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Effects of the occupational exposure on health status among petroleum station workers, Khartoum State, Sudan

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ABSTRACT

Objective: The hazards of petroleum station activities are greatly emphasized due to their negative impact on workers' health and safety concerns. This study aims to assess the effect of occupational exposure among the workers in various petroleum station at the Khartoum State, Sudan.
Methods: An analytical and experimental study design is followed where 60 participants were selected through purposive sampling technique. The participants were recruited from the petroleum workstation and were considered as the lead exposed group whereas the participants who lived faraway from the petroleum station and had no exposure to lead were considered as un-exposed group. To avoid the effects of smoking on lead concentration we further divided these groups into smokers and non-smokers. IBM, SPSS was used for the statistical analysis of the collected data.
Results: The results show that there is no significant difference in white blood cells (WBCs) count between exposed and unexposed lead group. We also did not find significant difference in Red blood cells (RBCs) count. Participant from both groups had normal range of haemoglobin (Hb). However, haematocrit (Hct) levels were elevated in both of these groups. We also tested the platelet count in these groups and found that platelet count was slightly lower in lead exposed group as compared to the unexposed group but average count was found within the normal range. Finally, the lead concentration in serum and urine was detected of the participants. Results reveal that the serum lead concentration of non-smokers (0.58 mg/l) in the exposed group was higher than in non-smokers of unexposed group (0.49 mg/l). The lead concentration in serum of smokers in exposed group was also high (1.49 mg/l) than the lead concentration detected in serum of smokers in unexposed group (1.14 mg/l). Urine lead levels of exposed group was also high than the unexposed group in smokers and non-smokers. Mean value of lead in urine among non-smokers of the exposed and unexposed group were 0.76 mg/L and 0.19 mg/L respectively. In the case of smokers, 1.59 mg/L and 1.16 mg/L were the mean value of lead in urine for both exposed and unexposed groups respectively.
Conclusion: From the given results it can be concluded that health safety measures for workers must be implemented to maintain good health status of workers at petroleum stations.

1. Introduction

Exposure to petrochemical industries such as fuel stations increases vulnerability of the front-line workers due to its integration of highly toxic compounds [1,2]. The escalated growth of the global population and increase in the automobile sector has raised the need for petrol, demonstrating an increased exposure of the occupationally-exposed personnel [3]. The detrimental effects of the exposure have been corroborated by the findings of the International Agency for Research on Cancer (IARC), which has recognised petrol and petrol engines as potentially human carcinogen factors affecting the health of exposed individuals [4].

Generally, the acronym of BTEX (benzene, toluene, ethylbenzene and the isomers of xylene) highlight the naturally occurring compounds in petrol which are hazardous [5,6]. Fowles & Silver [7] stated that the refuelling of vehicles is the primary source of exposure to benzene,

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where the degree of exposure is dependent on the liquid temperature and composition along with the dispensed fuel volume [8]. Various studies have shown severe detrimental effects of BTEX on neurological development and chronic health conditions [9–11]. Alyami [12] indicated that the increase in temperature increases the inhalation uptake. Similarly, the volatile organic compounds (VOCs) flux also increases when the pump has a canopy, i.e., roof [13]. Those countries which have warm climatic conditions, the focus is on reducing or limiting the exposure time of the fuel station workers, due to a spiraling health concern [12]. It is because the gasoline vaporisation rises at an increased ambient temperature [3].

The individual exposure to BTEX has been indicated by several studies such as Kuranchie et al. [1] in Ghana, Johnson & Umoren [14] in Nigeria, Kitwattanavong et al. [12] in Bangkok, Mehrifar, Zamanian & Sedaghat [15] in Iran, Moolla, Curtis & Knight [16] in South Africa and Rushton, Schnatter & Tang [17] in Australia. Only Hammad [18] has examined the occupational exposure for Sudan, however, it remains limited due to the specified period i.e. between 2013 and 2015. To bridge this gap, there lies a need to examine the health status of petroleum station workers employed at different petroleum stations of Sudan.

The significance of the study is further intensified through the findings of Ekpenyong & Asuquo [19], which revealed that occupational-related deaths account for about 0.07 % of the global workforce as a consequence of work-related disease. Additionally, it is outlined that about 5.3 % of the workforce suffers from work-related diseases. The research on environmental health has stated that BTEX constituents can cause detrimental aspects on the individuals' developmental, reproductive and immunological responses as well as systemic toxicity, despite the limited exposure to gasoline additives, industrial solvents and other petroleum products [20,21]. As a consequence, the working attendants and population living in the vicinity are exposed to an increased risk of developing leukemia caused by benzene, unlike the general population [22]. Fuel service station workers who work near VOC sources, such as gasoline vapor emissions and motor vehicle exhausts, may be exposed to highly elevated VOC levels [23].

