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Physical properties of dust resulting from cutting some building materials in Baghdad city

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***Abstract*— From a toxicological perspective, particles with diameters less than 10 micrometers are referred to as inhalable particles. These particles possess the capability to penetrate deeply into the respiratory system, resulting in severe health consequences such as lung and respiratory diseases. Exposure to suspended particles has been associated with mortality, heart conditions, and respiratory ailments, particularly among children and the elderly. the study extended over the period of work from September 2022 to February 2023. two construction sites were conducted, each of the construction sites is located in Baghdad. According to the suggested national ambient air quality standards in Iraq (Profile on Environmental and Social Considerations in Iraq 2011) all the average values for PM2.5 exceed the World Health Organization (15µg/m^3) and the Iraqi limit standard (35 µg/m^3). PM10 also exceeds the standard limits of WHO (45 µg/m^3) and the Iraqi limits (150 µg/m^3) The study on Iraqi tile and marble dust particle diameters as physical properties provides valuable insights into the characteristics of these materials. By analyzing the particle sizes, researchers gain a deeper understanding of their behavior, dispersion, and potential applications. The investigation involves some measurements and statistical analysis to establish correlations between particle dimensions and its health impact on tile setters.**

***Keywords*— Air pollution, physical properties, PM 2.5, PM 10.**

I. INTRODUCTION

Air quality indices (AQI) aim at expressing the concentration of individual pollutants on a common scale where effects, usually health effects, occur at a value that is common to all pollutants. Such transformations may make air pollution data seem more accessible, yet this often seems to be done with little understanding of how this information is to be used by society or how well it is understood [1]. There is no (or very limited) information about the health effects of air pollutants in Baghdad City. The current study aimed to treat air pollutants by air quality indexes to provide information about the trend of air pollutants and potential health risks to the residents of Baghdad. These particles are composed of a carbon core upon which high-molecular-weight organic chemical components and heavy metals deposit. One of the most important distinctions of particulate pollution is based on how the particles are introduced into the atmosphere [2]. The production and cutting of tiles at construction sites can generate dust, which may pose health risks to workers if not managed properly. The dust generated during tile manufacturing and cutting is typically composed of fine particles of various materials, such as clay, silica, and other minerals present in the tiles. The potential health effects of exposure to this dust depend on the composition of the materials and the duration and intensity of exposure [3]. Prolonged exposure to dust in the air can cause respiratory difficulties such as coughing, wheezing, and trouble breathing. Workers who are repeatedly exposed without sufficient protection may acquire chronic diseases throughout time [4]. To reduce worker exposure, construction sites must adopt adequate dust management methods. This might involve using local exhaust ventilation systems, wet-cutting processes, and suitable personal protection equipment (PPE) like respirators [5]. From a toxicology view point, the most important particles with diameters less than 10 micrometers are called inhalable particles which are characterized by their ability to penetrate deep into the respiratory system, causing severe health effects that lead to lung and respiratory diseases exposure to suspended particles leads to death, heart and respiratory diseases, especially in children and the elderly [6]. Health risks of particulate matter from long-range transboundary air pollution, genotoxicity and mutagenicity, cytotoxicity and pro-inflammatory and carcinogen induction [7]. Suspended particles negatively affect plants, directly and indirectly, which leads to reduced growth and productivity, and also contributes to the formation of acid rain [8]. and can cause severe damage to artistic works, historical monuments and buildings and lead to a reduction in their aesthetic appearance and life span [9]. The behavior of particles in the atmosphere and within the human respiratory system is determined largely, but not wholly, by their physical properties which have a strong dependence on size, varying from a few nanometres to tens of micrometres. A crude distinction is that particles of less than about 2.5 µm penetrate to the alveoli and terminal bronchioles, larger particles of up to 10 µm will deposit primarily in the primary bronchi and much larger particles (up to 100 µm), will deposit in the nasopharynx [10]. The

