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Risk Assessment and Mitigation in Paint Manufacturing in Khartoum State

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Abstract

Health and safety are fundamental human needs that play a crucial role in preventing work-related injuries and illnesses. This study evaluates the current state of occupational safety and health (OSH) practices in the paint manufacturing industry in Khartoum State, Sudan, with a focus on identifying gaps and areas for improvement. A cross-sectional study was conducted among 120 workers in 6 paint industries, using a structured questionnaire to collect data on OSH practices, training, and personal protective equipment (PPE) use. The findings reveal significant gaps in OSH implementation, including inadequate training (43%), limited commitment (58%), and high accident rates (53%). The study emphasizes the importance of effective safety measures, regulatory compliance, and best practices in minimizing occupational hazards. The results of this study can inform policy and practice aimed at improving OSH in the paint industry.

Keywords: Paint Industry; Occupational Health; Safety; Occupational Hazards; Sudan

1 Introduction

Painting is an occupation that involves the application of paint, pigment, colour, or other liquid-like materials to a solid surface. It is also regarded as the art or skill of using colour and paint for pictorial representation, beautification, and design (Bentley & Turner, 1998; Smith, 2002). Painting entails covering surfaces with paint to depict objects, symbols, or decorative patterns, and to enhance the aesthetic value of buildings, artworks, vehicles, and other structures. The rapid increase in human population has resulted in greater acquisition of property, including houses, buildings, and infrastructure, thereby increasing the demand for painting services. Painters are skilled workers who apply paint and other decorative finishes to interior and exterior surfaces of buildings, artworks, machinery, and related structures. Despite the importance of their work, painters constitute a high-risk occupational group due to frequent and prolonged exposure to multiple occupational hazards (Achalu, 2019).

The negative effects of work on health form the basis of occupational health, as exposure to workplace hazards can result in physical, mental, and behavioural disorders, and in severe cases, death (Achalu, 2019). Certain work conditions are directly associated with specific occupational health problems and diseases. Occupational diseases are those illnesses that occur exclusively as a result of exposure to hazards inherent in a particular occupation, indicating a clear cause-and-effect relationship between workplace hazards and disease occurrence (Achalu, 2000). Safety is defined as

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the condition of being free from injury, harm, damage, or loss of life and property, and the assurance that such harm will not arise within a given environment. In industrial contexts, safety and economic productivity are closely linked, as workers who perceive their workplace as safe are more motivated, efficient, and productive (Prashar & Bansal, 2009). Consequently, painters are required to adhere strictly to safety practices, including the consistent use of personal protective equipment (PPE) and other safety measures.

Personal protective equipment refers to clothing and devices worn by workers to protect the body from injury, accidents, or occupational hazards. Such equipment includes nose masks, respirators, gloves, coveralls, safety boots, and eye protection. The use of PPE significantly reduces exposure to occupational hazards and the risk of occupational diseases (Achalu, 2019).

Diseases associated with work can affect any organ of the body, leading to pathological changes. The nature and conditions of work largely determine the type and prevalence of occupational health problems within a given work environment. It is therefore essential to educate workers about occupational hazards and the health problems associated with their jobs, as work processes, products, and by-products may pose health risks not only to workers but also to the surrounding community (Asuzu, 1994).

Painters perform duties such as applying paint, stains, and coatings to walls, ceilings, and machinery; preparing surfaces through sanding and filling of cracks; installing scaffolding; and using hand and power tools. These activities are carried out in construction sites, homes, workshops, companies, and institutions, where painters are exposed to adhesives, sealants, paints, solvents, and asbestos-containing materials (Brock et al., 2000; Stoye & Freitag, 1998).

1.1 Occupational Health Hazards of Painters:

Workers are exposed to numerous occupational hazards in the workplace. A hazard is defined as any situation, substance, or process with the potential to cause harm to life, health, or property, while risk refers to the likelihood and severity of harm resulting from exposure to a hazard (Achalu, 2019). Workplace hazards may jeopardize workers' health, particularly among those who lack adequate awareness or training (Amanze & Agu, 2014). Occupational hazards may be physical, chemical, biological, ergonomic, or psychosocial in nature, and prolonged exposure can lead to accidents, injuries, and occupational diseases (Prashar & Bansal, 2010; Asuzu, 1994).

1.2 Physical Hazards:

Physical hazards are those that can be seen or felt and include noise, excessive light, extreme temperatures, vibration, ionizing radiation, slips, trips, and falls (Achalu, 2019). Exposure to physical hazards may result in hearing loss, visual impairment, heat stress, hypothermia, nerve damage, and musculoskeletal disorders (Gupta, 2010). Painters are particularly exposed to physical hazards such as working at heights, falling objects, confined spaces, poor ventilation, prolonged standing, improper manual handling of materials, exposure to ultraviolet radiation, and electrical hazards from live power lines or faulty equipment.

1.3 Chemical Hazards:

Chemical hazards arise from exposure to substances in the form of solids, liquids, vapours, gases, dusts, and fumes, which may enter the body through inhalation, skin absorption, or ingestion (Amanze & Agu, 2014). Painters are exposed to numerous chemical agents present in paints, solvents, pigments, and additives, including lead compounds, chromium, toluene, xylene, ketones, alcohols, esters, biocides, and resins (Bentley & Turner, 1998; Brock et al., 2000; Stoye & Freitag, 1998).

During paint mixing, application, sanding, and surface preparation, these substances may be inhaled or absorbed through the skin, especially in the absence of adequate protective equipment. Long-term exposure has been associated with respiratory diseases, neurological disorders, reproductive toxicity, and various cancers, including lung and bladder cancer (Kogevinas et al., 2003; IARC, 2010). Occupational exposure as a painter has been classified as carcinogenic to humans (Group 1) by the International Agency for Research on Cancer (IARC, 1989, 2010).

1.4 Biological Hazards

Biological hazards include exposure to living organisms such as bacteria, viruses, fungi, parasites, insects, and animals that can cause disease (Achalu, 2019). Painters may work in damp or unhygienic environments and may be exposed to mosquitoes, flies, rodents, or reptiles, as well as pathogenic microorganisms through inhalation, bites, or contaminated food and water, leading to infectious diseases and allergic reactions (Prashar & Bansal, 2009).

1.5 Mechanical and Ergonomic Hazards:

Mechanical and ergonomic hazards are related to poor tool design, faulty equipment, inadequate maintenance, and improper work postures. Ergonomic hazards result from repetitive movements, awkward postures, heavy lifting, and prolonged standing, all of which are common among painters (Achalu, 2019; Prashar & Bansal, 2009). These hazards are strongly associated with musculoskeletal disorders and chronic pain conditions.

1.6 Psychosocial Hazards:

Psychosocial hazards arise from psychological and social aspects of work, including poor work organization, job insecurity, excessive workload, inadequate communication, and interpersonal conflicts (Achalu, 2019). Painters may experience stress related to working at heights, noise, tight deadlines, job insecurity, and exposure to verbal abuse or harassment, which can negatively affect mental health, productivity, and overall well-being (Amanze & Agu, 2014).

1.7 Paints Disease

Painters may develop the following lung diseases

- Asbestosis
- Silicosis
- Allergic alveolitis

Research indicates that painters face a significantly increased risk of developing lung cancer due to occupational exposure to toxic substances present in paints, solvents, pigments, and fillers (Kogevinas et al., 2003; IARC, 2010a). Data from the Swedish Cancer Registry revealed that painters and lacquerers have a notably elevated incidence of lung cancer compared with the general population (Kogevinas et al., 2003). In addition, painters exposed to asbestos-containing materials are at high risk of developing mesothelioma, a highly aggressive and often fatal cancer of the pleura (IARC, 1989, 2010a).

All workers who regularly handle hazardous chemicals or are exposed to toxic fumes are advised to wear appropriate personal protective equipment at all times. Respiratory symptoms such as shortness of breath, persistent cough, chest pain, or other abnormalities should prompt immediate medical attention (Mayo Clinic, 2019).

Painting is a potentially hazardous occupation, exposing workers to solvents, additives, pigments, and toxic materials that may contain asbestos and lead, thereby increasing the risk of lung diseases and cancer (Bentley & Turner, 1998; Brock et al., 2000). Although modern water-based paints generally contain fewer toxic substances, painters frequently work in older buildings where legacy materials with high toxicity remain present (IARC, 2010a).

Even when using safer paints, painters are often required to sand or strip old coatings or work in renovation and demolition environments, increasing the likelihood of exposure to hazardous dusts and fibers (Kogevinas et al., 2003). Prolonged exposure under such conditions significantly increases the risk of chronic respiratory disease and malignancy.

Many fumes, gases, and dust particles can penetrate protective equipment, placing painters at continued risk despite safety precautions. A study published in the Journal of Occupational and Environmental Medicine reported that construction painters were exposed to elevated concentrations of paint dust containing lead, zinc chromate, and other inorganic compounds (IARC, 2010a).

Several hazardous chemicals—including benzene, phthalates, chromium, and lead oxides—have been reduced or replaced in paint formulations in some regions; however, they remain in use in other parts of the world. The adoption of water-based paints and powder coatings has contributed to reduced toxicity, although exposure risks persist (Stoye & Freitag, 1998; Brock et al., 2000).

1.8 Pigments and fillers

Paints may contain pigments, dyes, and fillers. Hazardous pigments and fillers, particularly chromate- and lead-based compounds, are increasingly substituted with safer alternatives, though some replacements may exhibit lower corrosion resistance or mechanical performance (Brock et al., 2000; Stoye & Freitag, 1998). Many paints in Western Europe are now lead- and chromate-free; however, regulatory practices vary widely across countries (IARC, 2010a).

1.9 Dyes

Unlike pigments, dyes are soluble in the paint medium and are used sparingly due to their limited resistance to light and environmental degradation. Their applications include transparent wood stains and transparent colourants (Zollinger & Iqbal, 2003).