According to Alam et al. [24], the frequency of the restrictive type of lung abnormality among the petrol pump workers was more in the case group as compared to the unexposed group. The preventive measures adopted during the last few years were associated with a reduction in the quantity of benzene in gasoline and the installation of systems to extract solvent vapours from gasoline pumps [25]. According to the study of Karakitsios et al. [26], fuel station employees are still highly exposed to benzene; although, vapour recovery technologies are installed in the refueling systems and benzene emissions are significantly reduced as compared to the past (52−15 $\mu g/m^3$).

Since 2008, Sudan has become an oil-producing country that produces about 100,000 barrels of oil per day. Thus, downstream petroleum product activity has become very important due to its driving need in the community. According to the Ministry of Petroleum & Gas [27], the total number of petrol stations in Sudan is 1086, of which 23.5 % are located in Khartoum State. Sudan has no standards in terms of occupational safety, despite the springing number of fuel stations. Moreover, the necessity of the regulatory framework concerning the occupational hazard has not been critically examined for Sudan. Therefore, it is essential to investigate the effects of the occupational health status among the workers and highlight the possible health and safety concerns for overcoming its detrimental effects. The present study aims to assess the impact of occupational exposure among petroleum station workers in Khartoum State, Sudan.

2. Methodology

2.1. Study design

The present study has employed an experimental and analytical approach for examining the occupational health outcomes of workers at petroleum stations. This design is used to develop a comprehensive understanding of the research scope and its objective. Consequently, the previous researches in different regions have also concluded holistic findings using the same research design [28].

2.2. Study procedure and sample

Sixty workers employed at the 24 petroleum stations in Khartoum State were recruited in the study based on the determined inclusion and exclusion criteria (Table 1). One major reason for not examining the female participants is the fact that the major workforce at the fuel stations is usually male [29].

The participants were equally divided into two groups, exposed group (EG) and unexposed group (UG), where each group consisted of ($n = 30$) members. In each group, 15 participants were smoker and 15 of them were non-smokers. Exposed group included healthy individuals, who were subjected to lead exposure at petroleum station. Their operating hours were set from 7:30 to 16:30, from Monday to Friday. Whereas, the unexposed group included healthy individuals, who were not subjected to any kind of lead exposure. Individuals from unexposed group were not working or living nearby fuel stations or any industrial area. Participants in unexposed group were also divided into smokers and non-smokers in order to compare the results with lead exposed group. All the selected participants did not consume alcohol.

2.3. Ethical consideration

Initially, an approval from the Institute Review board was obtained for conducting research. An ethical clearance in the form of informed consent was obtained from the respondents before commencing the study.

2.4. Laboratory tests

2.4.1. Complete blood count (CBC)

Venous blood specimens (5 mL) were collected from all the 60 individuals into K3-EDTA tubes and serum vacationer tubes. CBC was performed within 2−4 hours of blood collection using an auto-analyser (Cell-Dyn 1800 Sapphire, Abbott Diagnostics). The CBC included the following main parameters and indices;

- White Blood Cell (WBC) count
- Red Blood Cell (RBC) count
- Hemoglobin (Hb) concentration
- Hematocrit (Hct) percentage
- Platelets (PLT) count

2.5. Detected lead concentrations in blood and urine samples

The blood and urine samples were used as an indicator to detect the workers exposure to the petroleum products. Five millilitres of venous blood were collected in a plain container using a vacationer. The measurements were made using a flameless atomic absorption spectrometer (AAS) Model Buck Scientific 210 VGP.

Table 1
Inclusion and Exclusion Criteria.

Inclusion Criteria	Exclusion Criteria
Male participants	Female participants
At least six months of working at a fuel station.	Less than six months of working at a fuel station
An average of 72 -h work hours per week	An average of less than 72 -h work hours per week
No clear clinical complaints	Reporting of clinical complaints

2.6. Data analysis

All the data was analysed using the IBM, SPSS version 25.0 software. Pearson correlation test was implied to observe the statistical difference between lead exposed and unexposed groups of smokers and non-smokers.

3. Results

3.1. Demographic details

The data concerning the demographic details of the participants was gathered through the record provided by the petroleum station. It indicated that age limit of the participants for the experiment group was 25–55 years (mean 40 ± 10) for the exposed group and 20–50 years for the unexposed group, (mean 40 ± 10). The employment period of majority (44) of workers ranged from 1 to 5 years, while the remaining 11 had employment period of 6–10 years and only 5 worked for above 10 years.

