DOI: 10.7251/QOL2403083D **UDC:** 504.3.054:632.112

Original scientific paper

Environmental Assessment of Particulate Matter Pollution Generated by the Exploitation of Heliopolis Aggregates Quarry

Faten Djedid[1], Mohamed Bounouala[1], Amina Bouslama[2], Aissa Benselhoub[3], Nadiia Dovbash[4], Stefano Bellucci[5]

[1]*Laboratory of Mining Resources Valorization and Environment (LAVAMINE), Mining Department, Faculty of Earth Sciences, Badji Mokhtar University, Annaba, Algeria*
[2]*Department of Architecture, Faculty of Earth Sciences, Badji Mokhtar University, Annaba, Algeria*
[3]*Environmental Research Center (C.R.E), sis at Avenue Boughazi Said, Alzon; Annaba, Algeria, benselhoub@yahoo.fr*
[4]*National Scientific Centre «Institute of Agriculture of the National Academy of Agricultural Sciences», Chabany, Ukraine*
[5]*INFN-Laboratori Nazionali di Frascati, Via E. Fermi 54, 00044 Frascati, Italy*

ABSTRACT: In recent decades, extractive industries such as mining and quarrying have contributed to increasing environmental deterioration, particularly airborne emissions. Therefore, we aim to evaluate the environmental impacts of particulate matter (PM1, PM2.5, and PM10) emitted during the exploitation operations of aggregates in the Heliopolis quarry in Guelma, Algeria. For this purpose, dust samples were analyzed using XRD and XRF spectroscopy techniques. While preparing the gravel, we monitored air quality using a specialized device and analyzed flora samples from near the Heliopolis aggregates quarry. Furthermore, we conducted chemical and physical analyses of surface water samples and soil from a nearby farm. The obtained results show that the concentrations of PM (particulate matter) exceeded the WHO limit values for PM10 (50 µg/m^3) and PM2.5 (25 µg/m^3) within 24 hours. This was particularly noticeable in sampling stations S1 and S2, where the PM2.5 concentration was at 520 µg/m^3 and PM10 at 684 µg/m^3, and 516 µg/m^3 and PM10 at 676 µg/m^3, respectively. According to the XRD and XRF analyses, the quarry dust contains various minerals, including oxides and heavy metals. An analysis of the plants surrounding the Heliopolis quarry confirms the presence of dust containing the same mineral elements emitted from the quarry on the leaves and branches of trees, which hinders their natural growth and blocks sunlight.

Keywords: airborne pollution, mining operations, plant stress, soil and water pollution, Guelma, Algeria

INTRODUCTION

The ongoing industrial development has heightened environmental issues, causing increased air, water, and soil pollution. The proportion of natural resources has recently declined due to overexploitation (Dong et al, 2014). A specific example of this trend is evident in the production of concrete, where it now takes two tons of gravel to yield one cubic meter of concrete (Danielsen & Kuznetsova, 2014), recognizing that gravel is not a sustainable resource, the focus shifts towards sustainability by repurposing the quarry for activities such as investment projects once its operations conclude. This may include community-serving recreational investments for locals, such as open swimming facilities, sports stadiums *etc...* (Najafi, Hamzeh, & Moqimi, 2014).

The quarry dust composition varies depending on the geological characteristics of the area where the quarry is located. For instance, aggregates quarry dust in Nigeria typically contains heavy metals such as Cu, Pb, and Zn (Ajibade, Olisa, Oladipupo, Adegoke, & Adebayo, 2022), in contrast, our investigation at the Heliopolis aggregates quarry revealed the presence of SiO_2, CaO, MgO, and Fe_2O_3. This difference is due to the specific geological characteristics of each studied quarry site. Therefore, the diversity of the properties of these particles leads to the diversity of infection. (''World Health Organization'', 2021).

The environmental situation in Heliopolis is deeply concerning, particularly in light of the findings, especially concerning atmospheric particles found in quarry dust with an average aerodynamic diameter of less than or equal to 10 µm and 2.5 µm (PM10, PM2.5). Given that, the study area in Heliopolis experiences high temperatures during the summer frequently surpass 43 degrees Celsius as the map indicates in Figure 2, can even reach 45.5 degrees for the southern part of Heliopolis. Recent research has validated the significant role of temperature and humidity in intensifying pollution severity and dispersing these particles into the air, especially among workers (Materu, Sway, & Mussa, 2023).

