Occupational Exposure as a Painter: Understanding Paint Composition and Hazards

Occupational exposure in the painting industry poses significant health risks, including increased susceptibility to lung cancer, mesothelioma, bladder cancer, and potentially childhood leukaemia. Protective measures, including the use of appropriate PPE, are crucial in minimizing these risks.

Painters face substantial risks, not only in direct genetic damage but also in systemic and immunological alterations, emphasizing the critical need for stringent protective measures and continued research to mitigate these adverse effects.

Description of Paint Products

Paints are complex mixtures of various substances designed to provide colour, durability, and protective properties to surfaces. They consist of finely divided pigment particles suspended in a liquid medium composed of binders, volatile solvents or water, and additives. The composition of paints varies based on colour, durability, and specific requirements. Here are the main components of paints and their potential hazards to workers:

Pigments and Fillers

Pigments: These provide colour, opacity, and other physical properties to the paint. Common pigments include titanium dioxide (rutile and anatase forms) for white paint and carbon black for black paint. In the past, azo pigments containing 3,3'-dichlorobenzidine were used, which had low toxicity.

Fillers: Fillers are used to improve the performance of paint layers. Asbestos, once common, has been largely phased out due to health concerns. Special attention is given to hazardous pigments, especially chromate- or lead-based substances, which are being replaced with less toxic alternatives despite lower performance.

Binders (Resins)

Natural Resins and Oils: Historically, natural substances like shellac, rosin, and various plant and fish oils were used as binders.

Synthetic Resins: Modern paints primarily use synthetic resins such as cellulose-based resins, phenolic, alkyd, vinyl, acrylic, and polyurethane resins. These provide film hardness, gloss, adhesion, and resistance to environmental factors.

Solvents

Solvents: Solvents like toluene, xylene, aliphatic compounds, ketones, alcohols, esters, and glycol ethers are used to dissolve other components and improve application. Water-based paints have reduced the need for hazardous solvents.

Additives

Surfactants and Dispersing Additives: These control flow, wetting, and leveling properties. They include various chemicals such as polyurethanes, polyamides, and oleic acid.

Driers (Siccatives): Metal salts like cobalt, calcium, and zinc are used as catalysts in air-drying and heat-cure systems.

Rheological Additives: These influence coating performance during application and storage. Examples include methyl cellulose, polyvinyl alcohol, and polyacrylamides.

Plasticizers: These enhance flexibility and are added in small quantities.

Biocides: Added to prevent microbial contamination, examples include isothiazolinones and chloroacetamide.

Anti-Skinning Agents: Oximes and phenol derivatives prevent skin formation on the paint's surface.

Corrosion Inhibitors: Inorganic and organic inhibitors like zinc, chromium, and phosphates protect against corrosion.

Asbestos: Once used as a filler, asbestos has been phased out due to health risks.

Nanoparticles: Tiny particles improve paint properties; however, they can agglomerate and become part of the polymer matrix during drying.

Note: It's crucial for workers in the painting industry to be aware of these components and follow safety protocols, including using appropriate personal protective equipment and working in well-ventilated areas, to minimize exposure to hazardous substances. Additionally, regulatory guidelines and industry standards should be adhered to, promoting the use of safer, low-toxicity alternatives to protect the health and well-being of workers in the field.

Occupational Exposures in the Painting Industry:

Painting Process Exposure:

Chemicals: Workers are exposed to various chemicals found in paint products during application and removal processes.

Specific Exposures: Dichloromethane during paint stripping, diisocyanate in binders, silica in surface preparation, asbestos, and crystalline silica as bystanders during construction or demolition.

Exposure Routes: Inhalation and skin contact during manual handling, preparation, mixing, thinning, tinting, shading, and cleaning processes.

Types of Exposures:

Solvents: During paint application.

Pigments and Fillers: During mechanical paint removal.

Other Exposures: Emissions of various substances during varnish cooking and production processes.

Protective Measures:

Personal Protective Equipment (PPE): While PPE can reduce exposure, painters often do not wear respirators or gloves.

Nanoparticles: Use of nanoparticles in paint (0.5–5% w/w) improves properties, but exposure to individual nanoparticles is minimal due to agglomeration and incorporation into the polymer matrix.

Health Risks Associated with Painting Occupations:

Cancer Risks:

Lung Cancer: Painters have an increased risk of lung cancer. Cohort and case–control studies consistently show elevated risks, even after adjusting for smoking.

Mesothelioma: Painters also have an increased risk of mesothelioma, further suggesting asbestos exposure.

Urinary Bladder Cancer: There is a consistent increase in the incidence of bladder cancer among painters, supported by both cohort and case–control studies.

Childhood Leukaemia: Maternal Exposure: Positive associations were found between maternal exposure during painting and childhood leukaemia, indicating a potential risk factor. Paternal Exposure: Limited evidence suggests a positive association between paternal exposure and childhood leukaemia.

Lympho-haematopoietic Cancers: Inconsistent results were observed, making it difficult to draw conclusions regarding the association between painting occupations and lymphatic and haematopoietic cancers.

Toxicokinetics and Metabolism of Paint Components

Solvents

(a) Aromatic Hydrocarbons:

Benzene: For detailed toxicokinetics of benzene, please refer to the Monograph on Benzene in this volume.