Solvents in paints have diversified since the early twentieth century to include petroleum and coal-tar distillates, alcohols, esters, ketones, glycols, glycol ethers, and their derivatives (Stoye & Freitag, 1998). Regulatory restrictions in Western Europe have led to the removal of ethylene-glycol ethers and styrene from many formulations, while water-based coatings now rely on lower-toxicity solvents such as glycol ethers and n-butanol (Brock et al., 2000).

1.10 Additives:

Additives are chemicals incorporated into paints at low concentrations (0.1–5% by weight) to impart specific properties, including surfactants, driers, plasticizers, biocides, anti-skinning agents, defoamers, corrosion inhibitors, UV stabilizers, and catalysts (Stoye & Freitag, 1998; Brock et al., 2000).

1.11 Plasticizers:

Plasticizers such as dibutyl phthalate, diethyl phthalate, and dioctyl phthalate are commonly used to improve flexibility and durability. Other compounds include adipate and sebacate esters, tributyl phosphate, and castor oil (Stoye & Freitag, 1998).

1.12 Anti-skinning agents:

Anti-skinning agents delay surface film formation in liquid coatings and include oximes and phenolic derivatives. Compounds such as hydroquinone have been identified as potentially carcinogenic (IARC, 1999).

1.13 Corrosion inhibitors:

Corrosion inhibitors include inorganic pigments and organic inhibitors. Although red lead and chromate pigments are still used in specific heavy-duty applications, they are increasingly replaced by phosphate-based alternatives (Brock et al., 2000).

1.14 Asbestos:

Asbestos was historically used as a paint filler to improve durability, particularly in marine and industrial coatings. Its use declined after the 1950s, although asbestos-containing textured paints remained common until the early 1990s (Williams et al., 2007).

1.15 Nanoparticles:

The incorporation of nanoparticles (10–100 nm) at concentrations of 0.5–5% (w/w) enhances paint properties such as hardness, gloss, and weather resistance. Due to agglomeration and incorporation into the polymer matrix, occupational exposure to free nanoparticles is considered minimal (Aitken et al., 2006). Occupational exposure as a painter has been classified as Group 1 (carcinogenic to humans) by the International Agency for Research on Cancer, based on increased risks of lung cancer, mesothelioma, and bladder cancer (IARC, 1989, 2010a).

2 Khartoum Paint Industry Case Study:

Industrial employment in Sudan is concentrated in a small segment of the labor force, with about 14% of workers employed in industry overall (World Bank/ILO, 2026). Manufacturing contributes under 12% to national GDP and remains a relatively limited source of formal employment (Wikipedia, 2026). Much of Sudan's industrial base, including manufacturing plants and related labor, is concentrated in Khartoum (World Bank, 2025), suggesting that the paint industry's workforce and economic footprint are likely concentrated in the state's capital region.

The paint industry represents a significant industrial sector in Khartoum State, contributing to economic growth and providing employment opportunities for a considerable segment of the workforce. Despite these benefits, workers in the paint industry are routinely exposed to a wide range of occupational hazards, including chemical exposure, physical strain, and ergonomic risks. Consequently, assessing occupational safety and health (OSH) practices within this industry is essential to identify gaps and areas requiring improvement (International Labour Organization [ILO], 2019).

2.1 Estimated Employment in the Paint Subsector (Sudan/Khartoum):

Accurate official statistics specifically for the paint industry in Sudan are not published, but we can estimate based on broader industrial employment data and typical subsector shares.

2.2 Total industrial employment in Sudan:

According to World Bank/ILO estimates, the industry sector (including manufacturing, construction, mining, and utilities) employed about 13.98% of Sudan's workforce in 2022. If we assume Sudan's labor force was ~18.7 million in 2025 (Statista projection), this implies roughly 2.62 million people working in industry (18.71 million × 13.98%) in 2025.

2.3 Manufacturing employment within industry:

Manufacturing often accounts for a smaller share of industrial employment. In Sudan, manufacturing has historically been estimated at around 8% of total employment (excluding construction, utilities, etc.) — suggesting ~1.50 million workers in manufacturing (18.71 million × ~8%).

2.4 Paint subsector estimate:

Globally, paints and coatings form a small niche within manufacturing, typically 1–3% of manufacturing employment in similar developing economies (based on patterns seen in manufacturing cluster studies). Applying this range to Sudan:

- Low estimate: 1% of 1.50 million, ≈ 15,000 workers
- Mid estimate: 2% of 1.50 million ≈ 30,000 workers
- High estimate: 3% of 1.50 million ≈ 45,000 workers

These figures include workers in paint production, formulation, packaging, distribution, and affiliated services, and likely exclude informal jobs such as independent painters not formally employed.

2.5 Khartoum concentration:

Khartoum historically houses the majority of Sudan's industrial employment. Past World Bank industrial surveys show that around 60% of larger manufacturing firms are located within the Khartoum conurbation (Khartoum, Khartoum North, and Omdurman). Assuming a similar concentration in paint manufacturing, the majority (9,000–27,000 of the estimated paint sector jobs) would be in Khartoum State.

Health is a fundamental human need that falls within the domains of safety and psychological well-being, thereby warranting government intervention through policy formulation, regulatory enforcement, and continuous industrial and occupational monitoring (World Health Organization [WHO], 2020). Occupational risks exert a substantial influence on national economies by reducing workforce productivity and imposing significant financial burdens on healthcare systems, employers, and governments. These risks contribute to increased absenteeism, reduced efficiency, and long-term socioeconomic losses (ILO, 2019).

Occupational hazards also have direct and profound impacts on human health, often resulting in acute injuries, chronic diseases, or long-term disabilities. Occupational hazards are defined as harmful exposures, conditions, or practices present in the workplace that have the potential to cause injury, illness, or adverse health outcomes (Asuzu, 1994). Prolonged or repeated exposure to such hazards may lead to occupational diseases, which are illnesses directly attributable to workplace environments or job-specific activities (Achalu, 2019). While the paint industry contributes significantly to industrial development, it poses considerable risks to the health and safety of workers. Paint manufacturing and application involve the handling of hazardous chemicals, solvents, pigments, and dyes, which may result in occupational accidents and long-term health complications (Brock et al., 2000; Stoye & Freitag, 1998). The World Health Organization estimates that approximately 20% of global occupational diseases are attributable to chemical exposure (WHO, 2020). In the paint industry specifically, workers are commonly exposed to health hazards such as respiratory disorders, skin and eye irritation, neurological effects, and an increased risk of cancer (IARC, 2010).

Health and safety are therefore essential prerequisites for individual well-being and sustained productivity. Ensuring safe working environments requires strong governmental commitment, including the establishment of comprehensive occupational health policies, effective regulatory frameworks, and continuous monitoring of industrial practices. Such measures are critical for minimizing workplace risks and safeguarding the health of workers in the paint industry (ILO, 2019; WHO, 2020), Tables 1 and 2.

Table 1 Occupational risk and its economic costs

Category	**Approximate Global Value**
Work-related deaths per year	~ 2.3 million people (
Non-fatal workplace injuries per year	~ 395 million non-fatal injuries annually (International Labour Organization)
Work-related diseases per year	~ 160 million new non-fatal occupational diseases each year (International Labour Organization)
Economic cost	~ 4% of global GDP lost annually due to work-related injury, disease, and death (International Labour Organization)
Workers exposed to excessive heat	~ 2.41 billion workers (≈ 70% of the workforce) (International Labour Organization)

Table 2 Chemicals used in the paint industry and risk. HSE), MDPI. (2025), BLS Group. (2025). IARC. (2010)., NCBI Bookshelf. (1989)

Chemical	**Main Function in Paints**	**GHS Pictogram(s)**	**GHS Classification**	**Relevant H-Statements**
Titanium Dioxide (TiO_2)	Pigment (white)	🫁	Carcinogen (inhalation of respirable dust)	H351: Suspected of causing cancer.
Calcium Carbonate	Filler	⚠️ (dust)	Eye/respiratory irritant	H319 (eye irrit), H335 (resp irrit).
Iron Oxide Pigments	Pigments	⚠️	Mild respiratory irritant	H303, H333, H335.
Zinc Oxide (ZnO)	Pigment, fungicide	🐟	Very toxic to aquatic life	H410: Very toxic to aquatic life with long-lasting effects.
Chromium Oxide Green	Pigment	⚠️ / 🫁	Skin sensitizer; chronic exposure hazard	H317, H335, H373.
Acrylic Resins	Binder	⚠️	Skin/eye irritation	H315, H319.
Alkyd Resins	Binder	⚠️	May cause skin irritation	H315, H319.
Epoxy Resins (Bisphenol A type)	Binder	⚠️ / 🫁 / 🐟	Skin sensitizer; hazardous to environment	H315, H317, H319, H411.
Polyurethane Resins	Binder	🫁 / ⚠️	Respiratory sensitizer (due to residual isocyanates)	H334, H335, H317.
Isocyanates (TDI, MDI)	Crosslinkers	☠️ / ⚗️ / 🫁	Highly toxic; respiratory sensitizer	H331, H334, H335, H351.
Toluene	Solvent	🔥 / 🫁	Flammable; organ toxicity; reproductive toxicity	H225, H361, H373, H315, H336.
Xylene	Solvent	🔥 / ⚠️	Flammable; eye/skin irritant	H226, H312, H315, H332.
Ethyl Acetate	Solvent	🔥 / ⚠️	Highly flammable, irritant	H225, H319, H336.
Butyl Acetate	Solvent	🔥 / ⚠️	Flammable, central nervous system effects	H226, H336.
Mineral Spirits	Thinner	🔥 / ⚠️ / 🫁	Flammable, narcotic effects	H226, H304, H335, H336.
Glycol Ethers (EGME, EGEE)	Flow and leveling	🫁	Reproductive toxicity	H360: May damage fertility or the unborn child.

