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Health Effect of Occupational Exposure to Pollutants from Fuels, Abidjan, Côte d'Ivoire

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Abstract

The presence of chemical constituents from fuels in the work atmosphere can reduce workplace and have a serious impact on human health. In this study, we determined the constituents of unleaded and diesel fuel sold in the District of Abidjan, notably sulfur and lead, and assessed the impact on mechanics, pump attendants and painters. Twenty tow fuel samples collected in the district of Abidjan, including 14 from legal sites distribution and 8 from illegal sites, were analyzed to determine the sulfur and lead content. Blood was collected among 45 volunteers, including 15 mechanics, 15 painters and 15 pump attendants to hematological and biochemical analysis. The results show that sulfur levels ranged from 1530 ppm to 1900 ppm and from 94.9 ppm to 9.4 ppm in diesel and unleaded fuel respectively. Sulfur values below Côte d'Ivoire standard of 1500 - 3500 ppm for diesel and 500 - 1500 ppm for unleaded fuel but remain above international standard of 10 pp. Fuel characterization did not show the presence of lead in any of the tested fuel samples. Blood results showed MCHC values above of reference values for all professionals, while MCH values were below reference values. Neutrophil values were low compared with reference values in all occupational groups of mechanics and pump attendants, while lymphocyte results were 48.20% and 52.50% for mechanics and fuel attendants respectively were well above reference values. GGT values ranged from 42 ± 14.98 IU/l to 87 ± 3.45 were well above reference values. However, the GGT levels of pump attendants were significantly ($P < 0.05$) higher than those of other professionals.

Keywords

Fuels Exposure, Heavy Metals, Biomarkers, Workplace Pollution, Abidjan

1. Introduction

The expansion of African vehicle fleets by importing used vehicles that are often very old has led to an increase in the number of car professionals and the risk of exposure to gasoline and engine exhaust fumes [1] [2]. Indeed, the adverse effects of exposure to petroleum derivatives have been corroborated by the findings of the International Agency for Research on Cancer (IARC), which has recognized gasoline and gasoline engines as potentially carcinogenic to humans (Group 2B), affecting the health of exposed individuals [3]-[5]. Gasoline components include a mixture of chemicals such as aliphatic and aromatic hydrocarbons, metals, sulfur and oxygenates [6] [7]. Workers in the automotive sector can be exposed to petroleum by-products and engine exhaust, including pump attendants, auto mechanics and professional drivers, which can adversely affect their health [5]. In Africa, pump attendants perform a number of tasks during their working day, such as filling up cars and motorcycles, measuring tanks, transferring fuel from trucks to storage tanks and cleaning the service station. Pump attendants are exposed to fuel emissions through inhalation and dermal exposure [8]-[11]. Gas station attendants, auto mechanics and painters are commonly exposed to fuel in the course of their work. Mechanics, for example, siphon gasoline from the vehicle's tank by sucking it in with their mouths, and may ingest gasoline in the process, or when they disassemble and wash vehicle parts with gasoline without wearing gloves, increasing skin exposure [12] [13]. Toxicity of fuels depends on their composition, and intoxication can occur via the digestive, pulmonary or cutaneous routes, and can lead to hematological complications [14]. Organic lead compounds have also been widely used as additives in petrol, causing heart disease, stroke and cancer in humans, especially children. However, their use is now illegal in all countries [15]. Chronic diseases such as cardiopulmonary, respiratory and hematological disorders, as well as cancer, are potentially associated with exposure to lead, sulfur and nitrogen oxides and heavy metals present in diesel exhaust [16]-[20]. sulfur combined with oxygen generates sulfur dioxide (SO_2), a gas which is toxic on inhalation and can cause severe irritation of the mucous membrane of the respiratory tract, with cell damage and laryngotracheal and pulmonary edema [21]. According to a report by the United Nations Environment Programme (UNEP), in West Africa, sulfur content varies between 151 and 500 ppm for super unleaded and between 1500 and 3500 ppm for diesel, well below the European standard of 10 ppm [22]. In Côte d'Ivoire, many people are exposed to exhaust emissions in the course of their work, and many of them in the informal sector, such as mechanics, painters and petrol station attendants [23]. Therefore, the objective of the present study was to determine the constituents of fuels sold in Côte d'Ivoire, in particular sulfur and lead, and to assess their biological impact on the human health of automotive workers.

