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Potentially Toxic elements and Isocyanate content of selected Brands of Paints and Primers Used in Automobile Body Spray Painting within Jos-North, Plateau State, Nigeria

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Abstract

This study aims at determining the concentration of potentially toxic elements and isocyanates in selected paints and primers used in automobile body spray painting. The heavy metal and isocyanate content of both paints and primers were analyzed using Atomic Absorption Spectroscopy (AAS) and Gas Chromatography-Mass Spectrometry methods respectively. The analysis revealed that manganese and chromium concentrations in some paint samples exceeded permissible limits, while lead levels were significantly higher than the European Union's (EU) safety threshold. Conversely, cadmium, mercury, aluminium, copper, iron, nickel, arsenic, and cobalt were within acceptable regulatory limits. In primers, zinc concentrations were found to be above the EU limit, whereas other heavy metals remained below recommended levels. Additionally, all analyzed paint and primer samples contained isocyanate concentrations far exceeding the Occupational Safety and Health Administration (OSHA) exposure limit of 0.02 ppm, posing potential health risks to workers. These findings underscore the need for regulatory oversight, the adoption of safer alternatives, and enhanced protective measures to mitigate health hazards associated with automobile spray painting.

Keywords: Heavy metals, isocyanates, paints, primers, permissible levels, Jos.

Introduction

Paint is a mixture in which finely ground pigment particles are dispersed within a liquid medium. This liquid typically consists of a binder (resin) and a volatile solvent or water and often includes additives that provide specific properties[1]. Automobile paints is an oil-based paint employed by technicians and artisans containing substances such as volatile organic compounds (VOCs) and hydrocarbons, which pose significant toxicological risks to human health. Similarly, paints used for interior and exterior decoration are often dissolved in solvents that may release harmful compounds, capable of producing free radicals and triggering oxidative stress[2]. Exposure to these toxic substances has been linked to a range of health issues, from mild to severe, such as headaches, birth defects, cancer, organ damage, effects on the central nervous system—including memory loss, confusion, and seizures-as well as allergic, neuropsychological, respiratory, and other health impacts[3].

However, toxicity resulting from exposure to heavy metals has been shown to be a major health problem and there are several health risks associated with it. The toxicity depends on the dose absorbed, route of entry and duration of exposure[4]. Heavy metals such as lead, iron, cadmium, chromium, manganese, cobalt amongst others are responsible for certain diseases on man, animals and plant[5]. Heavy metals are well-known environmental pollutants due to their toxicity, persistence in the environment, and bioaccumulative nature[6].

Isocyanates are a highly reactive group of chemicals with low molecular weight. In the UK, they are recognized as a leading cause of occupational asthma and are widely used as key additives in the manufacturing of paints, varnishes, and polyurethane products[7]. Individuals exposed to isocyanates frequently report airway irritation and asthma-like symptoms, including coughing, wheezing, and shortness of breath, in addition to occupational asthma. Other respiratory conditions associated with exposure include rhinitis, hypersensitivity pneumonitis, and an accelerated decline in lung function. Furthermore, diisocyanates can lead to both irritant and allergic contact dermatitis, along with skin and conjunctival irritation[7].

Workers around the world are facing a global health crisis due to occupational exposure to toxic chemicals. Every year, more than one billion workers are exposed to hazardous substances, including pollutants, dusts, vapour and fumes in their working environment. Globally, over 2,780,000 workers die as a result of unsafe work condition and ethics per year[8]. United Nations' report published in 2018, by Baskut, T., the United Nations' special rapporteur on toxics, stated that a worker dies in every 30 seconds as a result of exposure to toxins and in every 15 seconds, a worker dies from dangerous working conditions in general.

However, most oil base paints used on vehicles contain isocyanates as well as some heavy metals such as lead, cadmium, mercury and chromium, despite the availability of other pigments that can be used as their substitutes. Major sources of these heavy metals include paint pigments and additives which have been overlooked in the past.