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construction sector has been a focal point for reconstruction following years of conflict and instability. Efforts are being made to rebuild damaged or destroyed structures and create new, modern facilities that meet international standards [11]. Iraq has been investing heavily in infrastructure projects, including roads, bridges, airports, and utilities. These projects aim to improve connectivity and enhance the overall quality of life for its citizens. With a growing population, there is a demand for residential properties. The construction industry is addressing this demand through the development of housing projects, both in urban and rural areas [12]. The construction industry is a significant contributor to employment in Iraq. The demand for skilled and unskilled labor has increased, providing job opportunities for the local workforce [11]. The role of construction activities in contributing to air pollution within urban environments, particularly in cities as large and densely populated as Baghdad, is substantial and critically relevant when assessing the health impacts on construction workers. This elucidates how construction sites become significant sources of airborne contaminants and how these emissions potentially affect the health of workers on-site [13]. Construction in urban settings involves various operations that inadvertently release pollutants into the atmosphere. These processes include land excavation, material transportation, equipment usage, and building demolition, among others. One of the most pervasive pollutants emanating from construction sites is particulate matter (PM), an assortment of fine particles and droplets suspended in the air. PM is categorized by size; PM10 and PM2.5 are especially harmful due to their ability to penetrate deep into the respiratory tract. Diesel engines, commonly used in construction machinery and vehicles, are a notable source of these fine particles [14]. Research has demonstrated that construction workers are at a higher risk of developing chronic respiratory diseases due to their prolonged exposure to contaminated air at construction sites [15]. Continuous inhalation of PM and other harmful substances can lead to reduced lung function, chronic bronchitis, and other obstructive pulmonary diseases. It is not uncommon for construction workers to experience symptoms such as coughing, wheezing, and shortness of breath post-exposure [16].

II. MATERIALS AND METHODS

A. Field of the Study

The field study was conducted at two construction sites; the study extended over the period of work from September 2022 to February 2023. Each of the construction sites is located in Baghdad.

B. Dust Samples Collection and Devices

Low Volume Sampler (Sniffer)

Air dust samples were collected using specific filters (Rade Co, LLC) with a low-volume sampler (Sniffer air vacuum sampler) of US origin. Before sampling, cellulose filters were dried in an oven for 15 minutes at 80 °C and weighed to record the initial weight (W1) with an accurate balance, then placed in a sealed container and prepared to be utilized at the sample location. In the sampling location, the filter was placed in the sampler device and put on a table near the cutting tile process elevated (1m) above the floor level and (1m) away from the tile's dust as adapted by a research done in biology department at university of Baghdad [17]. Three samples (1 sample for Iraqi mosaic tile cutting during summer and during winter, 1 sample for marble cutting) have been collected at each location. Each sample collected for 60 minutes. During sampling, the volume of air is recorded at the beginning of sampling time (V1) and at the end of sampling time (V2), and the latter volumes are used to estimate the total volume of air at a given time (Vt). At the last stage of the sampling process, the exposed filter was withdrawn from the sampler and weighed in the laboratory; this weight indicates the final weight (W2).

C. Laboratory Work

The air samples collected from construction sites, in addition to settled dust samples which were collected from the cutting tile process, were examined in the laboratories of the Environmental Research Center, at the Iraqi Ministry of Science and Technology. All samples followed the same analysis procedures in order to determine the physical properties and chemical constituents.

D. Determination of Iraqi tile and marble dust particle diameters as physical properties

The study on Iraqi tile and marble dust particle diameters as physical properties provides valuable insights into the characteristics of these materials. By analyzing the particle sizes, researchers gain a deeper understanding of their behavior, dispersion, and potential applications. The investigation involves some measurements and statistical analysis (like Dosimetry parameters such as deposition, clearance, retention, and translocation and dissolution of inhaled particles in and to different lung com-partments may be important for the persistence of particles in the lung and may correlate with adverse pulmonary effects [18] to establish correlations between particle dimensions and its health impact on tile setters. Static Image Analysis have been used to Captures images of particles on a slide and analyzes their dimensions. This technique is useful for powders, suspensions, and creams.

