Journal of Environmental Sciences

JOESE 5

Related health hazards with occupational exposure to cadmium and lead during spray painting in car and furniture workshops

Abeer E. Abdrabouh[1]; Ahmed E. Hagras[1]; Nesreen M. Essam[1] and Maie I. El-Gammal[2]

[1]Zoology Department, Faculty of Science, Mansoura University, Egypt

[2] Environmental Sciences Department, Faculty of Science, Damietta University, Damietta, Egypt

Reprint

Volume 52, Number 3: 1-8

(2023)

http://Joese.mans.edu.eg

P-ISSN 1110-192X

e-ISSN 2090-9233

Journal of Environmental Sciences

JOESE 5

ISSN 2090-9233

Journal homepage http://joese.journals.ekb.eg

Original Article

Related health hazards with occupational exposure to cadmium and lead during spray painting in car and furniture workshops

Abeer E. Abdrabouh[1]; Ahmed E. Hagras[1]; Nesreen M. Essam[1], Maie I. El-Gammal[2]

[1]Zoology Department, Faculty of Science, Mansoura University, Egypt

[2] Environmental Sciences Department, Faculty of Science, Damietta University, Damietta, Egypt

Article Info

Article history:

Received 19/ 7 /2023

Received in revised form 05/08/2023.

Accepted 09/08/2023

Keywords: *Spray painting, Hematological parameters, Liver, Kidney, Acetylcholinesterase.*

Abstract

Spray painting workers in car and furniture workshops are occupationally exposed to intense painting vapors. The main objective of this study is to evaluate health risk resulting from exposure to paintings spray, especially related to the included cadmium (Cd) and lead (Pb) metals. The studied groups (15-60) years old, were all non-smoker males; 20 workers selected from 6 car painting workshops, 30 from 6 furniture painting workshops and 20 healthy subjects away from exposure to paintings or other chemicals represented control group. Results showed significantly increased levels of Cd and Pb in serum and urine of car and furniture painters compared to control subjects, where metals concentration in car workers were more than in furniture ones. Results showed significant decrease in hemoglobin content, red blood cells and platelets count, along with significant increase in total leucocytes count in car and furniture painters compared to unexposed subjects. In parallel, disturbed liver and kidney functions represented by significant reduction in serum total protein and albumin contents were observed, along with remarkable elevation in aspartate aminotransferase, alanine aminotransferase, creatinine and uric acid. These results were accompanied by significant increase in urine total protein and albumin contents, as well as creatinine in exposed groups compared to control subjects. However, serum acetylcholinesterase levels decreased significantly in both car and furniture painters compared to control subjects. So, car and furniture painters are in potential risk lying through working environment, which requires attention, mitigations, and management to protect their health.

1. Introduction

Environmental contamination by heavy metals is a worldwide problem that associated with several ecological and health risks (Yuningtyaswari and Dwi, 2016; Vattanasit et al., 2021). People in artisanal activities are readily exposed to several compounds from various sources, including paints (Wang *et al.*, 2020).

Paint is a mixture of organic and inorganic compounds. However, inorganic pigments, including heavy metals, as cadmium (Cd) and lead (Pb) are integral parts of these components that give bright color, allow to spread and provide the adhesion to the painted surface (Tchounwou *et al.*, 2014; Careddu and Akkoyun, 2016). While paints are sprayed, these metals could be dispersed and suspended in the air, then easily inhaled by painters (Khan *et al.*, 2021).

In different paints, yellow, red and orange pigment colors are related to cadmium. However, these pigments are toxic, and may cause skin irritation (Bernhof, 2013). Cadmium effects on health are countless, varying from kidney damage, bone effects and many types of cancer. It was classified by the International Agency for Research on Cancer (IARC), as a human carcinogen (IARC,1993). However, the first observed chronic effect of cadmium is kidney damage manifested by excretion of excessive low molecular weight protein in the urine (Bernhof, 2013; Vattanasit et al., 2021). High levels of cadmium exposure by inhalation can cause death in human or animals (Gupta, 2013; Genchi et al., 2020).