2. Research Methods

2.1. Study Site and Population

This experimental study was carried out in the Department of Medical and

Fundamental Biochemistry at the Institut Pasteur de Côte d'Ivoire (IPCI). Samples of Unleaded and Diesel as well as blood samples from thirty (30) hydrocarbon industry professionals were collected in eight (8) communes of the Abidjan district from May to October 2022 (**Figure 1**). Individuals included in this study were those working in a garage or fuel sales station who gave their informed consent. Professionals who refused to give informed agreement or had other reasons outside the scope of the study, were not included.

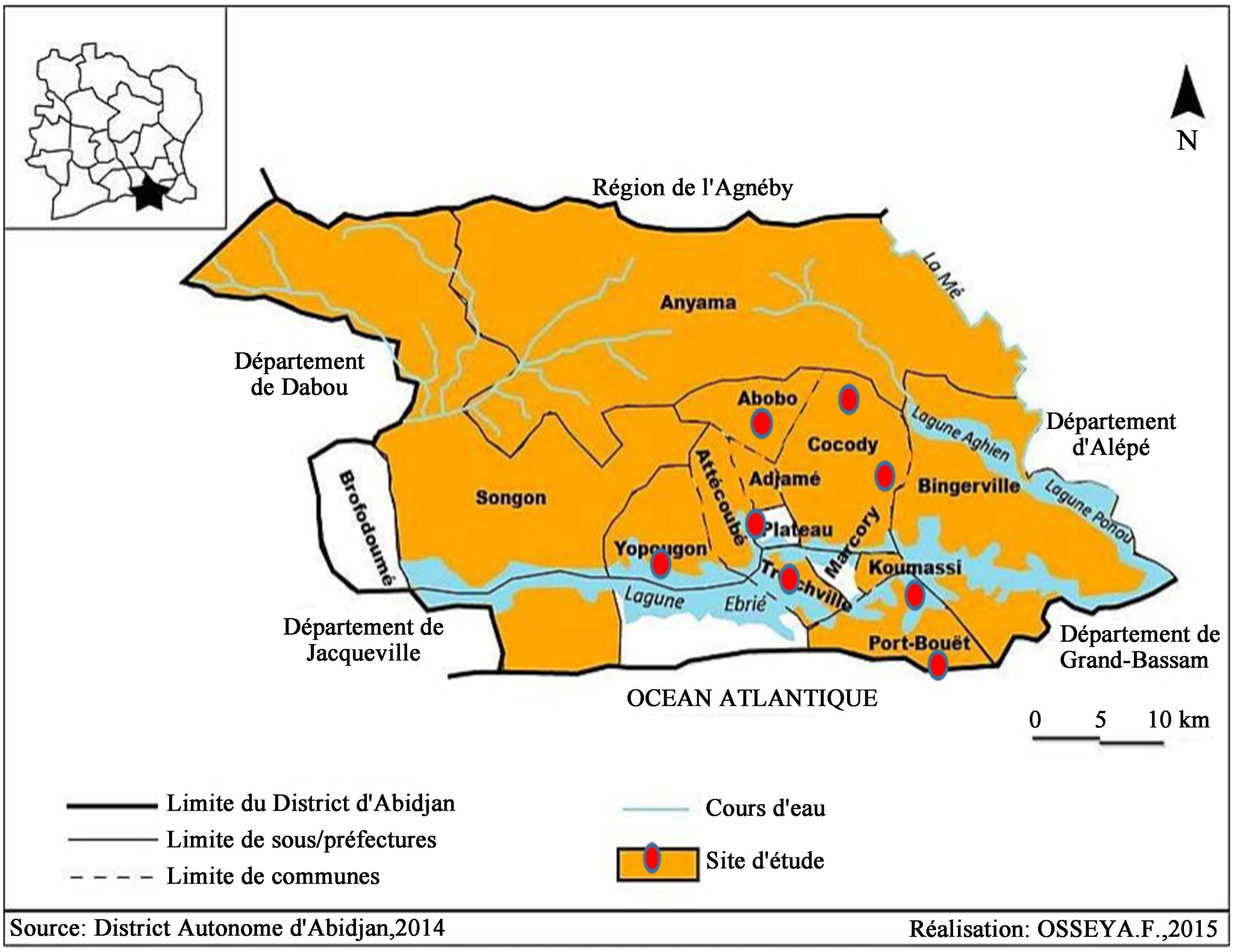


Figure 1. Biological and fuel sampling site.

2.2. Collection of Biological Samples

Twenty-four fuel samples were taken in the Abidjan district, including 14 from known service stations and 8 from illegal sites. Fuel samples were collected in special 1-liter glass vials. Each sample was carefully stored in a fume hood. Kottermann system Labor. Blood samples were collected at the elbow by venipuncture on subjects fasting for at least 12 hours. Blood was collected in three different tubes: a dry tube without anticoagulant, an EDTA tube and a citrated tube. Samples were transported to the laboratory, and the dry and citrated tubes were centrifuged at 3000 rpm for 10 minutes. Aliquots of plasma and serum were collected and stored at −20˚C for plasma and 4˚C for serum. Whole blood collected in EDTA tubes was used for blood counts.

2.3. Analysis of Biochemical and Hematological Parameters

