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Determination of the Sulfur Content of Gasoline from Four Major Fuel Distributors in Dakar

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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

Sulfur dioxide is an acidifying gaseous pollutant. It contributes to the acidification of the environment. When emitted into the air and in the presence of water, sulfur dioxide forms sulfuric acid, which contributes to the phenomenon of acid rain. Acidifying substances disrupt the composition of air, surface water and soil.
Sulphur dioxide (SOx) 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 service stations

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belonging to the most representative groups in terms of light petroleum product distribution in Senegal. The aim is to assess the environmental impact of sulfur dioxide emissions resulting from the use of gasoline by vehicles, and to reduce upstream sulfur content.

Keywords: Sulfur; Sox; energy; gasoline; station.

1. 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 [1]. SOx can also concentrate near ground level, causing smog. Humans can be exposed to SOx by breathing, drinking or eating the substance, as well as through skin contact. The adverse health effects of SOx, as with most air pollutants, depend on factors such as the duration and quantity of exposure [2-5]. 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. SOx 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 SOx exposure [5-9].

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.

2. MATERIALS AND METHODS

2.1 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). Oxidation products include CO_2, H_2O, NO, SO_2 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 [9-11].

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

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_2 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 [11-13].

$$SO_2 + hv' \rightarrow SO_2^* \rightarrow SO_2 + hv'' \quad (2)$$

2.2 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.

2.3 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 (Fig. 1).

Fig. 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. Detectiontakes place over the same time period.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 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.

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

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.

3.1.2 Results of sulphur content measurements on samples

Sample A: density 0,7400 kg/L

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.

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.

