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Original Article

Assessment of dust concentrations and chemical composition among exposed workers during low-rise building construction

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ABSTRACT

Introduction: Construction processes generate diverse types of dust. This study aimed to specify the concentration of Total dust (TD), Respirable dust (RD), and Particulate matter less than 2.5 ($PM_{2.5}$) among exposed workers and to identify the chemical composition contained in dust.

Methods: A cross-sectional study; TD, RD, and $PM_{2.5}$ were personally collected among the workers during the low-rise building construction processes according to NIOSH 0500, NIOSH 0600, and EPA-IP-10A, respectively, from January to June 2022. The concentrations of dust were analyzed by gravimetric method. The element and chemical composition were determined using X-ray diffraction and ICP-OES. One-way ANOVA was used to test the different concentrations of dust.

Results: The mean concentrations (GM ± GSD) were 1.43 ± 0.55 mg/m^3 of TD, 1.08 ± 0.33 mg/m^3 of RD, and 0.84 ± 0.25 mg/m^3 of $PM_{2.5}$. The dust concentrations were not significantly different between sites for TD ($p = 0.086$), RD ($p = 0.124$), $PM_{2.5}$ ($p = 0.065$), and TD and RD concentrations met the standard regulated by OSHA. The XRD pattern presented peaks of aluminum oxide, calcite, ferric oxide, magnesium oxide, and amorphous silica. Ca was the highest concentration of all dust types, followed by a little Fe, Al, and Mg, like those found in cement powder. Concrete drilling generated the highest dust concentration, followed by sweep cleaning tasks.

Conclusion: Construction workers are exposed to many chemicals in a dusty working environment. Assessing dust concentrations and their physicochemical properties is an imperative tool for improving safety in construction industries.

Keywords: Construction worker, Dust, Hazard assessment, Low-rise building, Physicochemical characteristics

Introduction

Numerous buildings are constructed to support economic growth and urban expansion. Over the past ten years, fifty percent of the buildings in Thailand have been built in Bangkok, the capital city. The building constructions are divided into high-rise and low-rise buildings, which consist of four major processes: demolition, earthworks, construction, and track out.[1] Under construction, several tasks produce a high concentration of dust consisting of cement mixing, concrete making, brick and concrete cutting, inner wall construction, concrete drilling, and grinding.[2] Health and Safety Executive states that construction dust is not just a nuisance of dust; it is small and rich in chemical composition. Inhaled building construction dust can cause health effects like other airborne particulate matter, leading to respiratory organs and lung diseases.[3]

In the surroundings of the building construction sites, the concentration of several dust types was performed. Total suspended particle (TSP), PM_{10}, and $PM_{2.5}$ were found to be 0.058, 0.016, and 0.007 mg/m^3 respectively; in the construction sites, PM_{10} was found to be in a range of 0.02 – 0.17 mg/m^3, RD was found to be 0.095 mg/m^3, PM_{10} and $PM_{2.5}$ were found to be 7731.32 and 532.14 µg/m^3.[4,5,6,7] For specific tasks during construction, the TSP concentration found in the concrete mixing (2.24 mg/m^3) and dismantling (1.20 mg/m^3).[8] For the personal air sampling found RD concentration in concrete/brick cutting (0.19 – 62.72 mg/m^3), plastering (0.002 – 1.07 mg/m^3), bricklaying (0.025 – 9.1 mg/m^3), and other work tasks (0.015 – 2.0 mg/m^3).[9,10]

Apart from particle size and concentration, chemicals contained have an impact on worker health as well. Construction dust is rich in chemical composition. The study in China found that the elements Ca, Al, and Fe were the most abundant urban fugitive from construction dust samples.[11] Consisted with another study in China that found Al, Mg, Fe, and K were crustal elements found in PM_{10} and $PM_{2.5}$ of construction dust.[12] Inhalation of Ca can cause respiratory irritation and lung damage, Fe (iron) causes respiratory health.[13,14]