These fine substances infiltrate deeply into the lungs and bronchi, enter the bloodstream, and exert effects on the vessels of the heart and brain. Recent evidence suggests that inhaling PM2.5 and PM10 also influences other human organs, contributing to the onset of various diseases (''WHO'', 2022).

About 7 million people succumb annually to the exacerbation of air pollution, with 90 % of these fatalities concentrated in low- and middle-income nations such as Algeria (Rentschler & Leonova, 2022), where, in 2022, PM2.5 concentrations were 3.6 times the World Health Organization's annual indicative value for air quality (''WHO'', 2022). Workers who spend more than eight hours in quarrying stations or other related quarry services face the risk of exposure to various dust particles containing significant elements like silicon dioxide (SiO_2) and calcium oxide (CaO), Aluminum (Al) which can cause several occupational diseases like silicosis (Liang, McCoy, Tomasallo, & Meiman, 2023). Hence, air pollution can result in an irregular heartbeat. Significant acute effects include an increased risk of coronary syndromes and high blood pressure (Argacha, 2023). Although legal emission standards are met in some cases, workers in this sector often suffer from symptoms such as headaches, eye allergies, and fatigue. This highlights the danger of exposure to these particles, even at low concentrations (Ferreira et al, 2023). Moreover, Primary emissions in mining arise from mechanical methods such as drilling and explosions, which release PM10, carbon dioxide, sulfur oxide, and various metals. Material transportation using diesel engines contributes significantly to the environmental impacts associated with quarrying activities (Boutemedjet, Bounouala, Idres, & Benselhoub, 2019; Bascompta, Sanmiquel, Gangolells, & Sidki, 2022).

Despite widespread attention, a practical system for early detection of air pollution remains lacking in new technologies (Li & Zhu, 2018). By employing our evaluation method, we can precisely gauge the environmental impacts of quarrying activities. This enables us to anticipate and tackle potential issues before they escalate, empowering us to make informed decisions to prevent further damage. Our goal is to raise awareness among people about the significance of acknowledging pollution stemming from particulate matter emissions and actively engaging in monitoring its dispersal (Yu & Zahidi, 2023).

Reducing air pollution yields numerous benefits, including enhanced health by mitigating respiratory diseases and reducing worker mortality rates. Additionally, it positively affects the economy, saves time, and plays a pivotal role in attaining environmental security and fostering sustainable development (Geng et al, 2019).

In this article, we will examine the environmental impacts of particulate matter emissions from quarries. These emissions include atmospheric pollution (dust), which can affect plant health, water quality, and soil accumulation. Our paper will discuss the most significant side effects of quarrying, with a specific focus on the environmental assessment of particulate matter produced by the mechanical preparation of gravel used in buildings and various urban constructions.

MATERIALS AND METHODS

Study Area

Our research has been conducted in Heliopolis, located approximately 5 km northeast of Guelma city in eastern Algeria, North Africa, as depicted in Figure 1a. This county is renowned for its substantial economic contributions. The region of Guelma is characterized by a plethora of tourist attractions, archaeological sites, a thriving agricultural sector, stunning landscapes, and a rich cultural heritage.

The Heliopolis quarry is situated on a terrain with a diverse geological composition as noticed in Figure1b. The area comprises a variety of rocks dating back to different eras, such as the lower Cretaceous and Jurassic, upper Cretaceous, Santonian, Senonian, Cenozoic Oligocene, and Quaternary.

