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Exposure to heavy metals in oil and gas wastes: A systematic review on health hazards assessment and mitigation in Nigeria

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Abstract

Heavy metals are toxic elements that are known to pose a significant threat to human health and the environment. In the oil and gas industry, heavy metals can be found in various waste streams, including drilling muds, production fluids, and produced waters. It is important to assess the health hazards associated with these wastes to ensure the safety of workers and the public. This systematic review aimed to assess the health hazards of heavy metals present in oil and gas waste in Nigeria. The study analyzed the levels of heavy metals in the waste, their sources, and the potential health risks associated with exposure. A comprehensive literature search was conducted to identify relevant studies published. The results of the study showed that high levels of heavy metals such as cadmium, lead, and mercury were present in the oil and gas waste in Nigeria. The exposure to these heavy metals can lead to serious health issues such as respiratory problems, kidney damage, and cancer. Based on the literature, there are several methods that can be used to mitigate the health hazards of heavy metals in oil and gas waste. These methods include incineration, treatment with chemicals, proper landfill management, and recycling. To ensure the safety of workers and the surrounding communities, it is essential that these methods be implemented and monitored properly. The findings of these studies call for increased public health interventions and the implementation of effective measures to prevent and mitigate the toxic impacts of petroleum waste on the health of local communities. The study also highlighted the need for effective regulations and more management strategies to minimize the exposure of the population to these hazardous substances and protect public health.

Keywords: Health hazard, Heavy metals, Oil & Gas wastes, Nigeria

1. Introduction

Oil and gas production and processing have been widely acknowledged as major contributors to environmental pollution, particularly in developing countries. Nigeria, one of the largest oil-producing countries in the world, generates large amounts of waste from oil and gas activities (Oyinlola & Adebayo, 2014). These waste materials are known to contain toxic substances, including heavy metals, which pose significant health hazards to the environment and human populations. The presence of heavy metals in oil and gas waste has been widely reported in different parts of the world, including Nigeria (Oyinlola & Adebayo, 2014; Adeyemo & Adeleke, 2018). The health hazards associated with exposure to heavy metals are well documented, including respiratory

problems, kidney damage, and cancer (Nriagu, 1989; Baquero et al., 2000). Therefore, there is a need to assess the extent of heavy metal contamination in oil and gas waste in Nigeria and its potential health impacts.

Health impact assessments (HIAs) are an important tool in the evaluation of potential health risks associated with environmental pollutants, including oil and gas wastes. In Nigeria, oil and gas waste disposal has become a major concern due to the significant impact it has on human health and the environment. The objective of this systematic review is to assess the health hazards associated with heavy metals in oil and gas waste in Nigeria. The study aims to analyze the concentration levels of heavy metals in the waste, their sources, and the potential health risks associated with exposure. This systematic review will provide valuable information on the extent of heavy metal contamination in oil and gas waste in Nigeria and will help to guide the development of effective regulations and management strategies to minimize the exposure of the population to these hazardous substances and protect public health.

1.1. Sources and type of heavy metals in oil and gas wastes

Oil and gas production processes generate a large amount of waste products, which may contain high levels of heavy metals. A literature review has found that oil and gas industries are among the major sources of heavy metal pollution in the environment. The sources of heavy metals in oil and gas waste include the release of drilling fluids and production water during the drilling process, the release of waste gases and liquids from production wells, and the discharge of produced water from the refining process (Adeleye et al., 2019). Heavy metals can be found in various waste products generated from oil and gas extraction activities, including produced water, drilling muds, and sludge from refining processes (Adewuyi et al., 2016). The heavy metals present in these waste products include Lead (Pb), cadmium (Cd), mercury (Hg), chromium (Cr) and zinc (Zn) among others (Eke, 2008; Khan et al., 2014). Heavy metals commonly found in oil and gas waste include lead (Khan et al., 2014). These heavy metals are toxic and can cause severe health problems, including organ damage and carcinogenesis (Khan et al., 2014; Samaila & Maidamma, 2020). These heavy metals can have adverse effects on the environment and human health. Some of the sources of heavy metals in oil and gas wastes are:

Drilling muds and cuttings: Drilling mud is a fluid that is used to cool and lubricate the drill bit, and remove cuttings from the borehole (Aghahoseini et al., 2017). Drilling muds and cuttings can contain heavy metals such as lead, mercury, chromium, and cadmium, which can leach into the soil and groundwater (Khanna, & Saxena, 2015; Aghahoseini et al., 2017). According to a study by Saghafi et al. (2017), the drilling fluids used in the drilling process are often contaminated with heavy metals such as lead, cadmium, and mercury. These heavy metals are introduced into the environment through the release of drilling fluids into the soil and groundwater. The study found that the concentration of heavy metals in drilling fluids was several times higher than the levels recommended by environmental regulations.

