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Effects of Mercury Concentration on the Health and Safety of Oil and Gas Workers

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ABSTRACT

Introduction: The processing of crude oil is characterized by numerous hazards, which have significant health, safety, and environmental impacts on neighboring communities. The occurrence of mercury and its toxic derivatives is considered one of the many negative impacts of oil and gas operations. However, there is limited research on mercury and its negative effects on workers in the Gulf Cooperation Council (GCC) region. This study examines the occurrence, exposure, and symptoms of mercury on the health and safety of oil and gas workers in Oman. It also explores the acute/chronic effects of mercury poisoning on the maintenance and inspection workers, who are more prone to the adverse effects of mercury poisoning during oil and gas operations.
Methods: The two-pronged approach of literature review and survey questionnaire was used to deduce the effects of mercury exposure and poisoning using 68 respondents with 1 – 6 years of working experience in the sector.
Results: Based on the questionnaire response rate of 72%, the results showed that over 90% of participants had experienced symptoms of elemental, organic, and methyl mercury poisoning. The common symptoms experienced are headaches, insomnia, weakness, hearing impairment, visual and sensory abilities. However, the respondents who experienced methyl mercury (MeHg) symptoms are due to consuming seafood and cigarettes, whereas elemental and organic mercury symptoms are due to oil and gas operations.
Conclusion: The findings highlight the need for robust health and safety measures to effectively detect, monitor and eliminate mercury compounds responsible for poisoning maintenance and inspection workers.

Key words: Health and Safety, Mercury Contamination, Oil and Gas, Petroleum Workers

INTRODUCTION

The exploration and exploitation of crude oil are prone to numerous hazards, significant socioeconomic, health, safety, and environmental impacts on neighbouring communities. Similarly, various researchers have demonstrated that petroleum exploration has numerous effects on human health, safety, and wellbeing. For example, a study reported that crude oil production had caused multiple health effects among workers in the industry.[1] The adverse effects have been ascribed to occupational hazards and work-related factors such as safety issues, pollution, noise, vibrations, and exposure to chemicals.[1,2] Globally, mercury is considered one of the most toxic chemicals that can pollute the environment.[3] The toxicity of mercury is due to its ability to penetrate and accumulate in the tissues and cells of humans, plants, and animals, as well as the environment after exposure.[4,5] Mercury is a globally persistent contaminant primarily sourced from petroleum exploration and exploitation.[6] In addition, the energy industry is the second-largest source of mercury.[7]

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The exposure of living things to mercury can result in various symptoms like vomiting, dizziness, headaches, allergies, loss of vision, hearing loss, compromised disease immunity, brain damage, and even death.[8,9] Research has shown that the persistence, accumulation, and toxicity of mercury greatly depend on the chemical form or type, concentration, and exposure length to mercury.[8,10] The most common forms include elemental, organic, and inorganic mercury, although the inorganic forms such as methyl mercury are considered the most hazardous form of a pollutant that enters the environment.[11,12] The major route for human mercury exposure is by consuming aquatic food products such as fish.[13,14] According to the findings in the literature, the consumption of fish contaminated with monomethyl mercury (MMHg) is a key route for the biomagnification of the contaminant in humans.[15,16]

The most popular form detected in the oil and gas industries is elemental mercury.[17] The study also reported that workers' exposure to mercury and other toxic and persistent substances pose a significant risk to the health and safety of workers in the oil industry. The study also reports that elemental mercury has been detected at different points of the refinery such as production units, separation units, and tank farm units.[17] Likewise, human exposure to different types of mercury is responsible for the various health problems associated with oil and gas workers.[18,19] Similarly, mercury exposure poses a significantly higher threat to the oil and gas industry when compared to other hazards.[1]Furthermore, studies have shown that the exposure of oil and gas workers to high levels of mercury could result in acute and chronic illnesses depending on the type, concentration, and exposure duration of mercury.[20,21] However, mercury is not only hazardous to human health but also detrimental to gas processes and equipment. For example, mercury deposits in cryogenic equipment result in the cracking of process equipment such as heat exchangers. Consequently, it is known to contaminate treatment liquids and sorbents, hamper their regeneration or disposal during oil and gas processes in the industry.[22]

The literature review shows the detrimental effect played by Mercury exposure to human health, safety and environment, in the oil and gas industry. However, there has been limited research on the presence and or prevalence of mercury in the oil and gas industry in the Gulf Cooperation Council (GCC) region. Therefore, there is a critical need to comprehensively understand the underlining dynamics and hydrocarbon matrices associated with mercury exposure in the region.

In this study, the effects of mercury concentration on the health and safety of oil and gas workers in Oman was examined using a two-pronged approach of literature reviews and administering survey questionnaires. The designed questionnaires were distributed to oil and gas workers in the selected region of Oman to solicit their opinions on the state of mercury exposure in their vicinity. It is envisaged that the findings of this study will assist stakeholders and policymakers in the design, development, and execution of sustainable strategies required for the detection, analysis, and removal of mercury during oil and gas operations. The effective achievement of these objectives will greatly improve human health and occupational safety in the oil and gas industry in Oman and the GCC region at large.