Formaldehyde / Donors	Preservative	☠️ / 🫁 / ☠️	Carcinogenic, acute toxicity	H301, H314, H317, H331, H350.
VOC Mixtures	Drying, flow	🔥 / ⚠️ / 🫁	Flammability, organ effects	Depends on mixture: H226, H336, H373.
Silica (Crystalline)	Thickener	🫁	Causes silicosis; carcinogen	H350, H372.
Lead Compounds	Pigments/dryers (old paints)	🫁 / 🐟	Reproductive toxin, organ toxicity	H360, H373, H410.
Cobalt/Manganese Driers	Drying agents	⚠️ / 🫁	Skin sensitizer	H317, H334, H341, H351.
Biocides (MIT, CMIT, BIT)	Prevent microbial growth	☠️ / ⚠️	Strong skin sensitizer	H314, H317, H319.

Key to GHS Pictograms:; GHS02 🔥 = Flammable; GHS03 ✴ = Oxidizer; GHS04 🧯 = Gas under pressure; GHS05 ☠️ = Corrosive; GHS06 ☠️ = Acute toxicity; GHS07 ⚠️ = Irritant / Harmful; GHS08 🫁 = Health hazard (carcinogen, respiratory sensitizer, reproductive toxicity, organ toxicity); GHS09 🐟 = Environmental hazard

Recent studies indicate that occupational exposure to paint is associated with an increased risk of several types of cancer, including lung, bladder, and pancreatic cancer, as well as lymphatic and hematopoietic malignancies (Kogevinas et al., 2003; IARC, 2010). These findings are consistent with the landmark evaluation by the International Agency for Research on Cancer (IARC), which classified occupational exposure as a painter as carcinogenic to humans (Group 1) in its 1989 monograph (IARC, 1989). The IARC report provided substantial epidemiological evidence demonstrating that exposures encountered during paint manufacture and application significantly contribute to elevated cancer risks among workers, particularly lung cancer and mesothelioma (IARC, 1989, 2010).

The manufacture of paint involves multiple processes that present considerable medical hazards to workers. Paint products contain thousands of chemical compounds, including pigments, extenders, binders, additives, and organic solvents such as toluene, xylene, ketones, alcohols, esters, and glycol ethers (Stoye & Freitag, 1998; Brock et al., 2000). Many of these substances are volatile or toxic and may enter the body through inhalation, dermal absorption, or ingestion, thereby increasing the risk of respiratory disease, neurological disorders, and long-term carcinogenic effects (IARC, 2010).

The paint industry in Khartoum State represents a significant source of employment, providing both direct and indirect job opportunities. Although precise employment statistics are not readily available, it is widely recognized that the sector employs a substantial workforce within manufacturing plants and across the broader supply chain, including distribution, retail, and paint application activities in construction and renovation (ILO, 2019). Indirect employment is particularly extensive, given the reliance of the construction sector on paint products and services.

Khartoum serves as the industrial hub of Sudan, historically hosting more than 70% of the nation's manufacturing industries and associated labor force (Central Bureau of Statistics [CBS], 2018). This concentration strongly suggests that paint manufacturing activities—and related occupational exposures—are disproportionately centered in Khartoum State. Consequently, workers in this region may face higher cumulative occupational risks compared with those in other parts of the country.

Companies such as Ayoub Paints Factory, identified as a leading paint manufacturer in Sudan, employ dedicated teams of workers and contribute significantly to local industrial development. This further illustrates the importance of the paint industry to Khartoum's economy while underscoring the need for effective occupational health and safety measures to protect workers from industry-specific hazards (ILO, 2019; WHO, 2020).

2.6 Basic Concept:

2.6.1 Hazard Identification:

- Chemical hazards: Exposure to toxic chemicals, solvents, and volatile organic compounds (VOCs).
- Physical hazards: Noise, vibration, and machinery-related injuries.
- Fire and explosion hazards: Risk of fires and explosions due to flammable materials and ignition sources.
- Ergonomic hazards: Musculoskeletal disorders and repetitive strain injuries.

2.6.2 Risk Assessment:

- Risk assessment methodologies: Using tools like HAZOP, FMEA, or risk matrices to identify and evaluate risks.
- Risk prioritization: Prioritizing risks based on likelihood, impact, and severity.
- Risk evaluation: Evaluating the effectiveness of existing controls and identifying areas for improvement.

2.6.3 Risk Mitigation Strategies:

- Elimination: Eliminating or reducing the use of hazardous substances.
- Substitution: Replacing hazardous substances with safer alternatives.
- Engineering controls: Implementing ventilation systems, safety interlocks, and other engineering controls to reduce risks.
- Administrative controls: Developing procedures, training programs, and policies to manage risks.
- Personal protective equipment (PPE): Providing PPE to workers to reduce exposure to hazards.

2.6.4 Risk Factors Involved:

- Environmental factors: Climate, temperature, and humidity in Khartoum State that may impact paint manufacturing processes.

- Regulatory factors: Compliance with local regulations, laws, and standards governing paint manufacturing and safety.
- Human factors: Worker training, experience, and behavior that can influence risk levels.
- Equipment and maintenance: Condition and maintenance of equipment, machinery, and facilities.

2.6.5 Best Practices:

- Regular risk assessments: Conducting regular risk assessments to identify and mitigate new or changing risks.
- Training and awareness: Providing regular training and awareness programs for workers on safety procedures and risk management.
- Continuous monitoring: Continuously monitoring and reviewing risk management strategies to ensure their effectiveness.
- Collaboration and communication: Collaborating with stakeholders, including workers, management, and regulatory bodies, to ensure effective risk management.

2.7 Gap Analysis:

Limited studies focus on the specific health and safety challenges of the paint industry. Insufficient data on the effectiveness of existing safety measures and regulations. Need for comprehensive analysis of technological innovations in improving health and safety outcomes

2.8 Aim of Study:

- Identify Risks: Determine potential hazards and risks in paint manufacturing in Khartoum State.
- Assess Risks: Evaluate the likelihood and impact of identified risks to prioritize mitigation efforts.
- Mitigate Risks: Develop and implement effective strategies to reduce or eliminate risks and ensure a safer working environment

3 Materials and Methods

This study aims to assess the implementation and availability of safety measures in 6 paint factories and 120 workers across Khartoum, Sudan. The research adopted a cross-sectional, descriptive study design, employing a mixed-methods approach to gather comprehensive data.

3.1 Geographical Context: Khartoum, Sudan

The geography of Khartoum, characterized by its arid plains surrounding the fertile riverbanks, can influence industrial operations, including waste disposal and environmental considerations. The climate, with common sandstorms from May to August, also presents unique challenges for air quality and worker safety. The city's rapid urbanization and established transport links to other parts of Sudan and neighboring countries highlights its importance as a center for manufacturing and distribution.

3.2 Study Population and Sampling:

- Target Population: All registered paint manufacturing factories operating within Greater Khartoum (Khartoum, Khartoum North, and Omdurman).
- Sample Size: A purposive sample of 6 paint factories and 120 workers is selected for this study.

3.3 Sampling Method

Selection Criteria:
The selection aims to represent a diversity of:

- Factory size: small, medium, large.
- Production capacity: varying levels of production.
- Ownership structure: local, international affiliates

3.4 Access to Factories

Access to these factories is facilitated through official channels, potentially involving the Ministry of Industry, local industrial unions, or relevant regulatory bodies will facilitate access to the selected factories. This sampling approach aims to provide a comprehensive understanding of safety practices in the paint industry by including a diverse range of

factories and workers. This approach likely involves selecting a sample of factories and workers that accurately represents the broader paint industry. Here's a breakdown:

3.4.1 Key aspects:

- Diversity: The sample includes factories of varying sizes (small, medium, large) and types (e.g., specialized paint manufacturers, general chemical manufacturers).
- Representation: The sample aims to represent the paint industry's various sectors, such as:
  - Industrial paint manufacturers
  - Automotive paint suppliers
  - Decorative paint producers
- Worker representation: The sample includes workers from different roles and levels, such as:
  - Production line workers
  - Quality control specialists
  - Safety officers
  - Management personnel

3.4.2 Benefits:

- Comprehensive understanding: By including a diverse range of factories and workers, the study can identify common safety practices, challenges, and areas for improvement across the industry.
- Generalizability: The findings are more likely to be applicable to the broader paint industry, rather than being limited to a specific segment or type of factory.
- Informative: The study can provide valuable insights for industry stakeholders, policymakers, and safety professionals seeking to improve safety practices in the paint industry.

3.5 Potential limitations:

- Sampling bias: If the sample is not representative of the industry, the findings may be biased or limited in their applicability.
- Data quality: The accuracy and reliability of the data collected from factories and workers may vary, potentially impacting the study's conclusions.

By acknowledging these aspects, the study can strive to minimize limitations and provide a comprehensive understanding of safety practices in the paint industry.

4 Data Collection Instruments:

Data is collected using a combination of:

4.1 Structured Questionnaires: Administered to factory managers or designated safety officers to gather information on:

- Factory demographics (size, age, number of employees).
- Existence and nature of formal safety policies and procedures.
- Availability and maintenance of safety equipment.
- Training programs for employees on safety protocols.
- Accident reporting and investigation procedures.
- Emergency preparedness plans (e.g., fire, chemical spills).
- Compliance with national and international safety standards (if any).

4.2 Observational Checklists: Used by trained researchers during on-site visits to objectively assess:

- General housekeeping and cleanliness of the factory premises.
- Ventilation systems (general and local exhaust ventilation for hazardous fumes).
- Proper storage and labeling of chemicals and hazardous materials (flammable liquids, solvents, pigments).
- Availability and proper use of Personal Protective Equipment (PPE) by workers (respirators, gloves, eye protection, protective clothing).
- Presence and accessibility of safety signage, emergency exits, and first-aid stations.
- Condition and maintenance of machinery and equipment (e.g., guarding, lockout/tagout procedures).