Table 2 shows the number of months these participants were exposed at the station. It shows that the highest frequency (15) was obtained from 25 to 28 months. Whereas, lowest frequency (1) was obtained for participants who were exposed for more than 96 months.

3.2. Complete blood count (CBC)

Table 3 shows the mean level of WBCsx10^9, RBCs x10^{12} /l, HB (g/dl) HCT% and PLTs10^9/ L of workers exposed to benzene in comparison to the unexposed group. The mean results of the exposed group provided the following values for WBCs (6.38), RBCs (5.02), HB (14.41), HCT (43.63), and PLTs (219.47). Whereas in case of unexposed group, mean values of (6.32), (5.09), (14.39), (43.86), and (240.65) were obtained for WBCs, RBCs, HB, HCT and PLTs, respectively.

Comparing the two sub-groups, the (HB & RBCs) parameters were agreed, while parameters for (WBCs & PLTs) were disagreed. Highest agreement for all the parameters were only indicated in the unexposed group.

3.3. Detected lead concentrations in the blood (serum)

The blood lead level (BLL) for the exposed group of non-smokers was 0.58 mg/L was higher than the lead concentration in unexposed group that was 0.49 mg/L. However, the lead concentration for the exposed group of smokers was 1.49 mg/L that was higher than the mean value for smokers in unexposed group (1.14 mg/l). These results do not correspond with the standard levels of lead (Pb) in the blood (0.1−0.5 mg/L) [30] mentioned in Table 4.

Table 5 illustrates that mean concentration of lead in urine among non-smokers of the exposed and unexposed group were 0.76 mg/L and 0.19 mg/L respectively. In the case of smokers, 1.59 mg/L & 1.16 mg/L was the mean concentration of lead in urine for both exposed and unexposed groups respectively. The results of the study provided for non-smokers were in agreement with the standard levels of lead in urine i.e. (0.12 – 0.27 mg/L). Whereas, for smokers' category, the results showed disagreement with the standard level of urine (0.12 – 0.27 mg/L).

Table 2
Exposed Month Duration (Exposed group).

Duration of Exposed Months	Frequency
Less than 24 months	15
25 to 28 months	7
49 to 72 months	5
73 to 96 months	2
Above than 96 months	1

4. Discussion

This study assessed the effects of occupational exposure among the selected petroleum station workers of Khartoum State, Sudan. The study found inconsistency concerning the mean level of WBCsx10^9, RBCs x10^{12} /l, HB (g/dl) HCT%, and PLTs10^9/ L, of workers when exposed to benzene. Besides, lab results regarding the concentration of lead in blood and urine further indicated that the results are higher than the expected population background of 0.1−0.5 mg/L in the country. For smokers, the mean detected lead concentration in the blood of both exposed and unexposed groups were 1.49 mg/L and 1.14 mg/L respectively.

Similarly, the mean detected lead concentration in urine of non-smokers in unexposed group was in agreement with the standard levels of lead in urine. However, a strong disagreement was identified for smokers in the given case.

Khalifa [31] conducted a study in Sudan on the exposed and unexposed group of workers who were exposed to benzene. The results showed that the mean values of Hb (g/dl), RBCs x10^{12} /l. WBCsx 10^9, PLTs10^9/ L were (12.6), (3.4), (3.3), and (124) respectively for the exposed group. While the results obtained for the unexposed group were (13.3), (4.8), (6.6), and (268), respectively. The results of this study for the same parameters were (14.41), (5.02), (6.38), (219.47) for the case group, comparing to (43.86), (5.09), (6.32), and (240.65) for the unexposed group.

Sirdah et al. [32] stated that the mean values of WBCsx 10^9, RBCs x10^{12} /l, HB (g/dl), HCT and PLTs10^9/ L were (4.71), (6.27), (16.3), (51.1), and (431) respectively for the exposed group. While, the results obtained for the unexposed group were (7.9), (4.68), (14.4), (41.9), and (231), respectively. Sirdahs' results corroborate the results of the present study concerning the same parameters with values; (6.38), (5.02), (14.41), (43.63), and (219.47) for the exposed group as compared to the unexposed group with values (6.32), (5.09), (14.39), (43.86), and (240.65), respectively. The high levels of lead in unexposed group indicates that some consequential exposure is occurring, which is present in a defined unexposed population.

Similarly, Hamad [33] study in Gaza Strip determined the levels of lead among gasoline station workers. Moreover, the mean detected lead concentration blood of the exposed group was (11.4 μg/dl =0.114 mg/l) and was compared to (5.3 μg/dl =0.053 mg/l) the unexposed group. These findings contradict the current results of 1.49 mg/l and 1.14 mg/l for both the exposed and unexposed groups. Another study of Moneim et al. [34] determined lead concentration in blood among fuel station workers in Khartoum City (Sudan). The results demonstrated that the mean detected lead concentration in the study group was (33.6 μg/dl=0.336 mg/l); while, it was (8.1 μg/dl=0.081 mg/l) in the unexposed group. However, in the present study the lead levels detected were 1.49 mg/1 and 1.14 mg/l for both exposed and unexposed groups.

