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Health risk assessment of heavy metals on workers at the Doura Oil Refinery, Baghdad

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Abstract

Pollutants resulting from oil refining operations cause harmful effects on public health, especially for workers exposed for long periods. Measuring the level of specific contaminants in the blood of refinery workers is necessary to understand the relationship between exposure to pollutants and health status. This study aims to determine the levels and nature of heavy metals in the blood of occupational exposure workers in the Al-Dora refinery, Baghdad. A total of 20 blood samples (15 exposed workers and 5 non-exposed individuals (control)) were investigated to assess the level of heavy metals. An atomic absorption spectrometer (AAS) was used to measure the levels of Cr, Cd, Pb, and V in the blood samples. The mean concentrations of heavy metals in the blood of the exposed group are significantly higher compared to the control groups, with Cr at 65.27 µg/dl, Cd at 163.93 µg/dl, Pb at 37.33 µg/dl, and V at 153.33 µg/dl. The results showed a significant difference between the exposed and control groups ($p<0.001$), which indicates a strong correlation between heavy metal levels in the blood and exposure status. There was also a correlation between the level of heavy metals in the blood of exposure groups, age, smoking, and duration of work. In particular, workers aged 15 years and more, smoking workers, and female workers had higher levels of heavy metals. Moreover, Cd and V levels exceeded permissible limits. Our findings highlight the importance of implementing comprehensive health and safety protocols to reduce the risk factors associated with age, smoking, and prolonged exposure among workers in oil refineries to improve workers' overall health and well-being.

Keywords: Heavy metals, Blood, Occupation exposure, Oil refinery, Al-Dora refinery.

تقييم المخاطر الصحية الناتجة عن التعرض للمعادن الثقيلة بين موظفي مصفاة الدورة للنفط في بغداد

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الخلاصة

يمكن ان تتسبب الملوثات الناتجة عن عمليات تكرير النفط في آثار صحية ضارة جداً، وخاصة للعمال المعرضين لها بشكل دائم. لذلك، فإن قياس مستوى الملوثات المحددة في دم عمال المصافي يعد أمراً ضرورياً لفهم العلاقة بين التعرض للملوثات والحالة الصحية. تهدف هذه الدراسة إلى تحديد مستويات المعادن الثقيلة في دم العمال المعرضين مهنياً في مصفاة الدورة، بغداد. تم تحليل 20 عينة دم (15 عاملاً معرضاً و5 أفراد غير

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معرضين) لقياس مستوى المعادن الثقيلة. تم استخدام مطياف الامتصاص الذري (AAS) لقياس مستويات الكروم (Cr) والكادميوم (Cd) والرصاص (Pb) والفاناديوم (V) في عينات دم العمال. كانت متوسطات تركيزات المعادن الثقيلة في دم المجموعة العاملة في المصفى أعلى بكثير وبشكل ملحوظ مقارنة بالمجموعة التي لا تعمل في المصفى، حيث كانت تركيزات الكروم 65.27 ميكروغرام/ديسيلتر، الكادميوم 163.93 ميكروغرام/ديسيلتر، الرصاص 37.33 ميكروغرام/ديسيلتر، والفاناديوم 153.33 ميكروغرام/ديسيلتر. أظهرت النتائج وجود فرق كبير بين المجموعتين (p<0.001)، مما يشير إلى وجود علاقة قوية بين مستويات المعادن الثقيلة في الدم وحالة التعرض. كما كان هناك ارتباط بين مستوى المعادن الثقيلة في دم المجموعات المعرضة والعمر والتدخين ومدة العمل. على وجه الخصوص، كان لدى العمال الذين تزيد أعمارهم عن 15 عاماً، والعمال المدخنين، والعاملات مستويات أعلى من المعادن الثقيلة. بالإضافة الى ذلك، تجاوزت مستويات الكادميوم والفاناديوم الحدود المسموح بها في العراق وعلى المستوى الدولي. تبرز نتائجنا أهمية الشروع العاجل بتنفيذ بروتوكولات صحية وسلامة شاملة لتقليل عوامل الخطر عند العمال في مصافي النفط لتحسين الصحة العامة والرفاهية بينهم.