- Waste management practices, particularly for hazardous waste.

4.3 Key Informant Interviews (Semi-structured): Conducted with a sub-sample of workers, safety committee members (if present), and relevant government officials (e.g., from the Ministry of Labor or environmental agencies) to gain qualitative insights into:

- Worker awareness and perceptions of safety hazards.
- Effectiveness of existing safety measures from the workers' perspective.
- Challenges faced in implementing and enforcing safety regulations.
- Attitudes towards occupational health and safety.
- Effectiveness of safety training.

4.4 Types of Safety Measures Available and Investigated:

The study investigated the presence and effectiveness of various safety measures, categorizing them broadly as:

4.4.1 Engineering Controls

- Ventilation Systems: Local exhaust ventilation (LEV) for specific processes (e.g., mixing, filling) and general dilution ventilation to control airborne contaminants (VOCs, dust).
- Containment and Storage: Designated, well-ventilated, and fire-resistant areas for storing flammable liquids and hazardous chemicals. Spill containment kits and procedures.
- Machine Guarding: Physical barriers and interlocks on machinery to prevent contact with moving parts.
- Fire Suppression Systems: Fire extinguishers (appropriate types for chemical fires), fire alarms, sprinkler systems (if available).
- Emergency Showers and Eyewash Stations: Easily accessible units for chemical splash emergencies.
- Noise Reduction: Insulation, machine enclosures, or other measures to reduce excessive noise levels.

4.4.2 Administrative Controls

- Safety Policies and Procedures: Written documents outlining safe work practices, emergency response, and hazard communication.
- Risk Assessments: Regular identification and evaluation of workplace hazards and the implementation of control measures.
- Safety Training Programs: Regular training for all employees on general safety, specific hazards, PPE use, emergency procedures, and chemical handling. This includes induction training for new employees and refresher courses.
- Work Permits and Lockout/Tagout Procedures: For high-risk tasks (e.g., confined space entry, maintenance on energized equipment).
- Emergency Preparedness and Response Plans: Clear protocols for fire, chemical spills, medical emergencies, and evacuation drills.
- Health Surveillance/Medical Examinations: Periodic medical check-ups for workers exposed to specific hazards (e.g., lead, solvents).
- Waste Management Protocols: Procedures for safe collection, segregation, storage, and disposal of hazardous and non-hazardous waste generated during paint manufacturing.
- Housekeeping: Programs for maintaining cleanliness and order in the workplace to prevent slips, trips, and falls.

4.4.3 Personal Protective Equipment (PPE)

- Respiratory Protection: Appropriate respirators (dust masks, half-face, full-face, supplied air respirators) for protection against fumes, vapors, and particulate matter. Fit testing and training on use and maintenance.
- Eye and Face Protection: Safety glasses, goggles, and face shields to protect against chemical splashes and flying debris.
- Hand Protection: Chemical-resistant gloves suitable for the specific chemicals handled.
- Body Protection: Chemical-resistant overalls, aprons, or other protective clothing.
- Foot Protection: Safety footwear with chemical resistance and slip-resistant soles.
- Hearing Protection: Earplugs or earmuffs in noisy areas.

5 Results

Quantitative data from questionnaires and checklists were analyzed using descriptive statistics (frequencies, percentages, means, standard deviations) to identify the prevalence of different safety measures. Statistical software (e.g., SPSS) will be used for this purpose. Qualitative data from interviews are analyzed using thematic analysis to identify recurring themes and insights regarding safety culture, challenges, and perceptions. Findings from both quantitative and qualitative data will be integrated to provide a comprehensive understanding of the safety landscape within Khartoum's paint factories.

5.1 Ethical Considerations

Ethical approvals were obtained from relevant research ethics committees in Sudan. Informed consent is secured from all participating factory managers and employees. Confidentiality and anonymity of participants and factories were maintained throughout the study.

5.2 Results Analysis

The study investigated 6 factories for the availability of safety programs. The results show that approximately 57% of paint factories have occupational safety and health programs, while 1% do not apply them, and about 30% apply them occasionally. The study reveals that the paint factories are mostly aware of the importance of safety and health programs. See Figure1.

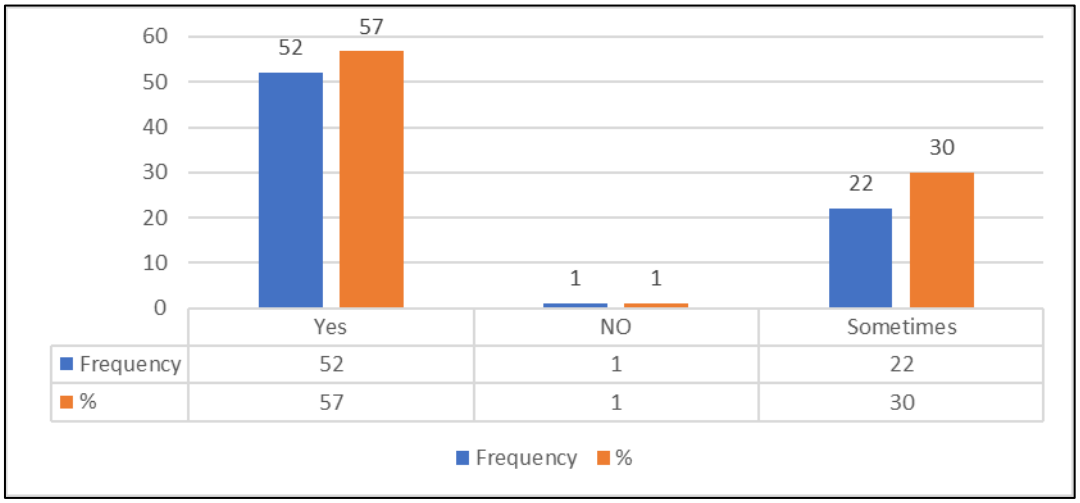

Figure 1 Availability of Programs of Occupational Safety and Health

Figure2 Shows that about 63% of the paint factories manage safety and health programs by the Security Department, about 18% by the Safety and Health Department, and 15% of them by the Human Resources Department. Through this study, it was found that most factories are interested in managing occupational safety and health programs.

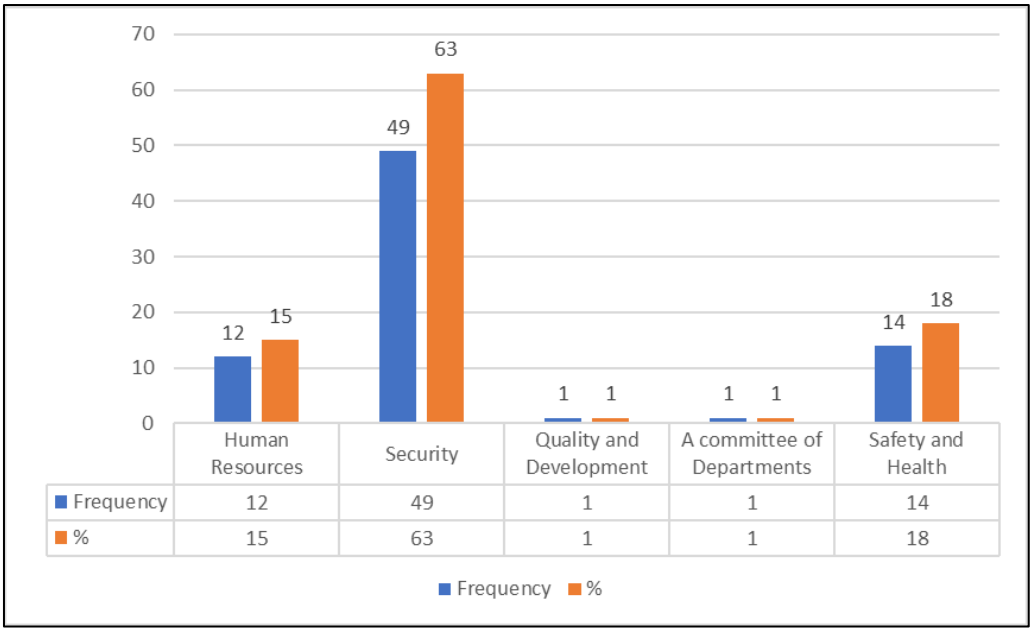

Figure 2 Management of Occupational Safety and Health

Figure 4 indicates that 38% of paint factories are committed to safety and health programs, 58% are limited, and 3% do not adhere to any safety and health programs. The study revealed that some factories do not have any interest or commitment to occupational safety and health programs.

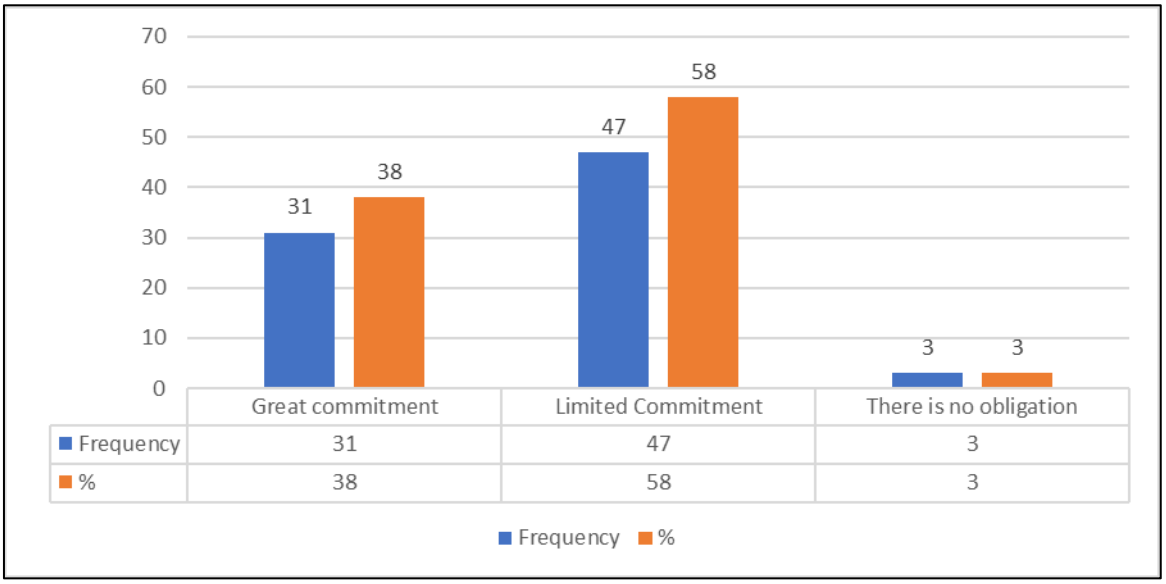

Figure 3 The Extent of Obligation of the Occupational Safety and Health Program

Figure 4 indicates that 53% of accidents and injuries occur in the work environment. This is a reference to the occurrence of accidents and injuries in the workplace in most factories due to a lack of application or attention to safety and health programs or the workers not receiving adequate training.