Blood counts were performed using the automated Sysmex XN-1000i system, combining hydrodynamic focusing and fluorescent flow cytometry. Alanine aminotransferase (ALAT), aspartate aminotransferase (ASAT), gamma-glutamyl transferase (GGT), lactate dehydrogenase (LDH), creatinine and CRP were measured on Roche Diagnostic's Cobas C311 Hitachi, equipped with a spectrophotometer. The principe is based on the TRINDER reaction, an enzymatic and colorimetric method using a chromogen. Intensity of the color developed is directly proportional to the concentration of the substance assayed. Fibrinemia was measured with the Sysmex CA-600 series using the quantitative radial immunodiffusion method.

Hematological parameters including hemoglobin (HGB), red blood cells (RBC), white blood cells (WBC), hematocrit (Hct), platelets (PLT), mean cell volume (MCV), mean cell hemoglobin (MCH), mean cell hemoglobin concentration (MCHC); lymphocytes, monocytes, neutrophils and eosinophils of people exposed to fuels were determined by an automatic analyzer (BC-3000 Plus Auto Hematology Analyzer, Shenzhen Mindray Bio-Medical Electronics Co. Ltd, China.

2.4. Sulfur and Lead Concentrations in Unleaded and Diesel Gasoline

Sulfur and lead contents were determined spectrometrically using an automatic analyzer, the X supreme 8000, in accordance with ASTM D 4294 version 2020. Prior to sample analysis, the analyzer underwent metrological control using a certified reference material (CRM): 1000 ppm or 0.1% by mass of di-n-butyl sulfide and 250 ppm or 0.25% by mass of sulfur in mineral oil). The sample is placed in a beam emitted by an X-ray source. X-ray characteristic excited radiation produced is measured and the accumulated count is compared with the counts of a previously prepared calibration standard to obtain the sulfur concentration. Two groups of standards are required to cover the concentration range, one from 0.015% to 0.1% by mass and the other from 0.1% to 5.0% by mass. The Super Unleaded samples were analyzed in the same way as the control sample (MRC).

