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CHANGES IN HEMATOLOGICAL INDICES AMONG WORKERS IN AUTOMOTIVE INDUSTRY

BY

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Abstract

Introduction: Workers in automotive industry are exposed to a variety of chemicals, especially heavy metals, degreasers, lubricants, metal cleaners, benzene, solvents, welding fumes and car exhausts. Many chemicals to which automotive industry workers are occupationally exposed, including heavy metals and organic solvents are haematotoxic. Several hematological indices such as hematocrit (Hct), hemoglobin (Hb), red blood cells (RBCs) have been used to assess the functional status of the oxygen-carrying capacity of the blood and also as indicators of exposure to heavy metals. **Aim of Work:** To study the changes in hematological indices among welders and spray-painters in automotive industry due to workplace exposures. **Materials and Methods:** The two exposed groups included 30 welders and 32 spray-painters in an automobile manufacturing factory in Helwan, Cairo. The non-exposed group included 44 administrative workers in the same factory. The three groups (2 exposed and one none exposed) were subjected to a questionnaire including medical and occupational histories and laboratory investigations: blood lead level, serum manganese level and complete blood count. **Results:** Statistically significant higher levels of blood lead and serum manganese were found among the exposed groups. Lymphocytes percentage was significantly lower among welders compared to the control. Hemoglobin was significantly lower among spray-painters compared to the control group. Platelet distribution width (PDW) was significantly higher among spray-painters compared to welders and control groups. The total leukocytes, mid-range cells (MID) and granulocytes counts showed a statistically significant positive correlation with blood lead level among spray-painters. Platelet count and plateletcrit (PCT) showed statistically significant positive correlation with serum manganese level among welders.**Conclusion and Recommendations:** Workplace exposures among welders and spray-painters in automotive industry may affect some hematological parameters and indices. Biomonitoring of lead, manganese levels in blood and regular CBC should be done for workers in automotive industry

Keywords: Lead (Pb), Manganese (Mn), Automotive industry, Welders and Spary-painters

Introduction

Automobile manufacturing industry is run by several workers, such as mechanics, spray-painters, welders, battery recyclers, and radiator and air-conditioner repairers (Ishola et al., 2017). Workers are exposed to a variety of chemicals, especially heavy metals, degreasers, lubricants, metal cleaners, benzene, solvents, welding fumes and car exhausts (El-Saadawy et al., 2011).

Welding is one of the main processes for joining parts of metals together in the automobile industry (Wang and Wang, 2019). Welding fumes are toxic to the human body due to abnormal absorption, distribution, metabolism, and excretion of the main components of these fumes, such as heavy metals (Seaman et al., 2015). Several hematological indices such as hematocrit (Hct), hemoglobin (Hb), red blood cells (RBCs) have been used to assess the functional status of the oxygen-carrying capacity of the blood and as indicators of exposure to heavy metals (Shah and Atindag, 2004). Lead induces anemia by two mechanisms: impairment of heme biosynthesis, and increased rate of RBCs destruction (Schwartz et al., 1990). A relationship was found between blood lead (Pb–B) and lead manganese (Pb–Mn) concentration. The interaction between Pb and Mn is thought to be mediated by a relationship between Pb and Mn porphyrin interactions in the RBCs (Wibowo et al., 1979). Mn accumulates in bone, liver, and kidney tissues, and consequently it may alter the process of hematopoiesis (Dorman et al., 2006 and Jones, 2014). It has been reported that Mn interferes with absorption of the dietary iron sharing the similar metabolic pathway as that of iron (Garcia et al., 2006). Thus, chronic exposure to high levels of Mn may lead to iron deficient anemia and decreased Hb (Chandel and Jain, 2016).

