Journal of HyoJeong Academia

Article

Impact of Environmental Exposure to Air Pollutants at Workplace on Respiratory Health of Dust-exposed Congolese Workers

Nlandu Roger Ngatu[1, 2*], Leon Ngombe Kabamba[2], Christian Mapong Wansu[1], Marie Miezi Nsimba[1, 4], Jose Nzunzu Lami[1, 4], Severin Luzitu Nangana[1] and Michel Nzaji Kabamba[2]

[1]Congo-Japan NCDs Research Team, Congo central province, Democratic Republic of Congo (DRC)
[2]Kagawa University Faculty of Medicine, Kagawa 761-0793, Japan
[3]Faculty of Medicine, Kamina University, Kamina, DRC
[4]Laboratory of Bio-organic Research, Department of Medical Chemistry and Pharmacognosy, Faculty of Pharma-ceutical Sciences, University of Kinshasa, Kinshasa, DRC
*Correspondence: ngatunlandu@gmail.com

Abstract: WHO considers ambient air pollution as the greatest environmental health risk. The "United Nations Environment Program Action Notes 2021" reported that 99% of world population live in places with atmospheric air pollutants levels above WHO's exposure limits. This mini-review included three studies from the "Congo Occupational/Environmental Health Research Project 2016-2020", focusing on the respiratory health of dust-exposed workers. They are case-control studies conducted by our Congo-Japan collaborative research team in stone quarry sites and construction sites in Katanga region, which is part of the African cooper-belt region. In total, 1,512 workers participated in those studies; the first one included 512 workers (256 female stone quarry workers, 256 unexposed female workers), the second included 570 workers (282 male cement conveyors at construction sites, 288 unexposed male stone quarry workers), whereas the third study included 441 workers (199 dust-exposed male artisanal coltan miners, 242 unexposed male workers). Control groups comprised local administrative office workers and market tax collectors. Participants answered a respiratory health questionnaire, underwent physical examination and lung function testing. Air quality was assessed by means of an air quality monitor. Results showed a lack of personal protective equipment use in both female stone quarry workers and male cement conveyors. Our first study conducted in stone quarry sites which included female workers, higher $PM_{2.5}$ (205 ± 13.2 $\mu g/m^3$ vs. 31.3 ± 10.3 $\mu g/m^3$; $p < 0.001$) was observed, as compared with controls. similarly, the second study which included male cement conveyors also showed higher $PM_{2.5}$ (197.0 ± 0.0 $\mu g/m^3$ vs. 29.0 ± 0.1 $\mu g/m^3$; $p < 0.001$), as compared with unexposed controls. Furthermore, third study which included male coltan miners showed extremely elevated $PM_{2.5}$ (215.0 ± 11.3 $\mu g/m^3$ vs. 33.0 ± 4.2 $\mu g/m^3$; $p < 0.001$) compared to control workplaces. Respiratory complaints were very common in all exposed workers' groups, with significantly reduced lung capacity in female stone quarry workers (mean PEFR: 344.8 ± 2.26 vs. 405 ± 67.7 L/s; $p < 0.001$), hand-operated cement conveyors (445.1 ± 89.0 vs. 482.3 ± 63.2; $p < 0.001$) and artisanal coltan miners in the third study (347.9 ± 66.9 vs. 493.67.4; $p < 0.001$). Dust-exposed Congolese workers are exposed to high air pollutants levels, which contribute to increased frequency of respiratory complaints and impaired lung function.

Keywords: Air pollutant, Construction worker, Particulate matter, Quarry worker, Respiratory health.

Citation: Nlandu Roger Ngatu, Leon Ngombe Kabamba, Christian Mapong Wansu, Marie Miezi Nsimba, Jose Nzunzu Lami, Severin Luzitu Nangana and Michel Nzaji Kabamba. Impact of Environmental Exposure to Air Pollutants at Workplace on Respiratory Health of Dust-exposed Congolese Workers. *JHJA* 2(2), **2024**.

Received: 14 July 2024
Accepted: 26 September 2024
Published: 13 October 2024

Publisher's Note: JHJA stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

According to the World Health Organization (WHO), environmental air pollution is one the major health threats.