Furthermore, lead is one of the most widely toxic metals in the environment. The world health organization (WHO) accounted for nearly a half million death and above 9 million are disable persons were recorded, especially in low- and middle-income developing countries (Vergara-Murillo et al., 2022). Pb is widely used in various paints because of its anticorrosive properties and its

ability to hold pigments together (Flora *et al.*, 2012). Occupational exposure to Pb causes toxic effects on almost all major systems in the body, including hematological, hepatobiliary, renal and cardiovascular systems, producing serious disorders, including anemia (Mazumdar and Goswami, 2016; O'Connor et al.,2018). In addition, heavy metals are reported to be antagonistic to the body elements, where they can inhibit and compete with proteins and enzymes for binding sites and also can impair the immune system (Nduka et al.,2019).

Acetylcholinesterase (AChE) is an enzyme of brain cholinergic system which hydrolyses the acetylcholine neurotransmitter to choline and acetate in the synaptic fissure. Elevated evidence has shown that reduced activity of AChE is an indication of several brain disorders, such as neurodegenerative disorders (Paul and Borah, 2017). Previous reports indicated that exposure to heavy metals showed adverse effects on acetylcholinesterase (AChE) enzyme activity (Carageorgiou *et al.*, 2004 and Richetti *et al.*, 2011). Mogwasi et al.,(2023) study also showed that even exposure to low levels of Cd and Pb can be responsible for behavioral abnormalities and cognitive deficit related with acetylcholinesterase (AChE) dysfunction. Therefore, measurement of AChE activity, as a human biomonitoring test is a precious tool in estimation of toxicants exposure (Knudsen and Hansen, 2007; Gupta *et al*.,2016).

In general, toxicity of metals was reported to come through bioaccumulation in certain tissues, which in turn, may cause damage to blood composition, liver, kidney and other vital organs (Gupta *et al*.,2016).

Therefore, thousands of occupationally exposed workers are routinely exposed to those hazardous, especially in the developing countries. Thus, the main objectives of this study is to evaluate blood and urine Cd, Pb concentrations, as well as the impacts of occupational exposure to these metals in spray paintings through hematological parameters, as well as liver and kidney functions, and comparing them with unexposed healthy group with shedding light on their relation to acetylcholinesterase activity..

2. Materials and Methods

2.1. Design and technical details

This study was carried on (6) car and (6) furniture painting workshops, where car workshops were conducted at Mansoura city, Egypt, while furniture workshops were located at Damietta city, Egypt. Workers in all workshops have never been used any type of protection equipment. The study was approved by the human research ethics committee of Mansoura University according to protocol number Sci-Z-P-2023-127.

2.2. Population characteristics

The study was performed on 70 non-smoking male individuals; 20 healthy unexposed subjects (controls); 20 workers selected from car painting workshops and 30 furniture painting workers. The age of studied volunteers ranged from 15 to 60 years, taken in consideration that the workers should be occupationally exposed to paints at least for 3 years.

2.3. Samples collection

Approximately, 4 ml of blood sample was drawn from each human subject. Only few droplets of blood were added to tubes with ethylenediaminetetraacetic acid (EDTA) that used for hematological analysis. Other samples of blood were collected in centrifuge tubes, where the sera were separated from coagulated blood by centrifugation at 1500 rpm for 10 min, then quickly frozen at -20^{o}C for subsequent biochemical analysis.

Similarly, urine samples were collected during the workday, centrifuged and aliquots were frozen at -20^{o}C till analysis.

2.4. Determination of serum and urine Cd&Pb concentrations

Cadmium (Cd) and lead (Pb) concentrations were estimated in serum and urine samples using Buck Scientific Accusys 211 atomic absorption spectrophotometer (AA500F) according to Asagba and Eriyamremu (2007).

2.5. Hematological parameters

Blood samples were measured using hematological analyzer (Sysmex XE-2100, Corp. Kobe, Japan) (Dacie and Lewis, 2001) for detecting red blood cells (RBCs) count, hemoglobin (Hb) content, and platelets (PLts) count, as well as total count of white blood cells (WBCs).