Workers in automobile industry are exposed to mixtures of organic solvents which include xylene, methanol, toluene, benzene, methylene chloride, acetone, and polycyclic aromatic hydrocarbons (Varona-Uribe et al., 2020). Benzene is mainly produced from fuel vapours and from solvents used for degreasing or as diluents at the workplace of automobile mechanics (Vitali et al., 2006). It was reported that hazardous emissions of petroleum derivatives in automobile factories led to higher risk of hematological dysfunctions (Obianime et al., 2017).

In developing countries, such as Egypt, there is a need to highlight the effects of chemical exposures, including heavy metals, especially Pb and Mn on hematological parameters among the exposed workers in automotive industry.

Aim of Work

To study the changes in hematological indices among welders and spray-painters in automobile industry due to workplace exposures.

Materials and Methods

- **Study design:** This is a cross-sectional comparative study.

- **Place and duration of the study:** The study groups included workers in an automobile factory in Helwan, Cairo. The duration of the study was 6 months from January to June 2023.

- **Study Sample:** The study included 106 participants divided into two exposed groups (62 workers) and one non-exposed group (44 workers).

-The exposed groups included:

1) A group of welders, which included all workers in the welding process who met the inclusion criteria (30 workers).

2) A group of spray-painters, which included all workers in the cars painting process who met the inclusion criteria (32 workers).

- Inclusion criteria of the exposed workers: Workers should have a work duration of at least one year in the current job and agreed to participate in the study.

- Exclusion criteria of the exposed workers: Workers who had other types of exposures from other jobs inside or outside the factory.

The control group (44 non-exposed workers) was recruited from the administrative department in the same factory who agreed to participate in the study.

- Inclusion criteria of the control group**:** Administrative workers with no history of exposure to any type of chemicals, fumes, or vapors in the factory.

- Exclusion criteria of the control group**:** 1) History of exposure to any type of chemicals, fumes, or vapors inside or outside the factory, 2) Past or present history of any hematological disease.

- Sample size calculation:

Based on evidence from a previous study by Kamal and Malik (2012) and by considering the mean of RBCs comparison between painting workers and non-exposed workers as primary outcome measure. G Power program 3.1.9.4 was used to calculate the sample size with independent t test comparison between two groups. Assuming 80% power, 0.05 level of significance and effect size d measure 0.62 with ratio of 1:1. The minimum required sample size to detect statistical significance difference would be 86 participants.

- **Study Methods:** All the studied groups were subjected to the following:

- **A questionnaire** including medical and occupational histories.
- **Laboratory investigations**: A blood sample of 10cc was obtained from each subject through venipuncture from the arm using a disposable plastic syringe under complete aseptic conditions. Each sample was then divided into three clean tubes; one of them was left to clot then centrifuged to separate the serum for determination of serum manganese level. The other two tubes contained dipotassium-EDTA and were used for determination of blood lead level and complete blood picture (CBC). The blood lead and serum manganese levels were determined by an atomic absorption spectrophotometry: Thermoelemental M6. The device consists of a light source called a hollow cathode lamp (HCL), which emits particular wavelengths of light that are only absorbable by the analyte; an 'atom cell', which converts the samples into gaseous atoms that can absorb light from the HCL; a 'detection system' that isolates and quantifies the wavelengths of interest; and a computer system to control instrument operation and collect and process data (Butcher, 2005).

Consent

A written consent to participate in the research, to give blood samples and to be clinically examined was voluntarily obtained from all participants.

Ethical Approval

Prior to the study, the Research Ethics Committee of the Faculty of Medicine, Cairo University approved the study protocol (N-17-2023). Approval of the administrative authority in the factory was also obtained. Strict confidentiality was followed during sample collection, coding and testing. Subjects were allowed to obtain copies of the results of their laboratory tests to enable them to undergo further investigations and management.