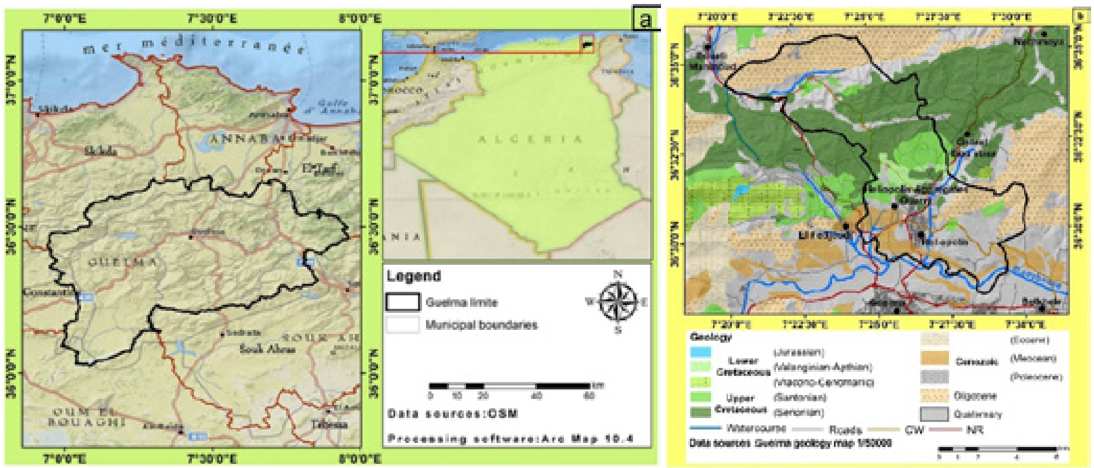

Figure 1. Study zone of Heliopolis, Guelma, Algeria: (a-geographical situation of the study area, b-geological map of Heliopolis)

Description of Aggregates Extraction Method

Figure 2 represents the aggregates exploitation method in open-pit mode (surface). The aggregates extraction methods primarily rely on the removal of vegetation cover (soil, trees and plants) to construct structures that facilitate access and exploitation.

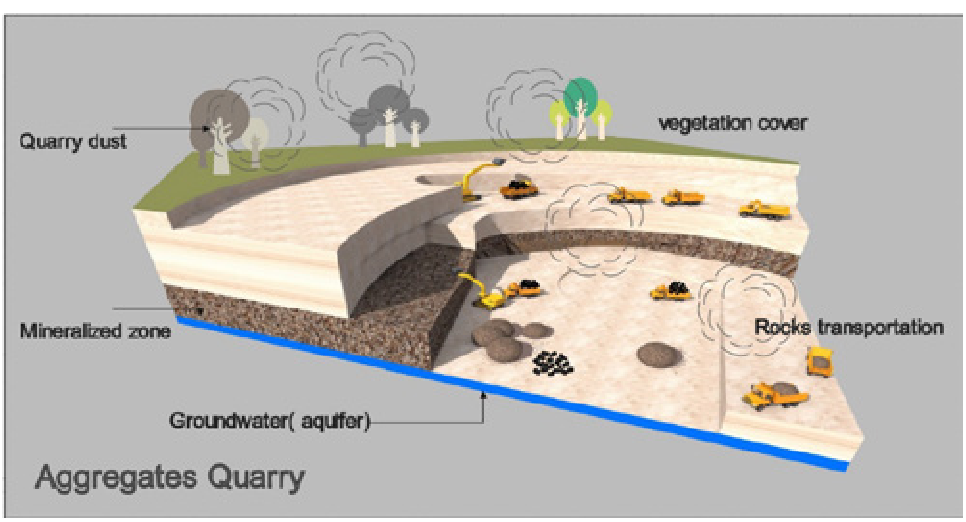

Figure 2. Aggregates exploitation methods

Quarrying depends on minimizing the aggregates stone size through drilling and blasting. Miners use explosives to smash and break rocks, after which they transport the stones to crushing stations. At Heliopolis Aggregates Quarry, they utilize two-wheel loaders and transport trucks. The quarry is equipped with three crushing stations (primary and secondary). The crushed rocks undergo initial screening, and in the second stage, the final gravel product becomes commercially available with varying grain sizes (0–3, 3–8, 8–15, and 15–20 mm).

Sample Collection Sites

We have installed six dust-monitoring stations (S1, S2, S3, S4, S5, and S6) at various distances between the inside and outside of the Heliopolis aggregates quarry from September 2021 to March 2022. These stations were set up to assess the air quality, as shown in Figure 3.