2.6. Liver function estimated parameters

Serum and urine total protein (TP) and albumin (Alb) contents were detected according to enclosed methods in kits of Spectrum Diagnostics Company, Egypt. However, serum levels of alanine aminotransferase (ALT), aspartate aminotransferase (AST) and total bilirubin (TB) were estimated according to Spinreact Kit, Ctra Santa Coloma, Spain.

2.7. Kidney function estimated parameters

Creatinine levels were assessed in both serum and urine samples of different volunteers, in addition to serum uric acid using the methods enclosed in kits of Spectrum Diagnostics Company, Egypt.

2.8. Determination of serum acetylcholinesterase (AChE) enzyme

Acetylcholinesterase enzyme is estimated in serum according to a colorimetric method of Biodiagnostic Kit, Co., Giza, Egypt.

2.9. Statistical analyses

The results were expressed as mean ± the standard error (SE). Differences between groups were assessed by one way analysis of variance (ANOVA) using the SPSS (version 13) software package for windows. Post-Hoc testing was performed for intergroup comparisons using Duncan's multiple range tests. The significance of differences among groups were based on the probability (P) ≤ 0.05.

3. Results and discussion

Exposure to different types of paintings is known by several health hazards, such as hematological, respiratory, renal, hepatic, as well as neurological

diseases related to different constituents, as volatile organic compounds and heavy metals (Abdel Maksoud *et al*.,2018). The present study focused on estimation of heavy metals (Cd and Pb) in serum and urine samples of volunteers and their correlation with health impacts. Results showed that occupational exposure to spray paintings in car and furniture workshops could participate in significant elevation of Cd and Pb concentrations in both serum and urine samples obtained from car and furniture painters compared to control subjects. Serum Cd increased by 281.56%, 153.07% and urine by 670% , 320% for car and furniture painters, respectively. However, serum Pb increased by 279.33%, 143.33% and urine by 403%, 315.38%, respectively, when compared with control subjects (Table 1).

Table (1): Serum and urine concentrations of Cd and Pb (µg/L) in painters of car and furniture painters compared to control group.

Serum &urine levels of Cd & Pb		Groups		
		Control	Car painters	Furniture painters
Cd (µg/L)	Serum	1.79±0.12	6.83 ^{a}±0.20	4.53 ^{ab}±0.20
	% of significant change	-	281.56%	153.07%
	Urine	0.10±0.01	0.77 ^{a} ±0.02	0.42 ^{ab}±0.02
	% of significant change	-	670%	320%
Pb (µg/L)	Serum	3.00±0.23	11.38^{a}±0.34	7.30^{ab}±0.21
	% of significant change	-	279.33%	143.33%
	Urine	0.52±0.02	2.62^{a}±0.16	2.16^{ab}±0.08
	% of significant change	-	403.85%	315.38%

Results are expressed as mean± SE. a: significant change on comparing different groups with control group ($p \leq 0.05$). b: significant change on comparing furniture painters group with car painters group ($p \leq 0.05$). % of significant change:|(mean of exposed painters-control unexposed)/control unexposed] x100.

The high occurrence of these metals is because they represented an integral part of components in several paints, where pigments containing Cd are characterized by red, orange and yellow bright colors (Flora et al.,2012). Additionally, Pb has anticorrosive properties, help in fast drying and increase durability with fresh appearance. El-Gammal and Niazy (2000) attributed diversity of elevation in Cd and Pb concentrations in serum and urine samples to the variation of the work environment that differ in premises and shop size, work practices, workload and chemical structure, type and toxicity of solvents, as well as duration, amount and route of exposure, which is regrettably cannot be detected due to technical limitations.

By categorizing duration of exposure in exposed painters, either car or furniture workers, Figure 1(a,b) illustrated that Cd and Pb concentrations were positively correlated with duration of exposure at car workshop painters. Although, in furniture workshop painters, Cd concentration showed no correlation with duration of exposure, but Pb concentration was positively correlated (Figure 1 c,d).