Data Management

- Microsoft excel 2013 was used for data entry and the statistical package for social science (SPSS) version 23 (SPSS, Armonk, New York: International Business Machines Corporation) was used for data analysis.
- Simple descriptive statistics (arithmetic mean and standard deviation) used for summary of quantitative data and frequencies used for qualitative data.
- Bivariate relationship was displayed in cross tabulations and Comparison of proportions was performed using the chi-square test or fisher exact whenever appropriate.
- One-way Annova and post-hook tests were used to compare normally distributed quantitative data. Pearson correlation was used to compare normally distributed quantitative data.
- The level of significance was set at probability (P) value <0.05.

Results

Table (1): Comparison between the studied groups as regards age, blood lead (Pb) and serum manganese (Mn) levels by ANOVA and Post Hoc tests.

	Groups 1,2,3	Mean ± SD	F	p-value	Post Hoc (Mean difference between groups)	p-value
Age (yrs)	**1.Welders**	54.53 ± 6.62	0.68	0.5	1,3 = 1.03	0.42
	2.Painters	54.88 ± 4.46			2,3 = 1.38	0.28
	3.Control	53.5 ± 5.11			1,2 = 1.37	0.8
Blood Pb (μg/dL)	**1. Welders**	24.08 ± 17.71	7.6	**0.001***	1,3 = 8.88	**<0.001***
	2. Painters	22.0 ± 7.28			2,3 = 6.81	**0.006***
	3. Control	15.19 ± 2.91			1,2 = 2.08	0.43
Serum Mn (μg/dL)	**1. Welders**	1.41 ± 0.7	15.31	**<0.00***	1,3 = 0.59	**0.001***
	2. Painters	1.74 ± 0.72			2,3 = 0.91	**<0.001***
	3. Control	0.83 ± 0.72			1,2 = 0.33	0.08

*: Statistically significant

Table (1) showed that the mean age of the exposed groups showed no statistically significant difference compared to the control group. Both welders and spray painters had statistically significant higher mean level of blood lead and serum manganese compared to the control group.

Table (2): Comparison between leucocytic counts parameters among the studied groups using ANOVA and Post Hoc tests.

Leucocytes counts	Groups 1,2,3	Mean ± SD	F	p-value	Post Hoc (Mean difference between groups)	p-value
WBCs (x10^9/L)	1.Welders	7.01 ± 1.68	0.07	0.93	1,3 = 0.01	0.98
	2.Painters	6.85 ± 2.1			2,3 = 0.17	0.73
	3.Control	7.02 ± 2.35			1,2 = 0.16	0.77
Lymphocytes (x10^9/L)	1.Welders	2.44 ± 0.79	0.88	0.42	1,3 = 0.21	0.25
	2.Painters	2.46 ± 0.91			2,3 = 0.19	0.3
	3.Control	2.65 ± 0.63			1,2 = 0.03	0.9
Lymphocytes %	1.Welders	34.82 ± 7.63	3.35	**0.039***	1,3 = 5.08	**0.016***
	2.Painters	36.29 ± 8.2			2,3 = 3.6	0.079
	3.Control	39.89 ± 9.77			1,2 = 1.48	0.51
MID cells (x10^9/L)	1.Welders	0.54 ± 0.26	1.14	0.32	1,3 = 0.08	0.16
	2.Painters	0.52 ± 0.23			2,3 = 0.05	0.3
	3.control	0.47 ± 0.18			1,2 = 0.02	0.71
MID %	1.Welders	7.54 ±3.46	0.47	0.63	1,3 =1.12	0.34
	2.Painters	8.1 ± 2.72			2,3 = 0.56	0.63
	3.Control	8.67 ± 6.71			1,2 = 0.56	0.66
Granulocytes (x10^9/L)	1.Welders	4.03 ±1.12	0.098	0.91	1,3 = 0.13	0.72
	2.Painters	3.86 ±1.38			2,3 = 0.03	0.92
	3.Control	3.9 ± 1.88			1,2 = 0.16	0.68
Granulocytes %	1.Welders	56.34 ±10.13	0.22	0.8	1,3 = 1.56	0.51
	2.Painters	55.6 ± 8.35			2,3 = 0.83	0.72
	3.Control	54.77 ±10.93			1,2 = 0.73	0.77

*Statistically significant RBCs: Red blood cells Hb: Hemoglobin
WBCs: White blood cells MID: Mid-range cells MPV: Mean platelet volume
PDW: Platelet distribution width PCT: Plateletcrit

Table (2) showed that the mean lymphocytes percentage was significantly lower among welders compared to the control group. All other leucocytic counts .parameters showed no statistically significant difference

Table (3): Comparison between erythrocytic, platelets and platelet indices parameters among the studied groups using ANOVA and Post Hoc tests.