1. Introduction

The refinery industries emit various pollutants, such as gases and heavy metals. When a heavy metal is known to have the potential to be harmful, or when it is relatively dense, they are considered toxic. Heavy metals are harmful when their concentrations exceed the permissible limits, internalizing human cells and causing severe tissue damage [1]. Certain heavy metals, such as zinc (Zn), lead (Pb), cadmium (Cd), mercury (Hg), copper (Cu), and nickel (Ni), were reported to induce effects on human health even at low concentrations [2], [3]. Heavy metals, including Cu, Cd, Ni, and Pb, are found in high concentrations in crude oil [4], [5]. Thus, heavy metals contamination has been dealt with as a major global concern [6], [7]. Various contaminants from the oil industry are released into the air, soil, and water, substantially impacting the ecosystem and causing severe health issues, especially for continuously exposed individuals in highly contaminated workplaces [8], [9].

Heavy metals are currently of much environmental concern [10]. Some recent studies have looked at the potential impacts of heavy metal emissions from oil, such as vanadium, and reported adverse effects on workers in all facilities that use and process crude oil [11]. Generally, anthropogenic and natural processes are the major causes of heavy metal contamination [12]–[14]. The most common exposure method at work is inhalation, where 5% to 35% of inhaled heavy metals are absorbed into the blood, which is also affected by the type, size, and location of heavy metals [15]. Humans may be exposed to heavy metals through their skin from products containing heavy metals besides polluted food ingestion [16]–[19]. Wind direction is a significant factor in the distribution of pollutants in the air, moving the particles of different heavy metals and contaminants towards remote regions [20], [21].

In addition to heavy metal exposure, workers in the oil and gas industries may also face high radiation exposure due to naturally occurring radioactive materials (NORM) associated with petroleum production processes. These combined hazards underline the critical need for enhanced regulatory standards and technological innovations to mitigate health risks and environmental impacts [22]. Cr is readily released into the environment during petroleum exploration due to leakages [23], [24], causing skin allergies and lung cancers [25]. Since Cd is present in phosphate fertilizers, it often enters the environment through the ground and is found in the crust of the earth [26]. Several studies have revealed that cadmium, even at deficient concentrations, may cause serious kidney diseases [27]. Pb poisoning is also a causative of severe disorders, and it destructively impacts the human body [28]–[30]. Long exposure to Pb has also been reported to cause anaemia [31]. V is likewise known to be present in crude oil and coal in different quantities [24]. V can be highly toxic to humans because it can affect important cellular functions, including cell cycle and cell survival mechanisms [32].

The existence of oil refineries in major urban areas can have a substantial impact on people's health, potentially causing respiratory problems and skin disorders. This study aims to compare employees' blood at the Al-Dora oil refinery, a crucial industrial facility in the Middle Euphrates region, with healthy individuals to assess the presence of heavy metals in their bodies.

2. The study area

Al-Dora Refinery is the main refinery in Iraq, located in Al-Dora city at latitude 33° 16′ 31″ N and longitude 44° 25′ 39″ E, on the western side of the Tigris River, about 4 km south of the center of Baghdad. Al-Dora Refinery is categorized by its important location on the banks of the Tigris Canal, covering an area of about (2,500,000 m^2) (Figure 1).