Toluene: Metabolized to benzyl alcohol and subsequently oxidized to benzoic acids, excreted as conjugates with glycine or UDP-glucuronate.

Xylene: Metabolized to methylbenzyl alcohol, forming methylhippuric acid conjugates with glycine. Limited aromatic hydroxylation to xylenol observed in humans.

(b) Chlorinated Solvents:

Dichloromethane (DCM): Mainly absorbed via inhalation, metabolized by CYP2E1 enzyme. Pathways yield formyl chloride, CO, CO2, and formaldehyde. Elimination occurs mainly through expired air and urine.

Trichloroethylene (TCE): Absorbed primarily through inhalation, widely distributed in liver, kidneys, cardiovascular, and nervous systems. Metabolized through oxidative pathways by various CYP isoenzymes and conjugation with glutathione, leading to the formation of toxic metabolites.

Metals in Paints:

Cadmium:

Absorption: Mainly through inhalation in the workplace; general population exposure through food and water.

Distribution: Binds to metallothionein and is transported to liver and kidneys via blood.

Excretion: Primarily via urine, with a half-life in the body estimated to be 7-16 years.

Chromium:

Absorption: Depends on solubility and particle size; higher for chromium(VI) compounds; occurs in lungs and gastrointestinal tract.

Distribution: Found in all organs, with highest concentrations in kidneys, liver, and bone.

Excretion: Via urine after inhalation and via feces after oral exposure.

Lead Compounds:

Absorption: Through inhalation, oral, or dermal exposure; settled deep in lungs is eventually absorbed; dermal absorption is negligible.

Distribution: Rapidly distributed in the body, especially in bone.

Excretion: Primarily in urine and via bile in feces.

Other Compounds in Paints:

Styrene:

Absorption: Rapid distribution in the body, highest concentrations in adipose tissue.

Metabolism: Converted to styrene-7,8-oxide, excreted as urinary mandelic and phenylglyoxylic acids.

PAHs (Polycyclic Aromatic Hydrocarbons):

Exposure: Occurs through waterproof coatings or pyrolysis of paint residues.

Toxicokinetics: Limited data; generally occur as complex mixtures; specifics vary among different

PAHs.

Aromatic Amines and Azo Dyes:

Toxicokinetics: Described in specific IARC Monograph volumes.

Genetics and Related Effects in Painters

Genetic Effects of Individual Paint Constituents

(a) Benzene

Refer to the dedicated Monograph section on Benzene for detailed information on its genetic effects.

(b) Toluene

Toluene exposure in workers exhibited inconclusive human genotoxicity results due to various limitations in study design and methodology. Nonetheless, some studies reported increases in chromosomal aberrations, micronuclei, and DNA strand-breaks (Chen et al., 2008). In experimental setups, toluene co-exposure with benzene enhanced clastogenic or aneugenic bone-marrow injury in mice, indicating potential synergistic effects (Wetmore et al., 2008).

(c) Xylene

Studies on xylenes displayed negative genotoxic results in various in vitro and in vivo assays. Indirect DNA fragmentation occurred at cytotoxic concentrations, suggesting genotoxicity might be mediated by cell death mechanisms (ATSDR, 2007b).

(d) Dichloromethane

Dichloromethane demonstrated consistent mutagenicity in microorganisms and exhibited various responses in mammalian systems. Dichloromethane-induced genotoxic effects in human cells suggested potential carcinogenic mechanisms, primarily linked to GST-mediated metabolism (IARC, 1999).

(e) Trichloroethylene

Exposure to trichloroethylene (TCE) demonstrated clastogenic effects, with increased micronuclei and DNA single-strand breaks observed in rodents. Although TCE itself might not be genotoxic, its reactive metabolites raised concerns, indicating potential genetic toxicity (ATSDR, 1997).

(f) Cadmium and Chromium

Refer to Monograph Volume 100C for detailed genetic effects of cadmium and chromium.

(g) Inorganic Lead

Lead exposure correlated with DNA strand-breaks, chromosomal aberrations, and micronuclei. The genotoxicity of lead was attributed to disruption of pro-oxidant/antioxidant balance and interference with DNA-repair systems, mediated through oxidative stress pathways (IARC, 2006).

(h) Styrene

Styrene exposure led to DNA adduct formation, particularly in humans. While mice developed lung tumors, the mechanism, potentially involving styrene 7,8-oxide, may not be significant in human lungs. Nevertheless, DNA adducts and chromosomal damage were observed in human workers, suggesting multiple mechanisms might be at play (IARC, 2002).

(i) PAHs

PAHs demonstrated genotoxic effects, primarily attributed to benzo[a]pyrene. Metabolic activation of PAHs led to the formation of DNA adducts, posing significant risks in human exposure scenarios (IARC, 2010d).

(j) Aromatic Amines and Azo Dyes

Refer to Monograph Volume 99 for detailed information on the genotoxic effects of aromatic amines and azo dyes.

Indirect Effects Potentially Related to Genotoxicity

Beyond direct genotoxicity, painters exhibited hematological changes, including altered white blood cell levels, and immunological responses to specific substances, further highlighting the complex and multi-faceted impacts of paint exposure on human health.