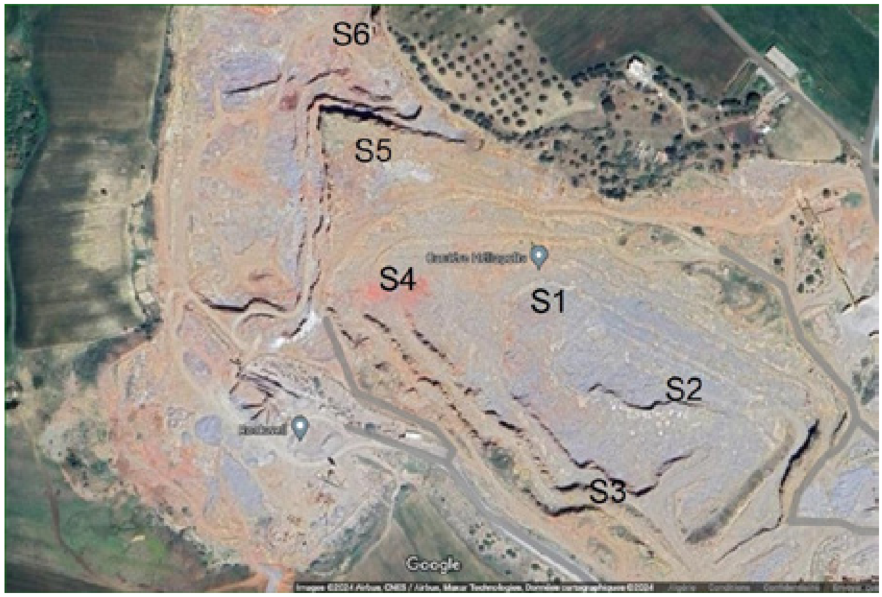

Figure 3. Dust sampling stations positions in Heliopolis quarry (''Google maps'', 2024)

Then, we used (XRF) X-ray fluorescence and (XRD) X-ray spectroscopy (Secchi et al, 2018) to analyze all of the dust samples collected from the quarry. In addition, we have applied an air quality monitor during the exploitation operations as seen in Figure 4a.

X-ray diffraction (XRD) analysis, an advanced analytical technique, offers numerous advantages for detecting mineral compositions within samples under study and processing, such as dust, rocks, and soil. This technology assists researchers in uncovering the environmental impacts of these formulations, allowing for precise analyses without distorting the sample or compromising its properties (''Analyse De Matériaux Par DRX (Diffraction Des Rayons X), 2023 ''). After preparing the sample—mineral dust gathered during exploitation activities—subsequently, we performed X-ray spectroscopy to ascertain the quantity and types of metal oxides present in the dust samples. This procedure was straightforward and automated (Zhou, Wang, Wang, & Liao, 2023) as noticed in Figure 4b, and Figure 4c.

Figure 4. Equipment used in the quantitative and qualitative analysis of dust emitted from the quarry (a: The air quality meter: a multifunctional air quality-measuring device PCE-RCM 8. Brand: Fambasis, b: Benchtop X-ray diffractometer BRUKER D2 PHASER, and c: Fluorescence spectrometer S8 LION, dispersive X-ray machine Bruker AXS (manufactured in Germany)

Flora Pollution Assessment

We collected six samples to assess the impact of quarry dust on plants and trees. The samples included three plant species: laurel, mallows, and wild thistle, found near the Heliopolis quarry. We also brought branches from pine, olive trees, and eucalyptus from a nearby farm. We then conducted a physico-chemical analysis of the samples at the soil and water analysis laboratory in Annaba, Algeria. After being sun-dried, the plants were pulverized and subjected to a variety of chemical treatments, one for each type of mineral. To ascertain the concentration and amount of significant chemical species, such as SiO_2, $CaCO_3$, and Al_2O_3, that were present in the dust samples, this technique is known as the chemical dosing method.

Water Pollution Evaluation

We gathered water samples from the surface water located near the aggregates quarry in Heliopolis, Guelma. After collecting the samples, we conducted a thorough analysis of the water's physical and chemical properties. Our main goal was to determine whether the quarry dust contained any significant elements that could potentially affect the nearby water source. This would help us establish a connection between the quarrying activities and their potential impact on the surrounding watercourses.