METHODS

The selected area of the study was Mina Al Fahal, which is described as one of the most important regions for petroleum operations in Oman.[23] At the time this study was conducted, various petroleum operations like distillation, catalytic reforming, catalytic cracking, alkylation and hydrotreating were going on. This study only focused on employees who worked within the tank farm and the various petroleum operation units located in Mina Al Fahal refinery. This group of people was chosen because, based on extant literature, they are primarily at risk of Mercury exposure.[20] Hence, the area was selected to identify employees who have been involved in oil and gas operations from January 2019 or before December 2020. The total number of workers engaged in the area is 68, and all were selected to participate in the survey. Hence, 68 was the chosen sample frame. Consequently, the selected sampling frame was administered the survey questionnaire (designed and conveyed through Google Forms) via email. The final sample comprised 49 usable questionnaires, which represents a response rate of 72%. Lastly, each returned questionnaire was analyzed, and the data was presented as observed in section 3 of the paper. The questionnaire data was collected using Google Forms, which automatically recorded the respondents' responses. The retrieved Google Forms were automatically analyzed to determine the number of participants who have responded, followed by analysis to determine the response rate of the questionnaire using the Total Design Method reported in literature.[24] The questionnaire comprised a total of 6 sections. The first section consists of six (6) open-ended and closed-ended questions. The second section consists of five (5) closed-ended questions that aim to identify the potential exposure of the participants to mercury unrelated to their occupation. The third, fourth, and fifth sections consisted of a single checklist of questions that required participants to tick any of the symptoms they may have previously experienced before the study. The last section consists of closed-ended questions that aim to determine how long participants have been experiencing the symptoms and when their symptoms started. To ensure the validity, consistency, reliability of the responses, the questionnaire was emailed to the participants for the second time.

RESULTS

The results are presented based on the six (6) sections of the questionnaire: general information, exposure, elemental mercury poisoning symptoms, methyl-mercury poisoning symptoms, organic mercury poisoning symptoms and duration of the symptoms. The general information about participants working in oil and gas operations was collected using the questionnaire. Figure 1 shows details of the sections of the participants currently working in the oil and gas region of the target location of the study. The details aim to answer the question, "Which Oil and Gas Operations Do You Work in?"

General Information

The results revealed that 55% and 45% of the respondents work in maintenance and inspection units in the oil and industry, respectively. (Figure 1)

The BMI was calculated from the height and weight of the participants based on the standard.[27] The results revealed that participants' average height and weight are; 172.41 cm and 86.21 kg, whereas the BMI is 29.1.(Figure 2)

Mercury Exposure

Over half of the participants (66.3%) either sometimes or often consume seafood, whereas 36.7% never have.(Figure 3). Figure 4 presents the distribution of participants that responded to having a mercury-amalgam filling.

Table 1 shows the different cigarette brands and their mercury content as deduced from the CDCP database

Mercury Poisoning Symptoms

In particular, 76.2% of participants experienced headaches, 71.4% emotional changes, 66.7% insomnia, 33.3% muscle atrophy, 33.3% weaknesses, 28.6% sensation disturbances, 23.8% nerve response changes, 23.8% experienced twitching, and 19% tremors. Overall, the findings showed that 43% of participants had experienced the symptoms of elemental mercury.

Figure 6 shows the distribution of participants who have experienced MeHg symptoms. The findings revealed that most participants (57.14%) had experienced one or more symptoms related to methyl-mercury exposure.

Figure 7 shows the distribution of participants who have experienced the symptoms of organic mercury. The findings showed that 39% of participants had experienced one or more symptoms of organic mercury poisoning. Figure 8 shows the time the participants were first exposed to mercury, as examined in this study.

Table 1: Cigarette brands and their mercury content[34]

Serial Number	Cigarette Brand	Mercury Content (µg/g) Per Cigarette
77109529	Marlboro Red	0.015
72430003	Marlboro Silver	0.016
77259649	Marlboro Gold	0.015
85548560	Marlboro Double Mix	0.015
8871590	Winston Gold	0.017
87998200	Winston Red	0.018
85793887	Winston White	0.016
01230035	Chesterfield Menthol	0.014
72079585	Chesterfield Red	0.15
0282003	L&M Red	0.017
85351010	L&M Blue	0.018
77521515	L&M Menthol	0.020