Produced water: Produced water is a by-product of oil and gas production, and it can contain heavy metals such as barium, chromium, mercury, and lead (Akande et al., 2015; Atari et al., 2018). Moreover, the discharge of produced water from the refining process has been found to be a significant source of heavy metal pollution in the environment (Etiaba & Eze, 2020). The study found that the discharge of produced water contains high levels of heavy metals such as lead, cadmium, and mercury, which are introduced into the environment through the surface water and groundwater.

Refinery waste and Pipeline corrosion: Refineries can generate waste streams such as sludge, slop oil, and contaminated soil, which can contain heavy metals such as nickel, lead, cadmium and chromium (Wang et al., 2017; Farhangi et al., 2016). Corrosion of pipelines can result in the release of heavy metals such as iron and lead into the surrounding environment (El-Fadel & Alameddine, 2008).

Crude oil and Natural gas: Crude oil can contain heavy metals such as cadmium, lead, and mercury (Al-Wabel et al., 2015). Natural gas can also contain heavy metals, including cadmium, lead, and mercury (Al-Wabel et al., 2015). Similarly, the release of waste gases and liquids from production wells has been found to be a significant source of heavy metal pollution in the environment (Li et al., 2018). The study found that the release of waste gases and liquids from production wells contains high levels of heavy metals such as lead, cadmium, and mercury, which are introduced into the environment through the air and groundwater

Exposure Routes and Population at Risk: The primary routes of exposure to heavy metals in oil and gas wastes in Nigeria include ingestion, inhalation, and dermal contact (Eke, 2008). Populations living in close proximity to oil and gas extraction sites are at the highest risk of exposure to these toxic metals (Adewuyi et al., 2016). This includes communities residing in oil-producing areas, workers involved in oil and gas extraction activities, and individuals consuming contaminated water and food sources (Eke, 2008).

Health Hazards Associated with Exposure to Heavy Metals: Exposure to heavy metals in oil and gas wastes can cause a range of health effects, including genotoxicity, oxidative stress, and neurotoxicity (Adewuyi et al., 2016; Khan et al., 2014). The toxic effects of these heavy metals on human health can vary depending on the type of metal and the level of exposure (Eke, 2008). Lead, for example, has been shown to cause developmental neurotoxicity, while cadmium can cause renal damage (Adewuyi et al., 2016). Chronic exposure to lead can cause cognitive and developmental disorders, as well as cardiovascular and renal damage (Kern et al., 2016). Mercury exposure can result in neurological and developmental damage, as well as respiratory problems (Jauhar et al., 2018). Cadmium is a known carcinogen and can cause renal damage and osteoporosis (Al-Saleh et al., 2019). Chromium is toxic when inhaled and can cause lung cancer (Shen et al., 2019). Additionally, the presence of heavy metals in oil and gas waste streams in Nigeria has been reported in several studies. For example, a study by Ebong et al. (2010) reported elevated levels of heavy metals (lead, cadmium, and mercury) in the water samples collected from the Niger Delta region of Nigeria. The study found that the levels of these heavy metals in the water samples were significantly higher than the permissible limits, which could result in adverse health effects to the population in the area if consumed. The following are some of the further findings regarding the health effects of heavy metals in oil and gas waste:

Arsenic

In a study by Hsu et al. (2017), elevated levels of arsenic were found in soil and water samples near oil and gas drilling sites in Pennsylvania. The study showed that exposure to arsenic from oil and gas wastes can pose a significant health risk to communities near these sites. Arsenic exposure has been linked to a variety of health problems, including skin lesions, renal failure, respiratory system disorders, panasthenia, pores, skin cancer, cardiovascular disease, lung, bladder, and liver cancer (Smith et al., 2000; Samaila, 2022). In a study by Banerjee et al. (2016), high levels of lead were found in soil samples near oil and gas drilling sites in Texas. The study showed that lead exposure from oil and gas wastes can pose a significant health risk to communities near these sites.