Another study carried out by Mohammed [35] in Sulaimaniya City (Iraq) found changes in the haematological and biochemical profile in correlation to the detected lead concentration among gasoline station workers, smokers and non-smokers, who were occupationally exposed to gasoline. It showed that the detected lead concentration in blood among gasoline station workers was (6.2 μg/dL), which was significantly (0.017) higher than the value obtained for unexposed group (2.1 μg/dL). It showed a significant (0.003) increase in blood lead concentration (10.6 μg/dL) of smokers as compared to non-smokers working at the station.

Cabaravdic et al. [36] determined the lead concentration in the urine of the attendants at a gas station and those who are professionally exposed to inorganic lead (n = 73; n = 81), during two periodic reviews performed in 2003 and 2008. It showed the level was (35.2) micromol/L (-1) (8.16 mg/l). Concerning the present study, the results of urine lead concentrations were (1.59 mg/l) for the exposed group and (1.16 mg/l) for the unexposed group, which means the above-mentioned results disagreed with the results of the present study. Another research was

Table 3
Complete Blood Count Test Results (Exposed/Unexposed groups).

Total Blood Count	WBC		RBC		Hb		HCT		PLT	
Normal Range	(3.5−10.5) *10^9 /L		(4.32–5.72) *10^9 /L		(13.5–17.5) g/dl		(38.8–50) %		(150–450) *10^9 /L	
Sample. No	EG	UG	EG	UG	EG	UG	EG	UG	EG	UG
1	5.2	6.9	5.83	5.78	16.6	16.3	52.8	50.8	218	262
2	3.7	4.7	5.05	6.01	14.1	17.4	31.3	51.4	164	135
3	5.6	4.4	4.97	5.55	14.4	15.4	44.4	47.5	205	210
4	4.2	5.2	4.63	5.29	13.9	14.8	42.3	45.2	241	84
5	3.8	4.8	5.1	5.43	14.6	15.6	43.9	47.9	101	269
6	6.5	2.2	5.56	4.43	15.3	12.5	46.3	38.9	251	44
7	6.6	7.2	5.56	4.12	15.2	12.3	46.8	37.3	261	98
8	6.6	5.7	4.71	4.43	14.6	11.7	42.8	36.6	316	138
9	4.7	8.1	5.73	5.44	15.7	15.8	52.6	46.7	204	422
10	5.3	6.7	4.81	4.86	14.9	15	45.8	44.3	231	296
11	5.4	9	4.71	4.95	13.7	12.9	40.7	40.8	196	349
12	3.4	7.9	5.41	4.73	15.1	13	46.6	40.1	196	398
13	8.9	5.9	4.68	4.82	12.8	13	38.6	38.6	177	214
14	8.9	5.4	4.63	5.56	13.4	15.8	40.5	48.1	269	274
15	18.5	8	4.89	5.07	14.1	14.9	43	44.5	187	299
AVG	6.38	6.32	5.02	5.09	14.41	14.39	43.63	43.86	219.47	240.65
Correlation	0.180		−0.004		0.109		−0.042		−0.299	
% of up normality	5.3	0	15.8	11.8	0	0	10.5	11.8	5.3	23.5

Table 4
Lab Results for Detected Lead Concentration in Serum (Normal levels for Pb in Serum (0.1 - 0.5 mg/L).

Detected Lead Concentration in Serum	Non-Smokers (mg/L)		Smokers (mg/L)	
Sample. No	EG	UG	EG	UG
1	0.66	0.41	1.03	0.55
2	0.57	0.26	0.28	0.65
3	0.58	0.49	0.5	0.77
4	0.49	0.47	1.42	0.44
5	0.45	0.33	0.4	0.75
6	0.38	0.47	0.16	1.13
7	0.47	0.35	0.63	0.58
8	0.5	0.29	0.72	0.78
9	0.33	0.19	1.49	0.36
10	0.52	0.28	0.71	0.32
11	0.47	0.49	0.17	0.34
12	0.56	0.18	0.37	0.57
13	0.45	0.38	0.88	0.71
14	0.48	0.26	0.72	1.14
15	0.41	0.25	1.01	1.03
Correlation	0.150		−0.268	

Table 5
Lab Results for detected Pb concentration in Urine (Normal level for Urine (0.12 – 0.27 mg/L).