In most places, particularly in Jos, visit to auto-painting sites has shown that quite a large number of automobile body sprayers do not appreciate the importance of safety equipment and protective clothing. Hence, the workers can easily inhale the chemical constituents of the paints, aerosols and respirable dust particles generated during scraping of the old paint because most of the work areas do not have proper ventilation. The situation worsens where the workers are not aware of the health risk associated with exposure to those chemicals and the toxins it introduces into their work environment. Therefore, this study aims at assessing the levels of some potentially toxic elements and isocyanate contained in selected brands of paints commonly sold in Jos metropolis.

Materials and Methods

Chemicals and Reagents: Conc. hydrochloric acid (HCl), hydrogen peroxide, conc. nitric acid (HNO_3), concentrated sulphuric acid (H_2SO_4), copper sulphate, Boric acid, selenium powder, sodiumhydroxide, ethanol, diethyl ether, bromocresol green and methylated spirit. The chemicalsand reagents used in this study were analytical grade products of May and Baker, England.

Collection of Sample: Five (5) different samples of paints and primers each were acquired from retailers in air-tight plastic sample container at Church Street, Jos-North Local Government Area of Plateau State, Nigeria. The automotive paints were selected based on the frequently used by spray painters as indicated on the questionnaire used to gather information from the workers.

Sample preparation and digestion: Each of the ten (10) sample bottles containing paints and primers was homogenized by stirring the sample thoroughly. Wet digestion of the samples was conducted following a modified procedure based on the method by Demirel, S., et al.[10]. A 10ml of sample was placed in separate 100 ml beakers. Each sample was treated with 25 ml of nitric acid and heated on a hot plate in a fume hood until the liquid evaporated. The resulting residue in each beaker was then mixed with 15 ml of perchloric acid and heated again until no more white fumes were emitted. After cooling to room temperature, the solutions were filtered using double filter paper into 100 ml conical flasks. Each filtrate was diluted to a final volume of 50 ml with deionized water and transferred into clean, labeled 50 ml plastic bottles. The digested samples were subsequently analyzed for total heavy metal concentrations using an atomic absorption spectrophotometer (AAS).

Elemental Analysis: Both the paints and the primers were digested and analyzed for heavy metals using Atomic Absorption spectroscopy (Buck Scientific Inc. Connecticut, USA).

Isocyanate Analysis: The isocyanate was analyzed using Gas Chromatography-Mass Spectroscopy (SCION 8700 SQ GC-MS, UK).

Statistical Analysis: The results were analyzed using one-way ANOVA and mean differences were sorted out based on Turkey-Kramer's Multiple Comparisons Test using Graph Pad InStat Software (2022).

Results and Discussions

Results: The results of some heavy metals and isocyanate contents in both paints and primers are presented in Table-1, 2, 3 and 4.

Table-1: Toxic Heavy Metals Concentration in Selected Brands of Paints Used in Automobile Body Spray Painting.

Metals (ppm)	Paints 1	Paints 2	Paints 3	Paints 4	Paints 5
Manganese	183.21+12.933	104.89+2.107	02.58+0.029	157.20+3.386	176.79+1.610
Cadmium	00.06+0.004	00.02+0.001	00.01+0.001	00.07+0.009	00.01+0.003
Zinc	92.47+0.902	21.67+0.769	69.93+0.418	53.83+1.342	76.41+1.319
Mercury	00.35+0.003	00.53+0.013	00.01+0.000	00.68+0.067	00.19+0.007
Aluminium	11.23+0.263	02.71+0.953	08.74+0.050	07.47+0.033	10.82+0.201
Copper	08.74+0.073	02.10+0.036	06.85+0.012	07.22+0.174	06.90+0.079
Iron	05.97+0.013	01.43+0.001	34.25+0.036	02.66+0.129	05.06+0.046

Nickel	00.10+0.000	00.02+0.003	00.08+0.000	00.13+0.033	00.02+0.003
Arsenic	00.06+0.003	03.66+0.009	00.04+0.000	01.56+0.236	00.34+0.044
Cobalt	00.36+0.009	00.09+0.000	00.28+0.000	00.13+0.033	00.26+0.009
Chromium	10.51+0.188	335.67+0.987	08.18+0.032	168.02+0.553	242.75+4.670
Lead	2868.05+25.33	4860.12+22.14	1082.51+1.98	2775.91+15.834	3105.52+53.328

Values are expressed as mean ± SEM, n = 3.

