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Environmental Concentration of Paint Particulate Matters and Dust Metals in the Paint Furniture Workshops

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Abstract

The present study employed six paint furniture workshops; A, B, C, D, E and F, which have small and different size and types of painting, in close to carpenter workshops at El-Shoaraa in Damietta city. The particulate matter of PM_{10} and $PM_{2.5}$ were measured, using Casella device for dust detective (Casella Cel-712 Microdust Pro Real-Time Dust Monitor). On the other hand, total suspended particulate (TSP) samples were collected using sampling air pump connected an open face holder on Whatman glass fiber filter. Metallic constituents of TSP were determined, using Atomic Absorption Spectrophotometer (A.A.S). The study results indicated that the mean concentrations of PM_{10} ranged from 26.85 to 44.41 µg/m^3, whereas, the mean concentrations of $PM_{2.5}$ ranged from 39.5 to 125 µg/m^3. The TSP concentrations ranged from 359 to 410 µg/m^3. The most paint particulate matters (PM) detected have unacceptable concentrations.
The mean heavy metals concentration of Pb, Cd and Zn in paint furniture workshops was (14.59, 7.59, 10.82) µg/m^3, respectively. Thus, the present study evaluated concentrations of dust that might generate in the indoor air of workshops involving spray painting and varnishing. Therefore, to protect air quality and painter's safety, and health concerns, occupational health and safety regulations, its implementation and enforcement within spray-painting furniture workshops must be improved and to ensure greater attention mitigations and management is given.

Keywords: TSP, PM_{10} and $PM_{2.5}$, Heavy Metals, Paint, Furniture Workshops

Introduction

The paints are used as a related activity in a variety of industries include motor vehicles, buildings, furniture, white goods, machinery, ships and aircraft. Spray painting in furniture finishing processes is one of the major activities of painting. Paint is a mixture of various chemicals that work together to provide color, protection, and durability to surfaces. The composition of paint can vary depending on the type (latex, oil-based, epoxy, etc.) and brand, but some common components are pigments, binder, solvents, additives, extenders, retarders, driers, fragrances and preservatives **(Hussain, 2024).** Spray painting is usually a mixture of resins or polymers which cure or harden to produce a durable coating on the application surface, coloured pigments and fillers, and solvents or water acting as carriers for the resins that evaporate during application and drying **(Ifjen et al., 2022).**

Paint is used to decorate, protect buildings and other objects, and industrial coatings, which are applied as finish-manufactured goods such as cars, vehicle restoration, wood and furniture, and prolong the life of natural and synthetic materials, which acts as a barrier against environmental conditions **(Veleva, 2012).** Spraying is a painting technique that employs a spraying device, by using a valve to release chemicals and paintings coupled with compressed gas, air, allows for easy and even application over various surfaces, with a choice of applying coating material to produce the required thickness film of a liquid material release in mod of aerosol or vapour. Coatings can differ between paint, ink, varnish, and various other materials. Spray painting is one of the primary methods of painting besides using a brush or a roller, because it is quicker, cleaner, and easier to achieve a uniform coat. Application may be manual or automatic, but the majority of spray operate by using manual finishing techniques. The most of them is inserted with dry filters to control particulate; paint droplets, which is generated by overspray **(Sefiane, 2014)**. A furniture spray painting is a tool that has gained popularity for many years with a professional, to complete the proses faster with less effort, and with a smooth and professional finish. **(Thorud et al., 2005 and Veleva, 2012**). Varnish as a homogeneous, Transparency or semitransparent liquid that is converted to a solid, after being applied as a thin layer **(Schurr and Allison, 1981).** However, Lacquer is a coating, dries by evaporation much rather oxidation or polymerization, so dry very rapidly **(Lu et al., 2004).** Alkyd is a prevailing product in the coating painting surface, since the 1930s. Therefore, they contend the water-based coatings such as acrylics and latex, and still make them a more preferable coating for architectural, machinery, wood and industrial applications, cause impedance to environmental factors and almost, the strong adhesion to all surface **(Stoye and Freitag, 1998; Chong, 2020).**

In the wood-furniture industry, emissions from spray painting comprise many sources, including operations such as finishing; spray booths, flash-off areas, ovens, mixing, touch-up and repair, gluing, and cleaning. The potential emissions to atmosphere from spray painting operations are sanding and blasting dust arising from surface preparation in some activities, such as smash repairing or timber painting **(Ratnasingam et al., 2009)**. Most of the dust is generated, so fine that literally find its way out into the work area **(NOHSC, 1999; SafeWork, 2022).**

There are various types of paints are based on synthetic paints, with a mixture of volatile organic solvents such as semi bright and matt lacquer "varnish", lacquer polyesters, polyurethane lacquer, acrylate, synthetic resins that give colour and appearance, used for surface coating of wood and furniture **(Thorud et al., 2005).**

Furniture spray painting is aerosol a solvent-intensive process, which, forming a mist of fine liquid paint droplets (10-50 μm). During the process, painter is exposed to the chemicals which are atomized, which can be absorbed through skin and mucous membranes, inhalation route **(McKeown, 2011)**.

Anthropogenic particulate matter (PM) originates from human activities, such as construction, agricultural and industrial emissions **(Liu et al., 2021).** Addition to airborne particulate matter (PMs), exposure to spray paint PMs (SPPMs) may also be associated with human health and pulmonary dysfunction **(Lai et al. 2017; Chen et al., 2019)**.

In the indoor environment, exposure to pollutants has increased with reduced ventilation that making many indoor environments act as concentrators of emissions from plastics, paints, and other building materials. Poor ventilation always increases the indoor pollutant when outdoor does not go through to dilute emission from paints and others **(Ruan and Rim, 2019)**.

The paints contain pigments for opacity as coloring materials and a variety of additives as drying materials (tenner) to accelerate solidification and formation, and organic solvents to regulate viscosity. Within wood manufacturing industry, exposure may occur to solvents, wood preservatives in glues and surface coating and to engine exhausts. Furniture painting workers are artisan that could be occupationally at risk hazardous attributed to the chemical composition of paints **(El Gammal, 2008; Ratnasingam et al., 2009, 2010)**. Inorganic pigments are anti-corrosion coloring components of paint that can influence and control the corrosion of metal substrates, known as “inhibitors.” These coating components are usually introduced into the primer layer. A variety of metals such as aluminum, chromium, lead, iron, and zinc are known as effective anti-corrosive pigments, and they are introduced into the coating formulation as finely ground metal or powdered metal oxide **(Veleva, 2012).**

Spray painting workers in furniture workshops are occupationally exposed to intense painting vapors the inhaled airborne metal particles, beside other constituents. Data revealed that occupational exposure to paintings spray induce several health hazards related to blood components, as well as liver, kidney and brain functions **(El-Gammal, 2008; Abdel maksoud et al., 2018; Abdrabouh et al., 2023)**.