Cadmium

Cadmium is a toxic heavy metal that is often present in oil and gas wastes. It is a toxic metal that has been linked to kidney damage, anemia, osteoporosis, an increased risk of certain cancers, bone disease and increased risk of bone fractures (NRC, 1999). In a study conducted by Navas-Acien et al. (2007), the authors found that workers in the petroleum industry had higher levels of cadmium in their blood compared to the general population. This suggests that workers in the petroleum industry may be at increased risk of cadmium toxicity. A study by Bose et al. (2018) found that cadmium levels in groundwater near oil and gas drilling sites were significantly higher than in control sites. The study showed that cadmium contamination from oil and gas wastes can pose a serious health risk to communities relying on groundwater for drinking and irrigation.

Lead

Lead is another heavy metal that is commonly found in oil and gas waste. Exposure to lead can cause brain damage, cognitive and developmental delays, and decreased IQ in children, behavioral problems, cognitive and developmental delays, cardiovascular disease, and kidney damage and an increased risk of cardiovascular disease (Kostial et al., 2016; Samaila, 2019; Samaila & Bello, 2022). In a study by Pirkle et al. (1994), the authors found that lead levels in the blood of workers in the petroleum industry were higher compared to the general population. This suggests that workers in the petroleum industry may be at increased risk of lead toxicity.

Mercury

Mercury is another heavy metal that is often present in oil and gas waste. Exposure to mercury can cause serious health problems such as neurological damage and can be toxic to the developing fetus (Harada, 1995). In a study by Nriagu et al. (1996), the authors found that workers in the petroleum industry had higher levels of mercury in their blood compared to the general population. This suggests that workers in the petroleum industry may be at increased risk of mercury toxicity.

Methods for /determination of Heavy Metals in Oil and Gas Wastes: There are several methods used for the determination of heavy metals in oil and gas waste, including atomic absorption spectrophotometry (AAS), inductively coupled plasma-mass spectrometry (ICP-MS), and X-ray fluorescence spectrometry (XRF) (Al-Mulhem et al., 2019). AAS and ICP-MS are widely used for the determination of heavy metals in complex matrices, while XRF is a non-destructive method that can provide qualitative and quantitative information about the elemental composition of samples (Al-Mulhem et al., 2019).

2. Literature review strategies

The literature review was conducted using electronic databases such as PubMed, Research gate, and Google Scholar. The search was not limited to studies published in a specific period of time and included keywords such as "health hazards", "heavy metals", "oil and gas waste", and "Nigeria". The search was limited by language, and the only English articles were included in the review. The studies included in the review were those that investigated the levels of heavy metals in oil and gas waste in Nigeria and the potential health risks associated with exposure. Studies that did not meet the inclusion criteria, such as those that published in other languages were excluded from the review. Relevant information from the selected studies was extracted and included in the study. The quality of the included studies was assessed using a quality assessment tool. The studies were then rated as high, medium, or low quality based on the results of the quality assessment.

3. Findings and discussion

Previous studies have shown that oil and gas wastes, such as drilling muds, produced water, and well bore cuttings, contain elevated levels of heavy metals (Chen et al., 2016; Fatoki & Adebayo, 2015). Some of the common heavy metals found in these wastes include lead (Pb), cadmium (Cd), and chromium (Cr). The presence of heavy metals in oil and gas waste is due to the naturally occurring mineral deposits in the sedimentary rock formations that are being drilled, as well as the use of drilling additives that contain heavy metals (Fatoki & Adebayo, 2015). The presence of heavy metals in oil and gas wastes is a concern because they can pose a risk to human health and the environment if not properly managed. Ingestion or inhalation of heavy metals can cause a range of health effects, including neurological damage, kidney damage, and cancer (Chen et al., 2016). The release of heavy metals into the environment can also contaminate soil and water, and impact aquatic life (Fatoki & Adebayo, 2015). In addition to the health and environmental risks, the presence of heavy metals in oil and gas waste also has economic implications. For example, the presence of heavy metals can

make the waste more difficult to dispose of, as it may not be eligible for conventional landfill disposal (Fatoki & Adebayo, 2015).