WHO considers ambient air pollution as the greatest environmental health threat. A report from the "United Nations Environment Program (UNEP) Action Notes 2021" stipulates that 99% of world population live in places with atmospheric air pollutants levels above WHO's exposure limits [1, 2]. Exposure to high particulate matter (PM) levels are associated with lung function impairment. A recent Indian study conducted among cement dust-exposed workers showed markedly decreased lung function capacity in exposed workers compared to controls, and a positive association between cement dust exposure and low peak expiratory flow rate [3].

Petrochemical industry, open and underground mining industries, cement factory and construction industries are among the major contributors to ambient air pollution (AAP) in countries of the sub-Saharan Africa region. A few studies conducted in Nigeria showed that quarry workers with a history of chronic dust-exposure had a greater risk of developing respiratory symptoms [4, 5]. Furthermore, studies conducted among dust-exposed workers from gold, diamond and platinum mining sectors showed high proportions of miners who developed silicosis, a chronic lung disease caused by silica dust [6].

In the Democratic Republic of the Congo (DRC), studies that explored the respiratory health of workers exposed to mineral dust are scarce. The present report is a review that includes studies that assessed the air quality in stone quarry, construction and artisanal coltan mining sites, and evaluated the respiratory health of exposed workers in Lomami and Haut-Katanga, formerly Katanga region.

2. Materials and Methods

2.1. Study design, sites and participants

This was a mini-review that included three studies, focusing on the air quality monitoring in working environment and the respiratory health of dust-exposed workers in DRC. They are case-control studies from the "Congo Occupational/Environmental Health Research Project 2016-2020" [7–9], focusing on the respiratory health of dust-exposed workers. These studies were conducted by our Congo-Japan collaborative research team in stone quarry sites and construction sites in Katanga area, which is part of the African cooper-belt region. In total, 1,512 workers participated in those studies; the first one included 512 workers (256 female stone quarry workers, 256 unexposed female workers), the second included 570 workers (282 male cement conveyors at construction sites, 288 unexposed male hand-operated cement conveyors), whereas the third study included 441 workers (199 dust-exposed male artisanal coltan miners, 242 unexposed male workers). Control groups comprised local administrative office workers and market tax collectors. Katanga region is located in southern area of DRC; it is part of the African copper-belt, which also includes a part of Zambia (Fig. 1) [10].

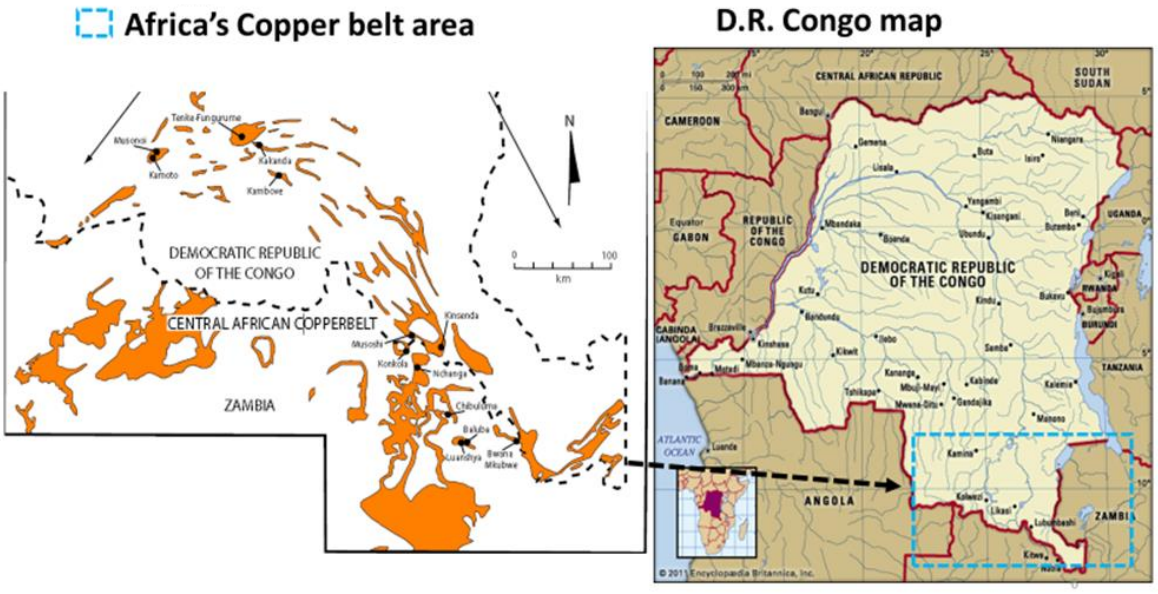

Figure 1. (a) Central African copper belt area; (b) map of the Democratic Republic of the Congo.