Evaluation Of Soil Contamination

We brought soil samples from a farm near the Heliopolis aggregates quarry at a depth of 50 cm to assess soil accumulation. These samples were analyzed for their physicochemical properties at the "Soil and Water Analysis Laboratory" in Algeria. Additionally, we conducted XRD and XRF analyses to identify the important elements present in the soil. These elements can have a direct impact on plants and may cause groundwater pollution.

METEOROLOGICAL CONDITIONS

Temperature Variations

We observe that the Heliopolis area has a relatively hot climate, as indicated on the map in Figure 5.

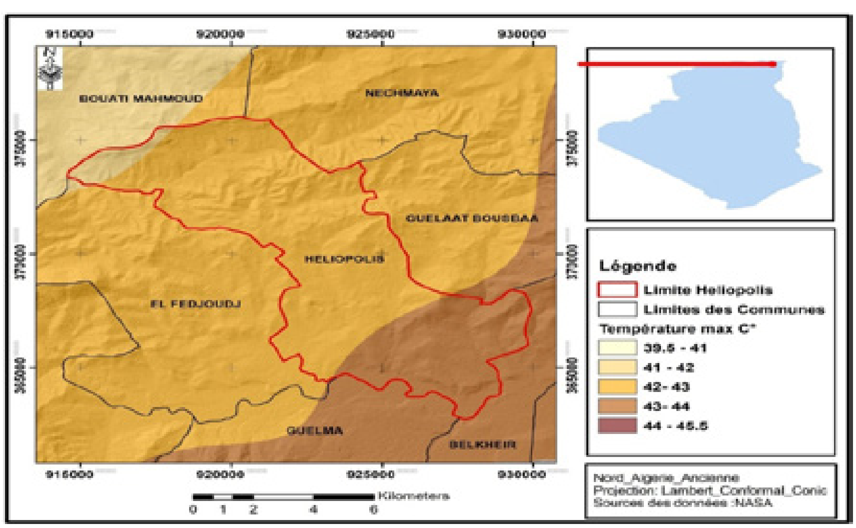

Figure 5. Temperature variations across the Heliopolis region

In the northwest, temperatures range from 39.5 to 41 degrees Celsius, while the central and eastern parts of Heliopolis experience temperatures between 41 and 43 degrees. In the southern region, temperatures soar to 45.5 degrees.

WIND ROSE

The wind rose chart for the Guelma study area presented in Figure 6 illustrates the number of hours that the wind blows in a specific direction throughout the year.

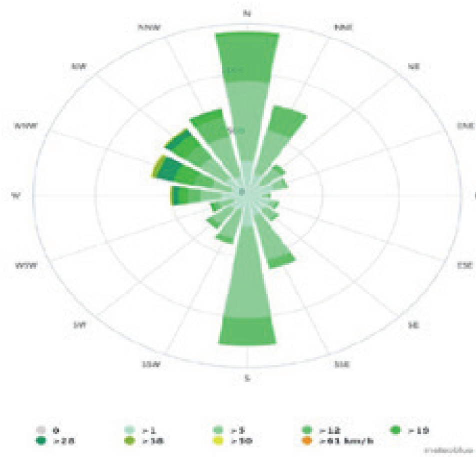

Figure 6. Wind rose chart of Guelma region (''Météo bleu'', 2024)

In this area, the prevailing wind direction is from the southwest (SW) towards the northeast (NE). As a result, station S6 experiences high levels of quartz and calcite, in addition to significant pollution of the flora in this side. This is attributed to the direct influence of the wind, which facilitates the spread of dust particles in the region.

RESULTS AND DISCUSSION

PM POLLUTION QUANTIFICATION

According to Figure 7, S1 and S2 are the most contaminated stations. The daily averages at S1 are PM2.5: 516 µg /m^3 and PM10: 676 µg/m^3, and at S2, PM2.5: 520 µg/m^3 and PM10: 684 µg/m^3, respectively.