The increase of these metals in blood was explained by O'Connor et al.(2018); Vergara-Murillo et al. (2022) where Cd and/or Pb inter the body through inhalation can path through the circulation and incorporated into bones. However, this process was suggested to be reversible after causing bone damage, where metals can be released back from bone into the blood.

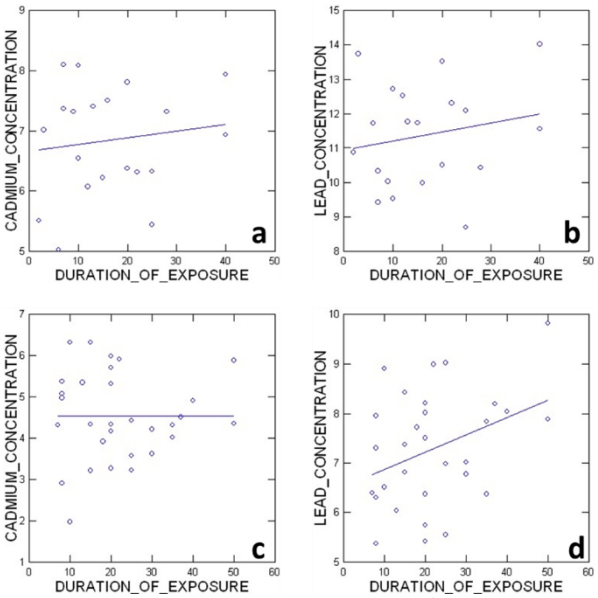

Figure 1: (a,b) Correlation between duration of exposure (years) and Cd&Pb concentrations in serum car workers, (c,d) Correlation between duration of exposure (years) and Cd & Pb concentrations in serum furniture workers.

In this regard, the present study showed remarkable decrease in RBCs count (-17.93%, -15.34%), Hb content (-14.91%, -8.87%) and PLts count (-16.85%, -13.15%), as well as significant increase in total count of WBCs (16.85%, 4.89%) in exposed car and furniture painters, respectively compared to control subjects (Table 2).

Table (2): Hematological parameters of car and furniture painters compared to control group.

Group / Parameter	Control	Car painters	Furniture painters
RBCs (10^{6}/ µL)	5.02± 0.07	4.12^{a}±0.05 -17.93%	4.25^{ab}±0.05 -15.34%
Hb (g/dl)	13.08±0.09	11.13^{a}±0.14 -14.91%	11.92^{ab}±0.08 -8.87%
Platelet (10^{3}/µL)	205.50±3.34	170.95^{a}±3.95 -16.81%	178.47^{ab}±1.82 -13.15%
WBCs (10^{3}/ µL)	5.52±0.10	6.45^{a}±0.31 16.85%	5.79^{ab}±0.12 4.89%

Results are expressed as mean± SE. a: significant change on comparing different groups with control group (p≤0.05). b: significant change on comparing furniture painters group with

car painters group (p≤ 0.05). % of significant change:[(mean of exposed painters-control unexposed)/control unexposed] x100.

Mazumdar and Goswami (2016) recorded the same results with workers of enamel paint industry, where their explanation depended on Pb that interferes with blood hemolysis through inhibiting certain enzymes and binding to channels and regulatory proteins. As a result, anemia could be developed through direct inhibition of the uptake and storage of iron by the body. However, Rahman and Siddiqui (2006) attributed the significantly increased levels of total count of WBCs to enhancement of leukocytosis and antibody production as a protective mechanism against exposure to xenobiotics, where WBCs are the first line of defense in the body. This may give an indication of various health problems, such as blood disorders, bone marrow and inflammatory diseases (Ibrahim *et al*.,2012; Abdel Maksoud *et al*.,2018).

Table (3): Serum biochemical parameters of painters in car and furniture workshops compared to control group.