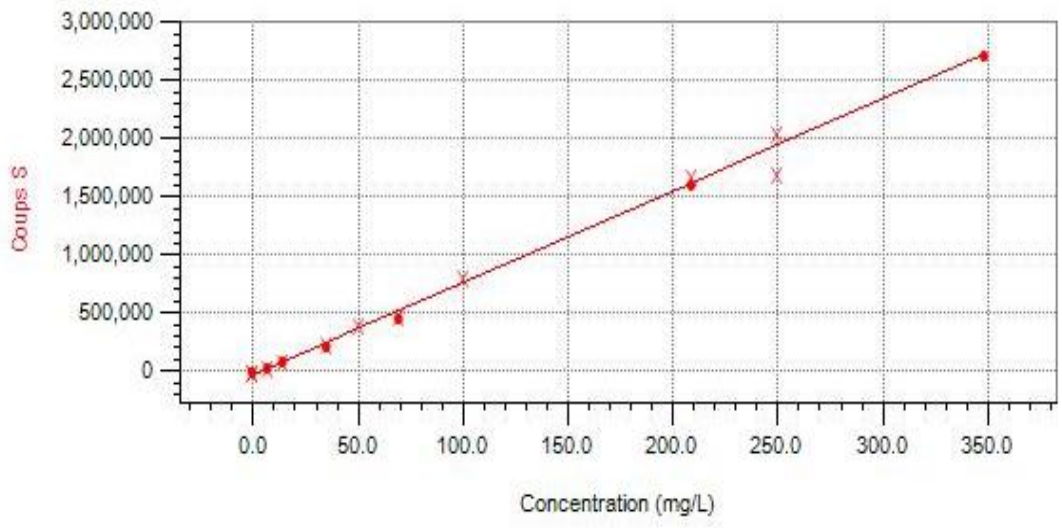


Fig. 2. Calibration curve

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

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

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

Table 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

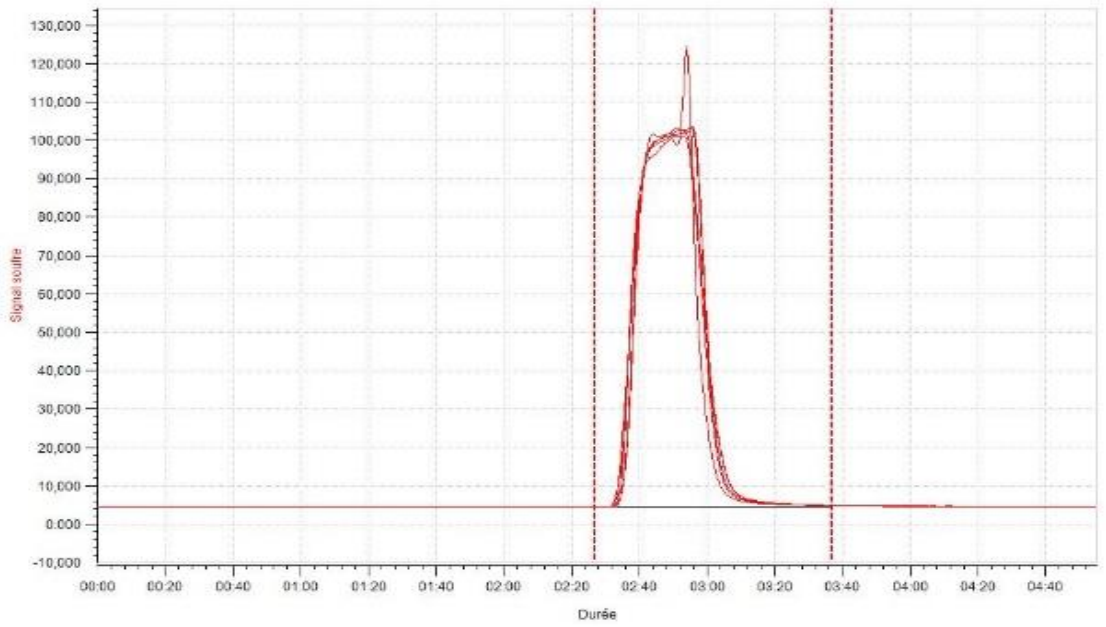


Fig. 3. Sulfur content of sample A

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

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.

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

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

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.

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

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

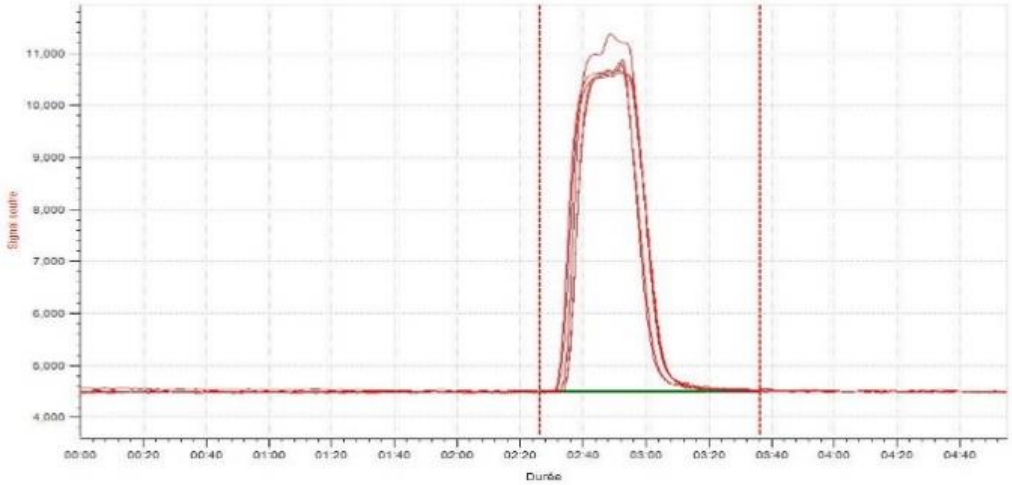


Fig. 4. Sulfur content of sample B

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

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	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