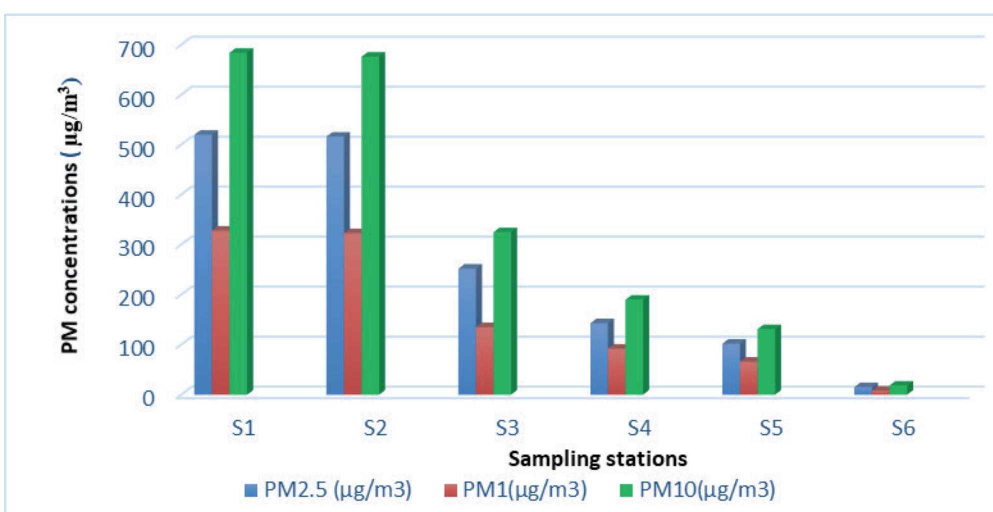

Figure 7. Dust concentrations in the Heliopolis aggregates quarry using an air quality monitor

These values exceed the WHO's maximum annual recommendations for PM2.5: 25 µg/m^3 and PM10: 50 µg/m^3 (''WHO'', 2024), as well as the Algerian limit concentration of 80 µg/m^3 (Kerbachi, Boumechhour, Arrar, & Boughedaoui, 2009).

Table 1. Minerals detected by X-ray diffraction (XRD) in Heliopolis aggregates quarry dust

Minerals (%)	S1	S2	S3	S4	S5	S6
Quartz	4.38*	1.34	2.26	1.3	2.63	8.25
Calcite	90.82	48.24	93.36	79.85	71.71	60.21
Dolomite	0.58	40	0.16	10.33	18.97	8.29
Siderite	0	0	0	0.21	0	0
Ankerite	0	9.03	0	0.53	2.53	2.53
Magnesite	0.62	0	1.33	2.37	0.44	2.86
Pyrite	0.28	0.10	0.10	0.20	0.06	0.32
Illite	0.49	0	1.07	0.87	2.27	9.77
Kaolinite	2	0.96	1.36	1.85	0.98	7.15
K-feldspaph	0.83	0.33	0.36	2.48	0.41	0.63
Total (%)	100	100	100	100	100	100

Note: *4.38% (4.38×104 ppm)

Among the major minerals identified, calcite ($CaCO_3$) exhibits the highest concentrations, with 93.36 % in S3, 90.82 % in S1, and 79.85 % in S4. Subsequently, there is a decrease in the percentage of calcite to 48.24 % at Station S2, although it remains notably high compared to other chemical elements. These findings were determined through XRD examination of all the dust stations listed in Table 1. Human exposure to calcite dust can irritate the eyes and respiratory system, causing asthma with continuous exposure (Lyu et al, 2022).