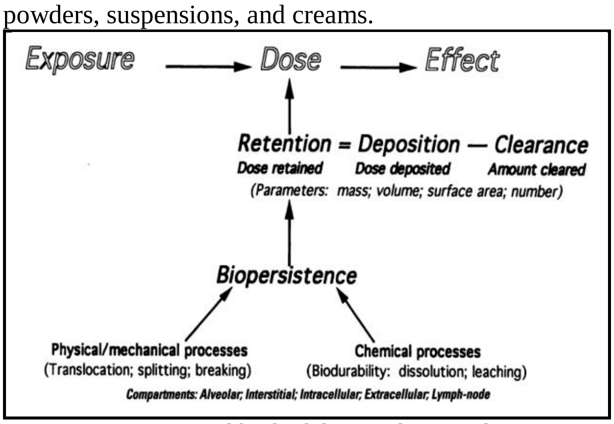

Fig. 1: Biopersistence and biodurability in relation to dose parameters for exposure-dose-effect relationships ofinhaled nonfibrous and fibrous particles.

III. RESULTS AND DISCUSSION

Studies indicate a strong link between particulate matter (PM10) pollution and negative human health outcomes. PM10 is an air pollutant that can impair human health [19]. In general, only fine dust particles pose a health risk. Dust particles that are PM10 or smaller are likely to have the biggest health effects since they may penetrate deep into the lungs. Particles bigger than PM10 are often held in the nose, mouth, throat, or main bronchi before exiting the body[20]. According to the suggested national ambient air quality standards in Iraq (Profile on Environmental and Social Considerations in Iraq 2011) all the average values for PM2.5 exceed the World Health Organization (WHO) and the Iraqi limit standard (10 µgm). PM10 also exceeds the standard limits of WHO (20 µgm) and the Iraqi limits (50 - 3 µgm) [21]. PM2.5 mass concentrations in Baghdad have been measured and found to be higher than the PM level that is recommended by “WHO” (10 µg m−3), and the limit of the “National Ambient Air Quality Standards (NAAQS)- U.S. Environmental Protection Agency (USEPA)” (12 µg m−3) [22].

Scanning electron microscope analyses of the dust studied here provided data on the composition of the tile and marble, including chemistry, sizes, forms, way of distribution and, partly, proportions of the individual pad constituents [23]. The examination of (SEM) for dust (tile and marble) showed that some particles had smooth edges (nearly spherical) and others had few sharp edges (amorphous shape), as shown in Figures (1, 2, 3 and 4), some particles were less than (2.0 µm) in diameter and others were larger. This result agreed with another study done by [24]. Depending on the particle size particulate matter (PM) is classified into:

(i) coarse particles, PM10 of diameter <10 µm;
(ii) fine particles, PM2.5 of diameter <2.5 µm; and
(iii) ultrafine particles, PM0.1 of diameter <0.1 µm.
PM is especially concerning, as it is sometimes inhalable, affecting the lungs and heart and causing serious health effects.

It has been shown that indoor PM levels often exceed outdoor ones [25]. Ramkissoon, et al(2022). observed that dry-cutting engineered particles under an SEM image can also easily be seen that the larger particles “attract” to smaller fractions to their surfaces. This is relevant when considering that inhalable particle fractions smaller than 100 µm may “carry in” significant amounts of smaller particulates and enter a body by respiration or gastrointestinal tract after swallowing larger particles. In alignment with previous reports of the composition of respirable dust from machined artificial/engineered stones, the current engineered stone emissions consisted generally of > 80% by weight crystalline silica and 8–20% resin [26]. Nonetheless, the high concentration of crystalline silica in the respirable dust from engineered stones may be cause for concern as quartz and cristobalite are the only crystalline silica minerals recognized as Group 1 carcinogens—“carcinogenic to humans”—by the “International Agency for Research on Cancer” [26]. During the specific application of nanoparticles, exposure can result in the inhalation of nanoparticles or absorption through direct contact with unprotected skin. The effects of this exposure are poorly understood requiring research to expand on the interactions between organic materials and nanoparticles. Studies on the inhalation of various common nanoparticles by mice have yielded insights into the potential adverse effects of exposure; however, the generalization of the results is limited by the experimental subject. Some of the health implications of nanoparticles to human organs [27] [28, 29]. A powerful tool that can contribute significantly to our knowledge of the physical and chemical characteristics of the marble and tile particles is electron microscopy including scanning electron microscopy. Electron microscopy provides particle sizes as these are physically measured on SEM thus offering a concrete and clear picture of the particles [30]. SEM pictures showed particle size (tile and marble) in the nanometer and micrometer range.