2.5. Density of Samples at 15˚C

ASTM D 4052 version 2021 was used to measure density at 15˚C. Density was measured using ANTON PAAR's DMA 1001 automatic density meter. Metrological verification of the equipment consisted in measuring air density at 20˚C to validate the calibration. To be validated, the standard must be between 1.00 and 1.40 kg/m^3. To measure density, 10 mL of fuel was drawn into a syringe. A volume of 2 mL of fuel sample is introduced into an oscillating sample tube. The change in oscillating frequency caused by the change in the mass of the tube is used in conjunction with calibration data to determine the density of the sample.

2.6. Statistical Analysis

Mean values and standard error of the mean (mean ± SEM) were calculated using Graph Pad Prism 7.0 (Microsoft. USA). Statistical analysis of results was performed using analysis of variance (ANOVA) followed by Student's t test. For both tests, the significance level was set at 5% (P = 0.05). For both tests, the significance level was set at 5% (P = 0.05).

3. Results

Sulfur and lead concentrations

Sulfur levels in diesel and unleaded fuel sampled at legal stations (SL) are presented in Figure 2 and Table 1. The results show that sulfur levels ranged from 1530 ppm to 1900 ppm, with an average of 1723 ± 59 ppm, and from 94.9 ppm to 9.4 ppm, with an average of 38.75 ± 11.82 ppm, in diesel and unleaded fuel respectively (Table 1). The highest levels were obtained at sites SL1 and SL2 for diesel and SL5 for unleaded fuel (Figure 2 and Table 1). Sulfur levels in diesel fuel are significantly higher than international standards, but similar to national values. Sulfur levels in unleaded fuels are below national values, but above international values (Table 1).

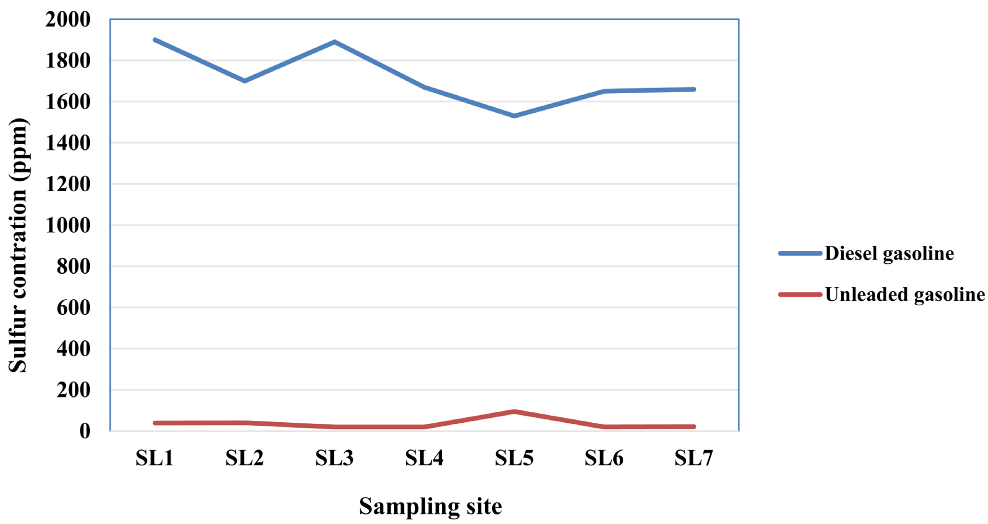


Figure 2. Mean of sulfur in diesel and unleaded gasoline from legal fuel stations (SL).

Sulfur levels in diesel and unleaded fuel collected from illegal stations (Sil) are presented in Figure 3 and Table 1. The results show sulfur levels between 910 ppm and 1600 ppm with an average of 1343 ± 150 (ppm) and between 22.6 ppm and 57.6 ppm with an average of 38.45 ± 7.574 (ppm) respectively in diesel and unleaded fuel (Table 1). The highest levels were obtained at sites Sil-1 for diesel and Sil-4 for unleaded fuel (Figure 3 and Table 1). Sulfur levels in diesel are well above international standards, but similar to national values. Sulfur levels in