The toxic metals; lead, cadmium, mercury and zinc are known to promote adverse health effects, such as carcinogenicity, nephrotoxicity, neurotoxicity and cardiotoxicity. Human exposure to these toxicants is predominantly secondary to anthropogenic activities **(IARC, 1989; ATSDR, 2012; Lai et al., 2018; Garaga, 2024).** Lead, a heavy metal, has been proven to influence the ecosystem negatively. Exposure to lead heavy metal may cause diverse health problems. It will be absorbed, bound to red blood cells, and distributed to the main compartments, bones and soft tissues, liver, kidneys, bone marrow, and brain **(Abdel maksoud et al., 2018; Abdrabouh et al., 2023; Halmo and Nappe, 2024).** The major sources of lead are, lead (Pb) smelters, automobile emissions and pigments and paints **(Dara, 1993; Chuitha et al., 2014)**.

The higher risk priority number in the furniture painting process, which required reducing by implementing of the defects and then improve the painting process quality. Numerous studies evaluated the exposure of human to dust in occupational environments by combining adverse health effects (**El Gammal, 2008; Vergara-Murillo et al., 2022; Abdrabouh et al, 2023; Garaga, 2024**). The characterization of human exposure is a critical component of occupational epidemiological studies and environmental **(Berglund, 2001)** and it is an essential step in regulatory processes **(NRC (National Research Council), 1991)**

Environmental concerns have led to changes in the ingredients in spray paint, moving away from harmful ones to environmentally friendly options**.** Moreover, many studies have been made to produce eco-friendly exceptional resin compounds from natural renewable resources, vegetable oils obtained from various seeds are considered the best natural sources **(Ifjen et al., 2022).**

This study monitored the dust concentrations and metal dust in the most common work environment; the spray paint and varnish workshops where the workers exposed to the adverse health effects due to the exposure to these compounds.

Materials and Methods:

Physical characteristics and activities in the workshops.

The studied environments are carpentry, varnishing and painting workplaces and found in a residential area, Al-Shoaraa which located at the northern direction of Damietta city, with high population density (46348 population) (**Damietta Governorate, 2023**). The study was conducted in six of spray painting and varnishing furniture workshops (A, B, C, D, E and F), which are located on the ground floor of building in very narrow streets. The selected workshops have a small size; the areas of the investigated workshops were limited; varies from 25m² to about 80m². The most painting workshops have poor natural ventilation through small windows. Almost, there is no exhaust ventilation in the most of workshops. The equipment has no fitted extraction ventilation or was frequently not working.

It occupies about 4-8 workers per a workshop, with lack of dust control, or personal protection. It was noted that the personal protection was not used appropriately, and filter respirators were saturated of dust and paint, and incorrect procedures are adopted. Each painting workshop different in premises and size of shop, and a unique environment that work practices, workload, and in chemical structure and type and toxicity of the solvent which is used **(Table 1).**

Table (1): Characteristics and Activities performed in Paint Furniture Workshops Evaluated.

Workshop	Characteristics	Products	Activities	No. of Painters
Varnishing (A)	Area: 60 m² No of windows: 3 Height: 4 m	Varnish, alcohol, turpentine, solvent, wax and paraffin	furniture surface finishing, such as varnishing, lacquering, waxing and coloring.	6
Varnishing (B)	Area: 75 m² No of windows: 2 Height: 4 m	Turpentine, solvent, Poly vinyl alcohol (PVA) paint, synthetic paint, lacquer and spackling	Paint wood, polish and touch up painted surfaces and dry surfaces	5
Varnishing (C)	Area: 45 m² No of windows: 2 Height: 4 m	Varnish, alcohol, turpentine, solvent, wax and paraffin	Wood and furniture surface finishing, such as varnishing, lacquering, waxing and coloring.	4
Spray Painting (D)	Area: 25 m² No of windows: 2 Height: 4 m	Varnish, alcohol, gasoline, turpentine, solvent, wax and paraffin	Wood and furniture surface finishing, such as varnishing, lacquering, waxing and coloring.	4
Spray Painting (E)	Area: 80 m² No of windows: 3 Height: 5 m	Turpentine, solvent, Poly vinyl alcohol paint, lacquer and spackling	Paint wood, Polish, touch up and dry painted surfaces prepare painting equipment.	8
Spray Painting (F)	Area: 55 m² No of windows: 2 Height: 5 m	Turpentine, lacquer and spacklingو solventو PVA Poly vinyl alcohol and synthetic paint. paint,	Polishing and painting wood and touch up painted surfaces and dry surfaces preparing equipment.	3

Painting Furniture Particulate Concentration Measurements:

Sampling

A total of 360 samples were collected twice a week, from each of the six painting workshops; Varnishing workshops (A, B, C,) and Spray paint workshops (D, E and F), along the months of March 2021 and June 2021, through 9 AM and 5 PM, along the period of day work in paint workshops. One hundred and ninety-two samples were collected inside each of the six paint workshops evaluated, and 72 samples were collected in the outside of workshops, at a distance of approximately 260 m and away from the influence of the paint workshop activities **(Martins et al., 2019)**.

Determination of Paint Furniture Dust; TSP, PM_{10} and $PM_{2.5}$

Total dust (TSP), particles of less than 10 µm in diameter (PM_{10}) and particulate matter of less than 2.5 µm in diameter ($PM_{2.5}$) were measured for each of the six workshops.

PM_{10} and $PM_{2.5}$ Measurements:

Particles of (PM_{10}) and ($PM_{2.5}$) were measured for each workshop using the Casella device for dust detective (Casella CEL-712 Microdust Pro Real-Time Dust Monitor) operated at 1.0 L/min ± 5% constant, along the sampling period. The time measuring ranged from 0.25 to 32 mm in 31 channel sizes, each unit being certified with NIST (National Institute of Standards and Technology) monodisperse latex on the size of calibrated channels. The sampling monitor was mounted 1.5 m high for indoor measurements in the painting furniture workshops **(Ruiz-Jimenez et al., 2019).**

Total Suspended Particulates (TSP) Measurement:

A total of 192 (TSP) suspended particulate samples were collected from painting workshops (A, B, C, D, E and F) between the months of March 2021 and June 2021, using sampling air pump connected an open face holder on Whatman glass fiber filter (pore size 0.45µ, diameter 47mm), operated at 1.5 L/min for a period of 8h at a height of 1.5 m above the ground level during workday.