Group / Parameter	Control	Car painters	Furniture painters
TP (mg/dl)	7.14±0.08	6.27[a]±0.12 -12.18%	6.40[a]±0.08 -10.36%
Alb (mg/dl)	5.03±0.03	4.16[a]±0.12 -17.3%	4.38[a]±0.06 -12.92%
AST (u/l)	28.90±1.08	50.05[a]±2.74 73.18%	40.93[ab]±1.63 41.63%
ALT (u/l)	26.55±1.03	45.30[a]±2.58 70.62%	35.40[ab]±1.72 33.33%
TB (mg/dl)	0.72±0.03	1.05[a]±0.05 45.83%	0.92[a]±0.03 27.78%
Creatinine (mg/dl)	0.85±0.02	1.20[a]±0.05 41.18%	1.01[a]±0.03 18.82%
Uric acid (mg/dl)	4.58±0.10	5.63[a]±0.18 23.93%	5.01[a]±0.10 9.39%
AChE (U/L)	7694.70±81.20	5783.65[a]±114.91 -24.84%	6497.57[ab]±76.58 -15.56%

Results are expressed as mean± SE. a: significant change on comparing different groups with control group (p≤0.05). b: significant change on comparing furniture painters group with car painters group (p≤ 0.05). % :significant change=[(mean of exposed painters-control unexposed)/control unexposed] x100.

Furthermore, the present study showed disturbed liver and kidney function in exposed workers compared to control subjects. This was represented by decreased serum total protein (-12.18%, -10.36%) and albumin (-17.30%, -12.92%) contents, along with significant increased levels of serum AST (73.18%, 41.63%), ALT (70.62%, 33.33%), TB (45.83%, 27.78%), creatinine (41,18%, 18.82%), and uric acid (23.93%, 9.39%) in car and furniture workers, respectively compared to control subjects (Table 3). These results were accompanied by significantly elevated urine total protein (240%, 200%) and albumin (400%, 300%) contents, as well as increased creatinine levels (453.67%, 134.41%), respectively compared to control subjects (Table 4). Several studies attributed reduction of serum protein and albumin contents to combination of metal ions with sulfhydryl groups of protein molecules inducing conformational changes in proteins related to the resulted thiol esters that are quite unstable and usually hydrolyzed (Chan *et al*.,2006; Nisha *et al*.,2009). Accordingly, frequent exposure to paint constituents either metals or organic solvents was reported by several authors to induce hepatocellular damage (Khan *et al*.,2010; Malaguarnera *et al*.,2012; Arora *et al*.,2016). Authors revealed that these chemicals could release free radicals that attack cell membrane integrity, increasing permeability leading to leak out of AST, ALT and TB into blood stream. However, Guyton and Hall (2006) added that elevation of TB could be attributed to the increased degeneration of hemoglobin. Moreover, the significantly increased serum and urine uric acid levels with painting exposure in both car and furniture painters is an indication of hyperuricemia. Baki *et al*.(2016) observed the same results with adult males aged (20-50) years who occupationally exposed to Pb for at least one year through employment in the following jobs; petrol attendants and refinery, battery factory, car radiatair repair, as well as paint pigments and corrosion pipe filters. Mohamed *et al*., (2003) explained this elevation may result from increased catabolism of tissue proteins, that could be considered as good indication of damaged kidney due to larger perfusion and increased concentrations of excreted compounds occurred in renal tubular cells. This was also in harmony with results of Chuhitha *et al*.(2014) in serum and urine samples of spray painting workers compared to control subjects. Batuman (2014) confirmed these foundations by taking renal biopsies from patients industrially exposed to lead. The author found interstitial nephritis and nephrosclerosis, suggesting a relation between elevated urate levels and nephropathy. This support that serum uric acid is a reliable biomarker of heavy metal exposure (Kute *et al*.,2013). In parallel, the increased creatinine levels either in serum or urine along with increased urine proteins are certainly refer to disturbance in kidney function, as mentioned by Arora et al.(2016).

Table (4): Urine biochemical parameters of painters in car and furniture workshops compared to control group.

Group / Parameter	Control	Car painters	Furniture painters
TP (g/dl)	0.05 ±0.01	0.17 [a]±0.02 240%	0.15 [a]±0.01 200%
Alb (g/dl)	0.001 ±0.0002	0.005 [a]±0.0005 400%	0.004 [a]±0.0005 300%
Creatinine (mg/dl)	0.93 ±0.04	5.15 [a]±0.24 453.76%	2.18 [ab]±0.14 134.41%

Results are expressed as mean± SE. a: significant change on comparing different groups with control group (p≤0.05). b: significant change on comparing furniture painters group with car painters group (p≤ 0.05). %

:significant change=[(mean of exposed painters-control unexposed)/control unexposed] x100.

