AMERICAN JOURNALS
Open Access, Peer Reviewed Journals

American Journal of Technology and Applied Sciences
ISSN (E): 2832-1766 Volume 48, May - 2026

ASSESSMENT OF THE COMPOSITION AND HEALTH RISK LEVEL OF WIELDING FUMES FROM FABRICATION FACILITIES IN PORT HARCOURT

OSUGBA, E. 1
UGBEBOR, J. 2
EJIKEME, U 3.
1,2 and 3; Center for Occupational Health, Safety and Environment,
Institute of Petroleum Studies, University of Port Harcourt, Rivers State, Nigeria
Lead Authors Email; emmanuelosugba@gmail.com

ABSTRACT

This study assessed the composition and health risk level of welding fumes from fabrication facilities in Port Harcourt. The objectives were to; ascertain the composition and concentration of heavy metals in welding fumes and to examine the cancer and non-cancer health risk of fume through inhalation. Using experimental design, Air samples from fabrication facility in Port Harcourt was obtained using Mini-Vol portable air sampler and analyzed for presence and concentration of heavy metals. Health risk assessment was evaluated based on non-cancer risk using hazard quotient (HQ) and cancer risk using Cancer Risk Index (CRI). The results revealed that the heavy metal identified in the fumes and their concentrations were Iron (1.8935µg/g), Nickel (0.0194µg/g), Zinc (0.0107µg/g), Manganese (0.0132µg/g), Lead (0.2696µg/g), Chromium (0.0089µg/g), Aluminum (0.0071µg/g), Cobalt (0.1803µg/g), Cadmium (0.0854µg/g), Magnesium (0.0064µg/g), Calcium (0.0628µg/g) and Potassium (0.7174µg/g) which are all higher than recommended limits. Non-cancer health risk assessment revealed that non-carcinogenic metals contain in the fumes posed no health risk to the welders (HQ>1.0)) while Cadmium and Chromium posed cancer health risk because their CRI of 1.62×10^(-6) and 1.8×10^(-5) respectively were higher than recommended limit of 1.0×10^(-6). These findings highlight the need for robust enforcement of occupational health and safety regulations aimed at reducing possible health risk concerns associated with welding fume exposure. It was concluded that safeguarding the health and well-being of welders through systemic safety interventions is critical to promoting sustainable occupational health practices in fabrication industries in Port Harcourt.

KEYWORDS

Health Risk Level, Welding Fumes, Fabrication Facilities, Port Harcourt

Introduction

Welding is a technique that involves the joining of metallic components through the application of heat or pressure, often accompanied by the introduction of filler material (Rahmani *et al*., 2016). This process has become integral to modern life, particularly with the rapid expansion of urbanization and industrialization. Over the years, welding has developed into a vital procedure utilized across various sectors and industries, from manufacturing to construction. It plays a key role in industries such as transportation, infrastructure development, and even mining, and is considered a standard procedure in many organizations globally. However, despite its widespread use and importance, welding is not without its risks (Rahmani *et al*., 2016). Welders are exposed to a variety of hazardous gases and fumes during the process, some of which are known to have detrimental effects on human health. These gases can include toxic elements such as carbon monoxide, nitrogen dioxide, and various metal oxides, all of which pose significant health risks. Among these, manganese (Mn) exposure has been linked to adverse mental health outcomes and neurotoxicity. Studies have shown that exposure to manganese, a common element in welding processes, can impair cognitive abilities and cause neurological damage, especially among workers who are frequently exposed (Rahmani *et al*., 2016).

Globally, welding is a major profession, with over one million workers employed as welders. Furthermore, it is estimated that more than three million individuals practice welding on a regular basis, either as part of their main job or as an occasional task (Isah & Okojie, 2006). The International Labor Organization (ILO) reports that welding constitutes approximately 0.2% to 2% of the total workforce in many developed nations. This highlights the significant role that welding plays in the labour market worldwide. Welders are employed in a range of industries, including the transportation device manufacturing sector, building construction, mining operations, and metallurgy, all of which are central to the development of modern economies. Despite the importance of welding, the profession is not without its dangers. It has been estimated that nearly 500,000 welders are injured annually because of workplace accidents, and they face a significantly higher risk of developing serious health conditions, including lung cancer. In fact, welders are reported to have a 30% to 40% greater chance of dying from lung cancer compared to other workers in different professions (Martin *et al*., 1997).