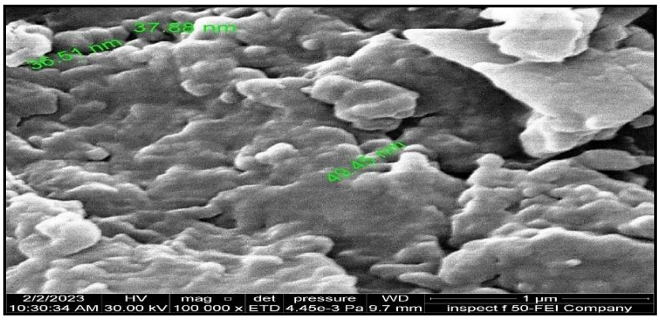

Fig. 2: Scanning electron microscopy pictures of tile particles in semi-spherical shape (100 000x magnification).

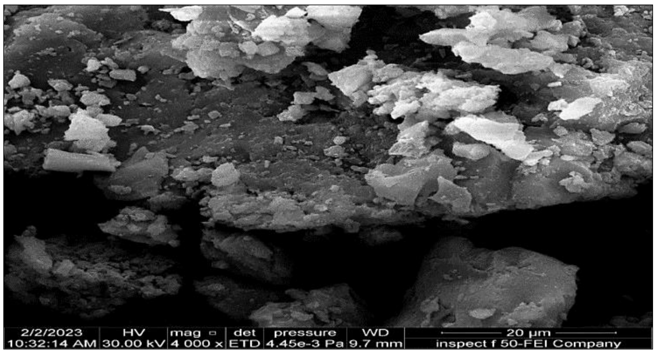

Fig. 3: Scanning electron microscopy pictures of tile particles Sharp edge (4 000 X magnification).

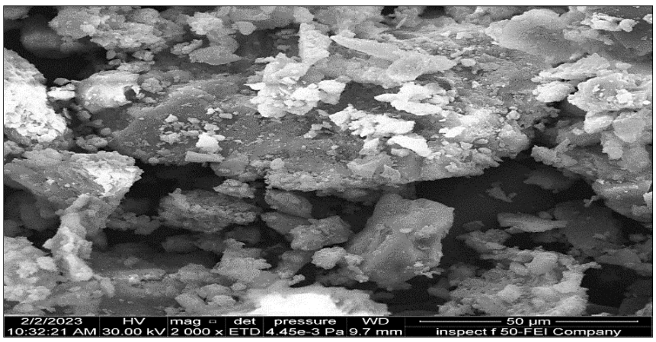

Fig. 4: Scanning electron microscopy pictures of tile particles with amorphous shape, Sharp edge (2 000 X magnification).

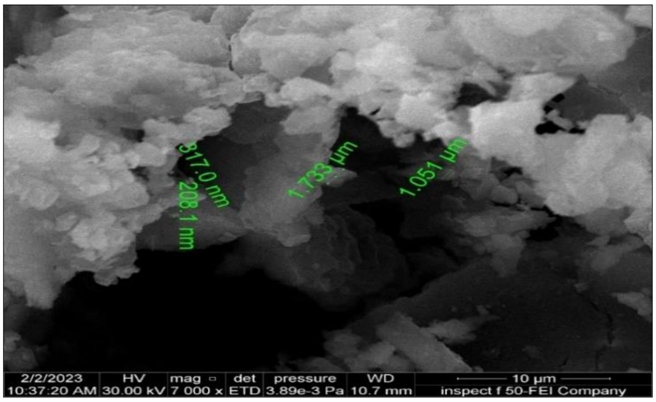

Fig. 5: Scanning electron microscopy pictures of marble particles accumulation semi-spherical aggregated in shape (7 000 X magnification).

Table 1: number and percentage of particles (tile and marble) of samples used in this study.