On the other hand, the inhaled airborne metal particles, beside other constituents could reach the brain and accumulate, then impairing its function through crossing blood brain barrier, promoting oxidative stress and inhibiting AChE activity in a neurodegenerative process (Phyu and Tangpong, 2014). This was clearly observed here in significantly decreased values of serum AChE activity (-24.84% and-15.56%) in both car and furniture painters, respectively compared to control subjects (Table 3). These results agreed with Richetti *et al*.(2011) who observed the same decrease with in vitro experiment of high Pb levels. Also, Carageorgion *et al*.(2004) found remarkable inhibition of AChE activity with short term exposure to Cd that cause oxidative stress in rats.

On comparing between car and furniture painters, car painters showed more adverse effects than furniture ones. This may be due to car paintings contain higher levels of metal (Cd and Pb) constituents than furniture (Vitayavirasuk *et al*.,2005). In addition, car painters may expose to painting sprays for longer periods (Vaghasia *et al*.,2013).

Conclusion and recommendations

Data revealed that occupational exposure to paintings spray induce several health hazards related to blood components, as well as liver, kidney and brain functions. So, we recommended the followings:

• Air purifying respirator or particular filter cartridges should be used. Use of personal protective equipment, direct skin contact should be prevented by gloves, wearing respiratory protection and face shields for reducing the concentration of spray components.

• Educational awareness programs for workers should be instituted about hazard of exposure to paints and information on safe handling practices.

• Closed-System operations should be used on large scales in painting, where workers should be isolated from direct contact with the painting operations.

Acknowledgements

Authors are grateful to all volunteers either workers or control subjects to achieve this work.

4. References

A Abdel maksoud, N.; Abdel Aal, K.;Ghandour, N.; EL-baz , M. and Shaltout,E. (2018). Assessment of hematotoxicity and genotoxicity among paint workers in Assiut Governorate: a case control study. Egypt. *J. Foren.Sci*.,8(6):1-11.

Arora, S., Tripathi, Y., Malhotra, V., Singh, K. and Gupta, S. (2016). Evaluation of renal and liver functions tests in car paint sprayers. *Int. J. Life. Sci. Scien. Res*., 2(6): 682-691.

Asagba, S. O. and Eriyamremu, G. E. (2007). Oral cadmium exposure alters haematological and liver function parameters of rats fed a Nigerian-like diet. *J. Nutr. Environ. Med*., 16(3-4): 267-274.

Baki, A.E., Ekiz,T., Özturk,G.T., Tutkun,E., Yilmaz,H., Yildizgoreni, M.T. (2016). The Effects of Lead Exposure on Serum Uric Acid and Hyperuricemia in Young Adult Workers: A Cross-sectional Controlled Study. *Arch. Rheumatol*., 31(1):71-75.

Batuman, V. (2014). The Persistence of Chronic Lead Nephropathy. *Am. J. Kidney Dis*., 64(1):1-3.

Bernhof R. A. (2013). Cadmium toxicity and treatment. *Scientific World J.*, Article ID 394652, p.7.

Carageorgiou, H., Tzotzes, V., Pantos, C., Mourouzis,C., Zarros,A. and Tsakiris, S. (2004). In vivo and in vitro effects of cadmium on adult rat brain total antioxidant status, acetylcholinesterase, (Na^+,K^+)-ATPase and Mg^{2+}-ATPase activities: Protection by L-cysteine. *Basic Clin. Pharmacol. Toxicol.*, 94(3): 112-118.

Careddu, N. and Akkoyun, O. (2016). An investigation on the efficiency of water-jet technology for graffiti cleaning. *J. Cult. Herit*., 19: 426-434.

Chan, W. H., Shiao, N. H. and Lu, P. Z. (2006). CdSe quantum dots induce apoptosis in human neuroblastoma cells via mitochondrial dependent pathways and inhibition of survival signals. *Toxicol. Lett*., 167: 191-200.