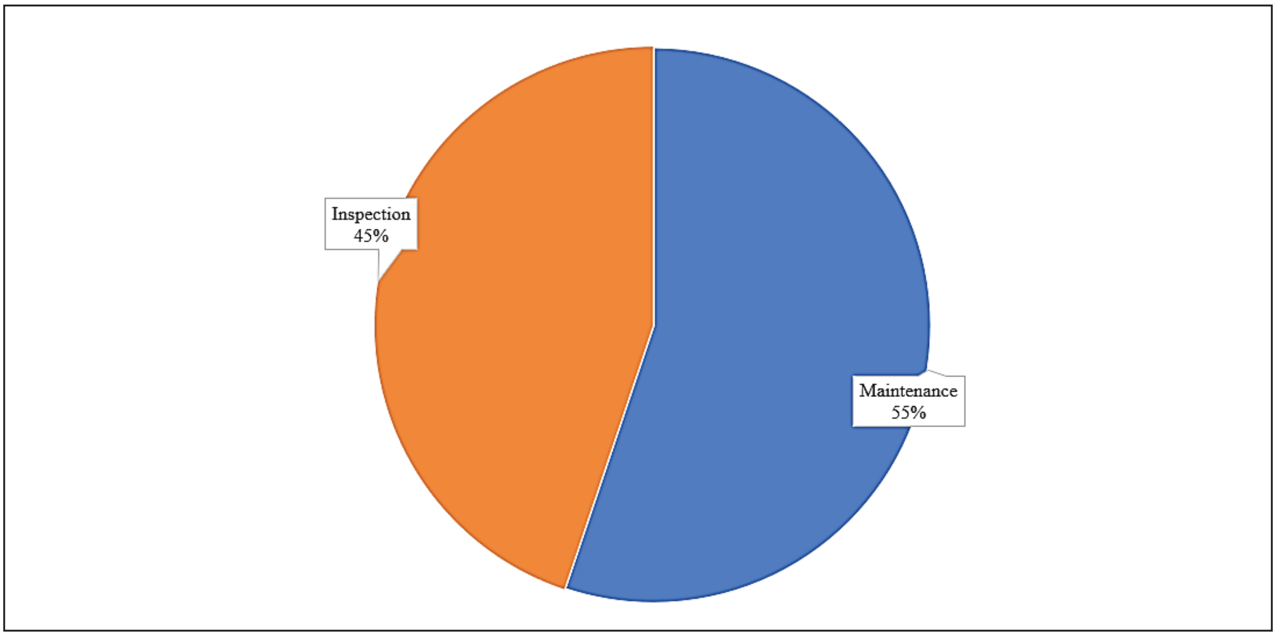

Figure 1: Distribution of participants' area of specialisation in the oil and gas industry