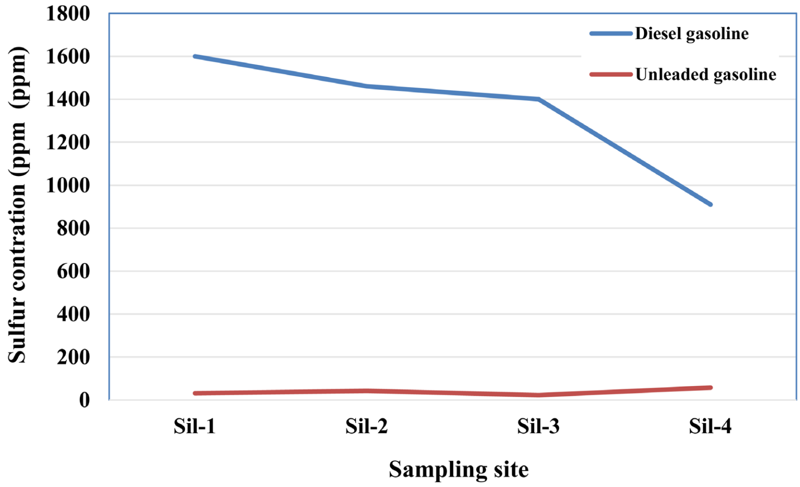


Figure 3. Mean of sulfur in diesel dans unleaded gasoline from illegal fuel stations (Sil).

Table 1. Mean of sulfur, lead and mass per volume of diesel gasoline et du unleaded gasoline from legal and illegal fuel stations

		Diesel gasoline		Unleaded gasoline		
	Legal Stations (SL)	Sulfur (ppm)	Mass per volume (g/L)	Sulfur (ppm)	Lead (g/l)	Mass per volume (g/L)
Legal fuel stations (SL)	SL1	1900	0.85250	39.2	0.0030	0.75806
	SL2	1700	0.86710	39.9	0.0030	0.75135
	SL3	1890	0.86353	19.4	0.0030	0.75862
	SL4	1670	0.86351	19.6	0.0030	0.75756
	SL5	1530	0.86413	94.9	0.0030	0.75013
	SL6	1650	0.86622	20.0	0.0030	0.75804
	SL7	1660	0.86423	20.5	0.0030	0.75820
	Max-Min	1900 - 1530	0.86710 – 0.85250	94.9 - 19.4	0.0030	0.75862 – 0.75135
	Mean	1723 ± 59 (ppm)	0.8628 ± 0.00215 (g/L)	38.75 ± 11.82 (ppm)	0.0030 ± 00(g/L)	0.7556 ±0.001559 (g/l)
Illegal fuel station (Sil)	Sil-1	**1600**	0.86476	31.1	0.0030	0.75053
	Sil-2	1460	0.82362	42.5	0.0030	0.75013
	Sil-3	1400	0.83363	22.6	0.0030	0.75806
	Sil-4	**910**	0.82276	**57.6**	0.0030	0.75613
	Max-Min	1600 - 910	0.86476 - 0.82276	57.6 - 22.6	0.0030	0.75806 - 0.75013
	Mean	1343 ± 150 (ppm)	0.8362 ± 0.009837 (g/L)	38.45 ± 7.574 (ppm)	0.0030 ± 00 (g/l)	0.7537 ± 0.001994 (g/l)
	p-value	0.0261	0.0119	0.467	- - - -	0.430
	NNV	1500 - 3500 ppm	0.820 - 0.880	150 - 500 ppm	0.013	0.720 - 0.790
	INV	10 ppm	0.820 - 0.880	10 ppm	0.013	0.720 - 0.790

unleaded fuel are below national values, but above international values (Table 1). Comparing legal (SL) and illegal (Sil) stations, there is a significant difference ($p < 0.05$) in diesel sulfur levels. On the other hand, there was no significant difference between legal (SL) and illegal (Sil) stations with regard to sulfur levels in unleaded fuel.