Determination of Metallic dust particles in paint workshops:

In the present study, heavy metals lead (Pb), cadmium (Cd), Zinc (Zn), were measured in the particulate matter in the paint furniture workshops, for a period of 30 days. Particulate matter was collected using the filtration technique. The filters were then extracted using concentrated HNO_3 (86 to 71 %) and the metallic constituents of TSP were determined by using Atomic Absorption Spectrophotometer (A.A.S). (Perkin-Elmer double beam 2380 atomic absorption spectrometer was used with adapted Perkin-Elmer hallow-cathode lamps and conventional 10-cm slot burner head for an air-acetylene flame).

Statistical analysis:

The results were statistically evaluated using SPSS (version 22) **(Core Team, 2025).** On the other hand, Bray-Curtis cluster analysis based on general characters, of the workshops evaluated was performed.

Results and Discussion

Tables (2 and 3) show the results to represent the monthly concentrations of PM_{10} and $PM_{2.5}$ inside the six paint workshops evaluated. The mean concentrations of PM_{10} in painting furniture workshops (B < A < C < D < F < E) was 26.85 µg/m^3, 32.85 µg/m^3, 33.83 µg/m^3, 34.74 µg/m^3, 41.55 µg/m^3 and 44.41 µg/m^3, respectively, **(Fig. 1)**. The highest concentration of PM_{10} is observed in Spray paint workshop **(D)** is 61 µg/m^3, whereas the lowermost of PM_{10} was 14.7 µg/m^3 in Varnishing paint workshop **(B), (Fig. 2)**.

Whereas, the monthly mean amounts of particulate matter < 2.5 microns ($PM_{2.5}$) inside the paint furniture workshop, $PM_{2.5}$ was 39.5 µg/m^3, 43.75 µg/m^3, 70 µg/m^3, 72 µg/m^3, 119.25 µg/m^3 and 125 µg/m^3, respectively (B < C < A < D < E < F) **(Fig. 3).** The highest concentration of $PM_{2.5}$ was observed in Spray paint workshop **(F)** was 134 µg/m^3, whereas the lowermost of $PM_{2.5}$ was 32 µg/ m^3 in varnishing paint workshop **(B), (Fig. 4)**.

As can be observed, the mean concentrations of $PM_{2.5}$ and PM_{10} were considerably higher than the World Health Organization's 24-hour mean PM10 limits (50 µg/m3), which resulted in more severe adverse pulmonary effects. One significant risk factor for pulmonary epithelial barrier failure was exposure to $PM_{2.5}$. **Chen et al. (2019)** provided evidence that exposure to SPPMs, particularly SPPM1, may raise the chance of developing pulmonary dysfunction. Additionally, **Yi-Chun et al. (2019)** showed that pulmonary dysfunction in human normal bronchial epithelial cells is caused by ambient concentrations of spray paint particle matter.

Table (4) shows the monthly mean concentrations of TSP inside the paint workshops **(A< C< B< D< E< F)** was 359 µg/m^3, 359.41 µg/m^3, 362.84 µg/m^3, 370.31 µg/m^3, 384.88 µg/m^3 and 410 µg/m^3, respectively, **(Fig 5).** The highest concentration of TSP was observed in Spray paint workshop **(F)** was 489 µg/m^3, whereas the lowermost concentration of TSP was 229 µg/ m^3 in varnishing paint workshop **(B), (Fig 6)**. Because the coarsest fractions are removed by gravity, the finest dust size was found when the compressor was not running, whereas the coarsest dust size is created during emery operations **(Black, 2015)**.

The concentrations of suspended particulates measured for paint furniture workshops exceed the maximum concentrations recorded at many cities in the world, and also exceed the ambient air quality standards of the Egyptian and U.S.A ambient air quality standard (230 µg/m^3) **(EEAA, 1994)** the U.S.A standard (260 µg/m^3 for 24 h.) **(Dara, 1993; Chuitha et al., 2014)**, and exceed the WHO Air Quality guideline (120 µg/m^3 for 24 h.) **(WHO, 2024)**. PM spray painting particles exposure enters the human body via respiration, able to enter the lungs are extremely small, their incredibly huge surface area makes it easier for them to interface with the respiratory epithelium's mucosa (**Zhao et al., 2015**). This PM may react with proteins, nucleic acids, and cell membranes, resulting in more severe pathogenic alterations and a loss of respiratory function epithelia. Lung cancer, chronic obstructive pulmonary disease (COPD), acute respiratory tract infections, and a host of cardiovascular disorders can result from this. Because they cause significant oxidative stress and inflammatory reactions, ultra-fine particles are particularly harmful (**Gao et al., 2015**).

For outside samples, the mean concentrations obtained for each of particulates; PM_{10} and $PM_{2.5}$ and TSP samples outside the paint furniture workshop were (39.5, 43.75, 70, 72, 119.25 and 125) µg/m^3, respectively, **(B < C < A < D < E < F) (Fig.7**). These outcomes indicate that the source, which is likely vehicular emission and population activities. These results were confirmed by **Martins et al. (2019)** by documenting that it would be better to spray outside because painting requires enough ventilation. The painting inside, however, requires that a well-ventilated location be selected, that any objects or areas be taped and covered, and that the following safety equipment be worn: respirator mask, gloves, coveralls, eye protection, or at least long sleeves and pants.

Table (2): Monthly Mean Concentrations of PM_{10} (µg/m^3) in the Paint Workshops Evaluated during the Study Period.

Workshops / Monthly Mean	A	B	C	D	E	F
1st Month	29.15	26.83	33.41	32.97	45.15	42.63
2nd Month	36.53	24.86	34.63	39.52	46.92	36.13
3rd Month	32.88	28.88	33.45	31.73	41.16	45.91
Mean	32.85	26.85	33.83	34.74	44.41	41.55
S. D.	8.43	6.83	4.90	7.93	7.78	10.24
Max. Conc.	51.1	37.1	42.1	44.1	61	56.8
Min. Conc.	19.8	14.7	25.4	20.9	27.7	19.6

Table (3): Monthly Mean Concentrations of $PM_{2.5}$ (µg/m^3) in the Paint Workshops Evaluated during the Study Period.