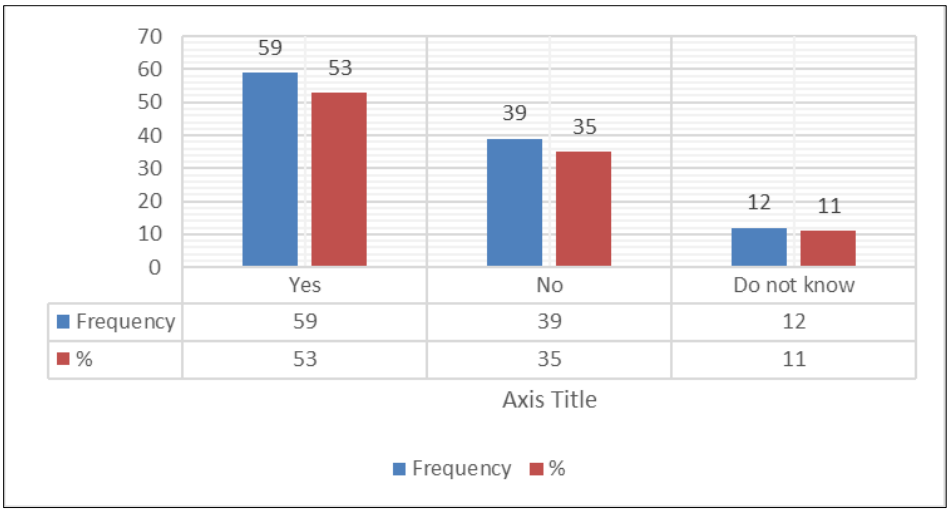

Figure 4 An accident and injuries occurred.

Figure (5) shows that 83% of workers in paint factories have awareness of occupational hazards and safety measures utilization. Employers should make sure that their employees know and understand the hazards that exist at their work sites and the adopted safe work practices. so, to achieve this, employees should be provided with the necessary safety information, instruction, and training. Training should be an ongoing process so that employees learn about new developments, and their knowledge and skills continue to improve.

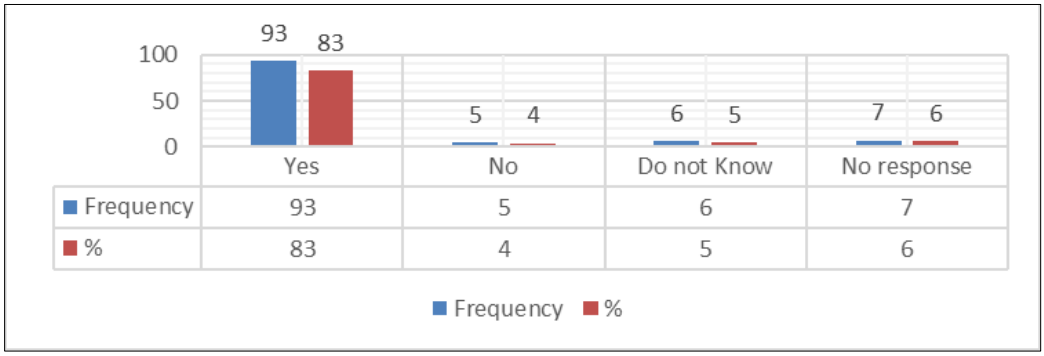

Figure 5 Awareness of Occupational Hazards and Safety measure utilization

Figure (6) indicates that 43% of employees have not been trained on the safety procedures that should be implemented, while the study reveals that 56% of them are familiar with the application of safety measures through the training provided to them and should also be trained to ensure they know how to access the available hazard information and understand the information on the labels and MSDS (material safety data sheets).

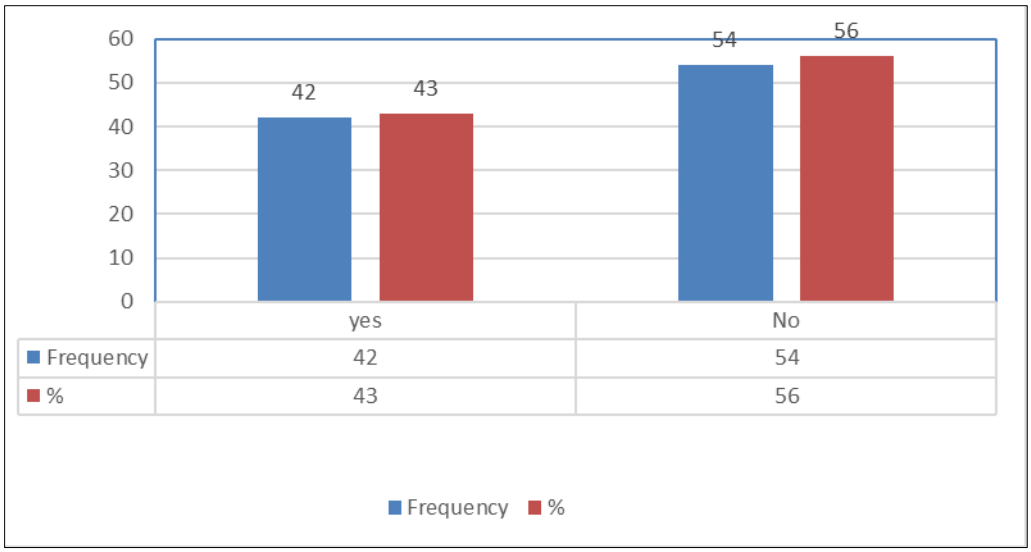

Figure 6 Formal training hazards and safety measures to be taken.

Figure 7 shows that 66% of workers use personal protective equipment, and about 26% of them do not use it. Through this study, it turns out that some workers don't know the importance of using personal protective devices, so they don't use personal protective equipment.

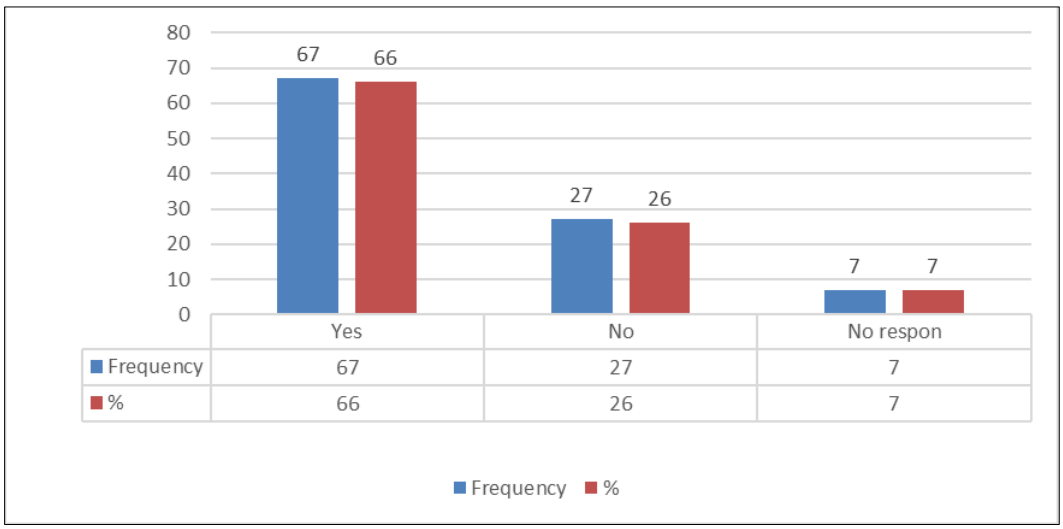

Figure 7 Use of personal protective devices

Personal protective equipment (PPE) provides a barrier to shield workers from exposure to chemical hazards, and Table 8 shows that 49% of workers use personal protective equipment occasionally and 23% use it regularly, while the study indicates that 15% do not know the importance of using personal protective equipment Figure 8.