	(Particles ≤1μm)	(Particles between1-5μm)	(Particles ≥5 μm)	total
Tile	3	0	0	3
Marble	2	2	0	4
Percentage	71.4%	28.5%	0%	

The results of the current study show that the accurate brake pad particle percentage (%) was calculated by using Scanning electron microscopy for different sizes (particle ⩽ 1, particle between 1-5, particle ⩾5) µm, Table (3-1).

1- Particle ⩽ 1----- (71.4) %.
2- Between (1-5) ----- (28.5) %.
3- Particle ⩾ 5----- (0) %.

Our results suggest investigating in detail the health effects of the prolific environmental release of micro and sub-micron-sized particles from tile and marble. If these effects are clearly established as adverse, the release in the atmosphere of the tile and marble should be hindered by the use of noxious particles hazardous carefully in order to avoid an environmental and occupational exposure with a risk on human health, in particular, for people vulnerable.

The discussion of the results presented in the previous section pertains to two main grounds. Firstly, the implications of the evolution of the phases based on the tile and marble cutting needs to be discussed, since the emission of the coarse and fine airborne particles through different processes in the dust deposit mild wear regime constitutes up to 71.4% of the total particle production.

Secondly, on the basis of the characterization methodology adopted to study the particles having a size range driving significant health issues and constituents, that has been of recent interest due to its adverse effects on humans [26] and other life forms [31].

Table 2, represents the elemental composition of a material, with data provided for each element in terms of atomic percentage, atomic percentage error, weight percentage, and weight percentage error. Results of carbon makes up approximately 19.1% of the atoms in the material, with a margin of error of 3.2%. In terms of weight, carbon contributes around 11.9% to the total weight of the material, with an error of 2.0%. Oxygen is the most abundant element in the material, constituting approximately 62.0% of the atoms, with a 6.9% error. In terms of weight, oxygen contributes around 51.3% to the total weight, with a 5.7% error. Sodium makes up a small percentage of the atoms (1.1%) and weight (1.3%) in the material, with relatively low errors. Similar to sodium, magnesium constitutes a small portion of both the atoms (1.0%) and weight (1.3%) in the material. Aluminum makes up a relatively small percentage of both the atoms (0.5%) and weight (0.8%) in the material, with low errors. Lastly, Calcium constitutes a significant portion of both the atoms (16.2%) and weight (33.5%) in the material, with relatively low errors.

Table 2: Elemental Composition Analysis with Atomic and Weight Percentages in Site 1.

Element	**Atomic %**	**Atomic % Error**	**Weight %**	**Weight % Error**
C	19.1	3.2	11.9	2.0
O	62.0	6.9	51.3	5.7
Na	1.1	0.4	1.3	0.5
Mg	1.0	0.3	1.3	0.4
Al	0.5	0.2	0.8	0.3
Ca	16.2	0.7	33.5	1.4

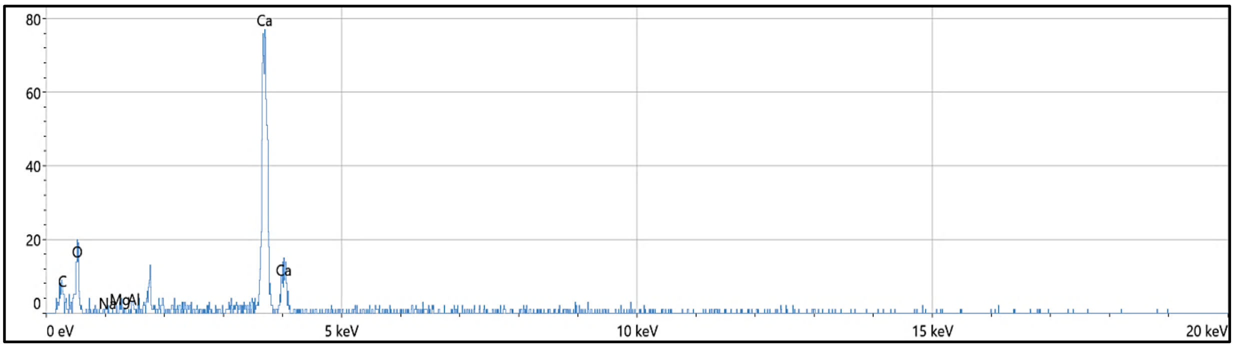

Fig. 6: SEM analysis shows the elemental compositions of the Iraqi mosaic tile dust.