Erythrocytic and p=latelet indices	Groups 1,2,3	Mean ± SD	F	p-value	Post Hoc (Mean difference between groups)	p-value
RBC's ($x10^{12}$/L)	**1.Welders**	4.83± 0.46	1.26	0.29	1,3 = 1.14	0.25
	2.Painters	4.54 ±0.46			2,3 = 1.42	0.15
	3.Control	5.97 ± 6.42			1,2 = 0.28	0.79
Hb(g/dL)	**1.Welders**	13.61± 1.69	4.55	**0.013***	1,3 =0.94	0.07
	2.Painters	13.03 ± 1.01			2,3 = 1.51	**0.004***
	3.Control	14.55 ± 2.99			1,2 = 0.57	0.31
Hematocrit %	**1.Welders**	37.89±4.17	0.26	0.78	1,3 = 0.67	0.57
	2.Painters	37.03±2.89			2,3 = 0.18	0.88
	3.Control	37.21 ± 6.46			1,2 = 0.85	0.5
Platelets ($x10^9$/L)	**1.Welders**	255.17± 76.54	0.34	0.71	1,3 = 6.63	0.66
	2.Painters	268.4±51.23			2,3 = 6.64	0.65
	3.Control	261.8±61.27			1,2= 13.27	0.41
MPV (fL)	**1.Welders**	8.65 ±0.71	1.86	0.16	1,3 = 0.45	0.057
	2.Painters	8.35±0.61			2,3 = 0.15	0.51
	3.Control	8.2 ± 1.3			1,2 = 0.29	0.24
PDW	**1.Welders**	15.69 ±0.27	6.32	**0.003***	1,3 = 0.06	0.44
	2.Painters	15.98± 0.41			2,3 = 0.23	**0.005***
	3.Control	15.75 ± 0.35			1,2 = 0.3	**0.001***
PCT %	**1.Welders**	0.22 ±0.06	0.096	0.91	1,3= 0.002	0.89
	2.Painters	0.22± 0.03			2,3= 0.005	0.66
	3.Control	0.22 ± 0.05			1,2= 0.003	0.79

*: Statistically significant RBCs: Red blood cells Hb: Hemoglobin
WBCs: White blood cells MID: Mid-range cells MPV: Mean platelet volume
PDW: Platelet distribution width PCT: Plateletcrit

Table (3) showed that hemoglobin was significantly lower among painters compared to the control. Platelet distribution width (PDW) was significantly higher among painters compared to the welders (p=0.001). Also a significantly higher PDW was observed among painters compared to controls (p=0.005). All other erythrocytic and platelet indices showed no statistically significant difference.

Table (4): Pearson correlation of leukocytic counts with blood lead level (Pb) and serum manganese level (Mn) among spray-painters.

Spray-painters	Pb (r)	p-value	Mn (r)	p-value
WBCs (x10/L)	0.39	**0.026***	0.22	0.23
Lymphocytes (x10/L)	0.15	0.42	0.21	0.27
Lymphocytes%	0.26	0.14	0.04	0.81
MID cells(x10/L)	0.36	**0.04***	0.04	0.79
MID %	0.04	0.79	0.11	0.53
Granulocytes (x10/L)	0.43	**0.01***	0.19	0.3
Granulocytes %	0.24	0.17	0.01	0.97

*: Statistically significant WBCs: White blood cells MID: Mid-range cells

Table (4) showed that the total leukocytic count together with mid-range cells (MID cells) and granulocytes count showed significant positive correlation with blood lead level among spray-painters. Also, no significant correlation was found between leukocytic counts and serum manganese among spray-painters.