Density (g/L) of diesel from legal (SL) and illegal stations is slightly different ($p < 0.05$). However, there was no significant difference between the densities (g/L) of unleaded fuel from legal (SL) and illegal stations (Table 1).

Lead value of unleaded fuel showed that lead levels were similar at both legal and illegal sales outlets, with an average of 0.0030 ± 00 g/L. This is below both national values (0.013 q/L) and international standards (0.013 g/L). This is below both national values (0.013 q/L) and international standards (0.013 g/L). This lead content is below national values (0.013 q/L) and international standards (0.013 g/L).

Blood composition and hematological parameters

Table 2 shows the results of hematology parameters including hemoglobin (HGB), red blood cells (RBC), white blood cells (WBC), hematocrit (HTC), platelets (PLT), mean cell volume (MCV), mean cell hemoglobin (MCH), mean cell hemoglobin concentration (MCHC), lymphocytes, monocytes, neutrophils and eosinophils.

Table 2. Hematological parameters of professionals.

Parameters	Mechanics	Fuel attendants	Painters	Reference value
RBC ($\times 10^3/\mu l$)	4.76	5.8	7.99	4 - 10
WBC ($\times 10^3/\mu l$)	5.27	5.45	5.30	3.8 - 6.0
Hgb (g/dL)	14.70	14.98	15.20	12 - 18
HTC (%)	42.70	43.40	44.10	37 - 54
MCV (fL)	84.20	79.05	82.65	80 - 95
MCHC (pg)	34.20	34.35	34.50	27 - 32
MCH (g/dL)	28.50	27.55	28.55	32 - 36
PLT ($\times 10^3/\mu L$)	221	176	163.5	150 - 300
Neutrophils (%)	37.30	30.70	48.15	40 - 70
Lymphocytes (%)	48.20	52.50	39.00	20 - 40
Monocytes (%)	6.20	8.05	8.50	2 - 10
Eosinophils (%)	6.52	6.55	4.00	1 - 6
Basophils (%)	0.50	0.67	0.31	0 - 1

Hematology parameters including hemoglobin (HGB), red blood cells (RBC), white blood cells (WBC), hematocrit (HTC, platelets (PLT), mean cell volume (MCV), mean cell hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC); lymphocytes, monocytes, neutrophils and eosinophils.

The study showed that for hematological parameters such as RBC, WBC, HGB, HTC and MCV, the values obtained remained within the reference values.

For MCHC, the results were above reference values for all professionals, while for MCH, the values obtained were below reference values. Blood count results showed that neutrophil values were low compared with reference values in all occupational groups of mechanics and pump attendants, while lymphocyte values were well above reference values. Lymphocyte results were 48.20% and 52.50% for mechanics and fuel attendants respectively.

Eosinophil counts were slightly above reference values, at 6.52% for mechanics and 6.55% for fuel attendants (**Table 2**).

Biochemical and immunological parameters

Biochemical and immunological parameters TGO, TGP, GGT, LDH and *C-reactive protein* are shown in **Table 3**. The results show TGO values ranging from 21 ± 5.84 IU/l to 26 ± 5.84 IU/l. The highest value (26 ± 5.84 IU/l) was observed among painters. However, TGO values are in line with reference values. TGP values obtained were 19 ± 5.84 IU/l; 25 ± 4.74 IU/l and 36 ± 4.74 IU/l for mechanics, pump operators and painters respectively. These TGP values are in line with reference values. GGT values ranged from 42 ± 14.98 IU/l to 87 ± 3.45. GGT values obtained from professionals are well above reference values. However, the GGT levels of pump attendants were significantly higher than those of other professionals (**Figure 4**).

Creatinine, a biomarker of renal function, showed no significant variation either with reference values or between professional values (**Table 3**). On the other hand, LDH, a muscle function enzyme, showed no significant difference (P value…) in activity, with concentrations within the normal range. As regards CRP and fibrinogen, two pro-inflammatory proteins, while fibrinogen levels were lower in mechanics and pump attendants than in the reference group ($p < 0.05$) (**Figure 4**), CRP levels did not vary significantly from normal values (**Table 3**).

