incorporate into them the recommendations based on the results and discussions found

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