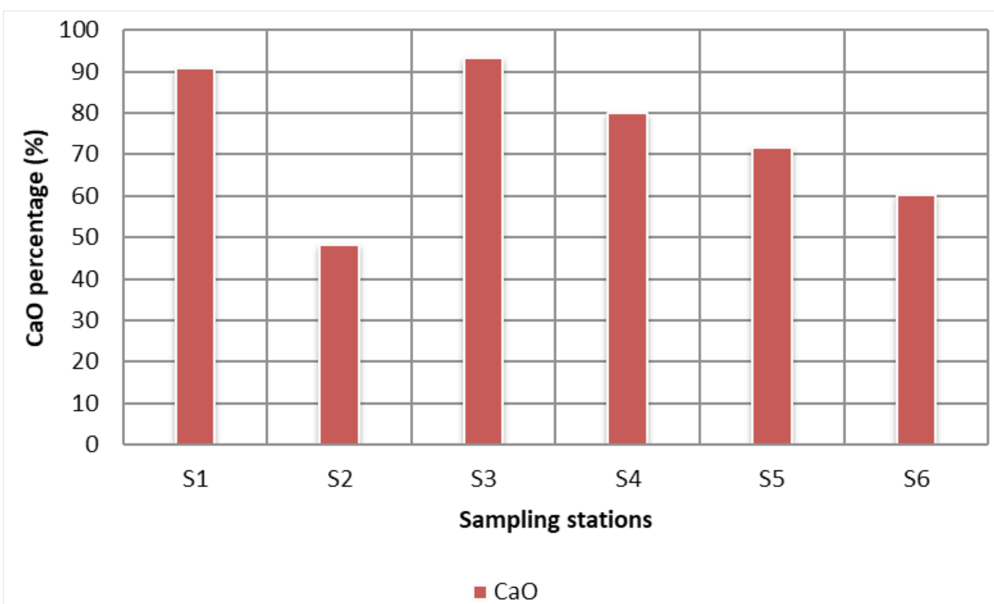

Figure 8. Differences in the amounts of CaO in quarry dust at sampling locations

The noticeable increase in the percentage of calcium oxide in Figure 8, especially at sampling stations S1 and S3, can be attributed to their proximity to primary crushing stations. Additionally, during the unloading of trucks, there is a significant increase in dust concentrations, specifically by 30 times. This increase is primarily due to the dispersion of airborne particles smaller than 2.5 μm in size, in contrast to periods when unloading is not taking place (Liu et al, 2023). It is worth noting that the prevalence of limestone characterizes the geological composition of the study area (Bouaicha, Dib, Belkhiri, Manchar, & Chabour, 2017), that is why nearly all sample stations have a high percentage of calcite dust.

Concerning the presence of the dolomite mineral $CaMg(CO_3)_2$, it is remarkable, reaching a substantial concentration of 40 % in S2. The main constituents of dolomite are magnesium carbonate, calcium carbonate, and limestone. It might also include heavy metals like lead (Semmeq et al, 2021), human respiratory health may be in danger from prolonged exposure to dolomite, and these include coughing, phlegm production that is elevated and breathing difficulty. A decrease in lung function may result from extended exposure, particularly at doses higher than 10 mg/m^3 (Neghab, Abedini, Soltanzadeh, Kashkooli, & Ghayoomi, 2012).

The XRF analysis depicted in Table 2 reveals important CaO concentrations at 55.78 %, 53.63 %, 48.94 %, 48.7 %, 47.1 %, and 30.38 % across all sampling stations (S1, S2, S3, S4, S5, and S6), its levels gradually decline with increasing distance from the emission source.

Table 2. XRF analysis results of dust samples

Station Content %	S1	S2	S3	S4	S5	S6
SiO_2	3.86*	1.25	1.38	0.26	3.45	18.20
Al_2O_3	0.42	0.13	0.27	-	1.54	8.77
Fe_2O_3	0.53	0.18	1.42	0.27	0.67	3.26
CaO	55.63	48.70	53.78	48.94	47.1	30.38
MgO	0.64	7.6	0.44	2.28	3.79	2.09
SO_3	0.18	0.01	0.04	-	0.15	0.99
K_2O	0.11	0.04	0.05	0.01	0.15	0.44
Na_2O	0.08	0.09	0.08	0.09	0.09	0.14

Note: *3.86 % (3.86×10^4ppm)