The injuries that welders may sustain can range from temporary to permanent, with some injuries affecting their long-term health and quality of life. Furthermore, there is a global concern regarding the exposure of over 110 million welders to harmful welding fumes, which have been linked to a wide range of respiratory and systemic health issues (Honaryar *et al*., 2019). The harmful effects of welding gases and fumes on health are well-documented. Exposure to these toxic elements has been proven to cause various forms of inflammation and respiratory problems, including eye and nose irritation, throat destruction, and even cancer. Inhalation of welding fumes, especially over extended periods, can lead to a range of diseases, including lung cancer, chronic bronchitis, asthma, and pneumonia.

Welders with prolonged or high cumulative exposure are at an increased risk of developing these life-threatening conditions (Matrat *et al*., 2016). Despite the severity of these risks, welders are often among the most underserved groups of employees when it comes to workplace safety. They frequently work in hazardous conditions that lack proper safety measures, making them more susceptible to the dangers of exposure. Many welding workplaces suffer from poor environmental conditions, inadequate safety protocols, and insufficient healthcare provisions for workers. These factors contribute to a high incidence of workplace accidents and health-related issues, which, in turn, have a negative impact on

national economies and the overall well-being of workers and their families (Tagurum *et al*., 2018; Antonini, 2003; Beyene *et al*., 2019). Such working conditions are not only detrimental to the physical health of workers but also undermine their overall quality of life. Health and well-being are crucial aspects of individual welfare.

Welding is a vital industrial activity, especially in cities like Port Harcourt, Nigeria, where fabrication services are central to economic operations. However, this occupation poses severe health risks due to the release of hazardous welding fumes during metalworking processes. These fumes are complex mixtures of gases and fine particles formed by vaporizing metals and compounds at high temperatures. Among the toxic elements commonly present are nickel, chromium, manganese, and other metallic oxides—all known to cause adverse health effects when inhaled (Thaon *et al*., 2012). Welders are particularly vulnerable due to the frequency and duration of their exposure. Inhalation of these fumes can result in acute symptoms such as eye irritation, headaches, nausea, and metallic taste, as well as more serious long-term conditions like chronic bronchitis, occupational asthma, reduced lung function, and even lung cancer (Antonini, 2003; Susi *et al*., 2000). Beyond the lungs, toxic particles can enter the circulatory system, affecting other organs and potentially leading to systemic conditions.

Scientific studies show that welding fumes contain multiple toxic components, including aluminium, cadmium, chromium, manganese, iron oxide, nickel, and zinc oxide, among others, which can accumulate in the human body over time and cause irreversible organ damage (Balkhyour & Goknil, 2010). Despite advancements in welding technology and safety innovations, many Nigerian welders remain exposed without adequate health risk mitigation measures. The issue has gained global attention as a public health concern, with international agencies recommending more stringent workplace controls. In Nigeria, however, enforcement remains weak, and welders continue to face significant risks. Studies have linked welding fumes to elevated rates of respiratory illnesses, particularly in areas with high concentrations of welders and poor regulatory oversight (Bakri *et al*., 2013). Given these conditions, there is a pressing need for detailed research into the ascertain the composition of the welding fumes as well as ass the health risk level of these welding fumes which the workers are exposed to on daily. Understanding these dimensions is essential to formulating effective interventions that protect health of the welding worker health, thus, this current research focused on assessment of health risk level of welding fumes from metal fabrication facilities in Port Harcourt. Therefore, the aim of the study are; to measure the concentration of heavy metal constituents in welding fumes generated within a fabrication facility in Port Harcourt and compare then to standard occupational exposure limits and to determine the non-cancer and cancer risk associated with the exposure to the toxic constituents in welding fumes generated within a fabrication facility in Port Harcourt

2.0 Materials and Methods

2.1 Research Design

This study adopts mixed research design which comprised of experimental research design and analytical research design. The experimental design was adopted to investigate and measure the composition of welding fumes and compare the outcome with recommended standards while analytical design was adopted to investigate health risk level of the welding fumes based on the cancer and non-cancer risk levels.

2.2 Study Area

The study area, Port Harcourt, is the capital of Rivers State and is in Nigeria's Niger Delta (as shown in Figure 1). Known for its strategic importance, Port Harcourt is home to Nigeria's second-largest seaport, making it a vital hub for maritime trade and the oil and gas industry. Situated on the Bonny River, the city is approximately forty miles (64 km) away from the Atlantic Ocean, making it ideally positioned for international trade and logistics.