Al causes respiratory irritation, Alzheimer's, and multiple sclerosis and Mg cause adverse respiratory health effects.[15,16] Despite enhancements in construction methods, materials, equipment, and workplace safety, the construction industry is among the most dangerous industries. Construction workers are exposed to multiple risks at work, especially; when they are exposed to many kinds of chemicals in air-polluted dusty environments. Due to poor environmental conditions at work sites and the unawareness of workers, the chance of diseases was high.[17]

As mentioned above, the studies of construction dust mainly focus on concentrations of different sizes of dust but rarely mention its chemical composition, especially direct exposure of the workers.[17] Besides, the previous study by Pusapukdepop et al. stated that dust released from the construction stage of a high-rise building greatly impacts the human respiratory system.[1] To our knowledge, the study of low-rise building construction is rare. Therefore, with a different perspective type of building, the low-rise building constructions in Bangkok were chosen in this present study. In this context, collecting the actual personal inhaled dust, including TD, RD, and $PM_{2.5}$, among construction workers involved in the main tasks of building construction. In addition, all types of collected dust were taken to analyze the element and chemical composition. This way was unique and consistent with the lack of study, as we were concerned about the impact of dust exposure.

Methods

In this study, 6 low-rise buildings constructed with a height of not more than 23 meters (8-9 floors) and within structural and finishing works in Bangkok, Thailand, were chosen. According to the National Institute for Occupational Safety and Health occupational exposure sampling strategy manual (NIOSH, 1977), 15 workers per site were selected. The eligibility criteria include males and females aged 18 years and older with active in construction work. Therefore, almost 90 workers were selected by accidental sampling. The workers were informed to participate and signed the informed consent before dust sampling. In this study, the ethics in accordance with the Declaration of Helsinki was approved (COA No. 095/2564, dated 17 September 2021) by the Human Research Ethics Committee of Thammasat University (Science).

The personal air sampling was collected from January to June 2022. According to the occupational exposure sampling strategy manual, NIOSH method 0500; MCE Filter, 5 micrometers (µm), 37 millimeters (mm), placed in a three-piece cassette connected with the air sampling pump at 2.0 liters per minute (L/min) for TD, NIOSH method 0600; MCE Filter, 5 µm, 37 mm, placed in closed-faced cassette conjunction with a 10 mm aluminum cyclone, connected with the air sampling pump at 2.5 L/min for RD, and EPA IP-10A; MCE Filter, 0.8 µm, 37 mm, placed in a size-specific impaction of particulate matter, connected with the air sampling pump at 4 L/min for $PM_{2.5}$. The personal air sampling pumps (SKC Air Check TOUCH) were calibrated pre-sampling and post-sampling, and the value was accepted within ± 5%. The MCE filters were desiccated 24 hours before and after sampling and weighed three times, and the average was used. Three types of dust sampling were performed in entire shifts at the breathing zones of each worker at the same time, and two field banks per set were prepared. The dust concentration was expressed as mg/m^3. One-way ANOVA was used to analyze the different concentrations of dust at a significant level of 0.05.

Five filter samples from each of the 6 construction sites (30 samples) were systematically selected to determine the XRD pattern of element compositions using the X-ray diffraction (XRD) series Bruker D8 advanced X-ray diffractometers. Other 30 samples were systematically selected, taken to digest, and analyzed for the concentration of chemical composition. The samples were subjected to wet with 5 milliliters (ml) of nitric acid analytical grade and digested on a slow-heating hot plate until nearly dry, made cool down, adjusted the volume with distilled water to 25 ml. The chemicals were analyzed by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) series Optima 2100DV, with the Perkin Elmer Winlab32 TM software, and presented in mg/m^3 of air.

Results

Six low-rise building construction sites in Bangkok were selected based on their qualifications. The sites were named B1, B2, B3, B4, B5, and B6. The tasks in each construction site consisted of (1) column casting (24%), (2) cutting wire and steel rod bundle (25%), (3) masonry and plastering (11%), (4) concrete drilling (16%), and (5) sweep cleaning (24%). The total number of personal air sampling was 90, as presented in Table 1.