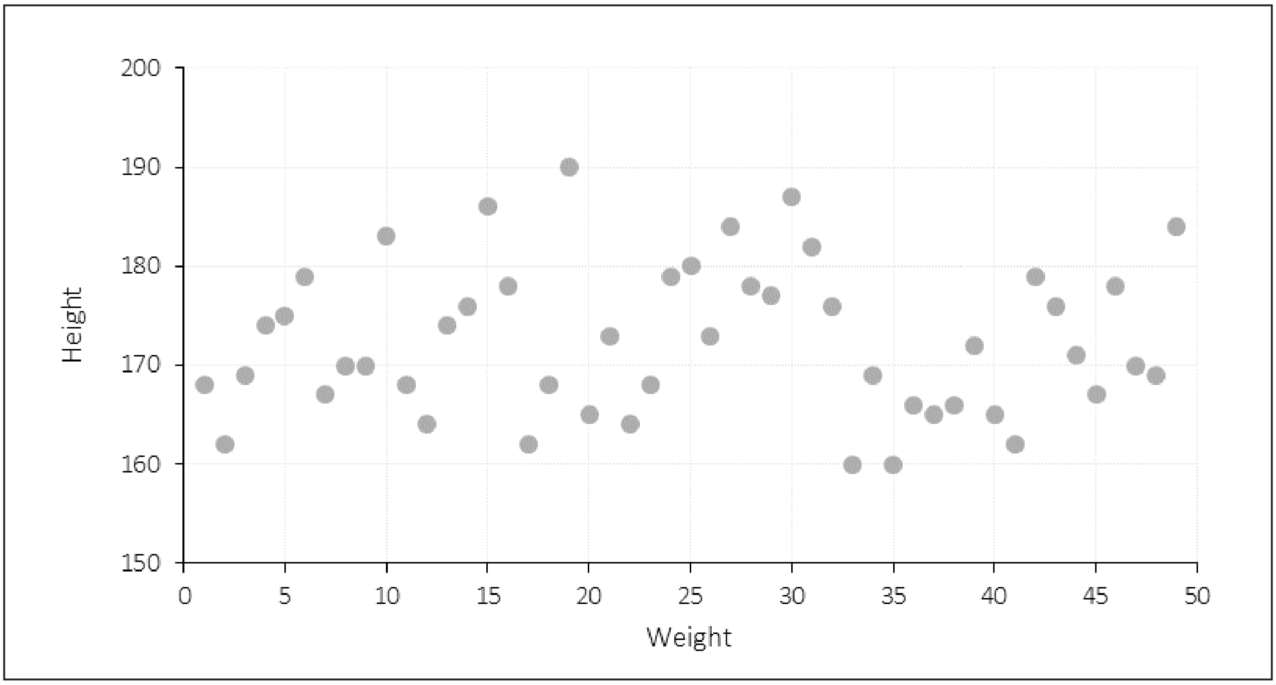

Figure 2: Height, weight, and BMI of the Participants

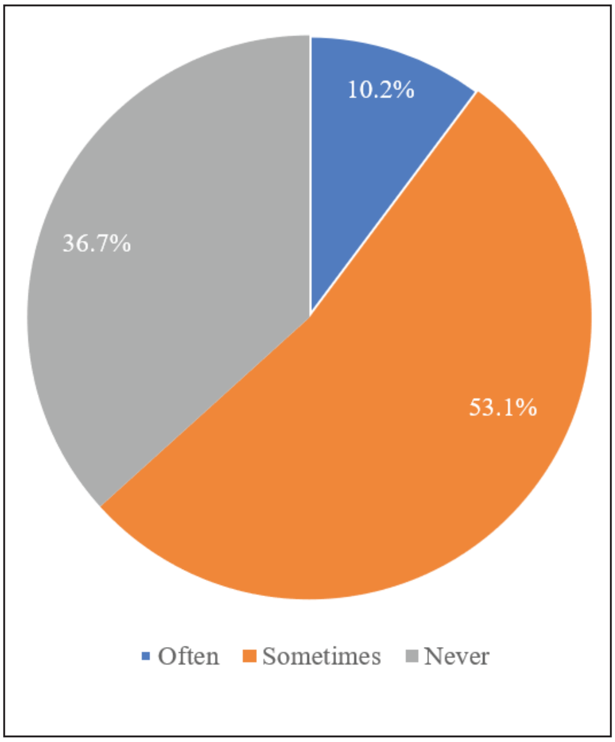

Figure 3: Distribution of participants that consume seafood

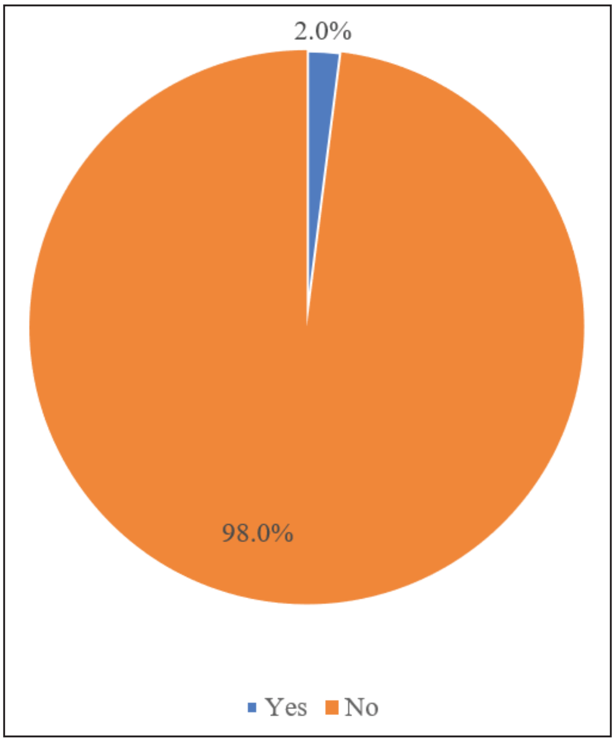