Table-2: Toxic Heavy Metals Concentration in Selected Brands of Primers Used in Automobile Body Spray Painting.

Metals (ppm)	Primers 1	Primers 2	Primers 3	Primers 4	Primers 5
Manganese	01.75+0.069	15.51+0.345	01.78+0.043	01.44+0.024	01.97+0.007
Cadmium	00.12+0.016	00.18+0.004	00.20+0.007	00.11+0.009	00.15+0.024
Zinc	269.60+14.758	238.23+1.675	270.05+1.855	198.86+2.268	191.76+0.344
Mercury	00.02+0.000	00.14+0.000	0.02+.000	00.01+0.003	00.01+0.000
Aluminium	33.71+1.846	29.80+0.208	33.35+0.439	26.97+1.132	26.92+0.769
Copper	25.96+0.657	23.32+0.047	24.26+0.380	19.17+0.423	20.81+0.158
Iron	17.61+0.152	15.95+0.010	16.32+0.715	13.99+0.485	13.94+1.106
Nickel	00.30+0.012	00.27+0.003	00.32+0.018	00.19+0.012	00.15+0.009
Arsenic	00.17+0.010	00.15+0.000	00.15+0.010	00.14+0.013	00.11+0.003
Cobalt	01.09+0.045	00.97+0.006	01.26+0.256	00.87+0.045	00.67+0.031
Chromium	31.39+1.359	27.96+0.142	30.17+1.060	24.91+0.751	23.18+0.342
Lead	81.64+2.121	73.33+0.157	80.29+0.166	62.06+1.214	55.75+1.122

Values are expressed as mean ± SEM, n = 3.

Table-3: Isocyanate Content of Selected Brands of Paints Used in Automobile Body Spray Painting.

Samples	Isocyanate (ppm)
Paints 1	288.79+1.868
Paints 2	404.30+1.512
Paints 3	33.69+0.791
Paints 4	22.46+0.125
Paints 5	128.35+0.384

Values are expressed as mean ± SEM, n = 3. PT=.

Table-4: Isocyanate Content of Selected Brands of Primers Used in Automobile Body Spray Painting.

Samples	Isocyanate (ppm)
PM1	33.12+0.486
PM2	52.00+0.109
PM3	38.25+0.195
PM4	47.81+0.402
PM5	35.72+0.224

Values are expressed as mean ± SEM, n = 3. PM=Primers.

Discussion: This study aims at determining the concentration of some potentially toxic elements and isocyanate in selected paints and primers utilized in automobile body spray painting.

Table-1 shows the concentration of heavy metals in selected brands of paints used in automobile body spray painting. Manganese concentration (183.21-02.58 ppm) were found to be above the recommended permissible limits of 90 ppm of the United State Consumer Product Safety Commission in four paint samples (PT1, PT2, PT3 and PT4), except PT2. This finding is in concordance with the study of Laura, F. L. et al.[11], who reported that the sample of paints analyzed contained manganese in concentration above the recommended limits. Cadmium (00.07-00.01ppm) and zinc (92.47-21.67 ppm) were observed in this study to be lower than the recommended permissible limits of 90 ppm of the United State Consumer Product Safety Commission with the exception of zinc which shows higher concentration in PT1. However, these results agree with the findings of Nduka, J. K. et al.[12], but disputes the report by Latif, M. T. et al.[13], who observed lower concentration of zinc. This variation in result could be attributed to difference in brand of paints analyzed. The concentration of both mercury (00.01-00.68 ppm) and aluminium (11.23-02.71 ppm) have been observed to be lowerthan the recommended permissible limits of 90 ppm of the United State Consumer Product Safety Commission. In the present study, copper (08.74-02.10 ppm) and iron (05.97-01.43 ppm) were seen to be below the 100 ppm limit of the European Union (EU). This outcome is in accord with the report of Kevin, O. O. etv al.[14], who reported lower iron level too. The nickel (00.17-00.02 ppm), arsenic (00.17-00.11 ppm) and Cobalt (00.36-00.09 ppm) were found to fall below the 100 ppm limit of the European Union (EU). These results are not in conformity with the findings of Jahan, Z.[15], which reported higher nickel and cobalt concentrations. Chromium (335.67-08.18 ppm) was observed to be above the 100 ppm limit of the European Union in three samples (P2, P4 and P5) and this outcome is in conformity with the report of Afolayan, G. O. et al.[16], while two samples (P1 and P3) were reported to be lower in concentration of chromium which disagree with the findings of Afolayan, G. O. et al.[16]. Lead (4860.12-1082.51ppm) concentration has been found to be abovethe 100ppm limit of the European Union (EU), and this finding is in concordance with the report of Mustapha, A. M. et al.[17].