Table 1: Detail of the tasks in the construction sites

Tasks	Tasks descriptions	TD: RD: $PM_{2.5}$
(1)	Column casting (cement mixing, dismantling wood block)	21: 21: 21
(2)	Cut wire and steel rod and bundle	25: 25: 25
(3)	Masonry and Plastering (cement mixing, brick cutting and laying)	9: 9: 9
(4)	Concrete drilling (drilling wall)	14: 14: 14
(5)	Sweep cleaning (sweeping, moving work)	21: 21: 21

Based on the data distribution with the outliers, the concentrations of TD, RD, and $PM_{2.5}$ for different sites and types of dust were described in terms of the geometric mean (GM), the geometric standard deviation (GSD), and the range. The mean concentration (GM ± GSD) of TD, RD, and $PM_{2.5}$ was found to be 1.43 ± 0.55 with a range of 0.82 – 3.66 mg/m^3, 1.08 ± 0.33 with a range of 0.58 – 2.09 mg/m^3, and 0.84 ± 0.25 with a range of 0.43 – 1.67 mg/m^3, respectively. Overall, the highest concentration of all dust types was found in construction site B2, as presented in Table 2. However, TD and RD concentrations did not exceed the standard regulated by OSHA at 15 mg/m^3 and 5 mg/m^3. Nevertheless, $PM_{2.5}$ has not yet been established as a standard.

The concentration level of building construction dust was transformed into Log-normal and tested for the differences within and between groups. The result showed that the concentrations of dust were not different for TD ($F = 2.006$, $df = 89$, $p = 0.086$), RD ($F = 1.791$, $df = 89$, $p = 0.124$), and $PM_{2.5}$ ($F = 2.255$, $df = 89$, $p = 0.065$).

Table 2: Concentration level of building construction dust

Sites	Total dust (mg/m³)		Respirable dust (mg/m³)		$PM_{2.5}$ (mg/m³)	
	GM ± GSD	Range	GM ± GSD	Range	GM ± GSD	Range
B1	1.37 ± 0.73	0.82 – 2.95	1.01 ± 0.44	0.60 – 2.02	0.79 ± 0.36	0.43 – 1.65
B2	1.69 ± 0.57	1.27 – 3.48	1.23 ± 0.30	1.01 – 1.87	0.95 ± 0.18	0.79 – 1.42
B3	1.29 ± 0.30	0.90 – 2.07	1.02 ± 0.21	0.73 – 1.55	0.83 ± 0.17	0.61 – 1.07
B4	1.26 ± 0.83	0.85 – 3.66	0.90 ± 0.43	0.58 – 2.09	0.72 ± 0.33	0.43 – 1.67
B5	1.46 ± 0.40	1.03 – 2.33	1.11 ± 0.30	0.86 – 1.85	0.85 ± 0.22	0.72 – 1.49
B6	1.55 ± 0.20	1.21 – 1.89	1.15 ± 0.18	0.87 – 1.51	0.93 ± 0.14	0.72 – 1.26
Total	1.43 ± 0.55	0.82 – 3.66	1.08 ± 0.33	0.58 – 2.09	0.84 ± 0.25	0.43 – 1.67

Considering the task performed, concrete drilling (Task 4) demonstrated the highest average concentration of all dust types at TD of 1.97 ± 0.48 mg/m³, RD of 1.39 ± 0.34 mg/m³, and $PM_{2.5}$ of 1.05 ± 0.25 mg/m³, while cutting wire and steel rod and bundle (Task 2) showed the lowest average concentration of all dust types at TD of 1.25 ± 0.29 mg/m³, RD of 0.97 ± 0.19 mg/m³, and $PM_{2.5}$ of 0.74 ± 0.18 mg/m³, as presented in Figure 1.