Figure 4: Distribution of participants who have had Mercury-amalgam filling

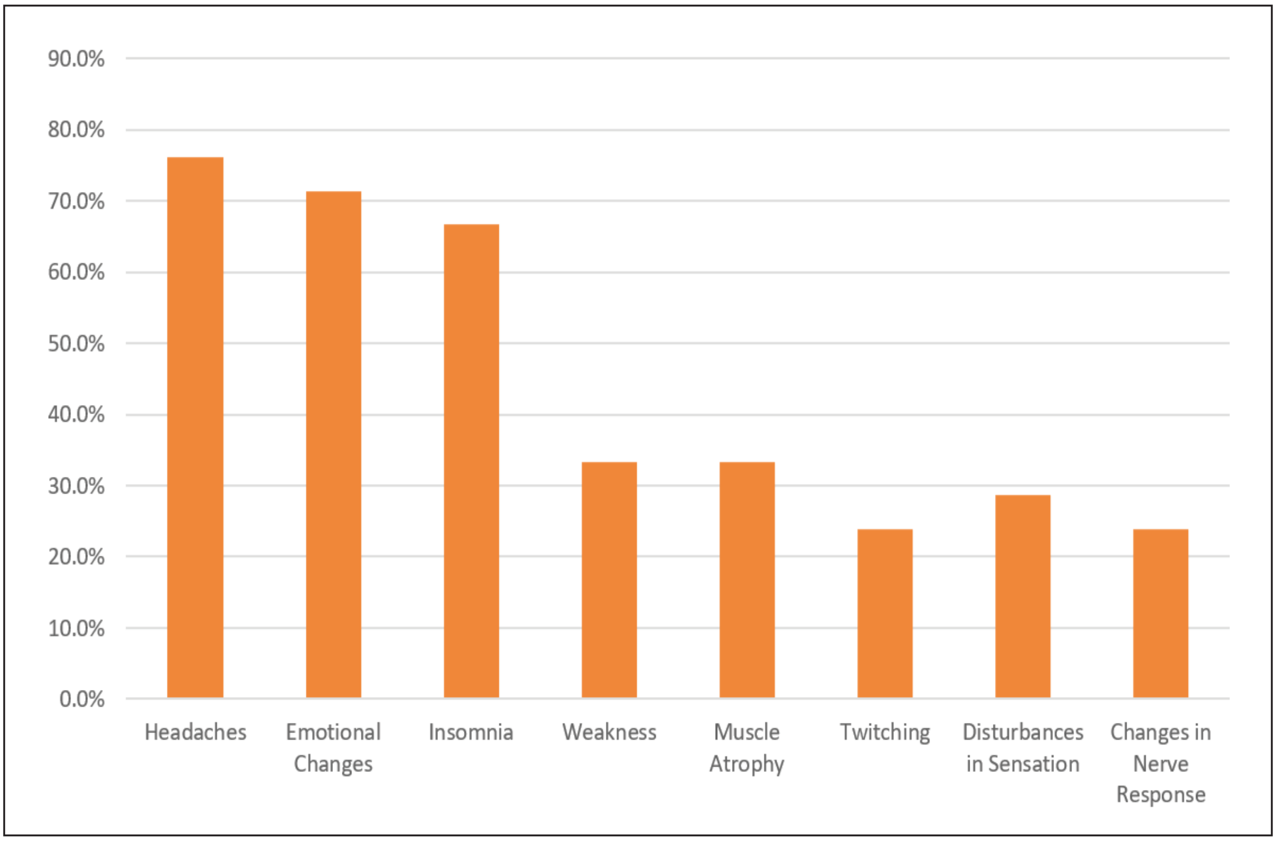

Figure 5: Distribution of participants who have experienced elemental mercury symptoms