Workshops / Monthly Mean	A	B	C	D	E	F
1st Month	64	32	35	67	123	134
2nd Month	79	35	36	78	113	129
3rd Month	68	37	45	68	124	110
4th Month	69	54	59	75	117	127
Mean	70	39.5	43.75	72	119.25	125
S. D.	6.92	9.18	10.58	6.19	8.81	11.99
Max. Conc.	79	54	59	78	124	134
Min. Conc.	64	32	35	67	113	110

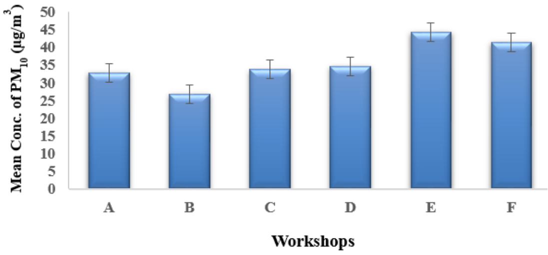

Fig. (1): Mean of PM_{10} Concentrations ± standard deviation in the Paint Workshops Evaluated

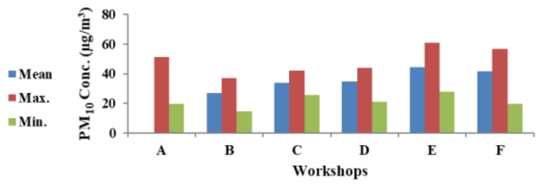

Fig. (2): Mean, Maximum and Minimum Concentrations of PM_{10} in the Paint Workshops Evaluated

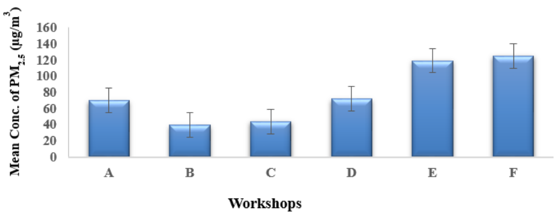

Fig. (3): Mean of $PM_{2.5}$ concentrations ± standard deviation in the Paint Workshops Evaluated

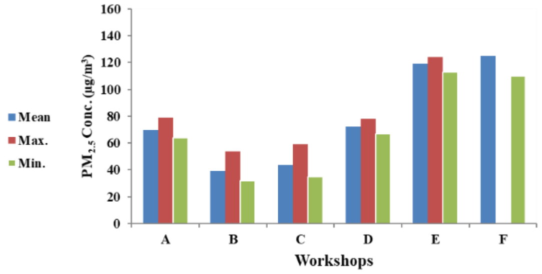

Fig. (4): Mean, Maximum and Minimum Concentrations of $PM_{2.5}$ in in the Paint Workshops Evaluated.

Table (4): Monthly Mean Concentrations of TSP (µg/m^3) in the Paint Workshops Evaluated during the Study Period.

Workshops / Monthly Mean	A	B	C	D	E	F
1st Month	294.125	334.125	352.875	412.375	365	434.25
2nd Month	341.25	363.375	342.375	397.625	404.75	405.625
3rd Month	404.875	390.875	363.125	338.875	389.25	385.375
4th Month	395.75	363	379.25	332.375	380.5	414.75
Mean	359.00	362.84	359.41	370.31	384.88	410.00
S. D.	65.78	70.74	53.84	46.44	35.60	46.47
Max. Conc.	477	476	482	455	465	489
Min. Conc.	243	229	232	286	320	328

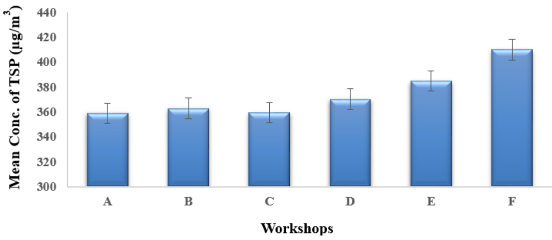

Fig (5): Mean of TSP concentrations± standard deviation in the Paint Workshops Evaluated

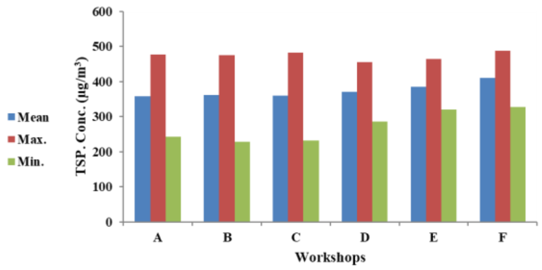

Fig. (6): Mean, Maximum and Minimum Concentrations of (TSP) in the Paint Workshops Evaluated.

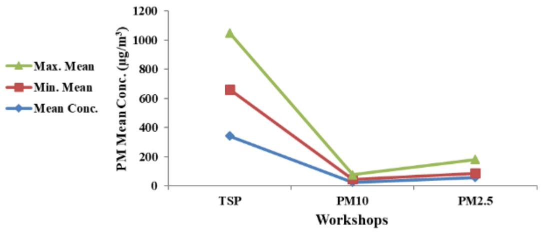

Fig. (7): PM Concentrations of TSP, PM_{10} and $PM_{2.5}$ Outside of Paint Workshops Evaluated during the Study Period

The high variation is explained by the different activities, and the way that each employee utilized the products, that every paint shop is a distinctive setting with varying shop sizes, locations, and chemical types and structures **(Table 1).** It is noticed, the high mean particulate concentration in spray paint workshops (**E and F**) is due to the high density of painting furniture works, lack of ventilation and non-using dust control and exhaust ventilation systems. Whereas, the low mean particulate concentration which recorded in varnishing paint workshops **(A and B)** is due to good ventilation, also the low density of works plays a role in the minimizing the concentration from other workshops **(Fig. 8), (El-Gammal and Niazy, 2000; Hafez, 2017 and Hagras et al., 2017)**.

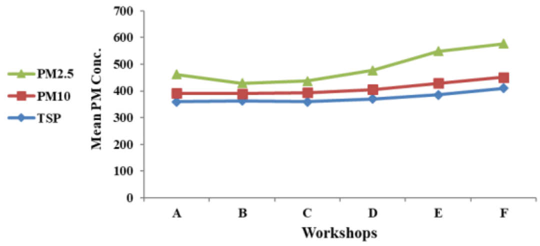

Fig. (8): Mean Concentrations of TSP, PM_{10} and $PM_{2.5}$ inside the Paint Workshops Evaluated During the Study Period.