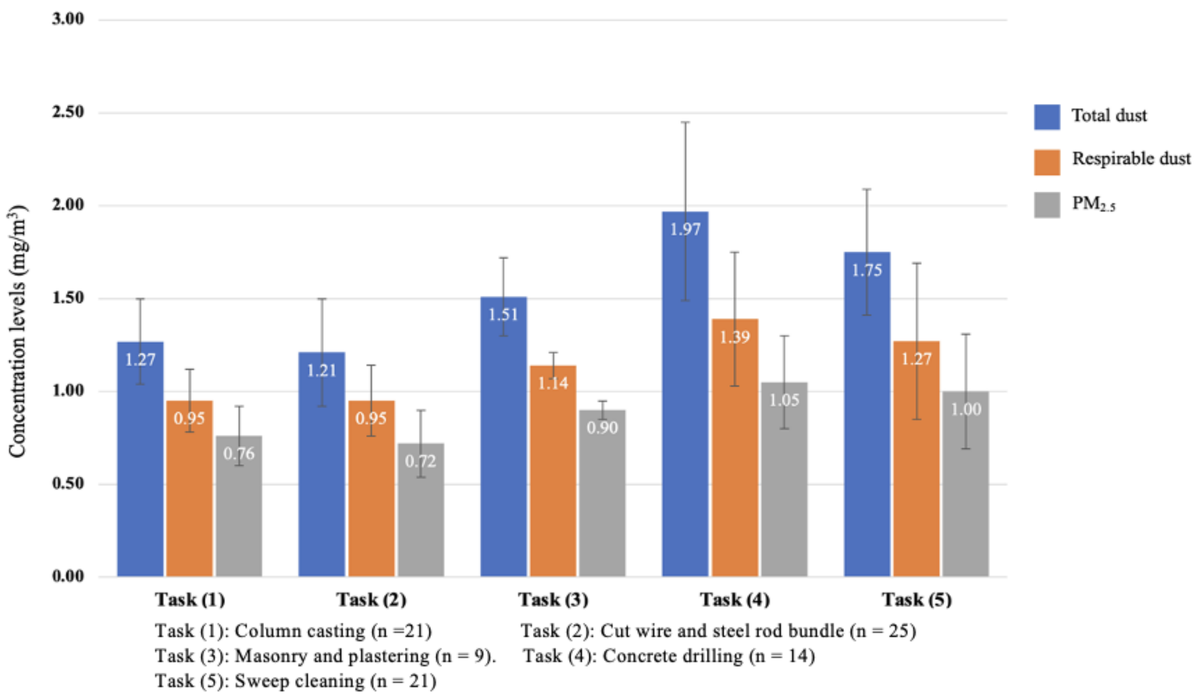

Figure 2: Average concentration level of TD, RD, and $PM_{2.5}$ by tasks

In this study, X-ray diffraction was used directly on the sample filters to identify elements and the crystal phase of dust. The representative result of the XRD pattern found aluminum oxide (Al_2O_3) at 2-theta values of 26.00° and 43.63°.[18] Several peaks of calcite ($CaCO_3$) were found at 2-theta values of 23.02°, 29.37°, 36.06°, and 39.50°.[19] Ferric oxide (Fe_2O_3) was countered at 2-theta values of 23.00° and 36.00°.[20] Magnesium oxide (MgO) presented at 2-theta values of 36.00° and 43.00°.[21] The broad peak of amorphous silica appeared around 2-theta values of 25.00° to 35.00°,[22] as shown in Figure 2.