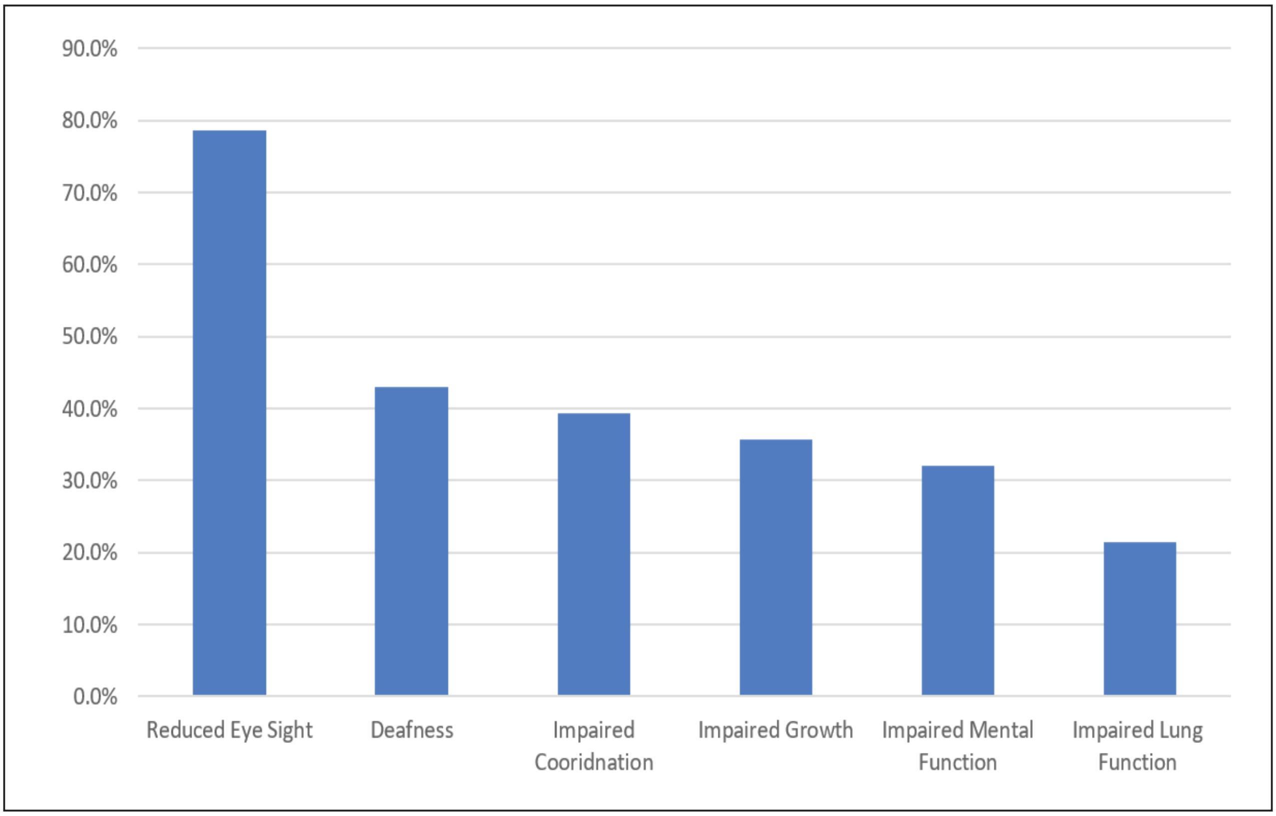

Figure 6: Distribution of participants who experienced Methyl-Mercury Symptoms

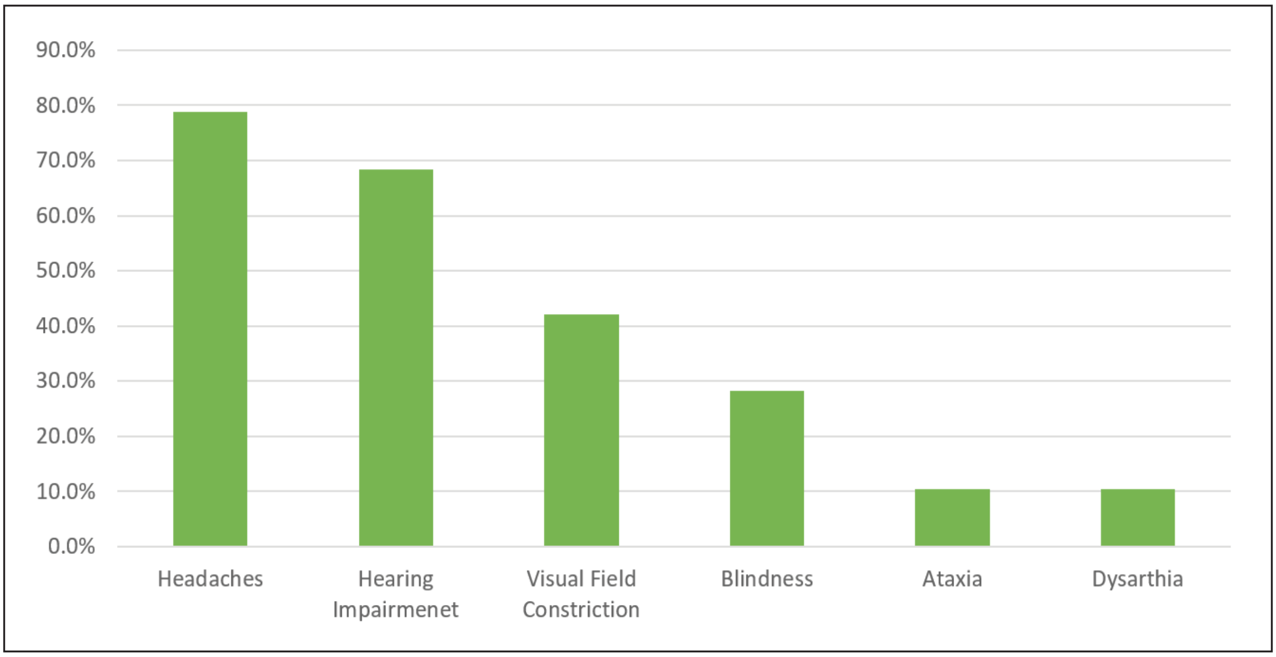

Figure 7: Distribution of participants who experienced organic mercury symptoms

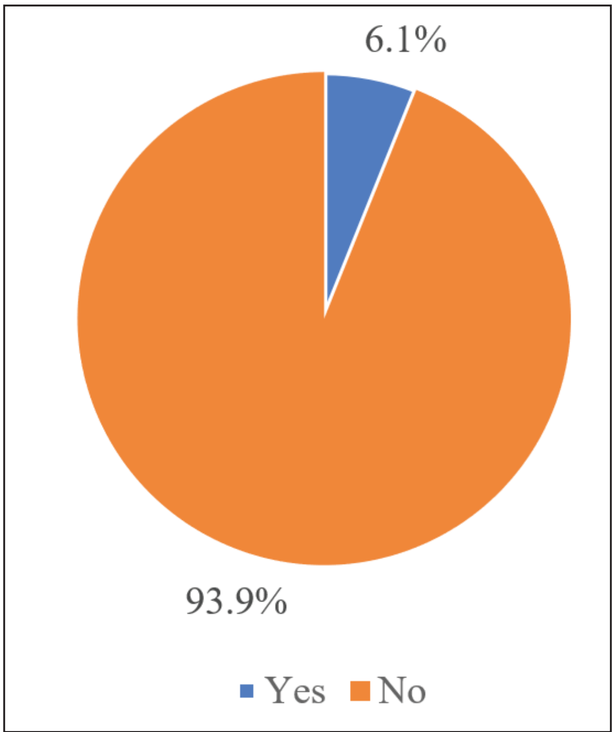

Figure 8: Distribution of the time participants were exposed to mercury

DISCUSSION

This study shows that the participants are either low-mid level (maintenance) or mid-high/managerial level (inspection) in the target location of the study. The maintenance and inspection operations of the oil and gas industry is susceptible to high levels of mercury.[25] Similarly, studies have shown that maintenance and inspection workers in oil and gas operations are exposed to high levels of mercury and its related compounds through inhalation and dermal absorption, which poses grave risks to their health and safety.[20] Mercury deposition in operational tools and equipment presents significant health and safety risks to maintenance or inspection workers.[26] According to another study, the risk of mercury is due to various factors ranging from the underestimation of the exact levels of mercury to lack of routine protocols for the monitoring, detection, and quantification of the contaminant particularly in liquid hydrocarbons.[20] Although more reliable sampling techniques and rigorous analytical procedures have become available, the gradual toxicity of mercury poisoning prevents its immediate detection and correlation with occupational exposure.[20] The prevalence of mercury in refinery operations not only poses detrimental health and safety problems but also process challenges ranging from the poisoning of catalysts to equipment corrosion.[26] Consequently, there has been an anthropogenic rise in mercury levels over the years, provoking socio-economic and environmental challenges. The study concludes that environmentally friendly procedures are required to detect, monitor, or capture mercury from process streams in industry. The second question examines the length of time the participants have been employed in oil and gas operations. The findings showed that 44.9% of participants answered between 3 – 6 years, 30.6% answered over six years, while the minority answered 1 – 3 years at 24.6%. Hence, participants may have had continuous exposure to mercury between the span of 1 to 6 years.