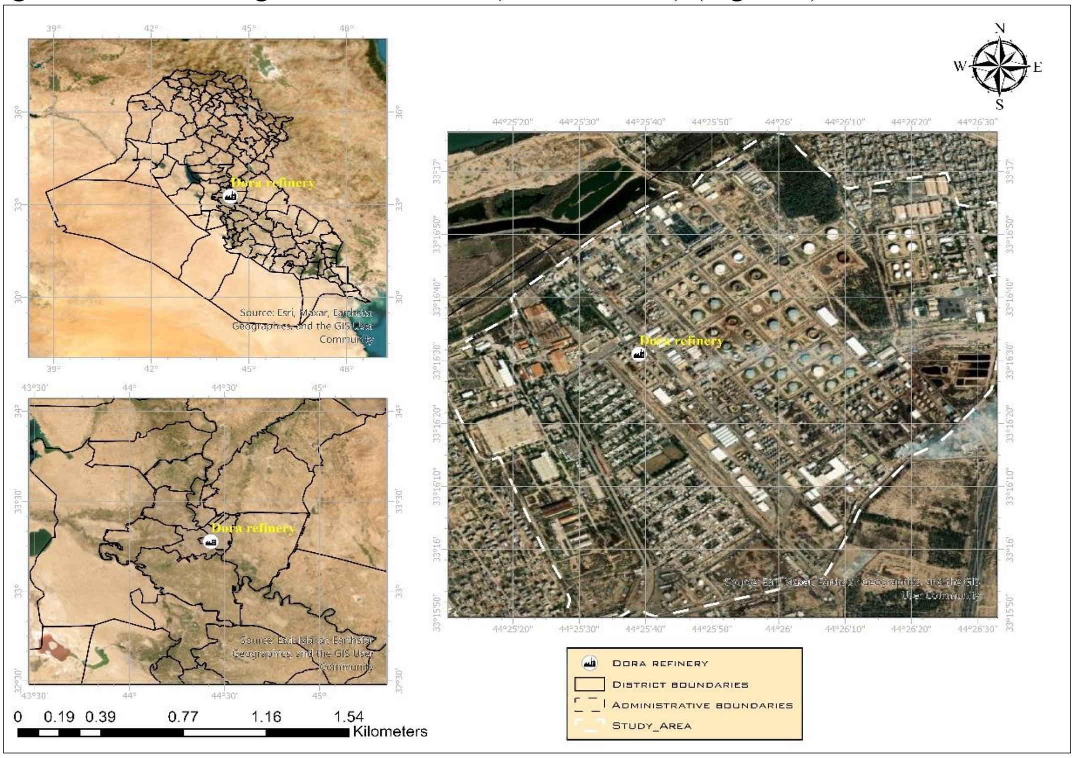

Figure 1: Location map of the study area (Al-Dora Oil Refinery).

3. Material and Method

Blood samples were collected from 20 individuals, including 15 adult employees and five non-exposed individuals aged 20-60. Each sample was selected based on various factors, including age, gender, duration of exposure, smoking habits, years of employment, and medical history. Each volunteer collected a 5 ml blood sample using the venipuncture technique in contamination-controlled conditions.

The blood samples were placed in sterile gel tubes and centrifuged for 20 minutes at 4500 rpm to extract the serum. Following a reported protocol, The serum was stored at a freezing temperature of -5°C [33]. Before analysis, all serum samples were diluted 1:10 with distilled water. The content of elements (Ca, Cr, V, and Pb) were measured using AAS at the Ibn Sina Laboratory or at the Qualitative Analysis Laboratory, Ministry of Industry and Minerals.

4. Results and Discussion

Blood samples from employees at the Al-Dora Oil Refinery were collected to measure the concentration of heavy metals and assess the severity of their exposure to refinery-related pollutants. The results showed that the exposure groups had significantly higher concentrations of Cr, Cd, Pb, and V than the non-exposed group (Figures 2 and 3; and Table 1). The results indicate that the exposed group had markedly higher concentrations of Cr, Cd, Pb, and V than the non-exposed group (Figures 2, 3, and Table 1), highlighting the need for immediate attention and action. Although Cr and Pb concentrations in the blood of exposed employees came within the permissible limits reported by World Health Organization [24], as well as studies by Lukman (2015) [34] and Sedik et al. (2021) [35], the concentrations of Cd and V exceeded these limits. Heavy metals generate highly reactive substances like free radicals, leading to the oxidation of protein sulfhydryl groups, protein depletion, DNA damage, lipid peroxidation, and various other effects [36]. In particular, heavy metal-mediated radicals lead to various mutagenic DNA modifications, showing the connection between oxidative damage and cancer; for example, Ca, Ni, and As inhibit DNA repair. Oxidative damage to DNA includes (i) base modifications (by Cr and Ni); (ii) crosslinking (by Ni, Cu, and Fe with oxidants); (iii) strand breaks (by Ni, Cd, Ce, and oxidants); and (iv) depurination (by Cu, Cr, and Ni) [37]. Therefore, severe health risks could have been created by heavy metal exposure at the refinery.