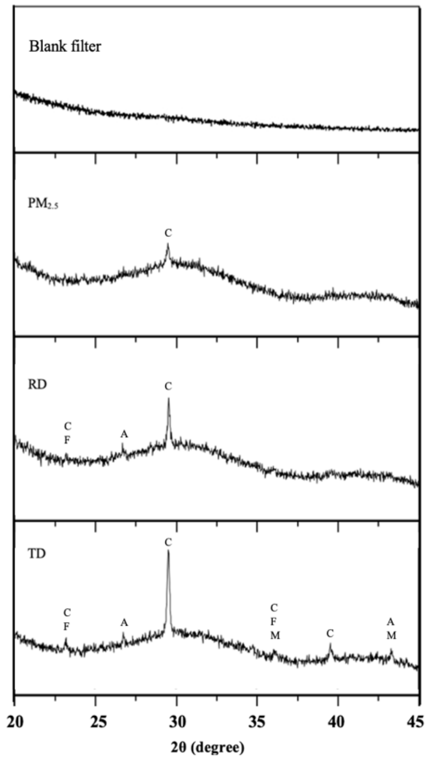

Figure 2: XRD pattern of TD, RD, and $PM_{2.5}$. The peaks corresponding to the different minerals are indicated by different letters. A: aluminum oxide, C: calcite, F: ferric oxide, and M: magnesium oxide.

Referring to the XRD patterns, the elements in dust consisted of Al, Ca, Fe, and Mg. Therefore, the concentration of the presented chemicals was analyzed using ICP-OES and reported in μg/m³ of air. The result indicated that Ca showed the highest average concentration in all dust types, TD was 76.20 ± 28.52 μg/m³, RD was 67.23 ± 29.06 μg/m³, and $PM_{2.5}$ was 57.71 ± 15.77 μg/m³. The others were found to be low concentrations; Fe in TD, RD, and $PM_{2.5}$ were 15.55 ± 9.11 μg/m³, 8.45 ± 4.87 μg/m³, and 10.03 ± 64.87 μg/m³, respectively; Al in TD, RD, and $PM_{2.5}$ were 8.79 ± 3.55 μg/m³, RD was 5.30 ± 2.14 μg/m³, and $PM_{2.5}$ was 5.59 ± 2.76 μg/m³, respectively. Mg was the lowest concentration found in all dust types, as presented in Figure 3.