Port Harcourt lies within geographical coordinates of longitude 6°41'S–7°11'E and latitude 4°0'N–5°0'N. This positioning places it in the southernmost region of Nigeria, contributing to its tropical climate and rich wetlands. The city is thought to cover an area of about 1,811.6 square kilometres, providing ample space for its rapidly growing population and expanding urban and industrial activities. Despite Port Harcourt's relatively low elevation, the surface morphologies and the evolution of its drainage system are not significantly shaped by structural geological controls. Instead, they are more influenced by the tropical environment, heavy rainfall, and the riverine nature of the area. The city's growth has been shaped by its proximity to waterways, facilitating transportation, trade, and the extraction of natural resources.

As the economic and administrative centre of Rivers State, Port Harcourt is the focal point for the region's business, industrial, and political activities. The city plays a crucial role in Nigeria's oil and gas sector, housing several oil companies and refining plants. It is often referred to as the "treasure base of the nation" due to its importance in Nigeria's economy, particularly in the context of the petroleum industry. Port Harcourt's rapid growth and development have also led to significant urbanization and industrialization, contributing to both the economic vibrancy and the environmental challenges of the region. In summary, Port Harcourt's geographical and economic significance makes it an ideal focal point for the study of occupational health hazards, particularly those associated with industries such as welding, oil refining, and manufacturing. The city's centrality in Nigeria's industrial landscape underscores the relevance of understanding the health impacts on its workforce, especially in sectors with significant exposure to hazardous substances

Figure 1: Map of Port Harcourt in Rivers State showing the Study Area (Source: Britannica. "Port Harcourt, Nigeria." 2025.)

2.3 Sample Collection procedures

In this study, Mini-Vol portable air sampler (see Figure 2) was employed to collect air samples in the welders' work environment in order to ascertain the composition of the welding fumes

Figure 2: Mini-Vol portable air sampler

The air samples collected using the Mini-Vol portable air sampler were subjected to chemical characterization, including the identification and quantification of pollutants particularly Heavy metals which includes Iron (Fe^{3+}), Nickel (Ni^{2+}), Zinc (Zn^{2+}), Manganese (Mn2+), Lead (Pb2+), Chromium (Cr3+), Aluminum (AI3+), Cobalt (Co2+), Cadmium (Cd2+), Magnesium (Mg2+), Calcium (Ca2+), and Potassium (K2+)

2.3.1 Mini-vol Portable Air Sampler

The Mini-Vol Portable Air Sampler with Serial Number: 2922 is an ambient air sampler for particulate matter and non-reactive gases. The basic principle of the Air metric operation is Gravimetric {Method of quantitative analysis by weight}. The Mini-Vol Portable Air Sampler is basically a pump controlled by a programmable timer which can be set to make "runs" within 24 hour or throughout a week. When used outdoors it is either placed on a tripod stand or hung from a bracket mounted on a variety of structures such as utility poles, trees, fence post etc. The sampler is equipped to operate from a DC power source of a battery pack, thus making the sampling site independent of line power. The chemical characterization of the observe air samples collection include Heavy Metals, Total Petroleum Hydrocarbon (TPH), Polynuclear Aromatic Hydrocarbon (PAH), BTEX etc. After the sampler has been assembled, adjust, verified to be in proper working order, and a filter loaded in the Filter Assembly, the sampler is ready to collect air samples. A pre-weighed membrane filter (47um) was used to collect particulate matter is placed in the filter holder assembly using a bicep. Air is drawn through a filter medium [A 47nm diameter filter cassette and filter holder assembly used to hold the filter media]. As soon as possible after the end of the sampling period the operator retrieved the exposed filter paper into a petri dish. Potential for filter paper damage or changes in sample mass due to a particle loss, passive deposition or volatilization increases if the filter is left in the sampler for extended periods. After sampling, the membrane filter was dried at 105°C, cooled in a desiccator and weighed to the nearest milligram. The mass concentration was calculated by measuring the mass of

particulate matter and dividing by the volume of air. The volume of Air was determined as follows (see Equation 3.2):

Volume of Air (m^3) = flow rate x time of sampling

$$V = q \times t \quad (1)$$

Where q is the flow rate in liters per minutes, t is the time of sampling in minutes

0.001(the conversion from liters to cubic meters)

$Vm^3 = 0.0001\ m^3/l$ x Ql/min x tmin

2.4 Data Analysis

The data analysis was based on evaluating the health risk indictors based on health risk assessment as presented below

2.4.1 Health Risk Assessment

The health risk assessments are targeted to combine the levels of pollution by toxic substance with the probability to ascertain the toxic effect on the people working or living around the polluted areas. However, the human health risk indices that was evaluated in this study categorized into cancer risks and non- cancer risk indices.