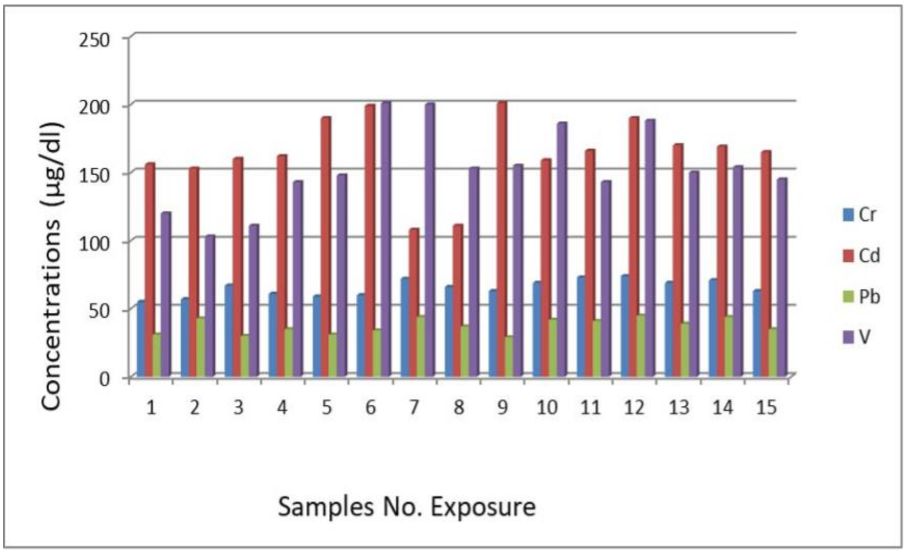

Figure 2: Heavy metal concentration in the human blood of the exposed group.

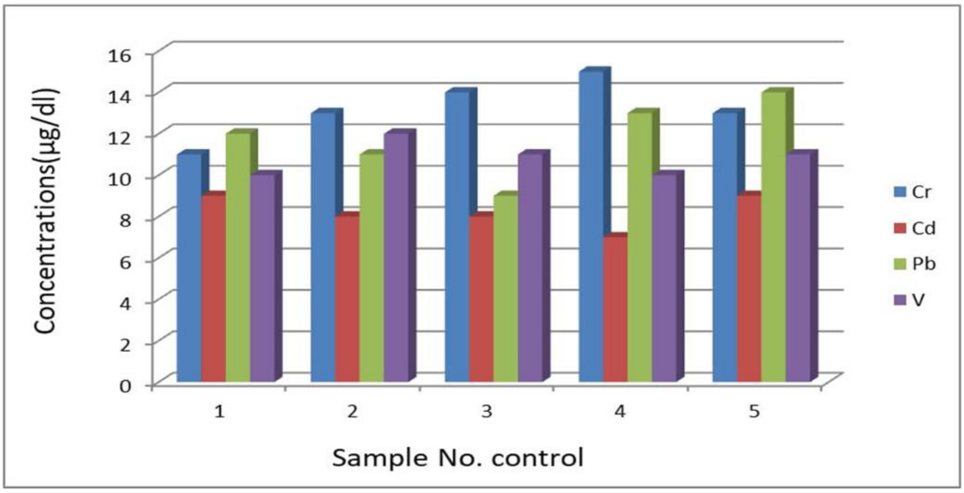

Figure 3: Heavy metal concentrations in the human blood of the control group.

Table 1: Metals concentration (µg/dl) in exposures and controls blood.

Element	Study groups	Mean ± SD	WHO, 2001 [24]	Sedik et al, 2021 [35]	Lukman, 2015 [34]
Cr	Exposure	65.27 ± 6.07	200		
	Control group	13.20 ± 1.48			
Cd	Exposure	163.93 ±26.98	70		11.63
	Control group	8.20 ± 0.84			2.03
Pb	Exposure	37.33 ± 5.63	40		45.43
	Control group	11.80 ± 1.92			12.08
V	Exposure	153.33 ±29.86	$0.5*10^{-6}$	0.0009	
	Control group	10.80 ± 0.84		0.0004	