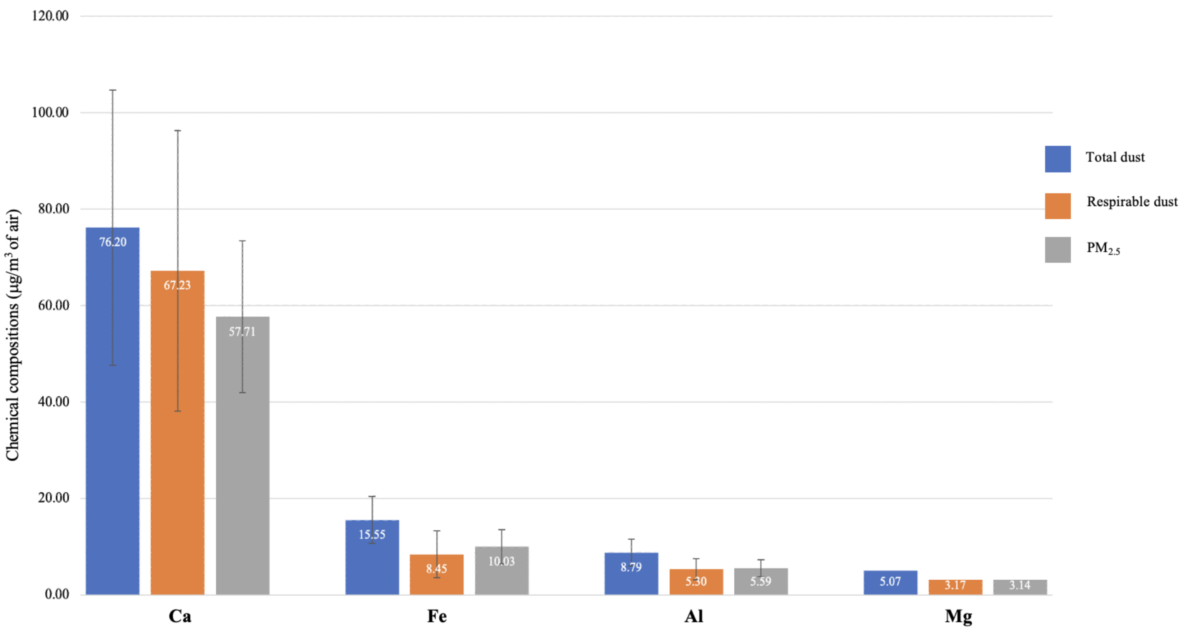

Figure 3: Average concentration of chemical compositions in TD, RD, and $PM_{2.5}$

Discussion

This study found the concentration of TD, RD, and $PM_{2.5}$ collected among workers in 6 low-rise building construction sites was similar; considering the tasks, it was found that column casting, cutting wire and steel rod and bundle, and sweep cleaning were observed in all construction sites. To study the concentration level of personal dust exposure concrete drilling was observed as a task that produced the highest concentration of all dust types. This agrees with the study by Park et al. who assessed the respirable dust in the apartment complex construction site.[9] This might be because concrete drilling is a process of making a hole in a circular cross-section by rotary drill force. Hundreds to thousands of revolutions per minute have generated a cloud of dust, which is pushed off while it is drilled. Those dusts might be in the range of sizes of respirable dust that can be inhaled and harmful to workers' respiratory health. Sweep cleaning was the task that generated second-height dust in our study. This agrees with the previous studies by Li et al. who found that hand sweeping with a brush in construction sites produced respirable dust concentrations higher than that of other sweeping methods.[2] On the other hand, the lowest concentration of dust was found in cutting wire and steel rods and bundles, as well as column casting, because the activities and materials used were obviously different from those used in concrete drilling and sweep cleaning.

Although tasks were varied in each site, the concentration of dust was not significantly different. It showed that methods, raw materials, equipment, or tools might play an important role in dust generated from building construction sites.[23] In addition, all types of dust (TD, RD, $PM_{2.5}$) were found in the building construction process. From the fact that the smaller the size, the deeper it penetrates the respiratory system, leading to respiratory health effects. Therefore, the necessary prevention measures should be considered.

The identification and quantification of crystalline phases of chemicals contained in dust were analyzed by X-ray diffraction. Aluminum oxide, calcite, ferric oxide, and magnesium oxide were the peaks of elements found in this study. Interestingly, a peak of crystalline silica was not found. The phase identification is different when cutting the cured cement and concrete blocks.[24] This is also different from the study in Korea performed in subway tunnel construction, where quartz (SiO_2) composition was found in particulate matter.[25] This finding confirmed that the more difference in raw materials, the more difference in element compositions.

From this study, it is possible that the element contained in the dust collected on filter papers can be identified directly with X-ray diffraction; however, to know the concentration of the chemical composition, ICP-OES was used. This study found that Ca was the highest concentration in all dust types, followed by Fe, Al, and Mg. This is in accordance with the study found in the fugitive construction dust sample.[11] It is because Ca is a major component of cement powder, which is the material used in the construction process. In this study, Fe, Al, and Mg were also found little in the component of dust samples.[26]

Considering the dust component in this study, it can imply that the dust spread from building construction sites is cement powder. Inhalation of cement dust can cause respiratory irritation and lung damage depending on the chemical composition and duration of exposure.[17] It is possible that construction workers may get the same effects. Therefore, identifying the elements and chemical composition in dust can result in efficient prevention for workers. Further study the respiratory health of construction workers, such as pulmonary function tests and respiratory symptoms, should be monitored and evaluated to reveal the relationship with the exposure to all types of dust (TD, RD, and $PM_{2.5}$).