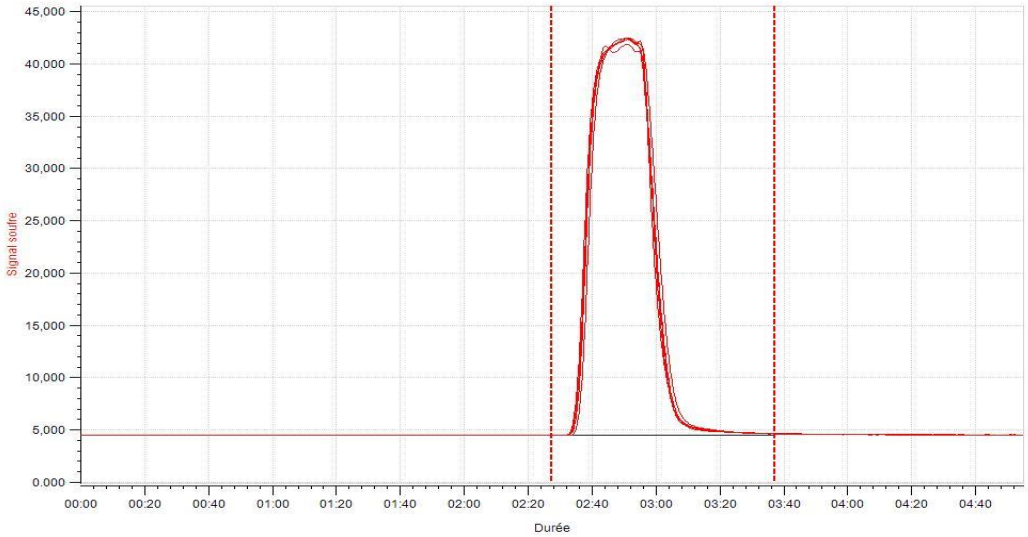


Fig. 5. Sulfur content of sample C

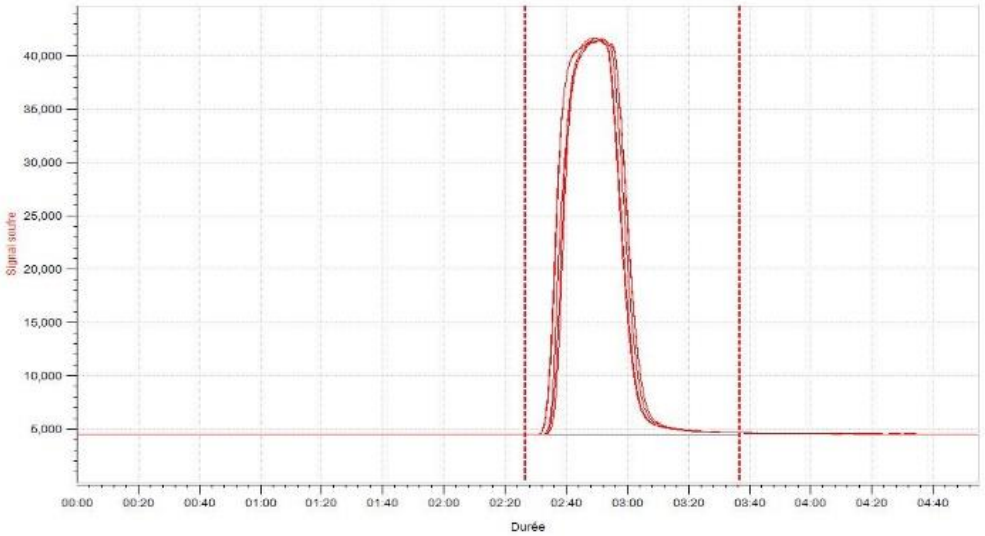


Fig. 6. Sulfur content of sample D

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

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

Injection number	Hits N	Surface signal N	Conc N (mg/L)	Conc. N mass (mg/kg)	Calibration range N
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

Sample D: density 0,7380 kg/L

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.

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

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

3.2 Discussion

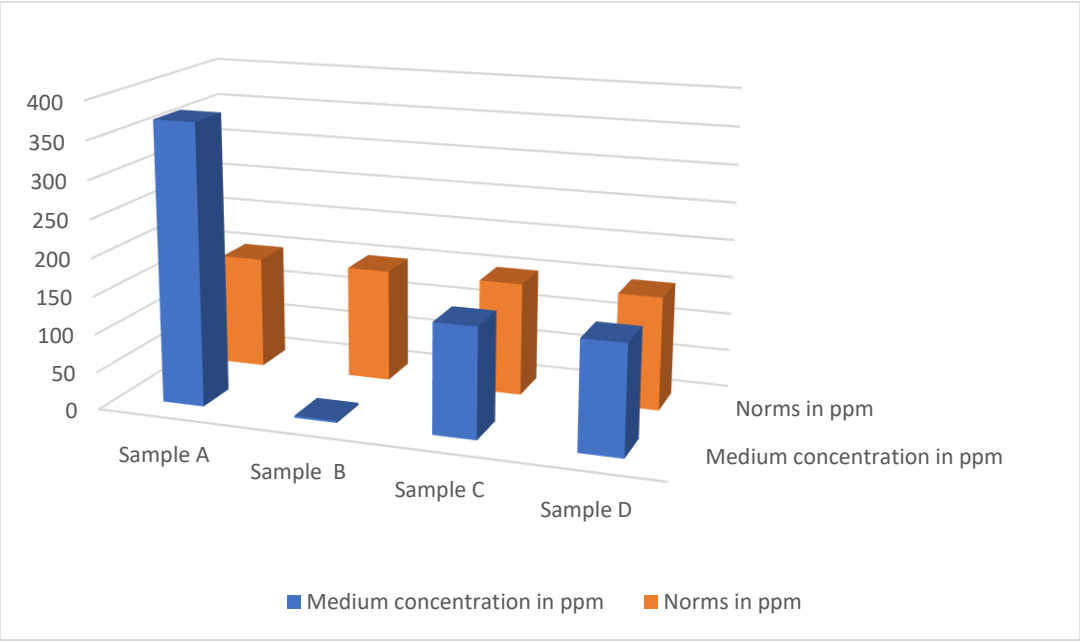
The results of the average sulfur content of the four samples shown in Table 9 show that station B has the best gasoline quality, followed by stations D and C respectively, with sulfur contents below the standard set at 150 ppm (European Directive 98/70/EC). The wisest choice is to refuel at petrol stations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

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. Fig. 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. Fig. 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. Fig. 1 shows a graph of approximately 2,09 mg/L, which represents the average value of the sulfur

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			



Graph 1. Average sample concentrations relative to standards

concentration measured over the five measurements carried out on sample B. Fig. 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. Fig. 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 Fig. 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 SOx is low. Fig. 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 Fig. 5, there are no peaks above the mean signal for sample D, which can be explained by the absence of contamination sources.

4. CONCLUSION

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. Sulfur pollution represents a major public health risk, due to the various pathologies that these elements can cause.

For public authorities and the general public, pollution remains a subject of common interest. The consequences of environmental degradation caused by sulfur pollution are economically and socially costly for both the environment and the populations concerned.

The results of our physico-chemical 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 SOx pollution by cars, in order to alert producers and decision-makers to the quality of hydrocarbons distributed in Senegal.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

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.

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