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RESEARCH ARTICLE

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Benzene Monitoring and S-Phenylmercapturic Acid Determination of Workers at Oil Sites in Congo-Brazzaville

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ABSTRACT

The toxicity of benzene is well known, and its leukemia effect established. It is a natural constituent of crude oil and the diseases associated with its exposure are recognized as occupational.

Objective: To assess occupational exposure to benzene among workers in an oil and gas production company.

Materials and methods: This was a descriptive, cross-sectional study which consisted first of the quantification of atmospheric benzene by individual measurements in a sample of the homogeneous exposure group of the producers. Secondly, urinary assays of S-phenylmercapturic acid were performed at the end of the shift in the selected workers.

Results: The study included 79 (47.88%) workers, 17 atmospheric samples were usable and 79 urinary assays at the end of the shift were performed. The average benzene concentration for all sites was 10 times lower than the regulatory average exposure value (1 ppm=3.2 mg/m3): average: 0.122 pp, median: 0.053 ppm and range: 0.019-1.448 ppm. All 79 urinary assays of S-phenylmercapturic acid with a biological exposure index of less than 25 µg/g creatinine: mean: 0.70 µg/g creatinine creates, median: 0.52 µg/g creatinine creates and extends: 0.23 to 6.7 µg/g creatinine.

Conclusion: Exposure was below the limit values for benzene in both atmospheric metrology and biometrology. This is an occupational group with low exposure to benzene. Medical surveillance will therefore have to be adapted according to the potentially exposing tasks.

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Introduction

Benzene or Benzol, which has a very stable aromatic molecular formula, is a clear, colorless, volatile, highly flammable liquid. It was first isolated by Faraday in 1825 from a liquid condensed by compression of petroleum gas and first synthesized in 1833 by Mitscherlich [1].

Historically, benzene has been used as a metal degreaser, organic solvent, feedstock and intermediate in the chemical and pharmaceutical industry (e.g., to manufacture rubbers, lubricants, dyes, detergents, and pesticides) and as an additive to unleaded gasoline [2]. It is naturally present in petroleum products and is also added to unleaded gasoline for its anti-knock and octane improvement properties. Today, benzene is mainly used in the petroleum industry and in the manufacture of organic chemicals.

Its toxic action on blood lines was suspected as early as 1897 by Lenoir and Claude, and its flattening effect was admitted as a compensable occupational disease in France from January 4, 1931. On the other hand, its proven leukemia effect led to its classification in the group of carcinogens (class 1 carcinogens) for humans by the International Agency for Research on Cancer (IARC) of the World Health Organization (WHO) in 1982 [1].

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In industrial toxicology, urinary excretion of S-phenylmercapturic acid (SPMA) is well correlated with external exposure to benzene in several studies in occupational subjects and as such, it is one of the metabolites currently considered to be biomarkers of workplace exposure to benzene [3].

In the Congo, oil exploration and production began in the 1960's, but the literature review found no studies conducted among service stations, refinery staff, the oil terminal and workers at the onshore and/or offshore sites of the various oil operators; notwithstanding that exposure to benzene and its analogues is a permanent risk at all petroleum sites in the country because benzene is a natural constituent of crude oil (0.4%) [4].

In addition, Congolese regulations also recognize illnesses related to chronic exposure to benzene and its derivatives as occupational [5].

Thus, in view of the findings described above, it appeared necessary to conduct a study in an oil exploration and production company whose objective was to assess occupational exposure to benzene in workers directly exposed.

Materials and Methods of Survey

Setting, type and population of survey

The study was conducted by the Department of Occupational Medicine and all onshore and offshore sites of Total Exploration and Production Congo (TEPC), the leading oil company in the Congo. This was an observational, descriptive cross-sectional study that took place from 1 October 2017 to 31 December 2017 or for a period of 3 months.

The study population consisted of workers from the company, who were over 18 years of age and who had freely agreed to take part in the study, working in the external installations of oil sites with a risk of exposure to benzene. The sampling technique was systematic and non-probability-In other words, the selection criteria allowed for the consecutive selection of a sample of operators and production technicians working at all TEPC's on-shore and offshore operational sites.

Method of survey

Conduct of the study: The study was conducted in two (2) phases:

First phase: evaluation of atmospheric benzene using GABIE badges: The G.A.B.I.E (Gas Adsorbant Badge for Individual Exposure) is a passive sampler designed by the Institut National de Recherche en Sécurité (INRS) of France. It allows for:

Passive sampling of gases such as BTX (Benzene, Toluene, Xylene),

- Air sampling in the respiratory area of personnel,
- Determination of the average concentration of these gases over a working day,
- The sample considers the professional gesture and the movements in the work area.