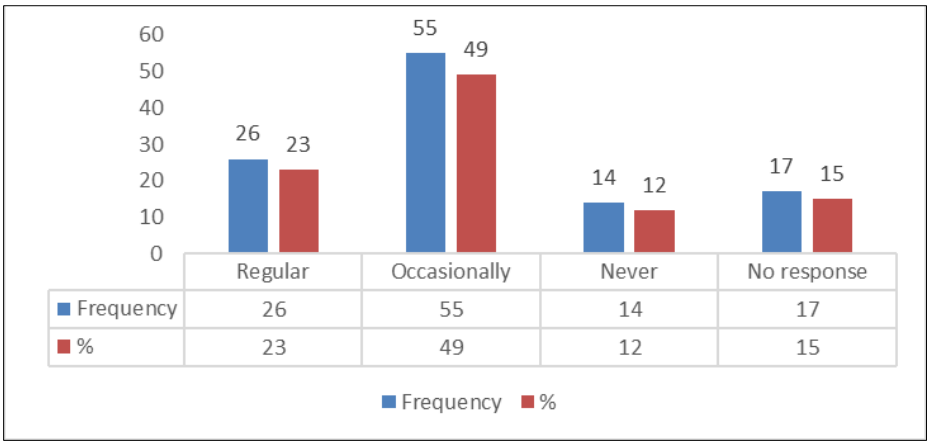

Figure 8 How often do you use personal protective equipment

The exposure of workers to the hazardous substances in paint spraying or paint production may cause acute or chronic health effects, so the worker must use the hand gloves, and Table 9 shows 50% (53 employees) used hand gloves, 35% (36 employees) don't use them, and 14% (15) do not know the importance of using hand gloves See Figure 9

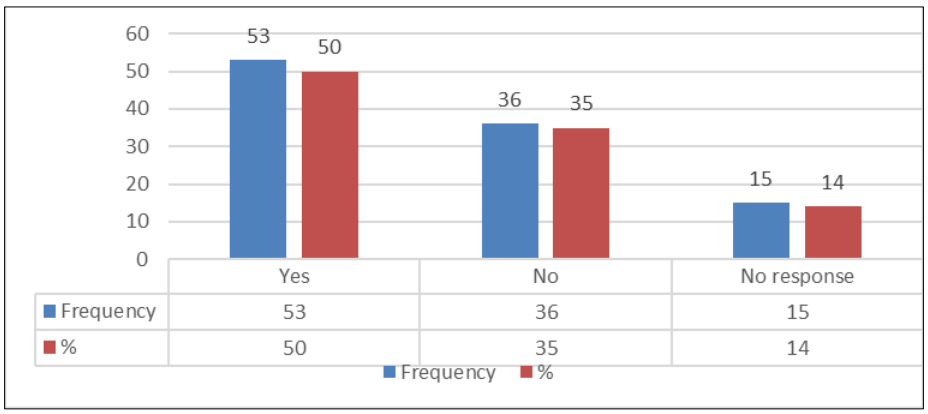

Figure 9 Use of personal Protective device (Hand gloves)

Figure (10) shows 58% (56 employees) don't use goggles, and 31%(30 employees) know the importance of wearing goggles, so they use them, while 10% (10) don't know the risk to their eyes due to working without eye goggles.

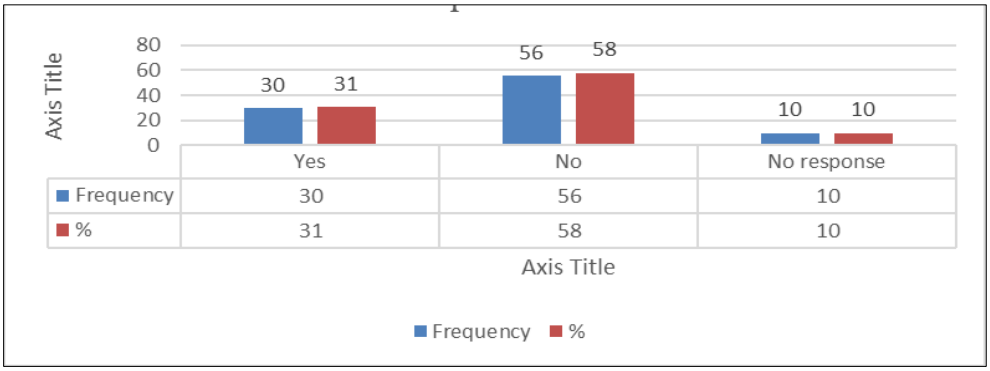

Figure 10 Use of personal protective devices (Goggles) among respondents

Figure 11 shows 33% (35 employees) don't use safety boots and 59% (62 employees) know the importance of using personal protective devices, while 8% (8 employees) don't know the risk that comes to their legs due to working without safety boots.

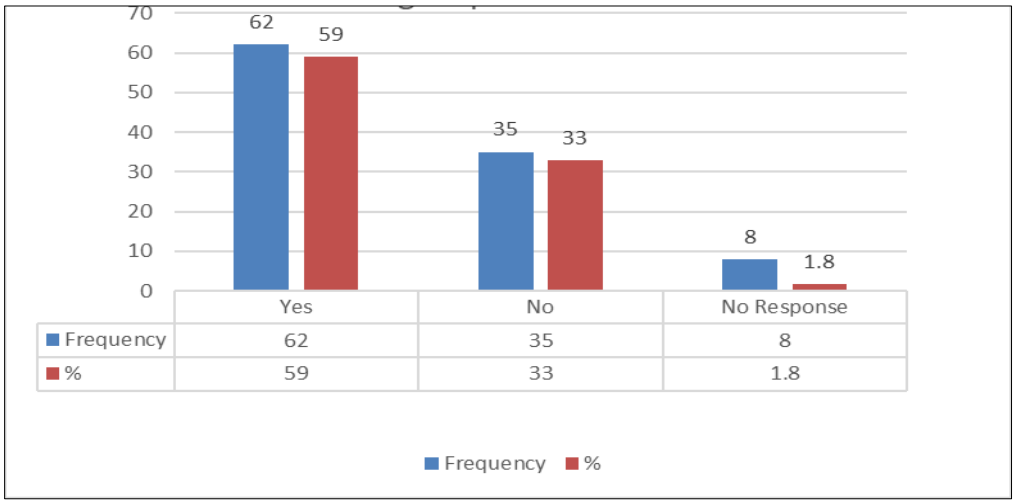

Figure 11 Use of Personal protective device (Safety boots) among respondents

Figure 12 shows 52% (46 employees) used masks, 35% (31 employees) worked without dust masks, while 10% (10) did not care about the risk to their bodies through smelling. The substances or processes are of high hazard, like dusts, mists, or fumes, so the employees and workers must use the dust masks while performing their tasks. Fresh air should be drawn from an uncontaminated source, and the contaminated air exhausted to a location that will not pose a hazard or further contamination to the workplace.

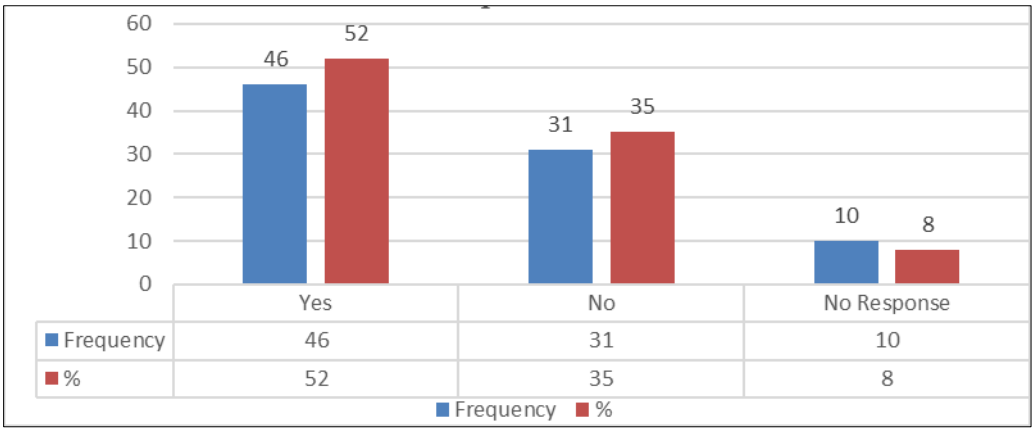

Figure 12 Use of personal protective device (Dust mask) among respondents

Figure 13 shows that 73% (79 employees) of workers wear aprons when performing their job duties because they know the importance of these clothes. And 21% (23 employees) do not wear aprons, while some do not know the importance of wearing aprons when dealing with paints or their components.

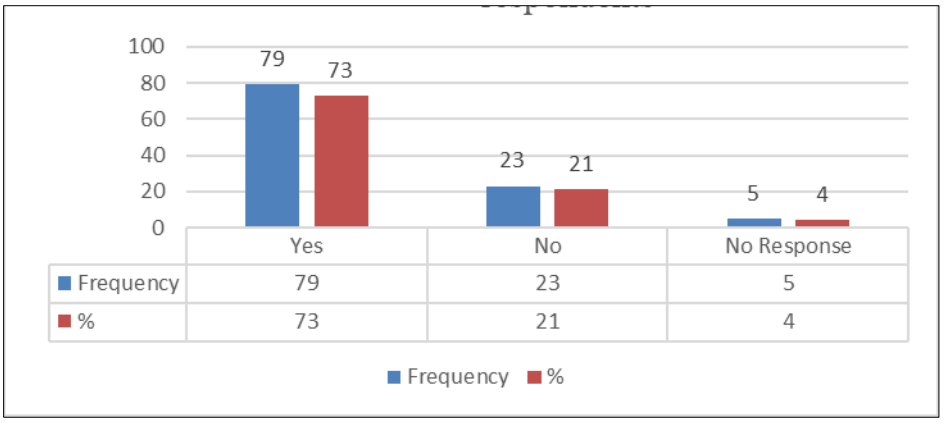

Figure 13 Use of personal protective device (apron)among respondents

Figure (14) shows that the most common occupational diseases suffered by employees are nervous tract disorders, such as 23% headache, 17% anxiety, 13% sleep disorder, and 11% dizziness. Also, other diseases include 12% poor eyesight and skin diseases like 14% itching and 11% skin irritations.