1, Non-Cancer Risk Indices: Non-carcinogenic hazards are typically characterized by the hazard quotient (HQ). (health risk from contamination was assessed concerning its chronic as well as carcinogenic effects, based on the calculation of ADI-inhalation, plus a reference dose (RfD) (see Table 3.1) that defined the toxicity values for each heavy metal, (Choudhury *et al*., 2021; Kumar *et al.,* 2023; Aydın *et al.*, 2023) hence, non-carcinogenic risk will be calculated using the hazard quotient (HQ) as follows:

$$\mathrm{HQ} = \frac{\mathrm{ADI\ oral}}{\mathrm{RfD}} \quad (2)$$

ADI is the average daily inhalation of contaminant (heavy metal) in air and expressed as units of the contaminated body exposed per unit of body mass and day, calculated using the following equations:

$$\mathrm{ADI\ inh} = \frac{C_{air} \times \mathrm{IRinh} \times \mathrm{EF} \times \mathrm{ED}}{\mathrm{Bw} \times \mathrm{AT}} \times 10^{-6} \quad (3)$$

Where ADI is the average daily intake (mg/kg/day); C is the concentration of the heavy metals in air (mg/kg); IRinh is the inhalation rate (mg/day), for adults (20 m^3/day) and children (10 m^3/day); EF is the exposure frequency, 310 days/year; ED is the exposure duration, for adults (30 years) and children (6 years); BW is the body weight, for adults (70 kg) and children (20 kg); and AT is the averaging time (day): for non-carcinogens, ED × 365 days, and for carcinogens (Ni and Cr) and 70 (lifetime) × 365 days (Chen *et al*., 2018, US, EPA 1992)

2, Cancer Risk Indices: Carcinogenic risk (CR) was estimated as the incremental probability of developing cancer during a lifetime due to inhalation of a potential carcinogen (Kumar *et al*., 2023; Aydın *et al*., 2023) as follows:

CR = ADI-inh × IUR, (4)

Where IUR is the inhalation unit risk (IUR) of each contaminant see Table 1

Decision criteria; If the HQ > 1, there may be potential non-carcinogenic effects on health, while HQ ≤ 1 means there is no experience of any health risks for exposure by non-carcinogenic contaminant, (Aydın *et al*., 2023, Choudhury *et al*., 2021, Kumar *et al*., 2023,). And if the value of CR exceeds 1 × 10^6, it represents a lifetime carcinogenic risk to the human body (Aydın *et al.,* 2023, Kumar *et al.,* 2023)

Table 1 health risk factors for cancer and non-cancer risk assessment due to inhalation (USEPA 1992)

s/n	Heavy metals	Inhalation RFC	Inhalation Unit Risk (IUR)
1	Iron (Fe^{3+})	10 (mg/m^3)	0.
2	Nickel (Ni^{2+})	0.2($\mu g/m^3$)	$2.4\times 10^{-4}(\mu g/m^3)^{-1}$
3	Zinc (Zn^{2+})	5.0(mg/m^3)	0
4	Manganèse (Mn^{2+})	0.05($\mu g/m^3$)	0
5	Lead (Pb^{2+})	30($\mu g/m^3$)	$1.2\times 10^{-5}(\mu g/m^3)^{-1}$
6	Chromium (Cr^{3+})	0.008($\mu g/m^3$)	$1.8\times 10^{-2}(\mu g/m^3)^{-1}$
7	Aluminum (AI^{3+})	5.0(mg/m^3)	0
8	Cobalt (Co^{2+})	0.3($\mu g/m^3$)	$7.7\times 10^{-3}(\mu g/m^3)^{-1}$
9	Cadmium (Cd^{2+})	0.01($\mu g/m^3$)	$1.8\times 10^{-2}(\mu g/m^3)^{-1}$
10	Magnesium (Mg^{2+})	10(mg/m^3)	0
11	Calcium (Ca^{2+})	5.0(mg/m^3)	0
12	Potassium	2.0(mg/m^3)	0

3.0 Results and Discussions

3.1 Components and concentration of welding fumes in the selected fabrication workshops in Rivers State

The first objective of this study aimed to identify the key heavy metal components found in welding fumes that are potentially hazardous to health of workers in the selected iron fabrication workshops in Rivers State. Understanding the specific contents of the fumes and their various concentrations is vital for assessing occupational exposure risks and guiding the development of appropriate control measures.