Table (5) and Figure (9) summarize the results of the mean, maximum, and minimum concentrations of TSP, PM_{10} and

$PM_{2.5}$ was 374.40 ±19.95, 35.71 ± 6.34 and 78.25 ± 36.51μg/m^3, in paint workshops evaluated (A, B, C, D, E, F), during study period.

Table (5): Comparing Mean Concentration of TSP, PM_{10} and $PM_{2.5}$ in (μg/m^3) during the Study Period in in the Paint Workshops Evaluated.

Workshop	**TSP**	**PM_{10}**	**$PM_{2.5}$**
A	359.00	32.85	70.00
B	362.84	26.85	39.50
C	359.40	33.83	43.75
D	370.31	34.74	72.00
E	384.87	44.41	119.25
F	410.00	41.55	125.00
Max. Mean	410.00	44.41	125.00
Min. Mean	359.00	26.85	39.50
Mean Conc.	374.40	35.71	78.25
S. D.	19.95	6.34	36.51

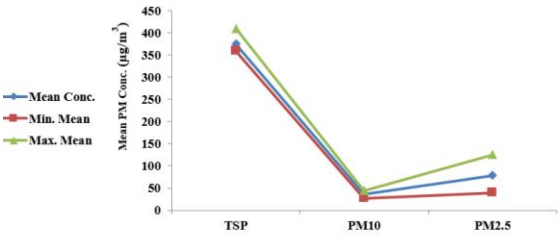

Fig. (9): Mean, Maximum, Minimum Concentrations of TSP, PM_{10} and $PM_{2.5}$ during the Study Period.

The application of cluster analysis based on the different particulates for different pain furniture workshops **(A, B, C, D, E and F).** The results indicated that the paint workshops **(D** and **F)** form two separate groups left the other Varnishing paint workshops Varnishing **A, B, C** and Spry paint **(E)** as similar group in evaluated (**Fig.10).** These workshops have similar characters, which may be the reason to form a group.

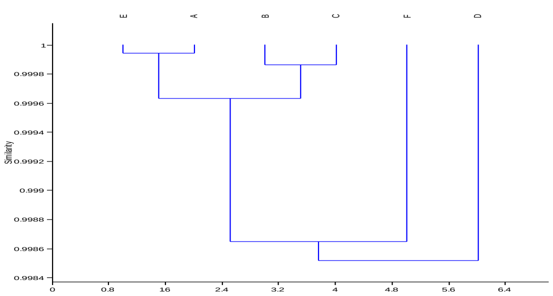

Fig. (10): Bray-Curtis Cluster Analysis Based on General Characters of Paint Workshops Evaluated (A, B, C, D, E and F) in a Residential Area, Al-Shoaraa at Damietta City, Egypt.

Metallic Constituents of Particulate Matter:

Table (6) provides heavy metals dust of **(Pb),** (**Cd)**, and (**Zn),** inside paint workshops evaluated **(A, C** and **E)** for a period of 30 days. The results show that the daily mean concentrations of (**Pb**) ranged from (19.16 μg/m^3 to 10.89, 13.03 to 7.88, 22.45 to 14.53) μg/m^3, respectively, in the workshop evaluated**,** during the study period. The highest daily concentrations of Pb was 22.45 μg/m^3, recorded in workshop **(E)** at a highly working day density, whereas the lowermost amounts of Pb was 10.23 μg/m^3 in varnishing paint workshop **(C).** (Pb) is a heavy metal commonly found in the environment and main component of paints. It is probably the most serious atmospheric heavy metal pollutant **(Martins et al., 2019; Vergara-Murillo et al. 2022; Abdrabouh et al, 2023; Simatupang et al. 2024)**. It is clear that the levels of lead particulates in painting furniture workshops in Damietta City were higher than the recommended air quality standards of (1 μg/m^3 for 1 yr) recommended by Egypt **(EEAA, 1994)**.

For the results of cadmium **(Cd**), concentrations show the daily mean ranged from (5.35 to 11.92 μg/m^3), (4.10 to 7.13 μg/m^3), and (6.88 to 12.6 μg/m^3) in workshops evaluated (**A, C** and **E)**, respectively, during the study period. The highest daily concentration of Cd was 12.6 μg/m^3, found in workshop **(E),** while the lowest concentration of Cd was 4.10 μg/m^3, recorded in workshop (**C)**. For the results of Zinc **(Zn),** concentrations show the daily mean ranged from (13.54 to 6.79 μg/m^3, 8,91 to 5.46 μg/m^3 and 18.66 to 9.90 μg/m^3), respectively, at workshops evaluated, during the study period. The highest daily concentration of Zn was 18.66 μg/m^3, found at workshop **(E),** while the lowest concentration of Zn was 6.46 μg/m^3, recorded at workshop **(C).** Zinc chromate or zinc yellow is used widely in the metal and painting industries **(Flyvholm, 1991).** As the likelihood of industrial sources for Zn is not found, so the high Zn concentration detected at painting furniture workshops, which emitted Zn from using chemicals in painting processes. Zinc is one of the metals whose oxides can result in acute and reversible syndrome **(Plum et al., 2010; (Akafuah et al., 2016)**.

Table (6): Mean Concentrations of Heavy Metals, Pb, Cd and Zn in SPM in Paint Furniture Workshops Evaluated (A, C and E) in (µg/m³)

Workshops	**A**			**C**			**E**		
Element / Sample No.	**Pb**	**Cd**	**Zn**	**Pb**	**Cd**	**Zn**	**Pb**	**Cd**	**Zn**
2	10.89	5.35	6.79	7.88	4.10	5.46	14.53	6.88	9.90
4	13.83	5.87	8.67	9.81	4.84	7.68	16.77	8.61	12.54
7	17.58	7.98	11.98	10.21	6.88	8.78	18.98	8.88	16.87
9	19.16	11.92	13.54	13.03	7.13	8.91	22.45	12.6	18.66
Mean	15.37	7.78	10.25	10.23	5.74	7.71	18.18	9.24	14.49
S. D.	3.73	2.99	3.07	2.12	1.50	1.60	3.38	2.41	4.00