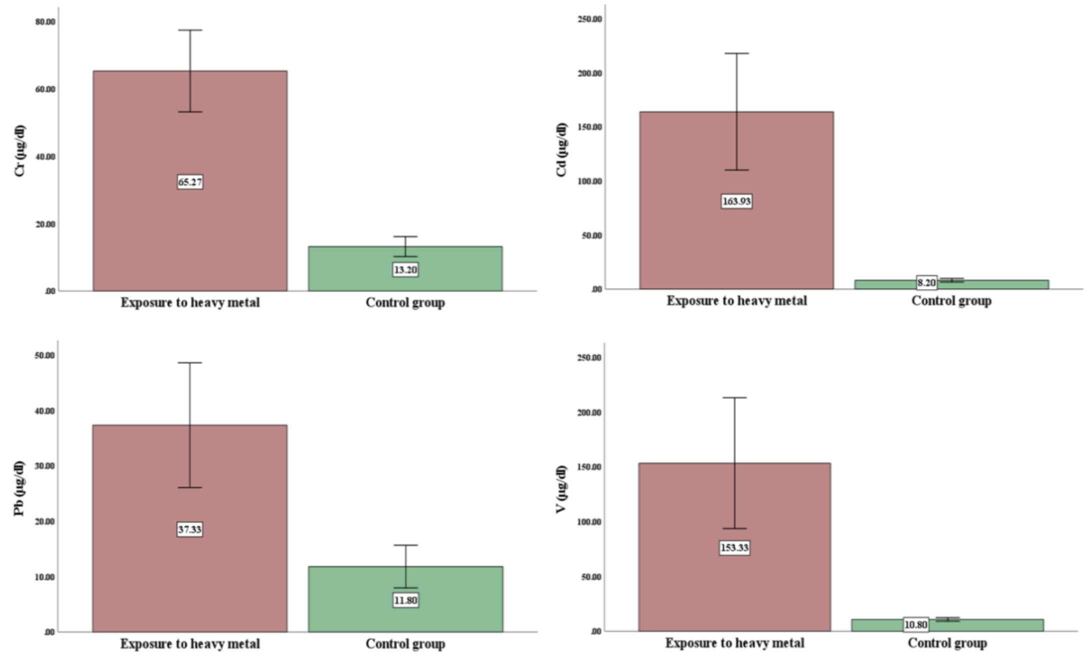

Figure 4: The mean differences in heavy metals between the two study groups.

The results correlate with age, showing a slightly higher difference in heavy metal concentrations among different age groups (Table 2). The mean differences in heavy metals according to the age of exposed employees, including < 30 years, 30-40 years, and ≥ 40 years, showed that the ≥ 40 age group had higher levels of heavy metals than other groups.

The results, when examined by the worker's gender, demonstrated a range of differences in heavy metal levels (Table 3). These variations can be best understood in the context of the long-term cumulative and synergistic effects of exposure to chemicals and gases, a factor that can explain the observed variability [38]. The results indicate that women exposed have slightly higher levels of heavy metal pollution and are more likely to experience adverse health effects. Previous findings from long-term studies showed that middle-aged women exposed to significant heavy metal pollution have a higher incidence of conditions like diabetes [39]. Given that many industrial sources have contributed to elevated metal levels over time, there is a clear need for rigorous regulatory standards and technological advancements to reduce emissions.

Workers with a work duration exposure of ≥15 years had greater heavy metals concentration than those with less exposure (Table 4). For refinery workers, prolonged exposure due to continuous work shifts results in higher intake levels of heavy metals. Our study calculated the intake based on factors such as the concentration of metals in the air, inhalation rates, and exposure duration. The findings indicate that longer exposure leads to higher intake and, consequently, greater health risks. For example, workers with 30 years of work were found to have statistically significant increased health concerns, such as hypertension, cardiovascular illnesses, and hepatic insufficiency [40].

The distribution of study participants according to smoking habits showed that smokers represented 8 participants (40.0%) while non-smokers represented 12 participants (60.0%) of the total study sample. The mean differences in heavy metal levels according to smoking habits revealed significant differences, with smokers having higher values than non-smokers. Blood lead levels, in particular, were greater in the group of smokers, correlating with the average number of cigarettes smoked each day [40]. Table 5 demonstrates that smokers in both the exposure and control groups had partially higher heavy metal concentrations than non-smokers.

Table 2: The mean differences (µg/dl) according to the age of workers exposed to heavy metals (N=15).

Study markers	Age groups	Number	Mean ± SD
Cr	< 30 years	4	64.00 ± 7.39
	30-40 years	8	64.63 ± 4.87
	≥ 40 years	3	68.67 ± 8.39
Cd	< 30 years	4	164.25 ± 6.55
	30-40 years	8	157.00 ± 34.46
	≥ 40 years	3	182.00 ± 13.86
Pb	< 30 years	4	37.25 ± 5.56
	30-40 years	8	36.75 ± 5.80
	≥ 40 years	3	39.00 ± 7.21
V	< 30 years	4	141.75 ± 15.20
	30-40 years	8	156.75 ± 37.46
	≥ 40 years	3	159.67 ± 24.67

Table 3: The mean differences (µg/dl) of study markers according to the gender of workers exposed to heavy metals (N=15).

Study markers	Gender	Mean ± SD
Cr	Male	64.58 ± 6.36
	Female	68.00 ± 4.58
Cd	Male	165.92 ± 22.59
	Female	156.00 ± 46.57
Pb	Male	37.08 ± 5.28
	Female	38.33 ± 8.15
V	Male	146.58 ± 28.10
	Female	180.33 ± 23.03

Table 4: The mean differences (µg/dl) according to the duration of work (years) among workers exposed to heavy metals (N=15).