2.2. Inclusion criteria

Inclusion criteria were as follows: voluntary participation, having at least one year of work experience, absence of contraindication for lung function test, provide informed consent, be present at workplace on the day of examination, not participating in a similar study.

2.3. Survey questionnaire, lung function testing and air quality monitoring

Participants answered a structured respiratory health questionnaire, which comprised questions related to anthropometric, sociodemographic and occupational characteristics, and respiratory health symptoms. In addition to a general medical check-up (including chest auscultation), lung function test was performed with the use of a peak flow meter. Peak expiratory flow rate (PEFR) was the parameter considered in this report. Air quality assessment was carried out three times at each quarry site, with a 30-minute interval, using BRAMC air quality monitor (BR-AIR-329). The concentrations of atmospheric particulate matter ($PM_{2.5}$) and volatile organic compounds (VOC) were the air pollutants measured and considered in this report. In each of the research protocols of the three studies included in this report, hygrometric or meteorological measurements were not planned.

2.4. Ethical consideration and statistical analysis

To participate in this study, each subject provided a written informed consent; participation was voluntary. Ethical approval of the DRC OSH research project was obtained from the ethics committee of the School of Public Health, University of Lubumbashi, DRC (approval number: UNILU/CEM/075/2015).

Group comparisons were performed using Student's t-test for continuous variables, whereas Fisher's exact test was used for categorical variables. Multivariate logistic regression analysis was performed, with adjustment for sociodemographic characteristics such as age, education level and smoking status, in order to determine factors associated with respiratory manifestations. Stata software v.15 was used for data analysis and the level of significance was set at p-value less than 0.05 (double-sided).

3. Results

3.1. Air quality in the working environments

It was observed that personal protective equipment (PPE) was not used by stone quarry workers and cement conveyors. Figure 2 presents results of environmental monitoring of atmospheric levels of $PM_{2.5}$ and VOC. It was observed that stone quarry (205.0 ± 13.2 vs. 31.3 ± 10.3 $\mu g/m^3$), construction (215.0 ± 11.3 vs. 33 ± 4.2 $\mu g/m^3$) and artisanal coltan mining sites (197 ± 0.0 vs. 29.0 ± 0.1 $\mu g/m^3$) had markedly higher $PM_{2.5}$ levels as compared with corresponding control sites ($p < 0.001$). Regarding atmospheric VOC, though relatively high levels were found in stone quarry and construction sites, as well as artisanal coltan mining sites as compared with control sites, no statistically significant difference was observed.