The metal elements in particles (SPM) on all sampling days of Pb, Cd, Zn in the workshop evaluated (A) were 15.37 ± 3.73, 7.78 ± 2.99, 10.25 ± 3.07 µg/m³, for workshop **(C)** was 10.23 ± 2.12, 5.74 ± 1.50, 7.71 ± 1.60 µg/m³, whereas, for workshop **(E)** was 18.18 ± 3.38, 9.24 ± 2.41, 14.49 ± 4.00 µg/m³, respectively **(Table 7)**. In comparing of dust heavy metal; Pb, Cd, Zn Pb concentration for paint workshop evaluated **(A, C, E).** The highest concentrations of Pb were (18.18 µg/m³) recorded at workshop **(E)**. However, the lowest concentrations of Pb were (10.23 µg/m³), recorded at workshop **(C)**. The highest concentrations of Cd were (9.24 µg/m³) recorded at workshop **(E)**, However, the lowest concentrations of Cd were (5.74 µg/m³), recorded at workshop **(C)**. The highest concentrations of Zn were (14.49 µg/m³) recorded at workshop **(E)**, However, the lowest concentrations of Zn were (1.60 µg/m³), recorded at workshop **(C)**. These results were according to work intensity in painting furniture workshops. This is confirmed by **Pandey et al. (1998)** and **Khan et al. (2021)**. Furthermore, **El-Gammal (2008)** who documented, as the primary source of lead pollution in the Damietta City area does not appear to be heavy industry or lead smelters.

Table (7): Mean Concentration of Heavy Metals; Pb, Cd and Zn (µg/m³) in SPM in the Paint Workshops Evaluated (A, C and E)

Workshop	**Pb**	**Cd**	**Zn**
A	15.36	7.78	10.24
C	10.23	5.73	7.70
E	18.18	9.24	14.49
Max. Mean	18.18	9.24	14.49
Min. Mean	10.23	5.73	7.70
Mean Conc.	14.59	7.59	10.82
S. D.	4.03	1.76	3.43

Distribution of the Heavy Metals (%) in SPM in the Painting Workshops Evaluated (A, C and E):

The distribution of the mean percentage amounts of (Pb, Cd and Zn) in the sampling sites (painting furniture workshops was evaluated for **(A, C and E),** as shown in **fig. (11).** Results showed that the exposure to spray paintings in furniture workshops could participate in significant elevation of Cd and Pb concentrations in samples obtained from workshops evaluated. Pb% constituted of SPM increased by 46%, 43% and 43% for painting workshops **(A, C and E)**, respectively, however, Cd % was 23%, 24% and 22 %, respectively. However, the percent of Zn mean concentrations was 31%, 33% and 35 %, respectively.

It was clearly noticed that the Pb percent was the highest percent between the evaluated metals (Pb, Cd, Zn) at the paint workshops **(A, C and E).** This is due to the fact that paints are one of the most notable environmental sources of lead, with the main source of lead in paints being the usage of lead-based compounds throughout the manufacturing process **(Yusuf, 2017)**. The high occurrence of the three metals (Pb, Cd, Zn) in the particulates samples due to exposure to intense painting vapors, consequently, they represented an integral part of components in several paints, where Pb has anticorrosive properties, help in fast drying and increase durability with fresh appearance, additionally, pigments containing Cd are characterized by bright colors **(Flora et al., 2012)**. The percentage diversity of Pb, Cd, and Zn concentrations in particulate measurement in the workshops is associated with differences in the work environment, including shop size and location, work practices, workload, and chemical structure; solvent type and toxicity;

and the amount, duration, and route of exposure, all of which are unfortunately undetectable due to technical limitations.

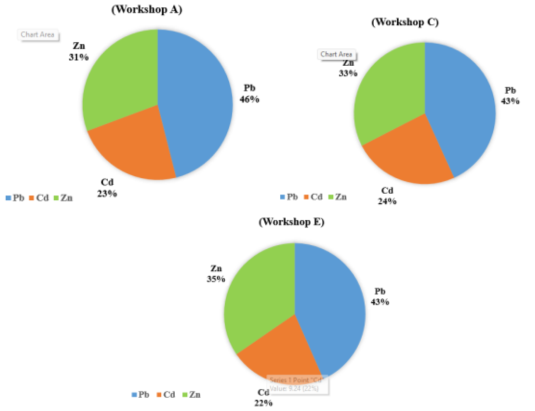

Fig. (11): Distribution of the Heavy Metals, (Pb, Cd, Zn) % in SPM in the Paint Workshops Evaluated (A, C and E).

Because of the risks that pollutants pose to human health and the environment, many countries have implemented regulations to control their emissions. These regulations usually set pollution limits for particular industries, such as painting (**Gupta et al., 2018**).

Conclusion and Recommendation:

The present study focuses on the evaluated the workshops involving spray paint and varnishing based on the concentrations of dust that might generate in paint workshops' indoor air and the metal elements in particles. Data revealed the high variation related to the exposure of spray paintings in furniture workshops could participate in significant elevation of Cd and Pb concentrations in samples obtained from workshops evaluated was explained by the different activities, and the method that each worker utilized the products that every paint workshop is a different setting with varying sizes, locations, and types of chemicals used.

To improve air quality and reduce health impacts in paint workshops, we then recommend increasing local ventilation, replacing solvent-based products with water-based ones, and establishing procedures for keeping the containers closed after use. Spray paint's ingredients must be changed from hazardous to ecologically benign due to environmental concerns

References

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.

Abdrabouh, A. E., Hagras, A. E., Essam, N. M., El-Gammal, M. I. (2023). Related health hazards with occupational exposure to cadmium and lead during spray painting in car and furniture workshops. Journal of Environmental Sciences, 52(3), 1-8.

Agency for Toxic Substances and Disease Registry (ATSDR). (2012). Toxicological profile for Manganese. U. S. Department of Health and Human sciences, Atlanta, GA.

Akafuah, N. K., Poozesh, S., Salaimeh, A., Patrick, G., Lawler, K. and Saito, K. (2016). Evolution of the automotive body coating process-A review. Coating, 6(2), 24.

Black, J. B. (2015). Toxicity value1000 workshop processes practices and materials, 5th ed., 9781138784727. Published by Taylor & Francis.

Chen, Y. C., Lin, C. H., Lung, S. C., Ku-F, C., Wang, W. V., Chou, Cheng-Tai, Lai, C. H. (2019). Environmental concentration of spray paint particulate matters causes pulmonary dysfunction in human normal bronchial epithelial BEAS-2B cell. Process Safety and Environmental Protection, 126, 250-258.