Study markers	Duration of work	Mean ± SD
Cr	< 10 years	62.33 ± 8.08
	10-15 years	65.14 ± 5.70
	≥ 15 years	67.20 ± 6.02
Cd	< 10 years	162.33 ± 6.51
	10-15 years	167.57 ± 32.02
	≥ 15 years	159.80 ± 30.68
Pb	< 10 years	36.67 ± 6.66
	10-15 years	37.14 ± 6.41
	≥ 15 years	38.00 ± 5.10
V	< 10 years	139.00 ± 17.35
	10-15 years	156.71 ± 38.27

	≥ 15 years	157.20 ± 24.08

Table 5: The mean differences (μg/dl) according to smoking habit among workers exposed to heavy metals (N=15).

Study markers	Smoking habit	Mean ± SD
Cr	Smoker	68.60 ± 6.19
	Non-smoker	63.60 ± 5.56
Cd	Smoker	165.20 ± 32.34
	Non-smoker	163.30 ± 25.80
Pb	Smoker	39.60 ± 5.73
	Non-smoker	36.20 ± 5.51
V	Smoker	157.20 ± 17.77
	Non-smoker	151.40 ± 35.13

Our study shows that employees at the Al-Dora Oil Refinery are subject to significant heavy metal exposure, similar to findings from areas near industrial complexes. Just as the atmospheric concentrations of lead and cadmium were greater near industrial sites, our biological monitoring results indicated that refinery workers had higher concentrations of heavy metals, such as Cr, Cd, Pb, and V, compared to non-exposed individuals. According to a previous study, People who live close to industrial complexes may be more exposed to harmful levels of lead, cadmium, and mercury in their blood and urine. They also noted that blood lead levels increased with age, males, and smoking, while urinary cadmium levels were higher in females and smokers [41]. Similarly, our study demonstrates that employees at the refinery, who are regularly exposed to industrial emissions, exhibit significantly higher levels of these metals in their blood. Refinery workers who smoke and those of older age have higher levels of heavy metals. Remarkably, female workers at the refinery exhibited higher cadmium levels, which could be attributed to biological factors like increased cadmium absorption due to iron deficiency, a common condition in women.

5. Conclusion

The study revealed that the concentration of heavy metals in the blood of refinery workers exceeded the international permissible limits. Exposed workers had significantly higher heavy metals levels than the control group. Among the age groups, workers aged 40 and above exhibited higher levels of heavy metals than younger workers. There were significant differences in metal concentrations based on work duration, with longer exposure associated with higher levels of heavy metals. Smokers had significantly higher heavy metal levels compared to non-smokers, and there were notable differences in metal concentrations between male and female workers, with females showing higher levels in some cases. Our results highlight the urgent need for enhanced regulatory standards and technological innovations to reduce heavy metal exposure at the Al-Dora Oil Refinery. Such approaches can dramatically reduce the health concerns of female refinery workers regarding heavy metal pollution and improve public health.

References

[1] J. Liang *et al.*, “Spatial distribution and source identification of heavy metals in surface soils in a typical coal mine city, Lianyuan, China,” *Environ. Pollut.*, vol. 225, pp. 681–690, 2017.

[2] T. Bachanek, E. Staroslawska, E. Wolanska, and K. Jarmolinska, “Heavy metal poisoning in glass worker characterised by severe dental changes,” *Ann. Agric. Environ. Med.*, vol. 7, no. 1, 2000.

[3] W. I. Mortada, M. A. Sobh, M. M. El-Defrawy, and S. E. Farahat, “Study of lead exposure from automobile exhaust as a risk for nephrotoxicity among traffic policemen,” *Am. J. Nephrol.*, vol.