Chuhitha, S., Kumar, R. V., Mohan, C. V., Madhavi, K. and Rao, P.P. (2014). The study of hepato-renal profile associated with lead toxicity in spray painters. *J. Evol. Med. Dent. Sci*., 3(31): 8697-8703.

Dacie, J.V. and Lewis, S.M. (2001). *Practical Haematology*, 9th edition. Churchill Livingstone, London, PP.633.

El-Gammal, M. I. and Niazy, A. S. (2000). A study of health hazards on painters in spray painting furniture workshops in Damietta city, Egypt. *J. Environ. Sci*., 20: 107-124.

Flora, G., Gupta, D. and Tiwari, A. (2012). Toxicity of lead: A review with recent updates. *Interdiscip. Toxicol.*, 5(2): 47-58.

Genchi G., Sinicropi M.S. , Lauria G., Carocci A., and Catalano A. (2020). The Effects of Cadmium Toxicity. *Int. J. Environ. Res. Public Health* 17: 3782. doi:10.3390/ijerph17113782

Gupta, V. (2013). Mammalian feces as bio-indicator of heavy metal contamination in bikaner zoological garden, Rajasthan, India. *Res. J. Anim. Veterin. Fishery Sci*., 1(5): 10-15.

Gupta, G., Yograj, S., Gupta, A. K., Langer, B. and Goni, M. (2016). Forced vital capacity,

forced expiratory volume in 1st second and forced expiratory ratio in automobile spray paint workers. *Int. J. Res. Medical Sci*., 4(9): 3724-3728.

Guyton, A. C. and Hall, J. E. (2006). Text Book of Medical Physiology. *Published by Elseveir*, a division of Reed Elsevier India Private Ltd, pp. 859.

Ibrahim, K. S., Amer, N. M., El-Dossuky, E. A., Emara, A. M., Elfattah, A. E. and Shahy, E. M. (2012). Haematological effect of benzene exposure with emphasis on muconic acid as a biomarker in exposed workers. *Toxicol. Ind. Health*, 28(10): 467-474.

International Agency for Research on Cancer (IARC) (1993). Beryllium, cadmium, mercury, and exposes in the glass manufacturing industry. IARC Monographs on the evaluation of carcinogenic risks to humans. *Lyon*., 58: 119–237.

Khan, A. A., Inam, S., Idrees, M., Dad, A., Gul, K. and Akbar, H. (2010). Effect of automobile workshop on the health status of automechanics in N. W. F. P., Pakistan. *Afr. J. Environ. Sci. Technol.*, 4(4): 192-200.

Khan, M.R., Ahmad, N., Ouladsmane, M., Azam, M. (2021). Heavy metals in acrylic color paints intended for the school children use: A potential threat to the children of early age. *Molecules*, *26*, 2375. https://doi.org/10.3390/molecules 26082375.

Knudsen, L. E. and Hansen, A. M. (2007). Biomarkers of intermediate endpoints in environmental and occupational health. *Int. J. Hyg. Environ. Health*, 210(3-4): 461-470.

Kute V.B., Shrimali J.D., Balwani M.R., Godhani U.R., Vanikar A.V., Shah P.R., Gumber M.R., Patel H.V., and Trivedi H.L. (2013). Lead nephropathy due to Sindoor in India. *Ren. Fail.,Jul*, 35(6):885-887.

Malaguarnera, G., Cataudella, E., Giordano, M., Nunnari, G., Chisari, G. and Malaguarnera, M. (2012). Toxic hepatitis in occupational exposure to solvents. *World J. Gastroenterol*., 18(22): 2756-2766.

Mazumdar, I. and Goswami, K. (2016). Correlation between blood lead levels and anaemia in commercial enamel paint industry workers. *J. Krishna Instit. Med. Sci. Univ.*, 5(3): 2231-4261.