Next, the participants were examined to ascertain if they had any underlying illnesses by analysing their body mass index. The result of BMI indicates the participants are mostly overweight. The participants were then examined to detect any underlying illnesses, which could indicate correlations between their BMI and exposure to various mercury concentrations while carrying out their maintenance and inspection operations in the oil and gas industry. The findings revealed that 98% of participants answered that they do not have any underlying illnesses, whereas 2% responded affirmatively. It is important to state the only participant that answered yes has type 2 diabetes, although this condition bears no correlation to the mercury symptoms. The potential level of exposure of the participants to mercury was also examined in this study. Hence, the participants were questioned about the level of mercury exposure during or after oil and gas operations. Firstly, the participants were asked if they had been previously exposed to any types of metals. The findings revealed that 30.6% and 69.4% answered yes and no, respectively. Since the participants did not specify the type of metal, exposure levels or location, it was difficult to determine their level of previous exposure to mercury. Similarly, seafood (such as tuna, shark, or swordfish) is a major source of mercury exposure.[28] Hence, the participants that frequently eat seafood and are hence exposed to mercury were examined.

Over half of the participants (66.3%) either sometimes or often consume seafood, whereas 36.7% never have. The results show that over 60% of the participants are either at risk or may have had some level of exposure to mercury or related compounds over time. This view is corroborated by findings in the literature that have shown that seafood consumption could result in organic mercury or methyl mercury poisoning.[29,30]

However, the participants are not at risk of elemental mercury poisoning from eating seafood since it largely enters the body through inhalation. The mercury-amalgam fillings are used to treat dental decay but pose threats to patients by releasing mercury vapor that can be inhaled and absorbed in the lungs.[31] Next, the participants were asked if they ever had a mercury-amalgam filling to ensure that any elemental mercury symptom stated is not a cause of the filling. Figure 4 presents the distribution of participants that responded to having a mercury-amalgam filling.

As observed, 98% of participants have never had a mercury-amalgam filling, whereas 2% have had it in the past. The results indicate that the participants could not have been exposed to mercury through fillings. Some cigarettes contain elemental mercury that could result in 2 mg of mercury being inhaled per cigarette.[32] This level of mercury exposure may increase or decrease depending on the cigarette brand. Regardless, participants were asked whether they had a history of smoking. The results revealed that 69.4% and 30.6% of participants answered no or yes, respectively, which indicates a high preference for smoking and risk of mercury exposure. Data from Muscat Duty-Free, showed that the brands of cigarettes sold in Oman are; Winston, L&M, Marlboro, and Chesterfield.[33] According to the Centre for Disease Control and Prevention, the brands mentioned contain about 0.015 μg/g content of mercury.[34] However, each of the following brands is safe based on the participant's weight, and height since the United States Environmental Protection Agency has stated that 0.1 μg/g of mercury per day is safe.[35] However, if participants have smoked brands outside those mentioned to be safe, they may be at the risk of elemental poisoning from their smoking history.

All brands of cigarettes had mercury content ranging from 0.014 to 0.018 μg/g, which is below 0.1 μg/g per day. Based on the data, 69.4% of participants have had mercury exposure from cigarettes. Despite the possibility of prior exposure, the mercury levels are insufficient to cause poisoning. Next, the participants were asked if they experienced any metallic taste in their mouths, even without taking any medication. The findings showed that 56.1% of participants responded affirmative, whereas 44.9% of participants responded negatively. The metallic taste in the mouth may be a result of high mercury inhalation, especially if participants did not intake any medication that can cause such ailments.[36]

The different symptoms of mercury poisoning were also examined in this study. The participants were given 3 sections with checklists to select the symptom they may have experienced in the past. The first mercury symptom section is elemental mercury poisoning. The findings showed that 21 participants stated they had experienced one or more of the elemental mercury symptoms. In particular, 76.2% of participants experienced headaches, 71.4% emotional changes, 66.7% insomnia, 33.3% muscle atrophy, 33.3% weaknesses, 28.6% sensation disturbances, 23.8% nerve response changes, 23.8% experienced twitching, and 19% tremors. Overall, the findings showed that 43% of participants had experienced the symptoms of elemental mercury. According to the CDCP, the victims of elemental mercury poisoning may have experienced it during maintenance and inspection operations that consist of mercury vapors.[34] The mercury vapors may have possibly been absorbed into the skin or through inhalation.

The second symptom section is methyl mercury (MeHg) poisoning. Figure 6 shows the distribution of participants who have experienced MeHg symptoms. The findings revealed that most participants (57.14%) had experienced one or more symptoms related to methyl-mercury exposure. Furthermore, the data shows that 78.6% of participants experienced reduced eyesight, 42.9% deafness, 39.3% impaired coordination, 35.7% impaired growth, 32.1% impaired mental function, and 21.4% impaired lung function. Various studies have reported that the consumption of seafood is a major source of methyl mercury (MeHg).[9,10,13] The concentration of mercury in fish ranged from 0.03 and 2.22 μg/g (wet weight) with methyl mercury accounting for 83% of the total content of mercury.[37] Likewise, the fish consumed by humans contain MeHg, which exhibits neurotoxic effects that cause severe damage to human health. [13] The toxic effect of MeHg affects the brain and cognitive development in fetuses and children by hampering the availability of nutrients such as long-chain polyunsaturated fatty acids, iodine, iron, and choline.[13] Overall, the findings of the present study and others reviewed in the literature showed that MeHg is a toxic compound that poses significant risks to human health, safety, and the environment.