Table 3, shows that Carbon constitutes approximately 17.8% of the atoms in the material, with a measurement error of 3.3%. In terms of weight, carbon contributes around 10.7% to the total weight of the material, with a measurement error of 2.0%. Oxygen is the most abundant element in the material, constituting approximately 62.1% of the atoms, with a measurement error of 6.1%. In terms of weight, oxygen contributes around 49.7% to the total weight of the material, with a measurement error of 4.9%. Magnesium makes up a small percentage of both the atoms (0.7%) and weight (0.8%) in the material, with relatively higher errors compared to carbon and oxygen. Calcium constitutes a significant portion of both the atoms (19.4%) and weight (38.8%) in the material, with relatively low errors compared to magnesium.

Table 3: Elemental Composition Analysis with Atomic and Weight Percentages in Site 2.

Element	Atomic %	Atomic % Error	Weight %	Weight % Error
C	17.8	3.3	10.7	2.0
O	62.1	6.1	49.7	4.9
Mg	0.7	0.5	0.8	0.6
Ca	19.4	0.9	38.8	1.7

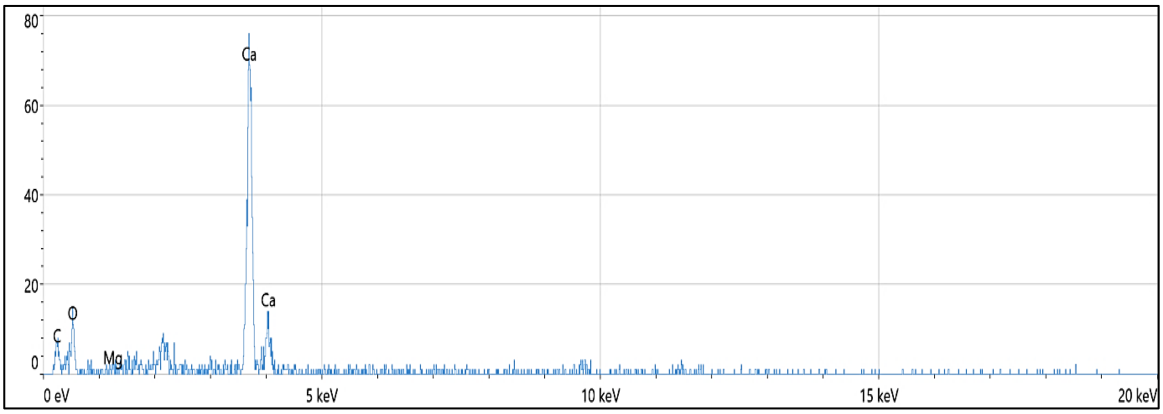

Fig. 7: SEM analysis shows the elemental compositions of the marble dust.

using a scanning electron microscope of the type SEM-thermo scientific with an accelerating voltage of 30 keV. The elemental percentages of the marble are tabulated in Table 3. Marble dust is the result of cutting and cleaning natural marble and it is obtained from marble factories. It has many risks to humans when inhaled; therefore, its safety conversion is an environmental necessity. In this work, it was added as a percentage to form the tile composites used for radiation shielding, especially at low energies. The SEM imaging analysis of marble dust was performed before the preparation of the composites, as shown in Figure 7.

IV. CONCLUSION

SEM pictures showed particle size (tile and marble) in the nanometer and micrometer range. Most frequent were semi-spherical agglomerates. Marble dust is the result of cutting has much risks to humans when inhaled than Iraqi-tile cutting dust. Most frequent were semi-spherical agglomerates. No fibers could be detected and the particle number concentrations distribution, with a maximum diameter at (1.051–1.733) µm. The main component of marble dust is calcium carbonate (CaCO3). particles had smooth edges (nearly spherical) and others had few sharp edges (amorphous shape), some particles were less than (2.0 µm) in diameter.