Mogwasi, R., Olale, K., Osunga, S. and Kenanda, E. O. (2023). Assessment of bio-accessibility of heavy metals (Cd, Pb, and As) through consumption of medicinal plants collected from different regions in Nyamira-Kenya. *Diagn. Ther.* , 2(1): DOI: https://doi.org/10.55976/dt.22023113516-33.

Mohamed, M., Abdellatif, M. D., Sabar, A. and Elglammal, M. D. (2003). Sodium fluoride ion and renal function after prolonged sevoflurane or isoflurane anaesthesia. *Eng. J. Anaesth*., 19: 79-83.

Nduka, J.K., Kelle H. I., and Amuka J.O. (2019). Health risk assessment of cadmium, chromium and nickel from car paint dust from used automobiles at auto-panel workshops in Nigeria. *Toxicol. Rep*., 6: 449-456.

Nisha, A. R., Nair, A. M., Gopakumar, N. and Joy, A. D. (2009). Assessment of cadmium concentration and its relation with serum biochemical parameters in cattle in cadmium industrial effluent contaminated area. *Ind. J. Anim. Res*., 43 (3): 206-208.

O'Connora D., Houa D. Yeb J., Zhangc Y., Okd Y.S., et al. (2018). Lead-based paint remains a major public health concern: A critical review of global production, trade, use, exposure, health risk, and implications. *Environ. Intern.* 85–101.

Paul, R. and Borah, A. (2017). Global loss of acetylcholinesterase activity with mitochondrial complexes inhibition and inflammation in brain of hypercholesterolemic mice. *Sci. Rep*. 7:17922 DOI:10.1038/s41598-017-17911-z.

Phyu M. P. and Tangpong, J. (2014). Sensitivity of acetylcholinestrase to environmental pollutants. *J. Health Res*., 28(4): 277-283.

Rahman, M. F. and Siddiqui, M. K. (2006). Hematological and clinical chemistry changes induced by subchronic dosing of a novel phosphorothionate (RPR-V) in wistar male and female rats. *Drug Chemi. Toxicol*., 29(1): 95-110.

Richetti, S. K., Rosemberg, D. B., Ventura-lima, J., Monserrat, J.M., Bogo, M. R. and Bonan, C. D. (2011). Acetylcholinesterase activity and antioxidant capacity of zebrafish brain is altered by heavy metal exposure. *Neuro Toxicol*., 32(1): 116-122.

Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K. and Sutton, D. J. (2014). Heavy metals toxicity and the environment. *NIH Public Access*., 101: 133-164.

Vaghasia K. K., Desai, K. R., George, L. B. and Highland, H. N. (2013). Evidence of oxidative stress, biochemical and histological alterations in kidney and liver on short term inhalation of a specific

mixture of organic solvents. *Int. J. Pharm. Sci. Health Care*, 6(3):113-130.

Vattanasit, U., Sukchana, J., Kongsanit, S., Dumtip, P. , Sirimano, V. , and Kongpran, J. (2021). Toluene and Heavy Metals in Small Automotive Refinishing Shops and Personal Protection of the Workers in Nakhon Si Thammarat, Thailand. *J. Environ. Public Health.* https://doi.org/10.1155/2021/8875666.

Vergara-Murillo, F., Martinez-Yanez, K.; Fortich-Revollo,A., Paternina-Caicedo, A., and Johnson-Restrepo, B. (2022). Biochemical and Hematological Markers in Workers with Chronical Exposure to Lead and Cadmium in Colombia. *Toxics*, *10*, 524. https://doi.org/10.3390/toxics10090524.

Vitayavirasuk, B., Junhom, S. and Tantisaeranee, P. (2005). Exposure to lead, cadmium and chromium among spray painters in automobile body repair shops. *J. Occup. Health*, 47(6): 518-522.

Wang, B., Su, Y., Tian, L., Peng, S., Ji, R. (2020). Heavy metals in face paints: Assessment of the health risks to Chinese opera actors. *Sci. Total Environ. 724*, 138163

Yuningtyaswari and Dwi, S. A. (2016). The effects of air freshener exposure at an early age on histological white rat (*Rattus norvegicus*) liver cells. *Am. Instit. Phys*., 1744(1): 1-4.