The third symptom section is organic mercury poisoning symptoms. Organic mercury poisoning is also termed *Minamata* or *Chisso-Minamata* disease.[38] It is medically described as a neurological disease that is caused by severe exposure to organic or methyl mercury, which is characterized by ataxia, feet numbness, muscle weakness, loss of vision, and damage to hearing and speech. Studies have shown that it can also result in mental insanity, paralysis, coma or even death of adults and fetuses.[39] Figure 7 shows the distribution of participants who have experienced the symptoms of organic mercury. The findings showed that 39% of participants had experienced one or more symptoms of organic mercury poisoning. As observed, 78.9% of participants had experienced headaches, 68.4% hearing impairment, 42.1% visual field constrictions, 28.3% blindness, 10.5% ataxia, and 10.5% dysarthria. Based on the outlined symptoms deduced in the study findings, it can be reasonably inferred that the participants may have experienced or are at risk of the *Minamata* or *Chisso-Minamata* disease. However, further studies are required to critically ascertain this assertion.

The length of time the participants have experienced the various symptoms and types of mercury poisoning was examined in the study. The objective was to understand when participants started experiencing the symptoms. Figure 8 shows the time the participants were first exposed to mercury, as examined in this study. The participants were queried about when or whether they first experienced the symptoms before working in oil and gas operations. The results showed that 93.9% and 6.1% of participants responded affirmatively (yes) and negatively (No), respectively. The findings indicate that the symptoms may not have been caused by lifestyle and dietary choices made by participants. Next, the participants were asked if they started experiencing the symptoms after working in oil and gas operations. The results showed that 81.6% of participants answered yes, while 18.4% of participants answered no. Therefore, the results indicate the mercury symptoms experienced may be a result of working in oil and gas operations, as earlier surmised. The findings corroborate the earlier submissions on the demographic information, lifestyle/food choices, operational area, and length of time working in the industry.

Limitations, Recommendations and Future Outlook

The objectives of the study were achieved through the questionnaire administered to 68 oil and gas employees employed in either the inspection or maintenance department. The findings showed that 48 out of the 68 respondents had experienced at least one type of mercury poisoning due to the consumption of seafood, cigarettes, mercury-amalgam fillings and working in the oil and gas industry. However, there are other known sources of mercury in the environment that could have affected the outcome of the study. Another limitation of this study is the sample size of the respondents. This study employed a small sample size which could have affected the generalisability of the findings, this can be increased in future studies. Furthermore, funding for more in-depth studies is required for a more reliable and accurate assessment of respondents to determine more insights into the occurrence and exposure to the various forms of mercury. For example, urine and blood tests can be conducted to accurately determine the exact type and concentration of mercury in the employee's body. Studies have shown that such tests provide more accurate information on mercury poisoning, despite the costs of the analyses. Furthermore, the current COVID19 pandemic was an added limitation to the successful accomplishment of this study. As data was collected online by the researcher, it was difficult to ascertain the precise number of people who received the link shared for the questionnaires against those who responded to the questionnaires. Thus it was difficult to determine the response rate. This method was employed due to strict protocols, which prohibit close contact with people amidst the covid 19 pandemic.

Based on the outlined limitations, this study recommends the engineering design and implementation of health measures and safety controls to detect, monitor and eliminate mercury in oil and gas operations. Further engineering controls can be added, such as ventilation systems with the ability to detect, capture, and disperse any mercury levels. If engineering controls are not possible, procedural controls can be implemented such as identifying locations suspected of mercury contamination and limiting exposure work time to limit exposure. Employees who do work in mercury-contaminated locations should be trained to limit their exposure and should be given monitoring equipment that detects mercury vapour levels. When possible, decontamination procedures should take place to protect workers. Each employee employed in such locations should be under regular medical surveillance to ensure the mercury levels within their body are on safe levels, and if not, further control measures should be taken It is envisaged that these recommendations will ensure a better understanding of the existence, types, exposure, and symptoms of mercury in crude oil as well as its health effects.

CONCLUSION

The study examined the effects of mercury concentration on the health and safety of Oil and Gas Workers in the target location in Oman. To this effect, the study sampled the opinions of 68 respondents who have 1 – 6 years of experience working in the oil and gas sector of the country. The study employed the two-pronged approach method of literature reviews and survey questionnaires to deduce the state, nature, and effects of mercury exposure among workers in the oil and gas industry. The findings revealed that the participants had experienced one or more forms of mercury poisoning. In addition, the study showed that the exposure to mercury at different concentrations among the target group in the study is due to the consumption of seafood, cigarettes, and occupational activities such as maintenance and inspection during oil and gas production. As a result, the participants were found to be prone to mercury exposure in the elemental, organic/inorganic and Methyl mercury forms, which pose significant risks to their health and safety. Findings also revealed that 75% of the participants felt headaches from elemental mercury exposure. In comparison, 78% felt symptoms associated with reduced eyesight arising from exposure to Methyl-Mercury. In contrast, exposure to headache was the symptom suffered by most participants 78%, who were exposed to organic mercury. Therefore, there is an urgent need to design, develop and implement robust health and safety measures to effectively detect, monitor and eliminate the sources of mercury poisoning in the oil and gas industry. Future studies are also required to assess the health effects of different forms and concentrations of mercury and investigate toxic gases exposure and health complications, which are required to suggest preventive and control measures. It is recommended that adequate funding be provided to research and develop novel technologies, strategies, and measures to prevent or mitigate contact, exposure and symptoms of mercury.

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