Table 2 shows the result of laboratory analyses on the content and concentration of welding fumes and the results revealed that welding fumes contain a mixture of several heavy metals in varying concentrations. These metals are by-products of welding operations involving alloys and steel-based materials. The concentrations of these elements, measured in micrograms per gram (µg/g), are compared with their respective limits of detection (LOD). The results show that Iron (Fe^{3+}) was the most prevalent metal, while Magnesium (Mg^{2+}) had the lowest concentration among the detected elements. The descending order of metal concentration in welding fumes was as follows, Fe > K > Pb > Co > Cd > Ca > Ni > Mn > Zn > Cr > Al > Cu > Mg. The findings indicate that the workers are regularly exposed to a combination of toxic and carcinogenic metals, with potential long-term health risks.

These results align with findings from Antonini et al. (2003), who also reported iron and manganese as the dominant metals in welding emissions. Similarly, the World Health Organization (WHO, 2016) emphasized the health hazards associated with inhaling such fumes, especially due to the neurological

effects linked to manganese and the carcinogenic potential of hexavalent chromium. The classification of welding fumes as Group 1 carcinogens by the International Agency for Research on Cancer (IARC) further supports the importance of identifying these components for risk assessment. The finding also aligned with the work of Zimmer and Biswas (2001) who showed that the composition of welding fumes is highly dependent on the specific materials involved in the process. This includes factors like the base metal composition, the coating on the metal, the filler material, the shielding gas used, and the type of electrode and flux material employed. For example, common metals found in welding fumes include aluminium, barium, beryllium, hexavalent chromium, chromium oxides, copper, iron oxide, lead, manganese, magnesium, molybdenum, nickel, and zinc oxides. These elements are released in various forms, including as solid particles or gases.

Table 2. Main Components of welding fumes

Metals	Concentration (µg/g)	Limit of Detection (LOD) (µg/g)
Iron (Fe^{3+})	1.8935	0.002
Nickel (Ni^{2+})	0.0194	0.002
Zinc (Zn^{2+})	0.0107	0.001
Manganèse (Mn^{2+})	0.0132	0.0005
Lead (Pb^{2+})	0.2696	0.0005
Chromium (Cr^{3+})	0.0089	0.0005
Aluminum (Al^{3+})	0.0071	0.001
Cobalt (Co^{2+})	0.1803	0.0005
Cadmium (Cd^{2+})	0.0854	0.01
Magnesium (Mg^{2+})	0.0064	0.001
Calcium (Ca^{2+})	0.0628	0.005
Potassium	0.7174	0.05

3.2 Non-cancer health risk associated with non-carcinogenic metals in the weld fumes

The non-carcinogenic metal contain in the weld fumes are Iron (Fe3+), Zinc (Zn2+), Manganèse (Mn2+), Aluminum (AI3+), Magnesium (Mg2+), Calcium (Ca2+) and Potassium. Table 3 present the results of the hazard quotient (HQ) assessment carried out to investigate the potential of non-carcinogenic health effect of exposure to the contaminant metal in the weld fumes. Based on the decision rules, the hazard quotient of all the metal contaminants are less than one which means that there is no experience of any health risks on the welders for exposure by the non-carcinogenic metals in the weld fume.

These results aligned with work of Mayur and Pratibha (2018) who examined the occupational hazards in welding, focusing on the risks faced by workers, particularly those in apprenticeship programs who often lack formal safety training. The study identified several health issues linked to welding, including skin burns, respiratory diseases, eye problems, hearing loss, cardiovascular diseases, and musculoskeletal disorders. These risks were largely attributed to inadequate use of Personal Protective Equipment (PPE), which is essential for minimizing exposure to harmful conditions like heat, toxic fumes, and radiation.