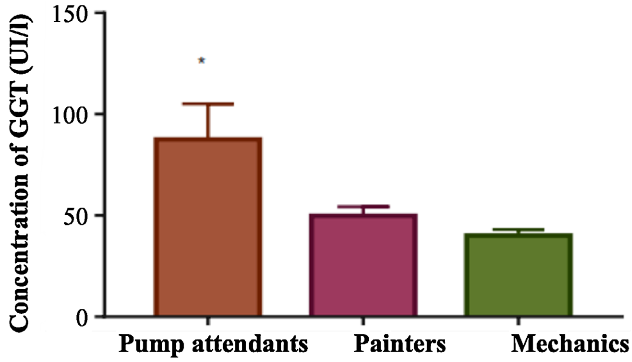
4. Discussion

This study is a preliminary project that examined the potential hematological and

Table 3. Biochemical and immunological parameters of professionals.

Parameters	Mechanics	Pump attendants	Painters	Value reference
TGO	21 ± 5.84	25 ± 5.84	26 ± 5.84	(8 - 49 UI/l)
TGP	19 ± 5.84	25 ± 4.74	36 ± 4.74	(7 - 48 UI/l)
GGT	42 ± 14.98	87 ± 3.45	50 ± 15.20	(7 - 32 UI/l)
CREATINE	9 ± 4.74	8 ± 4.74	10 ± 4.74	(5 - 12 mg/l)
LDH	208	163	195	(135 - 225 UI/l)
CRP	1	1	3	(<6 mg/l)
FIBRINOGEN	1.71 ± 0.41	1.62 ± 50	2.01 ± 1.09	(2 - 4 g/l)

Data were expressed as mean (±SD).



*Significant differences of each group (*P < 0.05).

Figure 4. Comparative analysis of GGT in professionals.

biochemical effects of fuel exposure in automotive workers such as pump attendants, auto mechanics and painters. The results showed that lead levels at legal stations were similar to those at illegal sales sites, with an average of 0.0030 ± 00 g/L. This figure is below the international and national standards of 0.0030 ± 00 g/L for lead. This value is below the international and national standards of 0.013 g/L. On the other hand, average sulfur levels were 1723 ± 59 ppm for legal stations versus 1343 ± 150 ppm for illegal sites for diesel, and 38.75 ± 11.82 ppm for legal stations versus 38.45 ± 7.574 ppm for illegal sites for unleaded fuel. Compared with the international standard of 10 ppm for these two types of fuel, sulfur concentrations are very high in both super unleaded and diesel, even though these levels are lower than the national standards, which are 1500 to 3500 ppm for diesel and 150 to 500 ppm for unleaded fuel [22]. Results show the high level of pollution to which the general population and automotive workers are exposed. Combined with oxygen, sulfur generates sulfur dioxide$_{(SO2)}$, a toxic inhalation gas that can cause severe nasal and pulmonary irritation when released into the environment [21]. Harmonizing fuel sulfur levels with international standards is therefore a key element in the global strategy to reduce the health impact of the transport sector [24].

When the hematological profiles of the professionals were compared with each other and with reference values, there were no significant differences between the RBC, WBC, HTC and PLT values compared with the reference value, and are often at the upper reference limit [8] [25]. However, the results show a drop in neutrophil counts among mechanics and pump attendants, with 37.30% and 30.70% respectively compared with reference values (**Table 2**) [26].