However, no significant correlation was detected between the leukocytic counts, blood lead level and serum manganese among the group of welders (results were not tabulated).

Table (5): Pearson correlation of platelets and platelet indices with serum manganese (Mn) and blood lead (Pb) levels among welders.

Welders	Pb (r)	p-value	Mn (r)	p-value
Platelets (x10/L)	0.23	0.9	0.37	**0.05***
MPV (fL)	0.13	0.94	0.08	0.65
PDW	0.02	0.91	0.12	0.53
PCT %	0.01	0.98	0.38	**0.04***

*: Statistically significant MPV: Mean platelet volume
PDW: Platelet distribution width PCT: Plateletcrit

Table (5) showed that platelet count and plateletcrit (PCT) significantly correlated with serum manganese level among welders. While no significant correlation was found between other platelet indices and blood lead level among the same group.

Also, no significant correlation was found between any of the platelet indices and blood lead level among spray-painters (results were not tabulated).

Discussion

Automotive industry involves high exposures to welding fumes together with various solvents in the spray-painting processes (Men et al., 2021). Anemia, leukopenia, lymphocytosis or lymphopenia, eosinophilia, thrombocytopenia and pancytopenia have been reported among welders due to heavy metal exposure (Bainin et al., 2022). Several studies showed significantly increased levels of heavy metals including lead among spray-painters (Ahmed et al., 2008, Basu et al., 2015, and Ishola et al., 2017). Many chemicals to which automotive industry workers are occupationally exposed, including heavy metals and organic solvents are haematotoxic (El-Saadawy et al., 2011).

The aim of the present work was to study the hematological changes among welders and spray painters in automobile industry.

The current study showed that both welders and spray painters had statistically significant higher mean level of blood lead and serum manganese compared to the control group (Table 1). It is to be noticed that the mean blood lead level of the exposed groups was higher than the biological exposure index (BEI) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) (20 µg/dL) (ACGIH, 2017). These results were similar to those obtained by a previous study which assessed the relationship between exposure to lead-containing welding fumes and the levels of reproductive hormones. The authors reported that the mean blood lead level among welders were significantly higher than the BEI recommended by the ACGIH, 2017 and was also significantly higher than the mean blood lead level in the non-exposed group (Dehghan et al., 2019).

Also it was in agreement with a study done by Oginawati et al., 2017 on Hematology analysis of lead exposure on painting workers and detected that the average blood lead level among spray painters were significantly higher compared to the control group. However, the average blood lead level among painters was less than the BEI recommended by ACGIH, 2017 .

In a study conducted by Mehrifar et al., 2020 in Iran on the effects of occupational exposure to manganese fume among welders; they found a significant increase in the average blood concentrations of manganese among welders compared to the control group.

The studied spray painters had significantly higher mean serum manganese compared to the control group (Table 1). This can be explained by the fact that manganese is a known component of paint either as a pigment or as a drier (Zuskin et al., 2007). It can also be explained by the exposure of painters to welding fumes from nearby welding processes.

Hematological parameters among the studied workers showed significant decrease in the mean lymphocyte percentage among welders in relation to control group (Table 2). These results agreed with those reported by Li and Taneepanichskul, 2021 in their study on associations between welding fume exposure and blood hemostatic parameters in Thailand. They found that the lymphocyte percentage among welders was lower than the control, but marginally significant. However, these results were different from those reported by Bainin et al., 2022 from Ghana in which the lymphocyte fraction was similar between the exposed and the control groups. These inconsistent results may be because some studies about welding fume focused on long-term effects of exposure to welding fumes without clarification of duration of exposure, welding techniques, or the intensity of exposure (Li and Taneepanichskul, 2021).