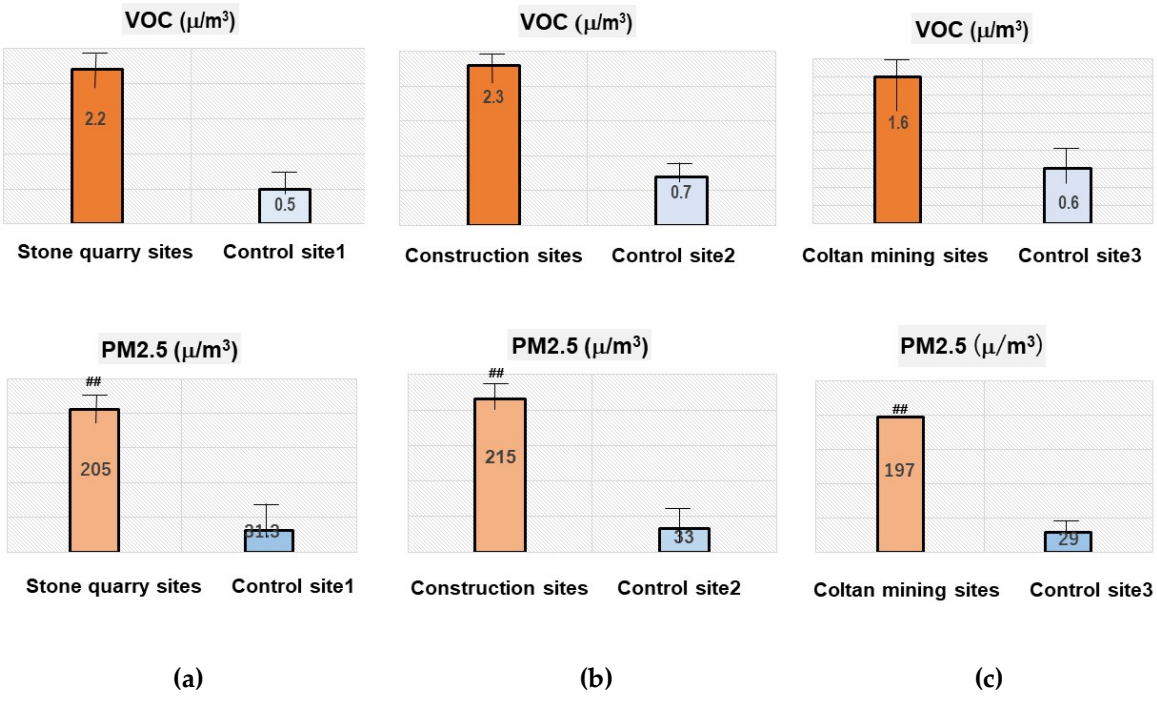

Figure 2. Mean values of workplace $PM_{2.5}$ and volatile organic compounds (VOC) levels in (a) stone quarry sties; (b) construction sites; (c) artisanal coltan mining sites in Katanga region, Democratic Republic of the Congo.

3.2. Characteristics of the study participants and air quality in the working environment

As shown in Table 1, a large proportion of workers from the exposed groups were current smokers; no statistically significant difference was observed when comparing mean age between exposed workers and controls. Respiratory manifestations were very common in all exposed workers' groups. Asthma was the respiratory disorder that was significantly more prevalent in coltan miners, 32.2% (vs. 2.1% in controls; $p < 0.0001$), chronic bronchitis was more prevalent in female stone quarry workers, 17.6% (vs. 1.1% in controls; $p < 0.001$), whereas rhinitis was more prevalent in female stone quarry workers (57.8% vs. 13.4% in controls; $p < 0.0001$) and coltan miners (70.3% vs. 17.7% in controls; $p < 0.0001$).

Table 1. Sociodemographics, frequency of respiratory manifestations , workplace pollutants and lung function status among dust-exposed Congolese workers (stone quarry workers, artisanal coltan miners) (N= 1,523)

Characteristics of participants (N=1,523)	**Female Stone Quarry Workers (n1= 512)**		**Hand-operated Cement Conveyors (n2= 570)**		**Male Coltan Miners (n3= 441)**	
1. Sociodemographics	**Controls** (n=256)	**Exposed** (n=256)	**Controls** (n=288)	**Exposed** (n=282)	**Controls** (n=242)	**Exposed** (n=199)
Age (mean; SD)	44.1 (9.4)	43.1 (0.8)	33.8 (8.6)	32.5 (8.4)	33.8 (9.2)	32.8 (8.4)
Gender F (n; %)	256 (100)	256 (100)	0 (0)	0 (0)	0 (0)	0 (0)
M (n; %)	0 (0)	0 (0)	288 (100)	282 (100)	441 (100)	441 (100)
Working years [mean (SD)]	8.3 (7.1)	2.92 (4.5)	6.4 (6.7)	4.7 (4.4)	5.66 (6.7)	5.7 (3.5)
Education level (n; %):						
-Highschool not completed	197 (76.9)	245 (95.7)	252 (87.5)	270 (95.7)	155 (64.0)	140 (70.4)
-Highschool or higher	59 (23.1)	11 (4.3)	36 (12.5)	12 (4.3)	87 (59.6)	59 (29.6)
Current smokers (n; %)	9 (3.5)	2 (0.8)	16 (5.6)	169 (59.9)	22 (4.1)	5 (7.8)