Chong, C. (2020). Comparing Solvent-Based and Water-Based Coatings. 12-16.

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

Core Team R. (2025). A language and environment for statistical computing. R. Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.for Statistical Computing, Vienna, Austria., Version 4.4.3 (2025-02-28), 11-95.

Damietta Governorate (PAISDT). (2023). Public Damietta Governorate Diwan.

Dara, S. S. (1993). "A text-book of environmental chemistry and pollution control". S. Chand & Company LTD, 1st ed., Ram Nagar, New Delhi, India, pp.1-57.

Egyptian Environmental Affairs Agency (EEAA). (1994): Law No. 4, 1994 which was amended by Law No. 9 of 2009 for the Protection of the Environment: Promulgating the environmental law and its executive regulation. Egypt, pp. 53.

EL-Gammal, M. I. (2008). Assessment of formaldehyde, ammonia and wood dust effects on the workers' health during wood working processing. J. Soc. Zool., 56, 261-280.

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.

Flyvholm, M. A. (1991). Contact allergens in registered chemical products. Contact Dermatitis, 25, 49-56.

Gao, X., Yawen, W., Shiqi, P. , Bin, Y., Caimei, F., Weiyi, C. and Xiaona, L. i. (2015). Comparative toxicities of bismuth oxybromide and titanium dioxide exposure on human skin keratinocyte cells. Chemosphere, 135, 83-93.

Garaga, R. (2024). Health Risk Assessment of Different Sources of Metals in PM10 and PM2.5 in the Largest City in Northeast India, Journal Article. Journal of Hazardous, Toxic, and Radioactive Waste, 28 (2).

Gupta, G., Chellappan, D. K., de Jesus Andreoli Pinto, T., Hansbro, P. M., Bebawy, M. and Dua, K. (2018). Tumor suppressor role of miR-503. Panminerva Med., 60, 17-24.

Hafez, N. M. (2017). Environmental hazards arising from the painting processes. Ph. D. Thesis, Faculty of Science, Mansoura University, pp. 65-90.

Hagras, A. E., El-Gammal, M. I., Abdrabouh, A. E. and Essam, N. M. (2017). Exposure to Airborne Particles and Organic Solvents Among Painting Workers. J. Env. Sci., Toxicology and Food Technology, 10, 26-38.

Halmo, L and Nappe, T. M. (2024). Lead Toxicity. Pennsylvania: StatPearls Publication, Treasure Island, chapter 5, Bookshelf ID: NBK541097.

Huang, C. L., Bao, L. J., Luo, P., Wang, Z. Y., Li, S. M., Zeng, E. Y. (2016). Potential health risk for residents around a typical e-waste recycling zone via inhalation of size-fractionated particle-bound heavy metals. J Hazard Mater, 317, 449-456. Hussain, M. Sh. (2024). Chemistry of Paint (1), Experiment Findings. Catalent Cell&Gene Therapy J. DOI: 10.13140/RG.2.2.30304.08963 I 10.1007/s11356-018-2669-8.

Ifjen, I. H., Maliki, M., Odi, H. D., Odiachi, I. J., Aghedo, O. N., Ohiocheoya, E. B. (2022). Review on Solvents Based Alkyd Resins and Water Borne Alkyd Resins: Impacts of Modification on Their Coating Properties. Chemistry Africa. The Tunisian Chemical Society and Springer Nature Switzerland AG, 5 (3).

International Agency for Research on cancer (IARC). (1989). Some organic solvents, resin monomers and related compounds, pigments and occupational exposures in paint manufacture and painting. IARC Monogr. Eval. Carcing. Risks chem. Hum., 47.

Khan, M. R., Ahmad, N., Ouladsmane, M. and 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.

Lai, C. H. and Yan, T. Y. (2016). Characteristics and aerosol size distributions of metal-containing paint particles at a spray-painting workplace RSC Advances, 114 (6), 113754-113761.

Lai, C. H., Lin, C. H., Liao, C. C. (2017). Respiratory deposition and health risk of inhalation of particle-bound heavy metals in the carbon black feeding area of a tire manufacture. Air Qual Atmos. Health, 10, 1281-1289.

Lai, C. H., Lin, C. H., Liao, C.C., Chuang, K. Y., Peng, Y. P. (2018). Effects of heavy metals on health risk and characteristic in surrounding atmosphere of tire manufacturing plant, Taiwan. RSC Adv,, 8, 3041-3050

Lin, C. H., Lai, C. H., Peng, Y. P, Wu, P. C., Chuang, K. Y, Yan, T. Y., Xiang, Y. K. (2018). Comparative health risk of inhaled exposure to organic solvents, toxic metals, and hexavalent chromium from the use of spray paints in Taiwan. Environmental Science and Pollution Research, 33, 33906-33916.

Liu, X., Song, H., Lei, T., Liu, P., Xu, C., Wang, D., Yang, Z., Xia, H., Wang, T., and Zhao, H. (2021). Effects of natural and anthropogenic factors and their interactions on dust events in Northern China. Catena, 196, 104919.

Lu, R., Harigaya, S., Ishimura, T., Nagase, K. Miyakoshi, T. Ishimura, T. (2004). Development of a fast drying lacquer based on raw lacquer sap. Progress in Organic Coatings. 51 (3), 238-243.

Martins, M. E., Priscia, F. B., Neemias, E. S., Paula, T. R., Renata, S. S., Isreal, F., Elisa, R. F., Andreia, S. F., Ronald, S. M., Izabela, B. M. and Sergio, M. C. (2019). BTEX in an occupational environment. Int. J. Environ. Impacts, 2 (2), 174–191.

McKeown, N. J. (2011). Medscape Reference. www.emedicine.com., volume 40, 1193-1205.

National Occupational Health and Safety Commission (NOHSC). (1999). National Guidance Material for Spray Painting, Spray painting and surface coating. Australian workplaces free from injury and disease, Annual Report, 1999-2000, Commonwealth of Australia 2000 ISSN 0818-3627, www.nohsc.gov.au.

National Research Council (NRC). (1991). Public Health and Hazardous Wastes Environmental

Epidemiology. Volume; 1, Research Council (US) Committee on Environmental Epidemiology. Washington (DC): National Academies Press (US).

Pandey, P. K., Patel, K. S. and Šubrt, P. (1998). Trace elemental composition of atmospheric particulate at Bhilai in central-east India. Sci. Total Environ., 215, 123-134.