Kamruzzaman et al. (2013) in their study of heavy metal contamination in soil and water samples from an oil and gas extraction area in Bangladesh found that lead, chromium, and cadmium levels were above the permissible limits set by WHO and FAO. Shafie et al. (2015) in their study on the presence of heavy metals in petroleum sludge in Malaysia found that the levels of heavy metals were within the permissible limits. Okoronkwo et al. (2015) analyzed the levels of polycyclic aromatic hydrocarbons (PAHs) in water, soil, and sediment samples from Ogoniland in Nigeria. PAHs are toxic chemicals that are commonly found in petroleum waste and are known to cause a range of health effects, including cancer. The results showed that the levels of PAHs in the water, soil, and sediment samples from Ogoniland were alarmingly high, indicating significant contamination by petroleum waste. The authors concluded that the high levels of PAHs posed a significant health risk to the local population, who relied on these water sources for drinking and domestic purposes. Nwachukwu et al. (2020) investigated the effects of oil spills on the quality of water sources in the Niger Delta region. The results showed that oil spills had a significant impact on the water quality, leading to high levels of toxic chemicals such as benzene, toluene and xylene. The authors concluded that this contamination posed a significant health risk to the local population and that urgent action was needed to address this issue. A study by Nwankwoala et al. (2016) evaluated the potential health risks associated with exposure to heavy metals in produced waters from the Niger Delta region of Nigeria. The results showed that exposure to high levels of lead and cadmium could lead to adverse health effects, including damage to the nervous system and reproductive system. Adewuyi et al. (2017) conducted a review of the health effects of petroleum waste exposure in the Niger Delta region of Nigeria. The authors found that exposure to petroleum waste was associated with a range of health effects, including respiratory problems, skin irritation, headaches, and neurological symptoms. The study also revealed that children were particularly vulnerable to the toxic effects of petroleum waste, and they reported higher incidence rates of respiratory problems and skin irritation compared to adults. The authors concluded that exposure to petroleum waste in the Niger Delta region posed a significant health risk to the local population and called for increased public health interventions to address the issue.

A study by Al-Sulaimani et al. (2019) measured the levels of heavy metals in produced waters from the Kuwait Oil Company and found high concentrations of lead, cadmium, and chromium. The authors concluded that these heavy metals pose a potential health hazard and that proper treatment and disposal methods should be implemented to reduce the risk of exposure. Similarly, a study by Onuoha et al. (2017) investigated the levels of heavy metals in drilling muds and production fluids in Nigeria. The results showed elevated levels of lead, cadmium, and nickel in the waste streams, which the authors noted could pose a health hazard to workers and the environment. They recommended the implementation of treatment and disposal methods to minimize the risk of exposure. A study by Omo-Ojo et al. (2018) found that exposure to oil and gas waste in Nigeria has resulted in a range of health effects, including respiratory problems, skin diseases, and birth defects. The authors concluded that the high levels of toxic substances, such as polycyclic aromatic hydrocarbons (PAHs), found in the air, soil, and water in areas affected by oil and gas waste disposal may be responsible for the observed health effects. Another study by Adebayo et al. (2019) assessed the health impact of oil spills in Nigeria and found that exposure to oil spills was associated with respiratory problems, skin diseases, and eye irritation. The authors suggested that the toxic substances in oil spills, such as benzene and toluene, may contribute to these health effects. The study also found that the people living in communities near oil spill sites were at an increased risk of exposure to toxic substances and were more likely to experience health problems as a result. In a study by Udoidiong et al. (2015), the authors examined the impact of oil and gas waste disposal on soil and water quality in Nigeria. The study found that the disposal of oil and gas waste has resulted in the contamination of soil and

water, which may have negative effects on human health. The authors concluded that measures should be taken to prevent further contamination and to mitigate the impact of oil and gas waste disposal on human health.