2. Respir. manifestations						
Rhinitis (n; %)	25 (13.4)	148(57.8)##	53 (18.4)	226(80.1)##	43 (17.7)	140(70.3)##
Chronic bronchitis (n; %)	2 (1.1)	45 (17.6) #	2 (0.7)	11 (3.9)	-	-
Asthma (n; %)	3 (1.6)	6 (2.3)	3 (1)	8 (2.8)	5 (2.1)	64(32.2)##
Morning cough (n; %)	6 (2.5)	95 (47.7) ##	43 (14.9)	144 (51.1)#	-	-
Morning sputum (n; %)	3 (1.6)	105 (41) ##	32 (11.1)	124 (44)#	8 (3.3)	99 (49.7) ##
Dyspnea at rest (n; %)	2 (1.1)	80 (31.3) ##	37 (12.8)	92 (32.6)	6 (2.5)	55 (27.6) ##
Dyspnea after effort (n; %)	1 (0.5)	99 (38.7) ##	-	-	6 (2.5)	60 (30.1) ##
Wheezing at rest (n; %)	17 (9.1)	69 (2.7)	14 (8)	51 (18.1)	35 (14.5)	85 (42.7) #
Wheezing after effort (n; %)	17 (9.1)	57 (22.3)	-	-	24 (9.9)	67 (33.7) #
3. Lung Function Test						
Peak Expiratory Flow Rate (PEFR; L/s) (mean, SD)	405 (67.7)	344.8 (2.3)#	482.3(63.2)	445.1 (89)#	493.2(67.4)	347.9(66.9)#

Notes: # denotes $p < 0.01$; ## denotes $p < 0.001$

Regarding respiratory complaints, morning cough (47.7% in female quarry workers vs. 2.5% in controls; 51.1% in cement conveyors vs. 14.9% in controls), morning sputum (41% in stone quarry workers vs. 1.6% in controls; 44% in cement conveyors vs. 11.1% in controls; 49.7% in coltan miners vs. 3.3% in controls), dyspnea at rest (31.3% in stone quarry workers vs. 1.1% in controls; 27.6% in coltan miners vs. 2.5% in controls) and wheezing at rest (42.7% in coltan miners vs. 14.5% in controls) were more frequent in dust-exposed workers than controls (Table 1). Furthermore, markedly reduced lung function capacity was observed in the first study that included female stone quarry workers (mean PEFR: 344.8 ± 2.26 vs. 405 ± 67.7 L/s; $p < 0.001$), hand-operated cement conveyors in the second study (445.1 ± 89.0 vs. 482.3 ± 63.2; $p < 0.001$) and artisanal coltan miners in the third study (347.9 ± 66.9 vs. 493.67.4; $p < 0.001$) (Table 1).

Table 2. Association between dust-exposure status and respiratory manifestations by logistic regression in Congolese stone quarry workers and informal coltan miners (adjusted analysis)

Respiratory manifesta-tions	**Quarry work**		**Construction work (cement)**		**Coltan mining**	
	aOR (SE)	95% CI	aOR (SE)	95% CI	aOR (SE)	95% CI
Morning cough	6.1 (1.9)	3.29-11.15#	3.39	2.12-5.41#	12.0 (3.7)	3.3-24.50#
Morning phlegm	2.6 (1.0)	1.24-5.52*	3.66	2.19-6.09#	4.7 (3.0)	2.45-11.62#
Wheezing after effort	3.4 (1.6)	1.28-8.78*	2.27	1.21-4.25*	0.3 (0.0)	0.09-0.78
Dyspnea at rest	3.9 (1.1)	2.22-7.02#	-	-	4.0 (2.1)	1.16-15.53*
Dyspnea after effort	5.2 (1.9)	2.46-10.84#	3.09	1.86-5.12#	4.1 (0.8)	1.21-13.73*
Rhinitis	2.1 (0.2)	1.18-3.39#	20.38	11.9-34.65#	5.5 (1.3)	4.95-6.36#
Chronic bronchitis	2.6 (0.7)	1.48-4.61#	2.06	0.33-12.08	-	-
Asthma	1.2 (0.7)	0.36-3.99	4.23	1.00-17.78*	4.9 (1.6)	2.41-17.06#

Notes: * denotes $p < 0.05$; # denotes $p < 0.01$; ## denotes $p < 0.001$; aOR is adjusted odds ratio (adjustment for age, educational level, smoking status); SE is standard error; CI is confidence interval.