Detected Pb concentration in Urine	Non-Smokers (mg/L)		Smokers (mg/L)	
Sample. No	EG	UG	EG	UG
1	0.2	0.2	1.59	1
2	0.47	0.14	1.15	0.53
3	0.76	0.14	0.79	1.01
4	0.41	0.16	1.41	0.43
5	0.58	0.12	0.31	0.41
6	0.73	0.15	0.66	0.74
7	0.33	0.17	1.05	0.7
8	0.64	0.13	0.82	1.16
9	0.35	0.12	0.6	0.81
10	0.67	0.13	0.79	0.84
11	0.39	0.17	0.63	0.87
12	0.34	0.19	0.41	0.81
13	0.49	0.16	0.72	1.16
14	0.31	0.13	0.99	0.72
15	0.36	0.17	0.13	0.87
Correlation	−0.549			

carried out by Cusick et al. [37] in Riyadh which measured the concentrations of lead, cadmium and chromium in blood, urine, and saliva samples. The samples were taken from fuel station workers and the relationship between the concentrations of such heavy metals and the working period inside the fuel stations were discussed. Findings of the study revealed a high concentration of lead, cadmium and chromium in the governing biological samples (blood, urine, and saliva) of the fuel station workers. These concentrations were associated with the exposure time to the heavy metals. Another study has shown an increase of the chromosol translocation on occupational exposure to pesticides in open-field farming [38]. Therefore, an expert should consider synergism between the toxic effects of single-factor risks with respect to binary toxicity type and the standard method of summation [39]. Similarly, Nduka and Kelle [40] have emphasised that the resident population and the artisans residing or working in auto-panel workshops might be exposed to heavy metal risks from paint dust matrix in car, which can immune their body. The findings discussed links with aforementioned literature that occupational exposures are the most self-evident scenario of body immunity.

Another recent study by Akinyemi et al. [41] investigated the impact of lead exposure on dopaminergic neurodegeneration and functioning, which revealed that the activation of protein kinase C is directly associated with neurotoxicity of lead. The study by Akinyemi et al. [41] was further extended by Renieri et al. [42], who investigated the presence of cadmium, lead, and mercury in muscle tissue of seabass and gilthead seabream. The results demonstrated that the species of seabass and gilthead seabream were safe for all the tested metals. The present study has investigated mechanisms of toxicity of harmful substances, with major emphasis on possible toxic effects on the immune system. A similar study by Fenga et al. [43] conducted review analysis to assess the immunological effects of occupational exposure to lead. The results concluded that exposure to lead is linked with its toxic effects on the immune system, which increases the incidence of infections, allergy and autoimmunity or cancer. Whereas, Rapisarda et al. [44] assessed the association between occupational exposure to lead and elevated blood pressure. The results showed that the blood pressure slightly increased as the result of occupational exposure to higher ambient lead. There was significant correlation between increased blood pressure and lead values. Lead is known to affect the immune system by dysregulating the haemoglobin and haematocrit concentration, which ultimately leads to anaemia. Lead also elevates the total leucocytes concentration and inhibits the aggregation of blood platelets. It is toxic to the body as it may leads to metal toxicity by increasing the oxidative stress in the body and disrupts the normal metabolic pathways [45].

Based on the findings, the present study recommends that the most effective and safest way of protecting the workers' health is to introduce a regulatory mechanism at national level. Similarly, private firms can also establish standards to limit workers' exposure by instigating policy statements and guidelines. Efforts must be initiated for providing the necessary resources such as training, medical surveillance and personnel awareness concerning their exposure. Moreover, unambiguous communication channels should be established for the characterisation of hazards, emergency preparedness, as well as community awareness programs. Similarly, appropriate engineering, as well as procedurals control, must be established. Furthermore, all the programs and assessments must be documented, such as inspections, analytical reports, monitoring reports, medical surveillance and trainings. It is also necessary to conduct a self-audit for revealing the necessary shortcomings. On-site protection can include the use of protective clothes among the workers, appropriate time-limit for the worker, regular medical examination and follow-ups along with the use of protective tools at the station. In case a worker has been exposed to a longer time, then the use of an ear loop face mask is advised.

The present study involves certain limitations, the first and foremost is the small sample size of the study. This study also has limits because of its sample type as the samples were collected from one region only, which leads to the need of comparative analysis of similar idea between population of two different regions. These limitations are important, therefore future studies in this area are suggested to be conducted and provide a comparative analysis of health status of petroleum station workers belonging from two different regions. This study also fails to explain the reason of elevated lead concentration in blood samples from unexposed group that might be due to some consequential exposure of that particular group. This needs to be investigated in the future studies.