21, no. 4, pp. 274–279, 2001.
[4] L. C. Osuji and C. M. Onojake, “Trace heavy metals associated with crude oil: A case study of Ebocha-8 Oil-spill-polluted site in Niger Delta, Nigeria,” *Chem. Biodivers.*, vol. 1, no. 11, pp. 1708–1715, 2004.
[5] Y. Kim, N. Y. Kim, S. Y. Park, D. Lee, and J. H. Lee, “Classification and individualization of used engine oils using elemental composition and discriminant analysis,” *Forensic Sci. Int.*, vol. 230, no. 1–3, pp. 58–67, 2013.
[6] R. I. Muslim, M. J. Issa, and B. S. AL-Obaidi, “Environmental assessment of heavy metals concentration and distribution in surface soils of Wasit Governorate/Iraq,” *Iraqi J. Sci.*, vol. 60, no. 4, pp. 803–818, 2019.
[7] S. H. Al–Dulaimi and A. M. Rabee, “Measurement of Pollution Level with Particulate Matter in Babylon Concrete Plant and Evaluation of Oxidative Stress and Hematological Profile of Plant Workers,” *Iraqi J. Sci.*, pp. 3834–3841, 2021.
[8] K. A. Djalali, A. R. Tualeka, P. Rahmawati, S. S. Russeng, A. Wahyu, and D. Kartikasari, “Determination of safe concentration of benzene exposure in workers in a laboratory of oil processing industry in Indonesia,” *Indian J. Public Heal. Res. Dev.*, vol. 10, no. 9, pp. 667–672, 2019.
[9] U. JACKSON, B. Xu, and N. REVOCATTE, “Investigation on Impacts of contamination of Oil exploration and Production on Environment and its Implications on people’s health. Case Study: NIGERIA,” *Int. J. Sci. Res. Publ.*, vol. 10, no. 4, pp. 69–77.
[10] M. B. Mahmood, “Estimation the levels of some heavy metals in the soil and vegetables irrigated with wells water in some agriculture fields at Al-Dora district–Baghdad,” *Iraqi J. Sci.*, pp. 1918–1925, 2016.
[11] L. Jacquin, C. Dybwad, G. Rolshausen, A. P. Hendry, and S. M. Reader, “Evolutionary and immediate effects of crude-oil pollution: depression of exploratory behaviour across populations of Trinidadian guppies,” *Anim. Cogn.*, vol. 20, pp. 97–108, 2017.
[12] C. N. Mbah and M. A. N. Anikwe, “Variation in heavy metal contents on roadside soils along a major express way in South east Nigeria,” *New York Sci. J.*, vol. 3, no. 10, pp. 103–107, 2010.
[13] K. Pan and W.-X. Wang, “Trace metal contamination in estuarine and coastal environments in China,” *Sci. Total Environ.*, vol. 421, pp. 3–16, 2012.
[14] C. Kennedy, R. Lordo, M. S. Sucosky, R. Boehm, and M. J. Brown, “Evaluating the effectiveness of state specific lead-based paint hazard risk reduction laws in preventing recurring incidences of lead poisoning in children,” *Int. J. Hyg. Environ. Health*, vol. 219, no. 1, pp. 110–117, 2016.
[15] D. E. Keil, J. Berger-Ritchie, and G. A. McMillin, “Testing for toxic elements: a focus on arsenic, cadmium, lead, and mercury,” *Lab. Med.*, vol. 42, no. 12, pp. 735–742, 2011.
[16] W. T. Wang Thanh, F. J. Fu JianJie, W. Y. Wang YaWei, L. C. Liao ChunYang, T. Y. Tao YongQing, and J. G. Jiang GuiBin, “Use of scalp hair as indicator of human exposure to heavy metals in an electronic waste recycling area.,” 2009.
[17] M. F. Reis *et al.*, “Human exposure to heavy metals in the vicinity of Portuguese solid waste incinerators–Part 1: Biomonitoring of Pb, Cd and Hg in blood of the general population,” *Int. J. Hyg. Environ. Health*, vol. 210, no. 3–4, pp. 439–446, 2007.
[18] L. A. Al-Rudainy, “Blood lead level among fuel station workers,” *Oman Med. J.*, vol. 25, no. 3, p. 208, 2010.
[19] H. Ali and E. Khan, “Assessment of potentially toxic heavy metals and health risk in water, sediments, and different fish species of River Kabul, Pakistan,” *Hum. Ecol. Risk Assess. An Int. J.*, vol. 24, no. 8, pp. 2101–2118, 2018.
[20] M. Al-Dabbas, G. Hussain, and M. Al-Jubory, “The Effect of North Refineries Company on Soil pollution of Baiji City-Iraq,” *Iraqi J. Sci.*, vol. 55, no. 3B, pp. 1319–1329, 2014.
[21] A. K. Al-jumaylii and S. Azize, “Monthly variation of some air pollutants in Hilla City–middle of Iraq,” *J. Univ. Babylon*, vol. 22, no. 1, 2012.
[22] K. Ali and D. B. Ibraheem, “Radiological hazard assessment due to natural occurring radioactive materials (NORM) in oil and gas production industry–East Baghdad oil field,” *Iraqi J. Sci*, vol. 58, no. 1A, pp. 115–126, 2017.
[23] M. A. Islam, M. J. Angove, and D. W. Morton, “Recent innovative research on chromium (VI) adsorption mechanism,” *Environ. Nanotechnology, Monit. Manag.*, vol. 12, p. 100267, 2019.