The mean red blood cells count and hematocrit were slightly decreased among welders compared to controls but not to statistically significant values (Table 3). These findings agreed to the results of the study done by Onwukwe et al. 2018, who studied changes in the haematological profile of automobile welders in Nigeria. They found that the welders had significantly lower red blood cells count and haemoglobin concentration. Toxic gases produced in the oxyacetylene welding process such as arsine, phosphine and carbon monoxide have a direct cytotoxic effect on RBCs and result in suppression of erythropoiesis. Arsine gas causes destruction of RBCs (Onwukwe et al. 2018). Also the welders in the present study had significantly higher blood lead levels (Table 1), which is known to cause anemia (Schwartz et al., 1990).

Hematological parameters of the studied painters showed significantly decreased mean hemoglobin level compared to the control group (Table 3). This was in accordance with the study done by Abdel Maksoud and his colleagues in 2018 on the assessment of hematotoxicity and genotoxicity among paint workers in Assiut governorate, Egypt, who detected that the mean hemoglobin level together with RBCs count and hematocrit were significantly lower among the exposed group compared to the control.

A significantly increased platelet distribution width (PDW) was found among spray-painters compared to the welders and the control groups (Table 3). This may be because spray-painters are exposed to benzene, which is one of the paint components (Kamal and Rashid, 2014). These results agreed with those reported by Huang and colleagues in 2014, in their study on the effects of benzene exposure on platelet parameters. They found that PDW and MPV were significantly higher among benzene-exposed group compared to the non-exposed group.

There was a statistically significant positive correlation between mean blood lead level among the studied painters and some of their leukocytic counts, which are: total white blood cell count (WBCs), mid-range cells (MID cells), and granulocytes. No statistically significant correlation was found between leukocytic counts and mean serum Mn level among painters (Table 4). This agreed with the results found by Soleman and co-workers in 2020, who studied lead exposure effect on peripheral blood parameters in Yogyakarta, Indonisia, and reported that lead was positively correlated with leukocytes among the lead-exposed population.

Serum Mn level positively correlated with platelets count and plateletcrit (PCT%) among exposed welders, while no significant correlation was found between blood lead level and platelet counts among welders (Table 5). These findings were partly consistent with the findings of a study done in China by Jiang et al., 2014, in which there was a positive association between the abnormality of platelets in male workers and exposure time. However, platelet count and neurological symptoms of these workers were not related to the urinary manganese level. The authors concluded that exposure to manganese for a long time may affect platelet count in male workers.

Conclusion

The current study showed that workplace exposures in automotive industry may affect some hematological parameters and indices. Lead and manganese were significantly increased in blood among both welders and spray-painters indicating high level of exposure to heavy metals in this industry. Hematological changes among exposed workers included significant decrease in lymphocyte percentage among welders, significant decrease in hemoglobin and significantly increased PDW among spray-painters, and non-significant decrease in RBCs count among welders. Blood lead level correlated positively with leukocytic counts (total WBCs, MID and granulocytes) in spray-painters, while serum manganese level correlated positively with platelet count and plateletcrit among welders.

Recommendations

Biomonitoring of lead and manganese for workers in automotive industry is recommended to monitor their exposure to those heavy metals. Complete blood count is also recommended regularly for early detection of any hematological abnormalities among workers who are exposed to solvents, paints and heavy metals.

Conflict of Interest

Authors have declared that no conflict of interest exists.