Table-2 shows the concentration of heavy metals in selected brands of primers used in automobile body spray painting. Manganese concentration (15.51-01.44 ppm) and cadmium (00.18-00.11 ppm) were both found to fall below the recommended permissible limits of 90 ppm of the United State Consumer Product Safety Commission. This conforms tothe findings of Nduka, J. K. et al.[12], which also reported lower levels of the elements. Zinc concentration (270.05-191.76 ppm) has been found to be higher than the 100 ppm limit of the European Union (EU), and this finding is in concordance with the report of Mustapha, A. M. et al.[17]. Mercury (00.14-00.01 ppm) has been observed to fall below the 100 ppm limit of the European Union (EU). This is not in agreement with the report of Howard, M., et al.[18], which showed higher mercury level. Aluminium (33.71-26.92 ppm), copper (25.96-19.17 ppm), iron (17.61-13.94 ppm), nickel (00.32-00.15 ppm) and arsenic (00.17-00.11 ppm) were observed to be lower than therecommended permissible limits of 90 ppm of the United State Consumer Product Safety Commission. This is in concordance with the findings of Kevin, O. O. et al.[14]. The concentration of cobalt (01.26-00.67 ppm), chromium (31.39-23.18 ppm) and lead (81.64-55.75 ppm) were found to fall below the recommended permissible limits of 90 ppm of the United State Consumer Product Safety Commission. These results agree with the report of Afolayan, G. O. et al.[16].

Table-3 shows the isocyanate content of selected brands of paints used in automobile body spray painting.The isocyanate concentration of all the paint samples, PT1 (288.79 ppm), PT2 (404.30 ppm), PT3 (33.69 ppm), PT4 (22.46 ppm) and PT5 (128.35 ppm) have been observed to be above the 0.02 ppm exposure limit of Occupational Safety and Health Administration (OSHA). This finding is in concordance with the report of Walter, E. R.[19], which also reported higher isocyanate content in spray paint.

Table-4 shows the isocyanate content of selected brands of primers used in automobile body spray painting. The isocyanate concentration of all the primer samples, PM1 (33.12 ppm), PM2 (52.00 ppm), PM3 (38.25 ppm), PM4 (47.81 ppm) and PM5 (35.72 ppm) have been reported to be above the 0.02 ppm exposure limit of Occupational Safety and Health Administration (OSHA). The present study agrees with the findings of Anjoeka, P. et al.[20], whose report showed an elevated isocyanate content.

Conclusion

In this study, the results highlight the presence of potentially toxic elements and isocyanates in selected paints and primers that workers use in automobile spray painting. While some heavy metals such as manganese and chromium, were found to

exceed permissible limits in certain paint samples, others, including cadmium, mercury and iron, remained within acceptable thresholds. Notably, lead concentrations were seen to be significantly above the recommended limits, raising concerns about potential adverse health effects. Similarly, in primers, zinc levels were observed to have exceeded the permissible limit, whereas most other heavy metals were within regulatory standards.

However, the isocyanate content of all tested paints and primers was observed to be substantially higher than the Occupational Safety and Health Administration (OSHA) exposure limit, clearly indicating potential risks for workers exposed to these materials. Given the toxicological implications of long term exposure to these hazardous chemicals, regulatory oversight and safer alternatives should be put in place. Protective and precautionary measures, including proper ventilation, use of personal protective devices and adoption of low-toxicity formulations, are recommended to minimize health risks associated with automobile body spray painting.

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