5. Conclusion and recommendations

The present study assessed the effects of occupational exposure among workers at different petroleum stations of Khartoum State, Sudan. WBCs count result showed that most of the participants within the exposed group had normal range; while, all the participants from unexposed group had the normal recommended range of WBCs. Similarly, RBCs count showed the normal levels as the recommended range in both exposed and unexposed group. Moreover, the Hb and PLTs concentration in blood explained that the exposed and unexposed groups were within the recommended normal range; however, some of the participants from unexposed group had PLTs concentration below the normal range. For Hct, results of the average mean value indicated that participants from exposed and unexposed groups were within the normal range of Hct. The detected lead concentration in blood for non-smokers were 0.66 and 0.49 mg /L for the exposed and unexposed groups, respectively. Whereas, results for the detected lead concentration in urine indicated non-smokers' agreement with the standard levels of lead in urine. The result of the study states that among all the tested parameters, the lead is the only one that significantly differs among exposed and un-exposed groups, both for smokers and non-smokers and may affect health status. Moreover, presence of lead in the samples of unexposed group highlights the need of screening, follow-up assessment, treatment and monitoring of those who are not directly exposed to lead, but may be affected indirectly. It is also recommended that the health status in terms of allergies, infections, blood pressure needs to be further investigated.

Authors statement

The authors confirm that this study is not published elsewhere, neither it is in consideration by any other journal. The authors declare that the content provided in this study is original and is complied on the format and policies of the journal. Ethical aspects of this study were further considered, as the data were collected after attaining an approval from the appropriate ethics review board. Consent for patients'/respondents' participation was further obtained.

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Declaration of Competing Interest

The authors report no declarations of interest.

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References

[1] F.A. Kuranchie, P.N. Angnunavuri, F. Attiogbe, E.N. Nerquaye-Tetteh, Occupational exposure of benzene, toluene, ethylbenzene, and xylene (BTEX) to pump attendants in Ghana: implications for policy guidance, Cogent. Environ. Sci. 5 (2019), https://doi.org/10.1080/23311843.2019.1603418.
[2] F. Rota, A. Conti, L. Campo, C. Favero, L. Cantone, V. Motta, E. Polledri, R. Mercadante, G. Dieci, V. Bollati, S. Fustinoni, Epigenetic and transcriptional modifications in repetitive elements in petrol station workers exposed to benzene and MTBE, Int. J. Environ. Res. Public Health 15 (2018) 735, https://doi.org/10.3390/ijerph15040735.
[3] L. Campo, F. Rossella, R. Mercadante, S. Fustinoni, Exposure to BTEX and ethers in petrol station attendants and proposal of biological exposure equivalents for urinary benzene and MTBE, Ann. Occup. Hyg. 60 (2015) 318–333, https://doi.org/10.1093/annhyg/mev083.
[4] Z.A. Kasemy, G.M. Kamel, G.M. Abdel-Rasoul, A.A. Ismail, Environmental and health effects of benzene exposure among egyptian taxi drivers, J. Environ. Public Health 2019 (2019) 1–6, https://doi.org/10.1155/2019/7078024.
[5] J.G. Speight, Handbook of Petroleum Product Analysis, John Wiley & Sons, 2015.
[6] B. Heibati, K.J.G. Pollitt, A. Karimi, J. Yazdani Charati, A. Ducatman, M. Shokrzadeh, M. Mohammadyan, BTEX exposure assessment and quantitative risk assessment among petroleum product distributors, Ecotoxicol. Environ. Saf. 144 (2017) 445–449, https://doi.org/10.1016/j.ecoenv.2017.06.055.
[7] J. Fowles, E. Silver, A Screening-level Risk Assessment of Petrol Exposures in New Zealand, 2015.
[8] V. Bhardwaj, B. Rani, A. Kumar, Determination of BTEX in urban air of Agra, Int. J. Adv. Res. Sci. Eng. Technol. 6 (2017) 801–808.
[9] B. Lv, S. Song, Z. Zhang, Y. Mei, F. Ye, Urinary S-phenylmercapturic acid as a key biomarker for measuring occupational exposure to low concentrations of benzene in chinese workers, J. Occup. Environ. Med. 56 (2014) 319–325, https://doi.org/10.1097/jom.0000000000000098.
[10] S. Hazrati, R. Rostami, M. Fazlzadeh, F. Pourfarzi, Benzene, toluene, ethylbenzene and xylene concentrations in atmospheric ambient air of gasoline and CNG refueling stations, Air Qual. Atmos. Health 9 (2015) 403–409, https://doi.org/10.1007/s11869-015-0349-0.
[11] S. Zoleikha, R. Mirzaei, M. Roksana, Exposure to chemical hazards in petrol pumps stations in Ahvaz City, Iran, Arch. Environ. Occup. Health 72 (2016) 3–9, https://doi.org/10.1080/19338244.2015.1058233.
[12] M. Kitwattanavong, T. Prueksasit, D. Morknoy, T. Tunsaringkarn, W. Siriwong, Health risk assessment of petrol station workers in the Inner City of Bangkok, Thailand, to the exposure to BTEX and carbonyl compounds by inhalation, Hum. Ecol. Risk Assess. 19 (2012) 1424–1439, https://doi.org/10.1080/10807039.2012.685814.
[13] A.R. Alyami, Assessment of Occupational Exposure to Gasoline Vapour at Petrol Stations, 2016.
[14] O. Johnson, Q. Umoren, Occupational hazards and health problems reported by workers in a sawmill in Uyo, Nigeria, J. Environ. Occup. Sci. 7 (2018) 17, https://doi.org/10.5455/jeos.20180615042801.
[15] Y. Mehrifar, Z. Zamanian, Z. Sedaghat, Harmful outcome of occupational exposure to petrol: assessment of liver function and blood parameters among gas station workers in Kermanshah city, Iran, Int. J. Prev. Med. 9 (2018) 100, https://doi.org/10.4103/ijpvm.ijpvm_296_16.
[16] R. Moolla, C. Curtis, J. Knight, Occupational exposure of diesel station workers to BTEX compounds at a bus depot, Int. J. Environ. Res. Public Health 12 (2015) 4101–4115, https://doi.org/10.3390/ijerph120404101.
[17] L. Rushton, A.R. Schnatter, G. Tang, D.C. Glass, Acute myeloid and chronic lymphoid leukaemias and exposure to low-level benzene among petroleum workers, Br. J. Cancer 110 (2013) 783–787, https://doi.org/10.1038/bjc.2013.780.
[18] O.H. Hamad, Occupational and Environmental Hazards Among Workers in Petroleum Stations, Khartoum State, Sudan 2013-2015, Doctoral dissertation, University of Gezira, 2018.
[19] C. Ekpenyong, A. Asuquo, Recent advances in occupational and environmental health hazards of workers exposed to gasoline compounds, Int. J. Occup. Med. Environ. Health (2017), https://doi.org/10.13075/ijomeh.1896.00800.