Table 3 Non-cancer health risk assessment of the welder's fumes in welding workshop in Port Harcourt

s/n	Heavy metals	Concentration of metal in Weld fumes (µg/g)	Average Daily Intake (mg/kg/day)	Hazard Quotient (HQ)
1	Iron (Fe^{3+})	1.8935	0.460×10^{-6}	4.60×10^{-8}
2	Zinc (Zn^{2+})	0.0107	0.003×10^{-6}	6.0×10^{-10}
3	Manganèse (Mn^{2+})	0.0132	0.003×10^{-6}	6.0×10^{-8}
4	Aluminum (AI^{3+})	0.0071	0.002×10^{-6}	4.0×10^{-10}
5	Magnesium (Mg^{2+})	0.0064	0.002×10^{-6}	2.0×10^{-10}
6	Calcium (Ca^{2+})	0.0628	0.015×10^{-6}	3.0×10^{-9}
7	Potassium	0.7174	0.174×10^{-6}	8.7×10^{-8}

Decision criteria; If the HQ > 1, there may be potential non-carcinogenic effects on health, while HQ ≤ 1 means there is no experience of any health risks for exposure by non-carcinogenic contaminant, (Aydın *et al*., 2023, Choudhury *et al*., 2021, Kumar *et al*., 2023,).

The outcome aligned with works of Ferreira (2012) conducted a comprehensive study on the exposure of welders to manganese (Mn) present in welding fumes, with a particular focus on personal respiratory exposure, biological monitoring, and the neurological effects of Mn exposure on welders. The overarching aim of the study was to evaluate the extent of Mn exposure among welders, assess its biological accumulation, and determine its potential influence on motor function and coordination. The study's findings revealed that Mn exposure in welding fumes did not surpass the occupational exposure limit recommended limit (OEL-RL) of 1 mg/m³, as stipulated by the Regulations for Hazardous Chemical Substances (RHCS). However, two of the exposure measurements exceeded the action level of 0.5 mg/m³, suggesting that although exposure was within acceptable limits, certain individuals faced heightened risk. Despite direct Mn exposure, no statistically significant correlation was observed between Mn levels in the welders' respiratory exposure and Mn concentrations in their nails. However, Mn concentrations in the nails of exposed welders were significantly higher than those of the control

group (p = 0.003), indicating that while Mn was being absorbed into the body, its deposition in nails may not directly reflect real-time respiratory exposure levels. Regarding motor function, the Purdue Pegboard Test results indicated a notable decline in finger dexterity and coordination among welders when compared to controls. Significant differences were observed in tests using the non-dominant hand at the beginning of the study (p = 0.016), and when pooled values for the non-dominant hand were analysed (p = 0.012). The welders consistently inserted fewer pins than the control group, particularly when using their non-dominant hand.

The outcome also aligned with works of Bakri (2018) who explored the relationship between exposure to metal fumes and lung health problems among welders in the automotive industry. The study synthesized data from over a hundred publications to assess the toxicity of metals commonly found in welding fumes and their association with specific respiratory conditions. Key findings confirmed that prolonged exposure to metal fumes significantly increases the risk of chronic obstructive pulmonary disease (COPD), metal fume fever, pulmonary fibrosis, lung cancer, and general respiratory impairment. The most hazardous metals identified included hexavalent chromium (Cr^{6+}), nickel (Ni), iron (Fe), cadmium (Cd), aluminium (Al), and beryllium (Be). These metals were linked to a range of adverse health outcomes, including lung inflammation, fibrosis, cancer, and irreversible damage to respiratory tissues.

3.3 Cancer health risk associated with non-carcinogenic metals in the weld fumes

The carcinogenic metal contain in the weld fumes are. Nickel (Ni2+), Lead (Pb2+), Chromium (Cr3+), Cobalt (Co2+) and Cadmium (Cd2+). Table 4 present the results of the cancer risk (CR) assessment carried out to investigate the potential of carcinogenic health effect of exposure to the contaminant metal in the weld fumes which involve estimating the incremental probability of developing cancer during a lifetime due to inhalation of a potential carcinogen. Based on the decision rules, which states that "if the value of CR exceeds 1×10^{6}, it represents a lifetime carcinogenic risk to the human body". the CR of Nickel (Ni2+), Lead (Pb2+) and Cobalt (Co2+) were within the safe zone for cancer risk while Chromium (Cr3+), and Cadmium (Cd2+) exceeded the limit which means that there I incremental probability of developing cancer by the welder during a lifetime due to inhalation of Chromium (Cr3+), and Cadmium (Cd2+) at the current concentration while there is no incremental probability of developing cancer by the welder during a lifetime due to inhalation of Nickel (Ni2+), Lead (Pb2+) and Cobalt (Co2+) at the current concentration.