One study found that elevated levels of lead, cadmium, and other heavy metals were present in soil samples near oil and gas drilling sites (Lerner et al., 2014; Samaila, 2018). Another study found that wastewater from hydraulic fracturing (fracking) operations contained elevated levels of heavy metals, including cadmium, lead, and nickel (Kersting et al., 2015). These heavy metals can have toxic effects on the nervous, respiratory, and reproductive systems, as well as the cardiovascular, digestive, and immune systems (Lerner et al., 2014). In addition, exposure to heavy metals in oil and gas waste can lead to birth defects and developmental problems in children (Harless et al., 2013). A study conducted in Texas found a correlation between proximity to oil and gas drilling sites and higher rates of birth defects, including neural tube defects and heart defects (Cohen et al., 2012). These findings indicate that heavy metals in oil and gas waste pose a significant health hazard to both humans and the environment. Studies have shown that heavy metals present in oil and gas waste can pose significant health hazards to humans and the environment. These metals can leach into soil and groundwater, contaminating drinking water and potentially leading to health problems in humans and wildlife (Harless et al., 2013). Further research is needed to better understand the specific health impacts of exposure to these metals and to determine appropriate methods for mitigating these risks.

4. Mitigation Strategies of health hazards caused by heavy metals in oil and gas wastes

Heavy metals are toxic substances that are commonly found in oil and gas waste. They pose significant health hazards, particularly to the workers in the industry and the surrounding communities. To mitigate the health hazards associated with exposure to heavy metals in oil and gas wastes, a number of strategies have been proposed in the literature. These include the proper management and disposal of oil and gas waste products, monitoring of heavy metal concentrations in the environment, and risk communication and education (Adewuyi et al., 2016). Additionally, efforts should be made to reduce the levels of heavy metals in oil and gas waste products through improved production processes and technologies (Eke, 2008). The followings are some of the further mitigation strategies:

Incineration

One study conducted by Gong et al. (2019) found that incineration is a promising method for reducing the levels of heavy metals in oil and gas waste. The process of incineration involves burning the waste at high temperatures, which destroys the toxic substances, including heavy metals, and reduces their toxicity.

Treatment with chemicals

A study by Li et al. (2020) found that the addition of chemicals such as sodium hydroxide and hydrogen peroxide can effectively remove heavy metals from oil and gas waste. The chemicals react with the heavy metals, resulting in the formation of metal hydroxides, which are less toxic than the original heavy metals.

Landfill management

A study by Song et al. (2017) found that proper landfill management, including the use of liners, can help prevent the migration of heavy metals from the waste into the surrounding environment. The liners help to prevent the heavy metals from leaching into the soil and groundwater, which can reduce their health hazards.

Recycling

Study by Zhang et al. (2018) found that recycling of oil and gas waste can also help reduce the levels of heavy metals in the waste. The recycling process allows for the recovery of valuable materials, including heavy metals, which can be reused or disposed of properly.

5. Contributions of the study

- The study highlighted the need for effective regulations and management strategies to minimize the exposure of the population to hazardous substances (heavy metals) and protect public health.
- The findings of these studies call for increased public health interventions and the implementation of effective measures to prevent and mitigate the toxic impacts of petroleum waste on the health of local communities

6. Implications of the study

The results of this review showed elevated levels of lead, cadmium, and nickel in the waste streams of some oilfields in Nigeria which could pose a health hazard to workers and the environment.

7. Recommendations

There is a need for further studies in the oilfields of Nigeria to identify the radiological hazards of radiation emitted by radioactive substances.

8. Conclusions

The literature indicates that heavy metals in oil and gas waste streams pose a significant radiological health hazard. High levels of lead, cadmium, and other toxic elements have been found in drilling muds, production fluids, and produced waters. The literature reviewed suggests that exposure to heavy metals in oil and gas waste products in Nigeria poses significant health hazards to the population and the environment. The populations most at risk of exposure are those living in close proximity to oil and gas extraction sites and workers involved in these activities. To mitigate these hazards, it is essential to implement effective management and disposal practices, monitoring of heavy metal concentrations, and risk communication and education. Health hazards assessment of oil and gas wastes in Nigeria is a significant issue due to the widespread environmental contamination and exposure of communities in the Niger Delta region. Previous studies have investigated the toxic impacts of petroleum waste on human health and the environment. There are several methods that can be used to mitigate the health hazards of heavy metals in oil and gas waste. These methods include incineration, treatment with chemicals, proper landfill management, and recycling. To ensure the safety of workers and the surrounding communities, it is essential that these methods be implemented and monitored properly. The findings of these studies call for increased public health interventions and the implementation of effective measures to prevent and mitigate the toxic impacts of petroleum waste on the health of local communities.

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