Plum, L. M., Rink, L. and Haase, H. (2010). The Essential Toxin: Impact of Zinc on Human Health. International Journal of Environmental Research and Public Health (IJERPH), 7 (4), 1342-65.

Ratnasingam, J., Ioras, F., Hunm, O. C., Manikam, M. and Farrokhpayam, S. R. (2009). Dust-emission from abrasive sanding processes in the Malaysian wooden furniture industry. J. Applied Sci., 9, 3770-3774.

Ratnasingam, J., Natthondan, V., Ioras, F. and McNulty, T.(2010). Dust, Noise and Chemical Solvents Exposure of Workers in the Wooden Furniture Industry in South East Asia. J. Appl. Sci., 10 (14), 1413-1420.

Ruan, T. and Rim, D. (2019). Indoor air pollution in office buildings in megacities: effects of filtration efficiency and outdoor air ventilation rates. Sustain Cities Soc., 49, 101609.

SafeWork (NSW). (2022). Spray painting and powder coating. code of practice, 5-54. Website www.safework.nsw.gov.au © Copyright SafeWork NSW 2022.

Schurr, J. M. and Allison, S. A. (1981). Polyelectrolyte contribution to the persistence length of DNA. Journal of Biopolymers, 20, (2), 251-268.

Sefiane, K. (2014). Patterns from drying drops. Journal of Advances in colloid and interface sciences. 206, 372-381.

Simatupang, M. M., Veronika, E., Irfandi, A., Azteria, V. (2024). Potential Impacts of Lead On Health: A Review of Environmental Exposure, Population at Risk, And Toxic Effects. Journal of Environmental Health. 16 (3), 277-288.

Stoye, D. and Freitag, W. (1998). (eds) In: Paints, coatings and solvents. 45-46.

Thorud, S., Merete, G., Ellingsena, Dag G. and Molanderab, P. (2005). Air formaldehyde and solvent concentrations during surface coating with acid-curing lacquers and paints in the woodworking and furniture industry. J. Environ. Monit., 7, 586-591.

Veleva, L. (2012). Protective Coatings and Inorganic Anti-Corrosive Pigments, (Chapter 28), n book: Paint and Coatings Testing Manual Book, MNL 17 (pp.282-299), 2nd ed., Publisher: ASTM International, OH, USA. https://www.researchgate.net/publication/261176552.

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.

World Health Organization (WHO). (2024). Environment, Climate Change and Health department, Air quality, energy and Health Unit, Geneva, 6th ed. (6.1).

Yi-Chun, C., Chia-Hua, L., Shih-Chun, C. L., Ku-Fan, C., Wen-Cheng, V. W., Cheng-Tai, C. and Chia-Hsiang, L. (2019). Environmental concentration of spray paint particulate matters causes pulmonary dysfunction in human normal bronchial epithelial BEAS-2B cell. Process Safety and Environmental Protection, 126, 250-258.

Yusuf, A. (2017). Assessment of Levels of Heavy Metals in Paints from Interior Walls and Indoor Dust from Residential Houses in Nairobi City County, Kenya. Ch. Sci. Int. J., 21 (1), 1-7.

Zhao, F., Huan, M., Liang, Y., Bing, W. and Yuliang, Z. (2015). Nanosurface chemistry and dose govern the bioaccumulation and toxicity of carbon nanotubes, metal nanomaterials and quantum dots in vivo. Science Bulletin, 60 (1), 3-20.

الملخص العربي

عنوان البحث: التركيز البيئي لجسيمات الطلاء وغبار المعادن في ورش طلاء الأثاث

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اهتمت هذه الدراسة بالقياسات البيئية للجسيمات الناتجة عن أعمال الدهانات بورش طلاء الأثاث ، وكذلك قياس العناصر الثقيلة حيث يعتبر غبار الدهانات المتطاير الناتج عن الرش من أهم المخاطر البيئية الناتجة عن ورش دهانات الخشب نظرا لما تحتويه من مذيبات عضوية وعناصر ثقيلة وبالتالي وضع التوصيات والاقتراحات للحد من هذه المخاطر الصحية.

وقد تمت الدراسة والقياسات في ست ورش لدهانات الأثاث (A, B, C, D, E and F) بمدينة دمياط - قرية الشعراء وهى تتسم بورش عمل صغيرة الحجم في اماكن ذات كثافة سكانية عالية والشوارع بينها ضيقة، وقد تمت قياسات جسيمات PM_{10} ، $PM_{2.5}$ باستخدام جهاز قياس الأتربة (كاسيلا). وكذلك تم تجميع عينات من الجسيمات العالقة الكلية (TSP) باستخدام مضخة هواء لأخذ العينات وتم قياس المعادن الثقيلة (الرصاص ، الكادميوم ، الزنك) بالجسيمات العالقة (TSP) باستخدام مطياف الامتصاص الذري (A.A.S). أشارت نتائج الدراسة إلى أن متوسط تركيزات PM_{10} تراوحت بين ٢٦,٨٥ ، ٤٤,٤١ ميكروجرام/م^{٣}، على التوالي. بينما تراوحت متوسط تركيزات $PM_{2.5}$ بين ٣٩,٥ ، ١٢٥ ميكروجرام/م^{٣}، على التوالي. وأوضحت النتائج أن متوسط تركيزات TSP يتراوح بين ٣٥٩ و٤١٠ ميكروجرام/م^{٣}. ورُصدت معظم جسيمات الطلاء (PM) بتركيزات غير مسموح بها. بينما أظهرت النتائج أن متوسط قياس تركيزات المعادن الثقيلة (الرصاص، والكادميوم، والزنك) في ورش طلاء الأثاث فكان (١٤,٥٩، ٧,٥٩، ١٠,٨٢) ميكروجرام/م^{٣}، على التوالي.

وبذلك أوضحت الدراسة بعض التأثيرات البيئية في ورش طلاء الأثاث من خلال التعرض للملوثات منها الجسيمات والعناصر الثقيلة مما يعرض العمال وسكان المناطق المحيطة بالورش لمخاطر التعرض لتلك الملوثات. وبناء على ذلك تم وضع الاقتراحات والتوصيات اللازمة من قبل الدراسة الحالية في محاولة للتقليل من هذا الأثر السلبي حفاظا على بيئة العمل وجودة الهواء والاقلال من الانبعاثات للحد من الآثار البيئية والصحية على العمال وسكان المنطقة الناتجة عن عمليات دهانات الاثاث في بعض الورش بمدينة دمياط.