[20] A.V. Sirotkin, A.H. Harrath, Influence of oil-related environmental pollutants on female reproduction, Reprod. Toxicol. 71 (2017) 142–145, https://doi.org/10.1016/j.reprotox.2017.05.007.
[21] J. Stolark, A Brief History of Octane in Gasoline: From Lead to Ethanol, Environmental and Energy Study Institute, 2016, pp. 1–6.
[22] G. Pilidis, S. Karakitsios, P. Kassomenos, Benzene Risk Assessment Evaluation Due to an Urban Filling Station Operation, University of Patras –Srcosmos, Greece, 2008.
[23] D. Yimrungruang, V. Cheevaporn, T. Boonphakdee, P. Watchalayann, H. F. Helander, Characterization and health risk assessment of volatile organic compounds in gas service station workers, Environ. Asia 2 (2008) 21–29.
[24] R. Alam, A. Zafar, A. Ghafoor, A. Naseem, Q. Ali, F. Imtiaz, Lung function abnormalities among fuel filling workers in Karachi, Pakistan, Cough 21 (2014) 028.
[25] M. Rokni, M. Mohammadyan, S.T. Hashemi, S.M. Asadi, P.J. Boogaard, B. Heibati, K. Yetilmezsoy, S.A. Abdul-Wahab, Risk assessment of workers exposed to crystalline silica aerosols, Hum. Ecol. Risk Assess. 22 (2016) 1678–1686, https://doi.org/10.1080/10807039.2016.1217391.
[26] S.P. Karakitsios, C.L. Papaloukas, P.A. Kassomenos, G.A. Pilidis, Assessment and prediction of exposure to benzene of filling station employees, Atmos. Environ. 41 (2007) 9555–9569, https://doi.org/10.1016/j.atmosenv.2007.08.030.
[27] Ministry of Petroleum & Gas, Distribution of Petroleum Stations in Khartoum State, 2015.
[28] M. Rezazadeh Azari, Z. Naghavi Konjin, F. Zayeri, S. Salehpour, M.D. Seyedi, Occupational exposure of petroleum depot workers to BTEX compounds, Int. J. Occup. Environ. Med. 3 (2012) 39–44.
[29] L. Tønnessen, Women at work in Sudan: marital privilege or constitutional right? Soc. Polit. 26 (2019) 223–244.
[30] G.D. Christian, Analytical Methods for Atomic Absorption Spectroscopy, United State of America: The Perkin-Elmer Corporation, 1994.
[31] M.E.S.A. Khalifa, Measurement of Complete Blood Count Among Fuel Benzene Station Workers in Khartoum State, Doctoral dissertation, Sudan University of Science and Technology, 2014.
[32] M.M. Sirdah, N.A. Al Laham, R.A. El Madhoun, Possible health effects of liquefied petroleum gas on workers at filling and distribution stations of Gaza governorates, East. Mediterr. Health J. 1 (2013) 289–294, https://doi.org/10.26719/2013.19.3.289.
[33] A.A.R.I. Hamad, Some Biochemical and Hematological Alterations Associated With Lead Exposure in Gasoline Station Workers in Gaza strip. Some Biochemical and Hematological Alterations Associated With Lead Exposure in Gasoline Station Workers in Gaza strip, 2008.
[34] H.A. Moneim, M.F. Abdul-Rahman, M. Janjo, M. Naeem, N.A. Al Hafez, Determination of the Concentration of Some Heavy Metals in the Vital Samples of the Workers of the Fuel Stations in Riyadh, 2016.