Table 4 Cancer health risk assessment of the welder's fumes in welding workshop in Port Harcourt

s/n	Heavy metals	Concentration of metal in Weld fumes ()	Average Daily Intake(/µg/g//day)	Cancer health risk (CR)
1	Nickel (Ni^{2+})	0.0194	0.002×10^{-6}	4.8×10^{-7}
2	Lead (Pb^{2+})	0.2696	$0..028 \times 10^{-6}$	3.36×10^{-10}
3	Chromium (Cr^{3+})	0.0089	0.001×10^{-6}	1.8×10^{-5}
4	Cobalt (Co^{2+})	0.1803	0.019×10^{-6}	1.46×10^{-8}
5	Cadmium (Cd^{2+})	0.0854	0.009×10^{-6}	1.62×10^{-6}

Decision rule; if the value of CR exceeds 1×10^6, it represents a lifetime carcinogenic risk to the human body (Aydın *et al.,* 2023, Kumar *et al.,* 2023)

The outcome aligned with works of Ferreira (2012) conducted a comprehensive study on the exposure of welders to manganese (Mn) present in welding fumes, with a particular focus on personal respiratory exposure, biological monitoring, and the neurological effects of Mn exposure on welders. The overarching aim of the study was to evaluate the extent of Mn exposure among welders, assess its biological accumulation, and determine its potential influence on motor function and coordination. The study's findings revealed that Mn exposure in welding fumes did not surpass the occupational exposure limit recommended limit (OEL-RL) of 1 mg/m³, as stipulated by the Regulations for Hazardous Chemical Substances (RHCS). However, two of the exposure measurements exceeded the action level of 0.5 mg/m³, suggesting that although exposure was within acceptable limits, certain individuals faced heightened risk. Despite direct Mn exposure, no statistically significant correlation was observed between Mn levels in the welders' respiratory exposure and Mn concentrations in their nails. However, Mn concentrations in the nails of exposed welders were significantly higher than those of the control group ($p = 0.003$), indicating that while Mn was being absorbed into the body, its deposition in nails may not directly reflect real-time respiratory exposure levels. Regarding motor function, the Purdue Pegboard Test results indicated a notable decline in finger dexterity and coordination among welders when compared to controls. Significant differences were observed in tests using the non-dominant hand at the beginning of the study ($p = 0.016$), and when pooled values for the non-dominant hand were analysed ($p = 0.012$). The welders consistently inserted fewer pins than the control group, particularly when using their non-dominant hand.

The outcome also aligned with works of Bakri (2018) who explored the relationship between exposure to metal fumes and lung health problems among welders in the automotive industry. The study synthesized data from over a hundred publications to assess the toxicity of metals commonly found in welding fumes and their association with specific respiratory conditions. Key findings confirmed that prolonged exposure to metal fumes significantly increases the risk of chronic obstructive pulmonary disease (COPD), metal fume fever, pulmonary fibrosis, lung cancer, and general respiratory impairment. The most hazardous metals identified included hexavalent chromium (Cr^{6+}), nickel (Ni), iron (Fe), cadmium (Cd), aluminium (Al), and beryllium (Be). These metals were linked to a range of adverse health outcomes, including lung inflammation, fibrosis, cancer, and irreversible damage to respiratory tissues.

4.0 Conclusions

This study set out to investigate and asses the health risk level of welding fumes from fabrication facility in Port Harcourt. Based on the analyzed data, the following conclusions are drawn in relation to objectives: one, welding fumes from fabrication facilities contain toxic substances which presents significant health risks and the concentrations of these toxic substances reported in the facility exceeded recommended occupational exposure limits, suggesting that the welders are routinely exposed to levels of hazardous substances that could cause long-term damage. Two, the non-carcinogenic metals have no potential health risk on the welders based on the level of the hazard quotients while carcinogenic metals particularly cadmium and chromium have potential of cancer health risk on the welders based on the level of their cancer risk index.