On the other hand, lymphocyte levels in pump attendants and mechanics were higher than in painters, at 52.20% and 48.20% respectively. These results reveal a hematological problem probably due to the high exposure of professionals to hydrocarbons, and could be attributable to the defensive role of lymphocytes against the chronic inflammatory process that could arise in automotive workers due to their high exposure to fuels [26]. Blood cell results showed elevated levels of MCHC in all professionals included in this study. These results corroborate other research which also found elevated levels of MCHC in these workers, compared to the control group [27] [28]. Also, some studies have shown that an increase in MCHC can be a valuable clinical indicator of increased spherocytosis observed during exposure to aromatic compounds [27] [29]. Conversely, a decrease in MCH levels was observed in all workers. However, MCH levels were lower in Fuel attendants than in car mechanics [10] [13]. Hematological disorders observed could be explained by the toxic effect of exposure of these professionals to these petroleum products, which are mixtures of aromatic compounds, heavy metals and other volatile compounds responsible for various hematological diseases [13] [26] [30].

Results of the biochemical and immunological parameters presented in **Table 3** show that the TGO, TGP, creatinine and LDH values measured in the workers were close to the reference values. However, the study showed elevated GGT values in all fuel-exposed workers, with a significant increase in the Fuel attendants (**Figure 4**). These results are in line with those of numerous studies which have also observed an increase in liver markers in workers exposed to gasoline and diesel fuel [16]. Exposure to organic solvents has been associated with changes in oxidative metabolism in the liver, due to its role in xenobiotic metabolism [16]. Increased GGT levels are observed in workers exposed to organic solvents, and aminotransferases indicate cholestasis and hepatic necrosis following exposure to organic solvents [16] [31] [32].

Our study also examined CRP and Fibrinogen levels in the blood of fuel workers. CRP and Fibrinogen are two pro-inflammatory biomarkers used to assess the toxic effects of complex, heterogeneous mixtures such as fuel by-products [33] [34]. Study showed no significant change in CRP levels in fuel-exposed workers. CRP levels obtained were 1mg/l for autos mechanics and fuel attendants, with a low risk of cardiovascular disorders, while for painters the CRP level was 3mg/l, reflecting a medium risk of cardiovascular disorders [34] [35]. However, this study showed no significant difference levels of CRP among workers compared with reference values. Concerning fibrinogen, the results showed a non-significant drop in its level in workers, but this drop was more marked in fuel attendants (**Figure 5**). Similar results also showed a statistically significant decrease in fibrinogen levels in workers, which would be associated with blood clotting and liver problems due to hydrocarbon exposure [34] [36].

5. Conclusion

Our study, which is one of the first of its type, showed that the concentrations of total sulphur measured in fuels is certainly lower than the Ivorian standard, but remains well above the international standard. This indicates a real risk of exposure to harmful hydrocarbon compounds for these women workers, putting their health at risk in the workplace. The biomarker profile study showed an increase in Gamma GT levels, a decrease in Neutrophil Polynuclear and a drop in fibrinogen concentration. This could suggest that these professionals are at risk of

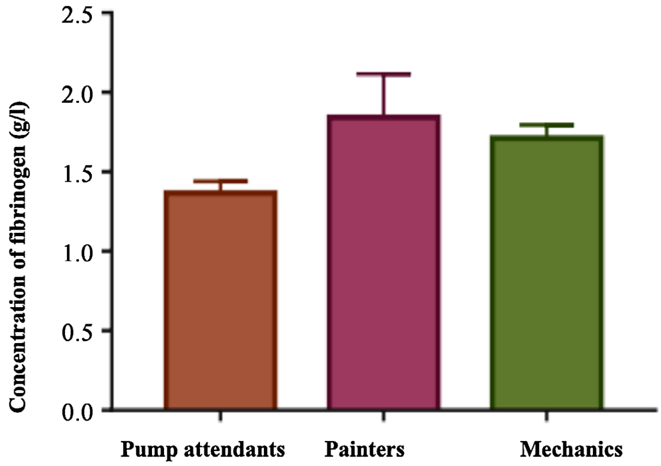


Figure 5. Comparative analysis of fibrinogen in professionals.

developing hematological and hepatic pathologies that could even lead to carcinogenic pathologies. It is therefore essential to harmonize Ivorian standards with international norms, in order to improve the quality of life of our populations, and fuel industry workers.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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