[35] S. Mohammed, Hematological, biochemical and blood lead level profile among gasoline exposed station workers in Sulaimaniya City, ARO, Sci. J. Koya Univ. 2 (2014) 2014, https://doi.org/10.14500/aro.10036.
[36] M. Cabaravdic, M. Mijanovic, J. Kusturica, A. Cabaravdic, Occupational exposure of workers at gas station to inorganic lead, Med. Arch. 64 (2010) 107.
[37] S.E. Cusick, E.G. Jaramillo, E.C. Moody, A.S. Ssemata, D. Bitwayi, T.C. Lund, E. Mupere, Assessment of blood levels of heavy metals including lead and manganese in healthy children living in the Katanga settlement of Kampala, Uganda, BMC Public Health 18 (2018), https://doi.org/10.1186/s12889-018-5589-0.
[38] B.M. Qaqish, O. Al-Dalahmah, Y. Al-Motassem, A. Battah, S.S. Ismail, Occupational exposure to pesticides and occurrence of the chromosomal translocation among farmers in Jordan, Toxicol. Rep. 3 (2016) 225–229, https://doi.org/10.1016/j.toxrep.2016.01.002.
[39] I.A. Minigalieva, B.A. Katsnelson, V.G. Panov, A.N. Varaksin, V.B. Gurvich, L. I. Privalova, M.P. Sutunkova, S.V. Klinova, Experimental study and mathematical modeling of toxic metals combined action as a scientific foundation for occupational and environmental health risk assessment. A summary of results obtained by the Ekaterinburg research team (Russia), Toxicol. Rep. 4 (2017) 194–201, https://doi.org/10.1016/j.toxrep.2017.04.002.
[40] J.K. Nduka, H.I. Kelle, J.O. Amuka, Health risk assessment of cadmium, chromium and nickel from car paint dust from used automobiles at auto-panel workshops in Nigeria, Toxicol. Rep. 6 (2019) 449–456, https://doi.org/10.1016/j.toxrep.2019.05.007.
[41] A.J. Akinyemi, M.R. Miah, O.M. Ijomone, A. Tsatsakis, F.A.A. Soares, A.A. Tinkov, M. Aschner, Lead (Pb) exposure induces dopaminergic neurotoxicity in Caenorhabditis elegans: involvement of the dopamine transporter, Toxicol. Rep. 6 (2019) 833–840, https://doi.org/10.1016/j.toxrep.2019.08.001.
[42] E.A. Renieri, I.V. Safenkova, A.K. Alegakis, E.S. Slutskaya, V. Kokaraki, M. Kentouri, A.M. Tsatsakis, Cadmium, lead and mercury in muscle tissue of gilthead seabream and seabass: Risk evaluation for consumers, Food Chem. Toxicol. 124 (2019) 439–449, https://doi.org/10.1016/j.fct.2018.12.020.
[43] C. Fenga, S. Gangemi, V. Di Salvatore, L. Falzone, M. Libra, Immunological effects of occupational exposure to lead, Mol. Med. Rep. 15 (2017) 3355–3360, https://doi.org/10.3892/mmr.2017.6381.
[44] V. Rapisarda, C. Ledda, M. Ferrante, Fiore M, S. Cocuzza, M. Bracci, C. Fenga, Blood pressure and occupational exposure to noise and lead (Pb) A cross-sectional study, Toxicol. Ind. Health 32 (2016) 1729–1736, https://doi.org/10.1177/0748233715576616.
[45] R.R. Ray, Haemotoxic effect of lead: a review, Proc. Zool. Soc. 69 (2016) 161–172, https://doi.org/10.1007/s12595-015-0160-9.