CONFLICT OF INTEREST

Authors declare that they have no conflict of interest.

REFERENCES

[1] R. Albarakat and V. Lakshmi, "Monitoring dust storms in Iraq using satellite data," *Sensors*, vol. 19, p. 3687, 2019.

[2] B. Bessagnet, N. Allemand, J.-P. Putaud, F. Couvidat, J.-M. André, D. Simpson, *et al.*, "Emissions of carbonaceous particulate matter and ultrafine particles from vehicles—a scientific review in a cross-cutting context of air pollution and climate change," *Applied Sciences*, vol. 12, p. 3623, 2022.

[3] C. Z. Li, Y. Zhao, and X. Xu, "Investigation of dust exposure and control practices in the construction industry: Implications for cleaner production," *Journal of Cleaner Production*, vol. 227, pp. 810-824, 2019.

[4] M. Lestari, P. Fujianti, N. Novrikasari, and R. F. Nandini, "Dust Exposure and Lung Function Disorders," *Respiratory Science*, vol. 3, pp. 218-230, 2023.

[5] Q. Luo, L. Huang, X. Xue, Z. Chen, F. Zhou, L. Wei, *et al.*, "Occupational health risk assessment based on dust exposure during earthwork construction," *Journal of Building Engineering*, vol. 44, p. 103186, 2021.

[6] M. Krzemińska-Flowers, H. Bem, and H. Górecka, "Trace Metals Concentration in Size-Fractioned Urban Air Particulate Matter in Łódź, Poland. I. Seasonal and Site Fluctuations," *Polish Journal of Environmental Studies*, vol. 15, 2006.

[7] R. Maynard, "Environmental toxicants: human exposures and their health effects," ed: BMJ *Publishing Group Ltd*, 2000.

[8] S. K. Prajapati, "Ecological effect of airborne *particulate matter on plants*," 2012.

[9] L. Jimoda, "Effects of particulate matter on human health, the ecosystem, climate and materials: a review," *Facta universitatis-series: Working and Living Environmental Protection,* vol. 9, pp. 27-44, 2012.

[10] G. Bagheri, O. Schlenczek, L. Turco, B. Thiede, K. Stieger, J.-M. Kosub*, et al.*, "Exhaled particles from nanometre to millimetre and their origin in the human respiratory tract," *medRxiv,* p. 2021.10. 01.21264333, 2021.

[11] Z. M. Hatem, M. M. Alsamarraie, A. Y. Flaih, and A. M. Oda, "Barriers to the adoption of industrialized building system in Iraqi construction industry," *Zanco Journal of Pure and Applied Sciences,* vol. 33, pp. 30-42, 2021.

[12] H. Al-Lami, N. N. Al-Mayyahi, Q. Al-Yasiri, R. Ali, and A. Alshara, "Performance enhancement of photovoltaic module using finned phase change material panel: An experimental study under Iraq hot climate conditions," *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects,* vol. 44, pp. 6886-6897, 2022.

[13] M. M. Mohsin, T. Beach, and A. Kwan, "Consensus-based urban sustainability framework for Iraqi cities: A case study in Baghdad," *Heliyon,* vol. 6, 2020.

[14] T. Schneider, D. H. Brouwer, I. K. Koponen, K. A. Jensen, W. Fransman, V. Duuren-Stuurman*, et al.*, "Conceptual model for assessment of inhalation exposure to manufactured nanoparticles," *Journal of exposure science & environmental epidemiology,* vol. 21, pp. 450-463, 2011.

[15] S. Yang, J. Liu, X. Bi, Y. Ning, S. Qiao, Q. Yu*, et al.*, "Risks related to heavy metal pollution in urban construction dust fall of fast-developing Chinese cities," *Ecotoxicology and Environmental Safety,* vol. 197, p. 110628, 2020.

[16] T. Yang, R. Chen, X. Gu, J. Xu, L. Yang, J. Zhao*, et al.*, "Association of fine particulate matter air pollution and its constituents with lung function: The China Pulmonary Health study," *Environment international,* vol. 156, p. 106707, 2021.