Table 2 shows the results of the multivariate logistic analysis. It was observed that, compared to controls, almost all listed respiratory manifestations (except asthma) were strongly and positively associated with stone quarry work, artisanal coltan mining and construction work (for cement conveyors). For example, regarding respiratory disorders, working at stone quarry sites was associated with about 2 times higher risk for rhinitis ($p < 0.01$) and

chronic bronchitis ($p < 0.01$); workers at construction sites had 20 times higher risk for rhinitis ($p < 0.001$), whereas those from artisanal coltan mining sites had 5 times higher risk for rhinitis. Both construction work ($p < 0.05$) and artisanal coltan mining ($p < 0.01$) were associated with a 4 to 4.9 times higher risk of developing asthma-like ailment, respectively.

4. Discussion

This research project was the first that explored the respiratory health of dust-exposed stone quarry workers, cement conveyors and artisanal coltan miners in the natural resource-rich D.R. Congo. A portable air quality monitor was used to measure ambient air dust concentrations. Similar devices have been used in previous studies [11, 12]. On the hand, Peak flow meter was employed for lung function testing. It is often used in research, especially when the study site is located from a healthcare setting [13].

It was observed that environmental air concentrations of $PM_{2.5}$ work sites were significantly higher than the 25 $\mu g/m^3$ exposure limit recommended by the World Health Organization. Most workers reported the lack of use of appropriate PPE against dust, particularly in regard to the protection of airways, eyes and skin (mask, goggles, gloves). Additionally, other safety measures aimed at reducing workplace dust levels were not applied at the workplaces. We also found that exposed quarry workers, cement conveyors and coltan miners had low socioeconomic status and education level in general; they were exposed to high air pollutants ($PM_{2.5}$, VOC) levels, which might have contributed to increased prevalence of respiratory disorders (chronic bronchitis, rhinitis, asthma) and complaints, including morning cough, morning sputum and dyspnea.

Moreover, in the multivariate logistic regression analysis, almost all respiratory manifestations were strongly associated with stone quarry work, construction work and artisanal coltan mining. Furthermore, this research showed that exposed workers had significantly reduced lung function capacity as compared with unexposed controls. Similar findings have been previously reported in studies conducted among artisanal miners [14] and cement industry workers in other countries [15]. Those reports show not only elevated prevalence of respiratory symptoms among dust-exposed workers but also an impairment of pulmonary function due to reduced respiratory parameters. Furthermore, a Taiwanese cohort study published by Lancet Planetary Health [16] showed that chronic exposure to fine particulate matters (PM) declined lung function performance and increased the risk of respiratory disorders. This fact supports our findings in regard to stone quarry workers, cement conveyors and coltan miners in DRC.

Coltan or columbite-tantalite is a rare metal used in the manufacturing of a variety of devices, particularly in computers and mobile phone; its use in technology has been fueling the ongoing armed conflict in eastern DRC [17]. However, the health risk associated with coltan mining in Africa has been unknown. Our study was the first to investigate the respiratory health risk of coltan miners in relation to hazardous dust-exposure at the mining sites.

5. Conclusion

This mini-review highlights the poor air quality in the working environment of stone quarry, construction and artisanal coltan mining sites in the Katanga region, DRC, exposing workers to high-risk for developing respiratory disorders. The use of appropriate PPE during work by quarry workers, miners, cement conveyors and other workers in the construction industry is recommended.

Author Contributions: Conceptualization of the mini-review, K.N.L. and N.N.R.; methodology, N.N.R., K.N.M. and M.M.N.; resources, C.M.W., S.L.N. and J.N.L.; writing—original draft preparation, N.R.N., J.N.L. and N.M.K.; writing—review and editing, N.R.N. and M.M.N.; supervision, N.N.R. and L.K.N. All authors have read and agreed to the final version of the manuscript.

Funding: his research received no external funding.

Data Availability Statement: Data can be obtained upon request to the corresponding author (N.N.R.).