References

1. Antonini, J. M., Taylor, M. D., Zimmer, A. T., & Roberts, J. R. (2004). Pulmonary responses to welding fumes: role of metal constituents. Journal of Toxicology and Environmental Health, Part A, 67(3), 233-249. https://doi.org/10.1080/15287390490275191
2. Aydın, H., Tepe, Y., & Ustaoglu, F., (2023). A holistic approach to the eco-geochemical risk assessment of trace elements in the estuarine sediments of the Southeastern Black Sea. Marine Pollution. Bull. 189, 114732
3. Bakri, S., Hariri, A., Ismail, M., Abdullah, S., & Kassim, I. (2018). Evaluation of respiratory symptoms, spirometric lung patterns, and metal fume concentrations among welders in indoor air-conditioned buildings in Malaysia. International Journal of Integrated Engineering, 10(5), 109-121.
4. Balkhyour, M., & Goknil, K. (2010). Total fume and metal concentrations during welding in selected factories in Jeddah, Saudi Arabia. International Journal of Environmental Research and Public Health, 7(7), 2978-2987. https://doi.org/10.3390/ijerph7072978
5. Beyene Gebrezgiabher, B., Tetemke, D., & Yetum, T. (2019). Awareness of occupational hazards and utilization of safety measures among welders in Aksum and Adwa towns, Tigray region, Ethiopia, 2013. Journal of Environmental and Public Health. https://doi.org/10.1155/2019/4174085
6. Chen, D., Li, F., Gao, Y., & Yang, M. (2018). Pilot performance of chemical demulsifier on the demulsification of produced water from polymer/surfactant flooding in the Xinjiang oilfield. Water, 10(12), 1874.
7. Choudhury, T.R., Acter, T., Uddin, N., Kamal, M., Sarwaruddin Chowdhury, A.M., & Safiur Rahman, M., (2021). Heavy metals contamination of river water and sediments in the mangrove forest ecosystems in Bangladesh: A consequence of oil spill incident. Environment. Nanotechnology., Monitoring. Management. 16, 100484.
8. Honaryar, M., Lunn, R., Luce, D., Ahrens, W., Mannetje, A., Hansen, J., Bouaoun, L., Loomis, D., Byrnes, G., Vilahur, N., Stayner, L., & Guha, N. (2019). Welding fumes and lung cancer: A meta-analysis of case control and cohort studies. Occupational and Environmental Medicine, 76(6), 422–431. https://doi.org/10.1136/oemed-2018-105447
9. Isah, E., & Okojie, H. (2006). Occupational health problems of welders in Benin City, Nigeria. Journal of Medicine and Biomedical Research, 5(1), 4–9. Available from http://www.bioline.org.br/pdf?jm0601
10. Kumar, S., Akash, P.B., Islam, R., & MacFarlane, G.R., (2023). Pollution status and ecological risk assessment of metal(loid)s in the sediments of the world's largest mangrove forest: A data synthesis in the Sundarbans. Maritime. Pollution. Bull. 187, 114514
11. Martin, C., Guidotti, T., & Langard, S. (1997). Respiratory hazards of welding. Clinical Pulmonary Medicine, 4(4), 194–204. https://journals.lww.com/clinpulm/Abstract/1997/07000/Respiratory_Hazards_of_Welding.3.aspx
12. Matrat, M., Gioda, F., Mattei, F., Cenee, S., Cyr, D., Févotte, J., Sanchez, M., Menvielle, G., Radoï, L., Schumaus, A., Woronoff, A.-S., Luce, D., & Stücker, I. (2016). Welding, a risk factor for lung cancer: The ICARE study. Occupational and Environmental Medicine, 73(4), 254–260. https://doi.org/10.1136/oemed-2015-102964

13. Rahmani, A., Golbabaei, F., Dehghan, F., Mazlomi, A., & Akbarzadeh, A. (2016). Assessment of the effect of welding fumes on welders' cognitive failure and health-related quality of life. International Journal of Occupational Safety and Ergonomics, 22(3), 426–432. https://doi.org/10.1080/10803548.2016.1184674
14. Susi, P., Goldberg, M., Barnes, P., & Stafford, E. (2000). The use of a task-based exposure assessment model (T-BEAM) for assessment of metal fume exposures during welding and thermal cutting. Applied Occupational and Environmental Hygiene, 15(1), 26–38. https://doi.org/10.1080/104732200301827
15. Tagurum, Y., Gwomson, M., Yakubu, P., Igbita, J., Chingle, P., & Chirdan, O. (2018). Awareness of occupational hazards and utilization of PPE amongst welders in Jos metropolis, Nigeria. International Journal of Research in Medical Sciences, 6(7), 22–33. http://dx.doi.org/10.18203/2320-6012.ijrms20182808
16. Thaon, I., Demange, V., Herin, F., Touranchet, A., & Paris, C. (2012). Increased lung function decline in blue-collar workers exposed to welding fumes. Chest, 142(1), 192–199. https://doi.org/10.1378/chest.11-0647
17. U.S, EPA (1992), Environmental Criteria and Assessment Office. Cincinnati, OH: United States Environmental Protection Agency; 1992. Integrated Risk Information System (IRIS).
18. World Health Organization (WHO). (2016). Constitution of the World Health Organization. WHO Chronicle, 1, 1–11.