Conclusions

The dust emitted from the low-rise building construction sites had varying sizes of TD, RD, and $PM_{2.5}$. There are no differences in concentration between the sites. XRD pattern of dust presented elements composition, namely, aluminum oxide, calcite, ferric oxide, magnesium oxide, and amorphous silica. The analysis of ICP-OES demonstrated Ca as the highest chemical composition, followed by a little of Fe, Al, and Mg, which is familiar to cement powder. The assessment of dust concentrations and their physicochemical properties brought about important information that led to the appropriate control measures and potentially enhanced construction workers' well-being.

References

1. Pusapukdepop J, Pengsa-ium V. Measures to Reduce the Impact of Dust from Construction in Bangkok. Available from: http://dx.doi.org/10.2139/ssrn.3192801
2. Li CZ, Zhao Y, Xu X. Investigation of dust exposure and control practices in the construction industry: Implications for cleaner production. Journal of Cleaner Production. 2019 Aug 1;227:810-24. Available from: https://doi.org/10.1016/j.jclepro.2019.04.174
3. Health and Safety Executive (HSE). Construction Information Sheet No 36 Revision 1. 2011. Available from: http://www.hse.gov.uk/pubns/cis36.htm
4. Yan H, Ding G, Li H, Wang Y, Zhang L, Shen Q, et al. Field evaluation of the dust impacts from construction sites on surrounding areas: a city case study in China. Sustainability. 2019 Mar 30;11(7):1906. Available from: https://doi.org/10.3390/su11071906
5. Xie L, Ding YC, Shi L. Study on Dust Emission Characteristics of Construction Sites in Hengyang City. InIOP Conference Series: Materials Science and Engineering. IOP Publishing. 2019 Aug 1;592(1):012134. Available from: https://doi.org/10.1088/1757-899X/592/1/012134
6. Thaveesubpital, Limsupreeya. Development of personal dust detector for construction activity. Engineering journal. 2020;33(109):59-73. Available from: https://ph01.tci-thaijo.org/index.php/kuengj/article/view/240548
7. Cheriyan D, Choi JH. A review of research on particulate matter pollution in the construction industry. Journal of Cleaner Production. 2020 May 1;254:120077. Available from: https://doi.org/10.1016/j.jclepro.2020.120077
8. Tao G, Feng J, Feng H, Feng H, Zhang K. Reducing construction dust pollution by planning construction site layout. Buildings. 2022 Apr 22;12(5):531. Available from: https://doi.org/10.3390/buildings12050531
9. Park H, Hwang E, Yoon C. Respirable crystalline silica exposure among concrete finishing workers at apartment complex construction sites. Aerosol and Air Quality Research. 2019 Dec;19(12):2804-14. Available from: https://doi.org/10.4209/aaqr.2019.05.0251
10. Sun J, Shen Z, Zhang L, Lei Y, Gong X, Zhang Q, et al. Chemical source profiles of urban fugitive dust PM2.5 samples from 21 cities across China. Science of the Total Environment. 2019 Feb 1;649:1045-53. Available from: https://doi.org/10.1016/j.scitotenv.2018.08.374
11. Mastrantonio R, Civisca A, Siciliano E, Inglese E, Lippolis T, Pompei D, et al. Exposure assessment to inhalable and respirable dust in the post-earthquake construction sites in the city of l'Aquila. Journal of Occupational Health. 2021 Jan;63(1):e12296. Available from: https://doi.org/10.1002/1348-9585.12296
12. Jiang N, Dong Z, Xu Y, Yu F, Yin S, Zhang R, et al. Characterization of PM10 and PM2.5 source profiles of fugitive dust in Zhengzhou, China. Aerosol and Air Quality Research. 2018 Feb;18(2):314-29. Available from: https://doi.org/10.4209/aaqr.2017.04.0132
13. Lyu Y, Zhang Q, Liu Y, Zhang WP, Tian FJ, Zhang HF, et al. Nano-Calcium Carbonate Affect the Respiratory and Function Through Inducing Oxidative Stress: A Cross-sectional Study Among Occupational Exposure of Workers and a Further Research for Underlying Mechanisms. Journal of Occupational and Environmental Medicine. 2023 Feb 1;65(2):184-91. Available from: https://doi.org/10.1097/jom.0000000000002713