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References

1. 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. Egyptian Journal of Forensic Sciences; 8:6. DOI : 10.1186/s41935-017-0029-3.
2. Ahmed K, Ayana G and Engidawork E (2008): Lead exposure study among workers in lead acid battery repair units of transport service enterprises, Addis Ababa, Ethiopia: a cross-sectional study. J Occup Med Toxicol; 3:30.
3. American Conference of Governmental Industrial Hygienists (ACGIH) (2017): TLVs and BEIs, Documentation of the Threshold Limit Values and Biological Exposure Indices. American Conference Governmental of Industrial Hygienists, Cincinnati, OH; 36–101.
4. Bainin I, Gyasi SF, Awuah E, Obeng-Ofori D, Abdallah F, et al. (2022): Manganese, Iron, Lead, and Zinc Levels and Haematological Profile among Welders in Bibiani Anhwiaso Bekwai District, Ghana. J Environ Public Health, Article ID 1508523. https://doi.org/10.1155/2022/1508523. Available at: https://europepmc.org/article/MED/35859574
5. Basu R, Biswas A, Biswas K, Mukhopadhyay A and Talapatra SN, et al. (2015): An attempt to search the health status of garage workers: a neglected part in India. Int J Adv Res; 3(7):1466–71.

6. Butcher DJ (2005): Atomic absorption spectrometry: Interference and background correction. In: Encyclopedia of Analytical Science (Second Edition), Editor(s): Paul Worsfold, Alan Townshend, Colin Poole. Elsevier; 157-163. ISBN 9780123693976,https://doi.org/10.1016/B0-12-369397-7/00025-X.
7. Chandel M and Jain GC (2016): Manganese-induced hematological alteration in Wistar rats. J Environ Occup Sci; 5(4):77-81. DOI: 10.5455/jeos.20161126061501
8. Dehghan SF, Mehrifar Y and Ardalan A (2019): The Relationship between Exposure to Lead-Containing Welding Fumes and the Levels of Reproductive Hormones. Ann Glob Health; 85(1): 125 (1–6). DOI: https://doi.org/10.5334/aogh.2617
9. Dorman DC, Struve MF, Marshall MW, Parkinson CU, James RA et al. (2006): Tissue manganese concentrations in young male rhesus monkeys following subchronic manganese sulfate inhalation. Toxicol Sci; 92:201-10.
10. El-Saadawy MS, Attwa EM, El-Tayeb IM and Zalat MM (2011): Dermatoses and hematological disorders among car mechanics in Zagazig city and their effects on quality of life. Zagazig Univ Med J; 17(2):142–56.
11. Garcia SJ, Gellein K, Syversen T and Aschner M (2006): A manganese-enhanced diet alters brain metals and transporters in the developing rat. Toxicol Sci; 92:516-25.
12. Huang J, Zhao M, Wang P, Li X, Ma L et al. (2014): Effects of Low Concentrations of Benzene Exposure on Levels of Platelet-Associated Antibodies and Platelet Parameters. JOEM; 56(10): 892-7. https://www.jstor.org/stable/48501234.
13. Ishola AB, Okechukwu IM, Ashimedua UG, Uchechukwu D, Michael EA, et al. (2017): Serum level of lead, zinc, cadmium, copper and chromium among occupationally exposed automotive workers in Benin City. Int J Environ Pollut Res; 5(1):70–9.
14. Jiang B, Liang Q and Huang H (2014): Physical examination data of 933 workers occupationally exposed to manganese [J]. Occupational Health and Emergency Rescue; 32(3): 141-3.
15. Jones A (2014): Manganese-induced Parkinsonism: Relationship to manganese accumulation in bone. Journal of Purdue Undergraduate Research; 4:87-8.
16. Kamal A and Malik RN (2012): Haematological evidence of occupational exposure to chemicals and other factors among auto-repair workers in Rawalpindi, Pakistan. Osong Public Health and Res Perspect; 3(4):229-38.
17. Kamal A and Rashid A (2014): Benzene exposure among auto-repair workers from workplace ambience: a pioneer study from Pakistan. Int J Occup Med Environ Health; 27(5):830-9. DOI: 10.2478/s13382-014-0295-3. Epub 2014 Oct 17. PMID: 25323989.
18. Li N and Taneepanichskul N (2021): Associations between welding fume exposure and blood hemostatic parameters among workers exposed to welding fumes in confined space in Chonburi, Thailand. PLoS One; 18;16(11): 0260065. DOI:10.1371/journal.pone.0260065. PMID: 34793518; PMCID: PMC8601467.
19. Mehrifar Y, Bahrami M, Sidabadi E and Pirami H (2020): The effects of occupational exposure to manganese fume on neurobehavioral and neurocognitive functions: An analytical cross-sectional study among welders. EXCLI J Mar 13; 19:372-86. DOI: 10.17179/excli2019-2042. PMID: 32327958; PMCID: PMC7174571.
20. Men JL , Men JY, Zhang YJ, Zhao L, Zhang J, et al. (2021): Investigation on occupational hazards in 20 automobile manufacturing enterprises in Shandong Province. Chinese .Journal of Industrial Hygiene and Occupational Diseases; 39(3):198-202. DOI: 10.3760/cma.j.cn121094-20200509-00245
21. Obianime AW, Odili O, Olorunfemi OJ, Wokoma TO and Chuemere AN (2017):