Organic compounds in the atmosphere are captured by diffusion. They are then trapped on an adsorbent material (active charcoal) at the bottom of the badge (Figure 1)

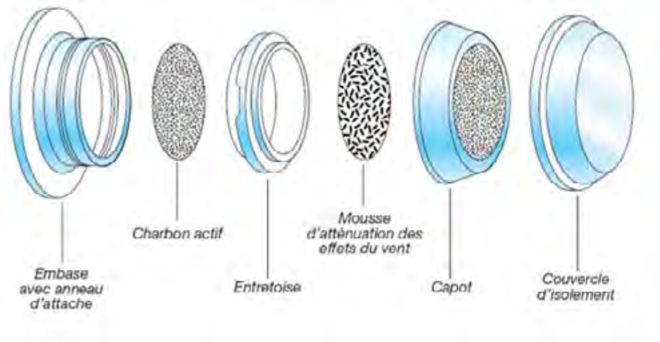

Figure 1: Composition of a GABIE badge

The badges were given to the operators at the beginning of the shift and returned at the end of the shift after a period of 8 hours to 12 hours.

Wearing the badge does not influence the work carried out by employees or the preventive or protective measures implemented at the workplace (iconography n°1).

At the end of sampling, the badge is closed and stored at room temperature. They were then shipped as quickly as possible to an accredited laboratory in France, by aircraft in the cargo hold for analysis.

The determination of benzene was carried out by gas chromatography, which is a technique for separating molecules that make up a gas mixture.

The result is a concentration of vapors collected in ppm (or mg/m3) reported over eight hours. These results show a good average representativity of the daily exposure and are valid for a group of persons belonging to the same homogeneous exposure group (HEG).

Urinary determination of S-phenylmercapturic acid (SPMA)

Urine was collected from onshore and offshore sites at the end of shift and at the end of rotation.

2 × 5 ml of urine was collected from the workers concerned, from 2 specific tubes supplied by the testing laboratory.

After collection, the samples were stored in the freezer (-20°C) before being transported to France in a carboglace, in the hold, by plane.

The analysis was carried out in the same laboratory as the analysis of GABIE badges.

The biological analyses concerned the liquid chromatography analysis of S-phenylmercapturic acid.

The determination of creatinuria was made by the Jaffe method. Results are rendered by µg/g creatinine to account for diuresis. The reference value for the professionally exposed population (BEI) is 25 µg/g creatinine.

Study variables

The various variables of the study were: socio-professional variables (sex, age, job held, place of work, pace of work, seniority, concept of smoking), atmospheric concentration of benzene and urinary S-Phenylmercapturic acid.

Operational definitions

Operator or technician: He is an oil worker working on an oil rig based at sea or on land. It carries out its activity in production or maintenance, contributing to the production of oil. The operator conducts his operations exclusively in the external installations of the oil sites while the technician performs both in the external installations and in the control room which is in the neighborhood.

Homogeneous Exposure Group (HEG): A HEG is a set of persons, positions or work functions for which exposure is of the same nature and intensity.

Onshore site: Onshore means exploration, research, drilling, onshore production, or onshore oil.

Offshore site: The offshore site refers to offshore oil platforms.

Statistical analysis

The data were entered and processed using Epi-info software version 7.2.2. The various tables and graphs were generated using Microsoft Office Excel 2016. For the quantitative variables, averages, medians, and standard deviations were calculated. The Khi2 and Spearman correlation tests were used to evidently put association links or to compare the different study variables.

Interpretation of the correlation coefficient r

- r=0.90 to 1,00 (-0.90 to -1.00): Very strong positive (negative) correlation
- r=0.70 to 0,90 (-0.70 to -0.90): high positive (negative) correlation
- r=0.50 to 0.70 (-0.50 to -0.70): Moderate positive (negative) correlation
- r=0.30 to 0.50 (-.0.30 to -0.50): Low positive (negative) correlation
- r=0.00 to 0.30 (0.00 to -0.30): negligible correlation

Differences were considered significant when p was less than or equal to 0.05 (<5%); 95% confidence intervals (5% margin of error) were calculated.

Results

Socio-professional characteristics of the population

During the study period, 165 workers were operating on all TEPC operational sites. From the selection criteria that were defined, 79 operators or 47.88% were selected to constitute the sample of the study. These were mainly workers operating primarily in the external installations of oil sites.

The workers were selected from five (5) sites of the six (6) operational sites available to TEPC. These are the following:

- One (1) onshore site on one (1) (100%): Djeno oil terminal
- Four (4) out of five (5) offshore sites (80%): Alima, Nkossa, Yanga and Sendji.