14. Zhang Z, Weichenthal S, Kwong JC, Burnett RT, Hatzopoulou M, Jerrett M, et al. A population-based cohort study of respiratory disease and long-term exposure to iron and copper in fine particulate air pollution and their combined impact on reactive oxygen species generation in human lungs. Environmental Science & Technology. 2021 Mar 5;55(6):3807-18. Available from: https://doi.org/10.1021/acs.est.0c05931

15. Niu Q. Overview of the relationship between aluminum exposure and Human Health. Neurotoxicity of Aluminum. Springer Nature Singapore. 2018 Jul 9;1-32. Available from: https://doi.org/10.1007/978-981-13-1370-7_1

16. Reamer Jr JL. An Analysis of Visible Airborne Magnesium Carbonate Chalk Particulates in a Gymnastics Facility and the Risk of Respiratory Health Effects (Doctoral dissertation, University of Wisconsin--Stout). Available from: http://digital.library.wisc.edu/1793/83624

17. Wang M, Yao G, Sun Y, Yang Y, Deng R. Exposure to construction dust and health impacts–A review. Chemosphere. 2023 Jan 1;311:136990. Available from: https://doi.org/10.1016/j.chemosphere.2022.136990

18. Li M, Liu W, Nie J, Wang C, Li W, Xing Z. Influence of yttria-stabilized zirconia content on rheological behavior and mechanical properties of zirconia-toughened alumina fabricated by paste-based stereolithography. Journal of Materials Science. 2021 Feb;56:2887-99. Available from: https://doi.org/10.1007/s10853-020-05494-6

19. Neupane BB, Sharma A, Giri B, Joshi MK. Characterization of airborne dust samples collected from core areas of Kathmandu Valley. Heliyon. 2020 Apr 1;6(4). Available from: http://dx.doi.org/10.1016/j.heliyon.2020.e03791

20. Hjiri M. Highly sensitive NO2 gas sensor based on hematite nanoparticles synthesized by sol-gel technique. Journal of Materials Science: Materials in Electronics. 2020 Mar;31(6):5025-31. Available from: https://doi.org/10.1007/s10854-020-03069-4

21. Ashok CH, Venkateswara RK, Shilpa-Chakra CH. Synthesis and characterization of MgO/TiO2 nanocomposites. J Nanomed Nanotechnol. 2015;6:2-5. Available from: http://dx.doi.org/10.4172/2157-7439.1000329

22. Chandraboss VL, Kamalakkannan J, Senthilvelan S. Synthesis of AC-Bi@ SiO2 nanocomposite sphere for superior photocatalytic activity towards the photodegradation of malachite green. Canadian Chemical Transactions. 2015;3(4):410-29.Available from: https://doi.org/10.13179/canchemtrans.2015.03.04.0235

23. Kumi L, Jeong J, Jeong J, Lee J. Empirical analysis of dust health impacts on construction workers considering work types. Buildings. 2022 Aug 1;12(8):1137. Available from: https://doi.org/10.3390/buildings12081137

24. Gharpure A, Heim JW, Vander Wal RL. Characterization and hazard identification of respirable cement and concrete dust from construction activities. International journal of environmental research and public health. 2021 Sep 27;18(19):10126. Available from: https://doi.org/10.3390/ijerph181910126.

25. Lee Y, Lee YC, Kim T, Choi JS, Park D. Sources and characteristics of particulate matter in subway tunnels in Seoul, Korea. International Journal of Environmental Research and Public Health. 2018 Nov;15(11):2534. Available from: https://doi.org/10.3390/ijerph15112534

26. Dunuweera SP, Rajapakse RM. Cement types, composition, uses and advantages of nanocement, environmental impact on cement production, and possible solutions. Advances in Materials Science and Engineering. 2018;2018(1):4158682. Available from: http://dx.doi.org/10.1155/2018/4158682