Acknowledgments: The authors would like to thank the president of the University of Kamina (D.R. Congo), and Mr Imon Sachiyo (I.A.A.P./Kagawa, Japan) for their continuous support to our research projects.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. World Health Organization (WHO), Air pollution. https://www.who.int/airpollution/ambient/about/en/
2. UN Environment, Towards a pollution-free planet. https://www.unenvironment.org/resources/report/towards-pollution-free-planet-background-report
3. Dushyant, K., Walia, G.K. and Devasenapathy, N. Lung function and respiratory morbidity among informal workers exposed to cement dust: a comparative cross-sectional study. *Ann. Glob. Health 89*(1), 47-60 (2023).
4. Nwibo, A.N., Ugwuia, E.I., Nwambeke, N.O., Emelumadu, O.F. and Ogbonnaya, L.U. Pulmonary problems among quarry workers of stone crushing industrial site at Umuoghara, Ebony state, Nigeria. *Int. J. Occup. Environ. Med*. *3*, 178-185 (2012).
5. Isara, A.R., Adam, V.Y., Aigbokhaode, A.Q. and Alenoghena, I.O. Respiratory symptoms and ventilatory functions among quarry workers in Edo state, Nigeria. *Pan Afr. J. Med. 23*, 212-221 (2016). DOI: 10.11604/pamj.2016.23.212.7640
6. Nelson, G. Occupational respiratory diseases in the South African mining industry. *Glob. Health Action 6*, 89-98 (2013).
7. Kabamba-Ngombe, L. et al. Respiratory health of dist-exposed Congolese coltan miners. *Int. Arch. Occup. Environ. Health 91*(7), 859-864 (2018). DOI: 10.1007/s00420-018-1329-0
8. Kabamba-Ngombe, L. et al. Respiratory health of cement conveyors in Haut-Katanga province in Democratic Republic of the Congo. *Environ. Risque Sante 18*(6), 500-507 (2019).
9. Kabamba-Ngombe, L. et al. Air quality in the working environment and respiratory health of female Congolese stone quarry workers. *Trop. Med. Infect. Dis. 5*(4), 171-175 (2020). DOI: 10.3390/tropicalmed5040171
10. Taylor, C.D. et al. Geology and nonfuel mineral deposits of Africa and the Middle East. In *USGS Open-File Report 2005-1294-E* (U.S. Geological Survey, 2005).
11. Shezi, B., Mathee, A., Cele, N., Ndabandaba, S. and Street, R.A. Occupational exposure to fine particulate matter (PM_4 and $PM_{2.5}$) during hand-made Cook ware operation: personal, indoor and outdoor levels. *Int. J. Environ. Res. Public Health 17*(20), 7522 (2020).
12. Debela, M. et al. Bagasse dust exposure and chronic respiratory symptoms among workers in the Metehara and Wonji sugar factories in Ethiopia: a longitudinal study design. *BMJ Open Respir Res 10*(1), e001511 (2023).
13. Wiwatanadate, P. and Liwsrisakun, C. Acute effects of air pollution on peak expiratory flow rates and symptoms among asthmatic patients in Chaing Mai, Thailand. *Int. J. Hyg. Environ. Health. 214*(3), 251-257 (2021).
14. Hentschel, T., Hruschka, F. and Priester, M. Global report on artisanal and small-scale mining, Mining, minerals and sustainable development. World Business Council for Sustainable Development/HED, 2002. https://www.iied.org/sites/default/files/pdfs/migrate/G00723.pdf
15. Ehsan, R., Ashkan, A., Lahya, A.S. and Hosein, Z. A study on respiratory problems and pulmonary function indexes among cement industry workers in Mashhad, Iran. *Medycyna Pracy 66*(4), 471-477 (2015).
16. Guo, C. et al. Effect of long-term exposure to fine particulate matter on lung function decline and risk of chronic obstruction pulmonary disease in Taiwan: a longitudinal, cohort study. *Lancet Planet. Health 2*(3), e114-e125 (2018). DOI: 10.1016/S2542-5196(18)30028-7
17. Harmon, R.S. Can the provenance of the conflict minerals columbite and tantalite be ascertained by laser-induced breakdown spectroscopy? *Anal Bioanal Chem. 400*(10), 3377-3382 (2011). DOI: 10.1007/s00216-011-5015-2