Table 1: Distribution of workers by site

		Effective		Percentage
Off-shore	Alima	11	53	67.10%
	Nkossa	25		
	Sendji	5		
	Yanga	12		
On-shore	Djeno	26	26	32.90%
Total		79		

shows the breakdown of all workers selected according to their place of work.

The average age of workers was 33.3 8.5 years, the median being 30 years, which is a relatively young population. The extreme ages were 25 and 60. The 30-39 age group was the most represented with 45 workers. All the workers were men.

The shift workers were either 8 × 8 days for those working on the onshore site or 14 × 14 days for those working on the offshore sites. The daily duration of the shift was 12 hours.

Average seniority was 9.4 7.9 years, median 7 years and extremes 4 years and 36 years.

All reported cases of smoking were active, and the average consumption of the overall smoking population was 1 pack/year.

All socio-professional characteristics are shown in (Table 2).

Table 2: Distribution of workers by socio-professional characteristics

Characteristics	Effective	Percentage
Age (years)		
Under 30 years	27	34.2
30-40	45	57
Over 40 years	7	8.9
Sex		
Female	0	0
Male	79	100
Work Rhythm		
Daytime	2	2.5
Shift work	77	97.5
Seniority at the post		
Less than 10 years	57	72.1
10-20 years	15	19
More than 20 years	7	8.9
Smoking		
Yes	3	4
No	76	96
Position Type		
Operator	39	49.4
Technician	40	50.6
Total	79	100

Benzene atmospheric metrology by GABIE badge

Of the 24 GABIE badges sent to the laboratory, 17 were usable and 7 had results below detection limits.

At the onshore site, the five (5) badges that were operable yielded the following results: 0.053 ppm, 0.024 ppm, 0.019 ppm, 0.02 ppm and 1.48 ppm. The average concentration of atmospheric benzene at the onshore site was 0.31 ppm.

At the offshore sites, twelve (12) badges were usable, the results were as follows:

- Alima: 0.019 ppm and 0.054 ppm with an average of 0.036 ppm
- Nkossa: 0.021 ppm, 0.02 ppm, 0.02 ppm and 0.019 ppm with an average of 0.02 ppm
- Yanga Sendji: 0.055 ppm, 0.056 ppm, 0.053 ppm, 0.071 ppm, 0.064 ppm and 0.066 ppm with an average of 0.061 ppm.

The average concentration of benzene at all sites was 0.12 ppm, the median 0.053 ppm, and the range 0.019-1.448 ppm.

Determination of S-phenylmercapturic acid

Urine samples from the 79 workers of the study were all usable. The average level of S-phenylmercapturic acid in our study population was 0.70 µg/g creatinine. The median was 0.52 µg/g creatinine with a range of 0.23 to 6.7 µg/g creatinine.

The Spearman r correlation coefficient between worker ages and SPMA assays was 0.22 with a p=0.54 and a confidence interval of -0.01 to 0.42. On the other hand, that between their seniority and the SPMA assays was -0.18 with a p=0.11 and a confidence interval of -0.051 to 0.39.

No link was found between smoking and SPMA dosing in workers (p=0.5014), or between the workstation (technician or operator) and SPMA dosing (p=0.5261).

Atmospheric benzene correlation and S-PMA

The Spearman r correlation coefficient between atmospheric benzene concentrations and S-phenylmercapturic acid assays in workers was 0.09 with a p=0.455 and a confidence interval of -0.15 to 0.31.

Discussion

The population of this study was relatively young, with an average age of 33.27 8.5 years and extremes of 25 and 60 years. Technicians and operators represent the lowest level of change in the category of workers at operational sites. These positions are usually filled by those who have recently been hired after a 2-year post-baccalaureate training. This finding is also observed by other authors who find middle ages below 40 years in oil workers: 30.8 years by Hofp et al in Norwegian offshore [6] and less than 40 years by Gardner in offshore installations of oil industries in Britain [7]. On the other hand, Bratveit et al, in Norway, in a study on benzene biometrology among operators of an oil industry, had recovered an average age of 42.3 years [8].

This youth of the population is perfectly correlated with seniority at the post. In this work, 72.15% of workers had seniority at the post of less than 10 years with an average of 9.4 years. However, in an American study of the risk of lymph hematopoietic cancers in 25,000 offshore workers exposed to benzene, the average seniority was less than 15 years [9].