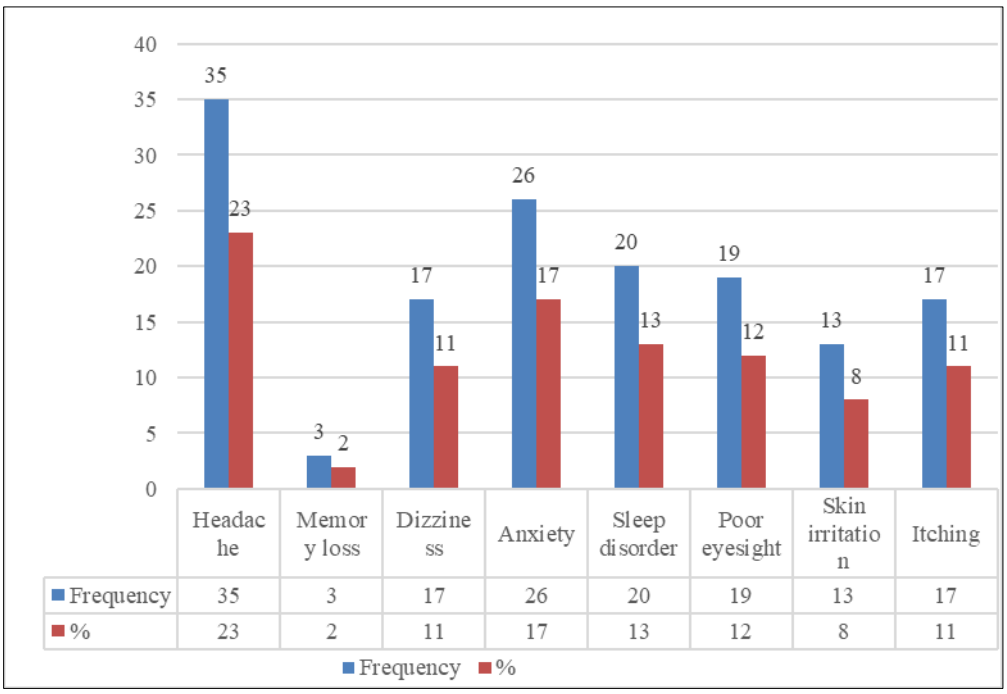

Figure 14 Self-reported occupational health programs respondent

Figure 15 shows that the most common occupational diseases suffered by employees are internal diseases (29% chronic fatigue, 8% weight loss) and respiratory diseases (19% productive cough, 13% chest pain, 10% dry cough, and 3% nose bleeding). also, table shows Eye diseases like Eye irritation (15%).

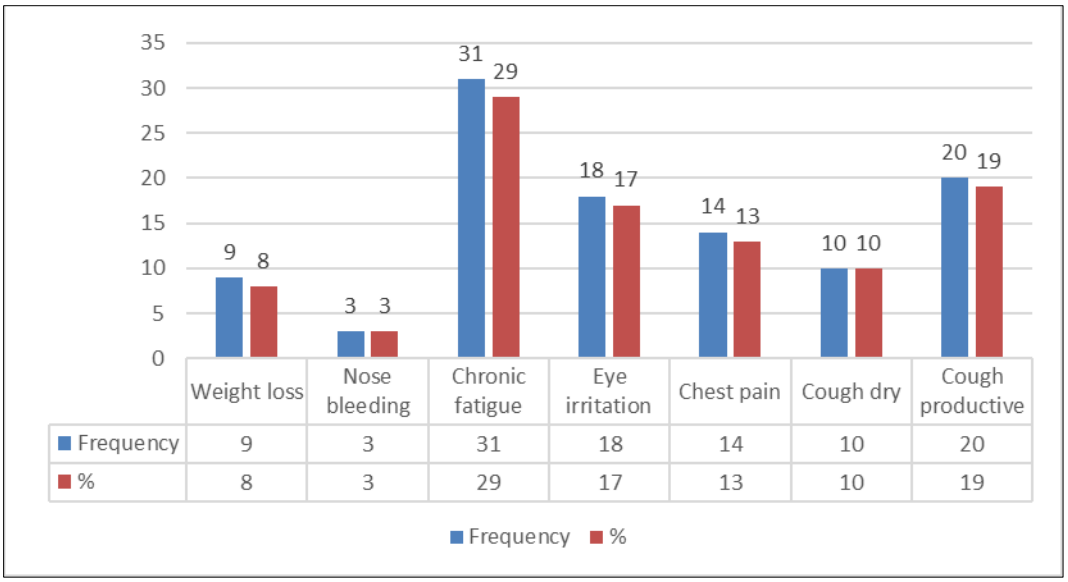

Figure 15 Self-reported occupational health Problems among respondents (continues)

5.3 Summary

This paper reviewed the occupational health hazards and diseases of painters with respect to painting, occupation, occupational health hazards, occupational diseases, personal protective equipment, general preventive measures of occupational diseases, and safety precautions for painters. The paper reviewed occupation as the various kinds of jobs/work people do to earn a living. Painting as the addition of colour or any liquid-like substance to a solid surface, an occupational health hazard as any processor condition that poses a threat to the lives of work men/women at the work place which can be physical, biological, chemical, mechanical, ergonomic or psychosocial. Moreso, the paper reviewed occupational diseases as those diseases that exclusively affect workers who are exposed to specific hazards related to their jobs.

The following are recommended safety control measures

- Learn correct procedures for working at heights, and select a safe working platform for the job.
- Avoid awkward body positions or take frequent breaks.
- Learn safe lifting techniques or call for assistance when necessary.
- Maintain safe distances from energized electrical equipment or utility lines.
- Keep work areas clear of clutter and equipment.
- Learn safety procedures for working in confined spaces.
- Maintain good ventilation during painting. Artificial ventilation may be required.
- Good lighting should be provided in a confined space.
- Wear appropriate eye wear, cover all, hand gloves, respirator, foot wear etc.
- Keep tools and equipment and their safety features in good working order. This can be achieved by routine inspection of working environment.
- Painters should check Safety Data Sheet (SDS) of the paint or coating product for the selection and use of appropriate personal protective equipment and safe use of the product.
- Protect your working area with warning flags and traffic cones when working road and traffic lines.
- Do not perform spray painting in tanks, tunnels or other confined spaces.
- Use ladders properly
- Scaffolds should not be loaded in excess of the working load for which they are intended (Edet, 2019 & Canadian centre for Occupational Health & Safety, 2021).

Based on the review of this paper, it was concluded that painters are a high-risk group of workers who are exposed to occupational hazards that pose a threat

Based on this paper review, the following recommendations were made:

- Painters should reduce work time in an environment where asbestos material or products are used.
- Painters should have regular medical check-ups as often as they work in such an environment.
- The Standard Organization of Nigeria (SON), which is the major regulating body of the Nigerian paint industry, and painting bodies like the Painters Guild of Nigeria should collaborate to organize workshops and seminars to educate painters on the hazards associated with the job and safety measures they can adopt to stay safe on the job.
- Paint manufacturing companies should reduce the percentage or quantity of poisonous, toxic or carcinogenic substances in paints so as to reduce the rate or level of effect on inhalation, absorption or ingestion into the body.
- Individuals who hire the services of painters should ensure that the painters have or wear appropriate personal protective wears before the commencement of work.

6 Discussion

The findings of this study underscore the significance of occupational safety and health training and the utilization of personal protective equipment in mitigating occupational hazards and enhancing worker health. These results align with previous research that has demonstrated the efficacy of occupational safety and health training in reducing workplace injuries and illnesses. Implementation of Occupational Safety and Health Programs.

The results reveal that the implementation and adherence to occupational safety and health programs are 58% of the surveyed factories demonstrating satisfactory implementation. Conversely, 61% of paint factories acknowledge the importance of safety and health programs, and 83% of workers exhibit awareness of occupational hazards and safety measures. Accident Rate: The study indicates that 53% of work accidents or injuries occur due to inadequate application and attention to safety and health programs. Furthermore, approximately 56% of employees have not received training on safety procedures, which exacerbates the risk of occupational hazards. Occupational.

Diseases: The findings show that the most prevalent occupational diseases among employees are eye diseases (12% reported poor eyesight), internal diseases (29% reported chronic fatigue), respiratory diseases (19% reported productive cough and 13% reported chest pain), and skin diseases (11% reported skin conditions and itching). Causes of Occupational Diseases: The primary reason for the emergence of these occupational diseases among workers is their failure to consistently use personal protective equipment, coupled with a lack of awareness regarding associated risks and inadequate training.

6.1 Challenges

The paint industry in Khartoum State faces significant challenges in maintaining adequate health and safety standards, resulting in negative consequences for workers and the environment.

- Inadequate OSH Implementation: Many paint factories in Khartoum State have inadequate occupational safety and health (OSH) implementation, with only 57% of factories applying OSH programs.
- Limited Commitment: Some factories show limited commitment to OSH programs, with only 38% showing great commitment.
- Accidents and Injuries: 53% of accidents and injuries occur in the workplace, highlighting the need for improved safety measures.
- Worker Awareness: 83% of workers are aware of occupational hazards and safety measures, but only 43% have received formal training.
- Mean and Standard Deviation: The study calculates the mean and standard deviation of OSH practices in paint factories, with results indicating a high level of awareness and implementation of safety measures.
- Correlation Analysis: The study finds a significant correlation between OSH practices and variables such as age and experience.

Recommendations:

- Occupational safety and health training be provided to all workers in the paint industry.
- The use of personal protective equipment should be made mandatory in the workplace.
- Employers ensure that workers have access to regular health checkups and medical care.
- Establish dedicated OSH departments.
- Enhance commitment to OSH initiatives.
- Improve accident reporting mechanisms.

By implementing these recommendations, the paint industry can reduce the incidence of occupational diseases and create a safer working environment for its employees.

Recommended standard engineering controls, PPE, exposure-control notes, first-aid actions, storage & disposal for the major groups of paint chemicals.