[17] S. Hammoudeh, W. Gadelhaq, and I. A. Janahi, "Asthma Among Arab Nations: An Overview," *Handbook of Healthcare in the Arab World,* pp. 2827-2854, 2021.

[18] G. Oberdörster, J. Ferin, and B. E. Lehnert, "Correlation between particle size, in vivo particle persistence, and lung injury," *Environmental health perspectives,* vol. 102, pp. 173-179, 1994.

[19] S. N. M. Tarmizi, A. Asmat, and S. M. Sumari, "Temporal and spatial PM10 concentration distribution using an inverse distance weighted method in Klang Valley, Malaysia," in *IOP conference series: earth and environmental science*, 2014, p. 012048.

[20] M. E. Al-Defiery, S. J. Hadi, and A. A. R. Hassan, "Monitoring of PM10 concentrations on Babylon province, Iraq," *Mesopotamia Environmental Journal (mesop. environ. j) ISSN: 2410-2598,* vol. 2, pp. 47-56, 2016.

[21] S. H. Ali, M. A. Najemaden, and R. T. Ahmed, "Using GIS techniques for mapping the pollution of particulate materials in Kirkuk," *Sustain Resour Manag J,* vol. 3, pp. 58-66, 2018.

[22] A. J. Al-Yasiri, "Iraq's Post-2003 Environmental Pollution: Issues And Solutions," *Akkad Journal Of Contemporary Economic Studies,* vol. 1, pp. 1-16, 2021.

[23] P. Dimopoulos Eggenschwiler, D. Schreiber, V. Papetti, S. Gramstat, and D. Lugovyy, "Electron Microscopic Characterization of the Brake Assembly Components (Disc and Pads) from Passenger Vehicles," *Atmosphere,* vol. 13, p. 523, 2022.

[24] V. V. Tran, D. Park, and Y.-C. Lee, "Indoor air pollution, related human diseases, and recent trends in the control and improvement of indoor air quality," *International journal of environmental research and public health,* vol. 17, p. 2927, 2020.

[25] H. Sadeghi, "The effect of indoor air quality on health and performance of labors in joinery factories," *The British University in Dubai*, 2020.

[26] C. Ramkissoon, S. Gaskin, L. Thredgold, T. Hall, S. Rowett, and R. Gun, "Characterisation of dust emissions from machined engineered stones to understand the hazard for accelerated silicosis," *Scientific Reports,* vol. 12, p. 4351, 2022.

[27] H. L. Karlsson, P. Cronholm, J. Gustafsson, and L. Moller, "Copper oxide nanoparticles are highly toxic: a comparison between metal oxide nanoparticles and carbon nanotubes," *Chemical research in toxicology,* vol. 21, pp. 1726-1732, 2008.

[28] F. Usman, B. Zeb, K. Alam, Z. Huang, A. Shah, I. Ahmad*, et al.*, "In-depth analysis of physicochemical properties of particulate matter (PM10, PM2. 5 and PM1) and its characterization through FTIR, XRD and SEM–EDX Techniques in the Foothills of the Hindu Kush Region of Northern Pakistan," *Atmosphere,* vol. 13, p. 124, 2022.

[29] D. A. Aloraini, M. Elsafi, A. H. Almuqrin, S. Yasmin, and M. Sayyed, "Synergistic effect in ionizing radiation shielding with recent tile composites blended with marble dust and BaO micro/nanoparticles," *Crystals,* vol. 13, p. 1057, 2023.

[30] N. Ali, I. Adil, A. Magsi, and E. Asif, "Particle size, morphology and characterization of indoor and outdoor airborne particulate matter for toxic metals in Karachi," *International Journal of Environmental Science and Technology,* vol. 17, pp. 3969-3982, 2020.

[31] G. M. Ingo, C. Riccucci, G. Pisani, M. Pascucci, D. D'Ercole, E. Guerriero*, et al.*, "The vehicle braking systems as main source of inhalable airborne magnetite particles in trafficked areas," *Environment International,* vol. 158, p. 106991, 2022.