Toxic air and soil in automobile workshop impact negatively on the health status of automechanics: the Nigeria environment. Int J Pharm Pharmacol; 1(3):111.

22. Oginawati K, Dwilestari H and Junianto N (2017): Hematology Analysis of Lead Exposure on Painting Workers (Case Study: Informal Automobile Painting Industries in Karasak, Bandung. In: International Conference of Occupational Health and Safety (ICOHS-2017), KnE Life Sciences, pages 674–86. DOI 10.18502/kls.v4i5.2597
23. Onwukwe O, Azubuike N, Udeani T, Onyemelukwe A, Chukwuagu C and Achukwu P (2018): Changes in the Haematological Profile and Frequency of Nuclear Abnormalities in Exfoliated Buccal Cells of Automobile Welders in Enugu, Nigeria. Res J Environ Toxicol; 12(2): 56-62. DOI: 10.3923/rjet.2018.
24. Schwartz J, Landrigan PJ, Baker EL, Orenstein WA and von Lindern IH (1990): Lead-induced anemia: Dose–response relationships and evidence for a threshold. Am J Public Health; 80(2): 165–8.
25. Seaman DM, Meyer CA and Kanne JP (2015): Occupational and environmental lung disease. Clinics in Chest Medicine; 36(2):249–68.
26. Shah SL and Atindag A (2004): Hematological parameters of tench (Tinca tinca L.) After acute and chronic exposure to lethal and sublethal treatment mercury treatments. Bull Environ Contam Toxicol; 73:911-8.
27. Soleman SR, Andini SA and Rosita L (2020): Lead Exposure Effect on Peripheral Blood Parameters among People around Bus Terminal in Yogyakarta. Asia Pac J Med Toxicol; 9(1): 11-6. http://apjmt.mums.ac.ir.
28. Varona-Uribe M, Ibáñez-Pinilla M, Briceno-Ayala L, Herrera D, Chuaire-Noack L, et al. (2020): Biomarkers of susceptibility and effect in car painters exposed to organic solvents. Colomb Med (Cali) Mar; 51(1):3646. DOI: 10.25100/cm.v51i1.3646.
29. Vitali M, Ensabella F, Stella D and Guidotti M (2006): Exposure to organic solvents among handicraft car painters: A pilot study in Italy. Ind Health Apr; 44(2):310-7.
30. Wang H and Wang Y (2019): High-velocity impact welding process: a review. Metals; 9(2):144.
31. Wibowo MD, Salle´HJA, del Castilho P and Zielhuis RL (1979): An effect of erythrocyte protoporphyrin on blood manganese in lead-exposed children and adults. Int Arch Occup Env Health; 43(3):177–82.
32. Zuskin E, Schachter E, Mustajbegović J, Pucarin-Cvetković J and Lipozencić J (2007): Occupational health hazards of artists. Acta dermatovenerologica Croatica; 15(3):167-77.