7 Conclusion

The paint industry plays an important role in economic development and employment generation, particularly in urban and industrial centers such as Khartoum State. However, the evidence reviewed in this study clearly demonstrates that paint manufacturing and application are associated with significant occupational health and safety risks. Workers are routinely exposed to a complex mixture of hazardous substances, including organic solvents, pigments, fillers, additives, heavy metals, asbestos, and, more recently, nanoparticles. These exposures occur through inhalation, skin contact, and, in some cases, ingestion, especially during paint production, application, surface preparation, and paint removal processes. Epidemiological and toxicological evidence consistently links occupational exposure in the paint industry to a wide range of adverse health outcomes. These include respiratory diseases such as asbestosis, silicosis, and allergic alveolitis, as well as skin and eye irritation and long-term chronic conditions. Of particular concern is the strong association between painting-related occupations and increased risks of cancer, notably lung cancer, mesothelioma, bladder cancer, and hematopoietic malignancies. The classification of occupational exposure as a painter as a Group 1 carcinogen by the International Agency for Research on Cancer underscores the seriousness of these risks. Despite global progress toward safer formulations, such as water-based paints and reduced use of lead- and chromate-containing compounds, workers in many developing countries, including Sudan, remain vulnerable. This is due to continued use of hazardous materials, limited regulatory enforcement, inadequate occupational health infrastructure, and insufficient use of personal protective equipment. Moreover, painters frequently work in older buildings that contain legacy toxic materials, further increasing their exposure risk.

In conclusion, improving occupational health and safety in the paint industry requires coordinated efforts involving government authorities, industry stakeholders, and workers. Strengthening regulatory frameworks, enforcing exposure limits, promoting safer chemical substitutions, and ensuring adequate training and use of protective equipment are essential. Addressing these challenges will not only protect workers' health and lives but also enhance productivity, reduce healthcare costs, and contribute to sustainable industrial development in Khartoum State and similar settings.

Compliance with ethical standards

Acknowledgement

The authors would like to thank the College of Engineering and Technology of Industries, Sudan University of Science and Technology, Sudan for the support during the study. Thanks are extended to all managers, supervisors, and worker in the manufacturing of paints ın the State of Khartoum for their collaboration during the study.

Disclosure of conflict of interest

The authors declare that no conflict of interest.

Statement of ethical approval

Ethical approvals were obtained from relevant research ethics committees in Sudan.

Statement of informed consent

Informed consent is secured from all participating factory managers and employees. Confidentiality and anonymity of participants and factories were maintained throughout the study.

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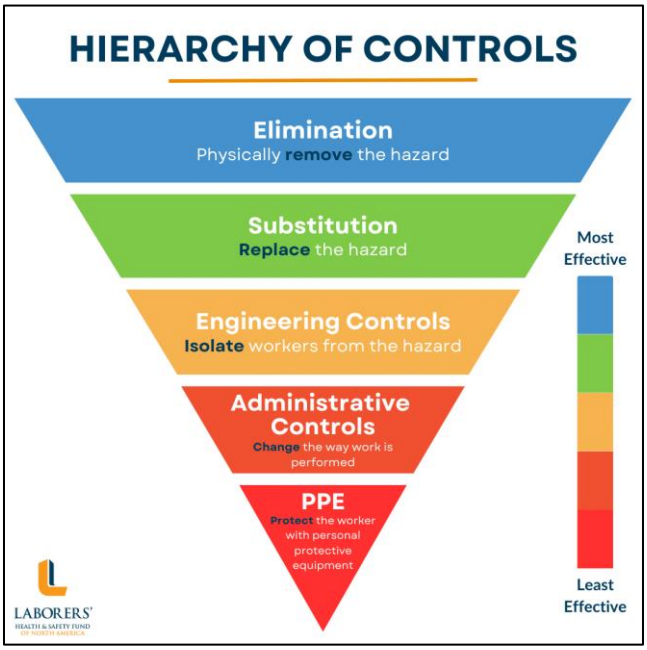
Annexes 1 Table 3 Standards engineering control

https://lhsfna.org/understanding-the-hierarchy-of-controls-engineering-controls/



Chemical group/examples	Primary hazards	Engineering controls	PPE (minimum)	Exposure guidance/notes	First aid (brief)	Storage & disposal
Organic solvents(toluene, xylene, ethyl/butyl acetate, mineral spirits, glycol ethers)	Flammable; CNS depression; respiratory irritation; some reproductive toxicity (glycol ethers)	Local exhaust ventilation (LEV) at source; solvent-safe general ventilation; explosion-proof electricals;	Chemical-resistant gloves (nitrile/ butyl), safety goggles, chemical-resistant apron, flame-resistant coveralls if ignition risk, half- or full-face respirator with	Use workplace exposure limits (OSHA/ACGIH/Local). Minimize vapor concentration; use less-solvent formulations (low-VOC) if possible.	Remove from exposure; if inhaled, move to fresh air and monitor breathing; for skin contact, wash with	Store in cool, ventilated flammable-storage cabinets away from oxidizers. Dispose via licensed hazardous-waste

		grounding for flammable liquids	appropriate cartridges or supplied-air where needed		soap & water; for eye contact flush 15+ min and seek care if irritation persists.	contractor; do not pour down drains.
Isocyanates / polyurethane systems(TDI, MDI, prepolymers)	Potent respiratory sensitizers; skin sensitization; asthma risk	LEV / booth spray capture; closed mixing systems; isolation for curing ovens; monitoring for isocyanate levels	Full-face supplied-air respirator or PAPR with organic vapor/particulate protection during spray; nitrile gloves + sleeve protection; impermeable coveralls; eye/face protection	Even low-level exposures can sensitize — implement medical surveillance and fit-testing. Use prepolymers with lower free isocyanate where feasible.	For inhalation remove to fresh air and seek medical attention; for skin contact remove contaminated clothing and wash; if breathing difficulty occurs, emergency care.	Store raw isocyanates sealed, cool, dry; segregate from amines and moisture. Waste handled as hazardous — isolate and use licensed disposal.
Epoxy resins & hardeners	Skin sensitizer (allergic contact dermatitis); eye irritation; some chronic effects	Local exhaust at mixing and curing; glove boxes for repetitive tasks; good housekeeping to avoid dust/residue	Nitrile or neoprene gloves, goggles, long-sleeve coveralls, chemical-resistant aprons; respirator if sanding cured films (dust)	Avoid skin contact; implement rotation and washing stations. For sanding cured epoxy use dust controls and respirators rated for particulates.	Wash skin thoroughly; if eyes, flush and seek medical attention for irritation.	Store sealed; separate from strong acids/oxidizers; cured scrap can often be disposed as non-hazardous after confirming local rules, but uncured wastes are hazardous.
Pigments — heavy metals & lead-containing(lead, chrome, cadmium, cobalt, manganese)	Neurotoxicity (lead), carcinogenicity (some chromium forms), sensitization	Process isolation, LEV, dust suppression (wet methods), HEPA filtration for airborne particulates	Disposable/coverall gowns, gloves, eye protection, and respiratory protection (P2/P3 or supplied-air) when dust or fumes present; shoe removal/overshoes to avoid take-home contamination	Use substitution where possible; regular biological monitoring for lead/other metals; strict hygiene practices (no eating in areas).	Remove from exposure; if ingestion suspected, seek immediate medical eval (esp. lead). For eye contact flush and seek care.	Store pigments in sealed containers; label hazardous metal pigments; wastes require hazardous-metal disposal per regulations.

Titanium dioxide / crystalline silica (dust)	Respiratory carcinogen risk from respirable dust/silica; lung disease	Dust capture at source, wet methods, local exhaust, HEPA vacuums for cleanup	Respirator with P3/HEPA filters for dusty operations; protective clothing to reduce dust spread; safety glasses	Minimize generation of respirable dust; substitution with lower-dust formulations; follow exposure limits and medical surveillance.	Move to fresh air if inhaled; if symptoms persist, seek medical attention. For eye contact flush.	Store powders sealed, label as hazardous if required. Dispose as industrial non-reactive waste per local rules; avoid airborne release.
Biocides / preservatives(MIT/CMIT, BIT, formaldehyde donors)	Skin sensitizer; respiratory irritant; some are carcinogenic (formaldehyde)	Closed handling for concentrates; LEV; minimization of aerosolization; controlled dosing	Gloves resistant to biocide (nitrile), goggles, apron; respirator for aerosol exposures	Avoid concentrated exposure; substitution with less hazardous preservatives when possible; limit worker contact time.	Skin: wash thoroughly. Eye: flush and seek care. Inhalation: fresh air and medical attention if severe.	Store locked and labeled; segregation from food and incompatible materials; dispose via hazardous-waste systems.
Driers and metal additives(cobalt, manganese)	Skin sensitizers; possible chronic toxicity	LEV, dust controls when handling powders	Gloves, goggles, respirator for powders, coveralls	Use minimal additive amounts and closed dosing; consider safer alternatives where possible.	Wash exposed skin; for inhalation move to fresh air.	Keep in sealed containers; treat wastes as metal-containing hazardous wastes.
Formaldehyde & donors	Carcinogen; respiratory irritant	Closed systems; ventilation; continuous monitoring where used frequently	Chemical splash goggles, gloves, full-face respirator or cartridge respirator when airborne levels possible	Substitute non-formaldehyde preservatives where feasible; implement exposure monitoring and medical surveillance.	Remove to fresh air, rinse eyes, seek urgent medical care for high exposure.	Store cool, away from heat; label carcinogen; dispose as hazardous.
General finished-paint operations (spray booths)	Inhalation of aerosols, overspray, flammability, slip hazards	Enclosed spray booths with downdraft ventilation, solvent recovery, explosion-proof lighting; regular maintenance	Respirators (spray-rated cartridges or supplied-air), chemical gloves, goggles, hearing protection (machinery), anti-slip footwear	Keep booth inspection records; maintain filters and solvent capture; use grounding and bonding for flammable product transfer.	If exposed to high vapors, move to fresh air; for skin/eye contact follow washing/flush procedures and seek care if needed.	Maintain fire-safety systems; store partially-full containers closed and in flammable cabinet. Waste coatings and washwaters are hazardous — manage accordingly.