[24] C. WHO, “Air quality guidelines,” *World Heal. Organ. Reg. Off. Eur. Copenhagen, Denmark*, 2000.
[25] K. Shekhawat, S. Chatterjee, and B. Joshi, “Chromium toxicity and its health hazards,” *Int. J. Adv. Res.*, vol. 3, no. 7, pp. 167–172, 2015.
[26] A. Kabata-Pendias, *Trace elements in soils and plants*. CRC press, 2000.
[27] Agency for Toxic Subtances and Diases Registry, “Case Studies in Environmental Medicine,” *ATSDR*, pp. 1–63, 2011, [Online]. Available: https://www.atsdr.cdc.gov/csem/cadmium/docs/cadmium.pdf
[28] A. Ara and J. A. Usmani, “Lead toxicity: a review,” *Interdiscip. Toxicol.*, vol. 8, no. 2, pp. 55–64, 2015.
[29] T. Dignam, R. B. Kaufmann, L. LeStourgeon, and M. J. Brown, “Control of lead sources in the United States, 1970-2017: public health progress and current challenges to eliminating lead exposure,” *J. Public Heal. Manag. Pract.*, vol. 25, pp. S13–S22, 2019.
[30] H. Ali and E. Khan, “What are heavy metals? Long-standing controversy over the scientific use of the term ‘heavy metals’–proposal of a comprehensive definition,” *Toxicol. Environ. Chem.*, vol. 100, no. 1, pp. 6–19, 2018.
[31] R. Z. Sokol and N. Berman, “The effect of age of exposure on lead-induced testicular toxicity,” *Toxicology*, vol. 69, no. 3, pp. 269–278, 1991.
[32] M. Altamirano-Lozano, L. Alvarez-Barrera, and E. Roldán-Reyes, “Cytogenic and teratogenic effects of vanadium pentoxide on mice,” *Med. Sci. Res.*, vol. 21, no. 19, pp. 711–713, 1993.
[33] M. Daves, D. Trevisan, and R. Cemin, “Different collection tubes in cardiac biomarkers detection,” *J. Clin. Lab. Anal.*, vol. 22, no. 6, pp. 391–394, 2008.
[34] L. A. Alli, “Blood level of cadmium and lead in occupationally exposed persons in Gwagwalada, Abuja, Nigeria,” *Interdiscip. Toxicol.*, vol. 8, no. 3, pp. 146–150, 2015.
[35] S. A. K. Al-Hiyaly and L. Alwan, “Impacts of Oil Industrial Process upon Occupationally Exposed Workers at Al-Dora Refinery,” *Iraqi J. Oil Gas Res.*, vol. 1, no. 1, pp. 72–81, 2021.
[36] A. T. Jan, M. Azam, K. Siddiqui, A. Ali, I. Choi, and Q. M. R. Haq, “Heavy metals and human health: mechanistic insight into toxicity and counter defense system of antioxidants,” *Int. J. Mol. Sci.*, vol. 16, no. 12, pp. 29592–29630, 2015.
[37] J. Briffa, E. Sinagra, and R. Blundell, “Heavy metal pollution in the environment and their toxicological effects on humans,” *Heliyon*, vol. 6, no. 9, 2020.
[38] M. Golara and S. Shokat Sadry, “Employees occupational diseases: Reference to oil and gas companies,” *JLS*, vol. 5, pp. 4317–4322, 2015.
[39] M. Hendryx, J. Luo, C. Chojenta, and J. E. Byles, “Exposure to heavy metals from point pollution sources and risk of incident type 2 diabetes among women: a prospective cohort analysis,” *Int. J. Environ. Health Res.*, vol. 31, no. 4, pp. 453–464, 2021.
[40] A. H. Al-Dosky, D. J. Al-Timimi, and S. A. Al-Dabbagh, “Occupational exposure to lead in Duhok city, Kurdistan region, Iraq,” *Duhok Med. J.*, vol. 5, no. 2, pp. 76–85, 2011.
[41] J. H. Sung *et al.*, “Environmental and body concentrations of heavy metals at sites near and distant from industrial complexes in Ulsan, Korea,” *J. Korean Med. Sci.*, vol. 33, no. 5, 2018.