The population included in this study was exclusively male. This could be explained, on the one hand, by the difficulty of being a technician or an operator, which requires considerable physical effort, and, on the other hand, by the isolation and exposure to chemicals which counter-indicate work in this environment to breastfeeding and pregnant women. In general, women are naturally excluded from these occupations as soon as they become pregnant for the first time. Hofp et al [6] and Kirkeleit et al [10] in Norway in their cohorts of workers at oil sites also had an exclusively male study population. On the other hand, in some studies, in offshore oil sectors, the authors found heterogeneous populations, although mostly male to more than 70% [8,11].

The oil sector is one of the sectors, such as the health sector, where activities must be maintained on an ongoing basis. Workers take turns at their shifts for 24 hours a day. In this work, 97% of the workers included had a shift work rhythm.

The notion of active smoking in this study was found in only 4% of workers. This concept is sought because tobacco smoke contains benzene [12]. In Hofp's work in Norway, 33.3% of workers were smokers [6] and 52% in a study on workers' exposure to benzene in Algeria [13]. The cultural characteristics of each population could be an explanation for the differences observed.

The exposure of workers to benzene at the various offshore and onshore sites of this company is a reality because benzene is a natural constituent of crude oil and therefore it is a permanent risk. To estimate the actual exposure to benzene in this working environment, reference is made to the measurements taken on working time (8 hours or 12 hours) and under normal conditions for the performance of the task. In this work, we used the passive GABIE badges of the INRS for the metrological study of benzene during working time. The GABIE badge is a passive badge that simplifies the measurement of exposures to gases and vapors in industrial atmospheres and allows the level of exposure to benzene and other volatile organic compounds to be defined over 8 working hours. It is therefore comparable to average exposure value [14,15].

Measurements of average air exposure levels at all sites (0.12 ppm) were below the average exposure value which is set at 1 ppm in this company. On the other hand, the analysis of a GABIE badge assigned to a producer working in an area of high concentration showed higher benzene concentrations equal to 1.448 ppm and therefore higher than the average exposure value. However, there is variability in exposure levels based on the sites, positions and tasks performed by workers.

The benzene vapor exposure data available in the literature relate to operations at offshore sites with values below the average exposure value and similar to those found in this study. During a regular activity in an offshore oil industry in Norway, the observed extent was 0.001-0.69 ppm [8]. In Bulgaria, Pesatori et al found an atmospheric benzene concentration in the range of 0.024 to 0.09 in a study of the early effects of low exposure to benzene among workers in an oil industry [11]. In Norway, Kirkeleit et al, in 2 different benzene exposure studies found average benzene levels of 0.02 ppm [16] and 0.23 ppm [10]; and Hopf et al, which evaluated exposure in offshore petroleum workers, found an average level of atmospheric benzene at 0.02 ppm [6].

S-phenylmercapturic acid is a biomarker of choice for benzene relative to its sensitivity for low ambient exposure to benzene [17-19]. All urinary assays of this biomarker performed at the end of the shift were lower than BEIs and can be considered as a reflection of very low producer exposure on the day of measurement. This finding, thanks to a biological marker, is consistent with the results of atmospheric sampling. The internal absorbed benzene dose appears to be low. These results are comparable to those described in the literature. These various studies carried out in the oil sector found in their study population very low and lower mercapturic acid concentrations than BEIs [6,10,16,17,19,20].

In this work, no link was found between SPMA urinary assays on the one hand and on the other hand with the age of the producer, seniority at the post, the workplace, smoking, the concentration of benzene in the ambient air.

The very low level of exposure in the oil sites of this company, the limited sample of the study and the uniqueness of the measurements on a working day, could be an explanation for the lack of correlation between environmental measurements and bio metrology in this work. Moreover, the literature on work carried out at the crude oil production site [17,20] and at petrol stations [12,21] finds a good correlation between S-acid levels on the one hand and SPMA and atmospheric benzene concentrations.

The lack of association between smoking and SPMA urinary assays in this work may be due to the very small number of smoking workers in our sample, comparisons under these conditions are not optimal. In contrast, urinary excretion of SPMA acid is known to increase with tobacco consumption [8]. In fact, Boogard et al, in a comparative study of benzene bio metrology in the Netherlands, found high levels of SPMA among smokers ($p<0.001$) [17].

Conclusion

This study quantified benzene exposure among workers at onshore and offshore sites in this oil exploration and production company, while measures to reduce exposure levels are already in place. In normal operation, technicians and operators are very little exposed because the values found in ambient metrology and bio metrology are very low compared to occupational exposure limit values and biological exposure indices for all operational sites investigated notwithstanding variability by site and tasks performed.

Ultimately, this is an occupational group with low exposure to benzene. In addition, there is a need to maintain the preventive measures already in place and to adapt the medical follow-up according to the potentially exposing tasks.

Conflict of interest

The authors do not declare any conflict of interest in relation to this article.

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