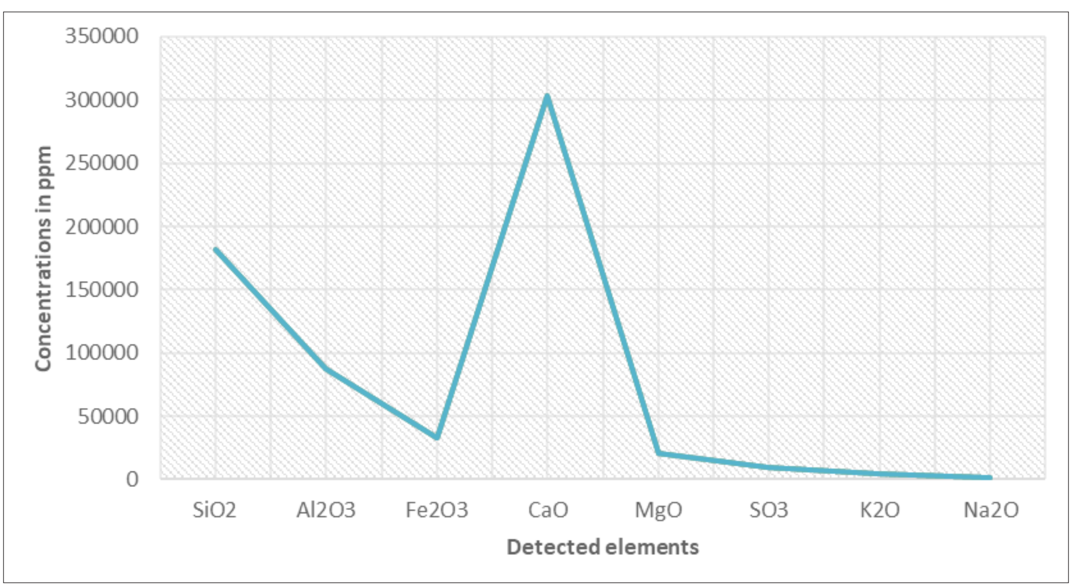

Figure 9. XRF analysis of the quarry dust sample collected at station S6

Despite the generally low presence of silicon dioxide (SiO_2) in all dust-sampling stations, station S6 stands out with an observed concentration of 18.20% (18.2×10^4 ppm) as noticed in Figure 9.

Although not to the same extent as silicon dioxide, aluminum oxide Al_2O_3 concentrations are detectable in the dust samples and diminish gradually. Additionally, several other minerals are present in low concentrations, including Fe_2O_3, MgO, SO_3, K_2O, and Na_2O.

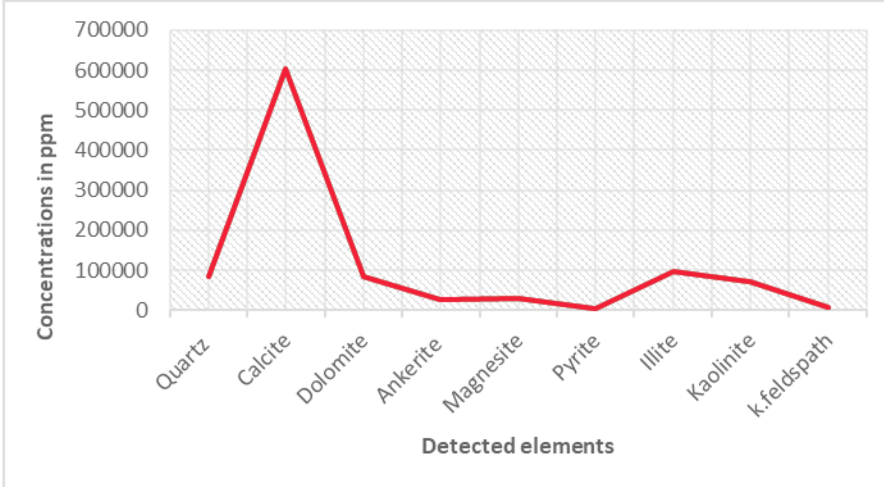

Figure 10. XRD analysis of the quarry dust sample collected at station S6

Station S6 has a relatively higher amount of quartz. Compared to other stations (8.25×10^4 ppm). In addition, trace amounts of the following minerals were detected: Siderite, Ankerite, Magnesite, Pyrite, Illite, Kaolinite, and K-feldspar. As noticed in Figure 10.

Table 3 reveals that plant and tree samples close to the quarry display elevated CaO concentrations.

Table 3. Physicochemical analysis results of the flora samples (3 plants and 3 trees)

Samples	Pine tree branch	Olive tree branch	Laurel plant	Mallows	Wild thistle	Eucalyptus leaves	Method norms
CaO, mg/kg	3500	2500	8325	3725	2925	3125	Volumetric NFT 90 005
Al_2O_3, mg/kg	22	80	75	62.5	25	70	APHA 3500 AL D
SiO_2, mg/kg	30	375	225	525	50	175	DIN EN ISO 16264-H57

Notably, the laurel plant registers 8325 mg/kg; mallows show 3725 mg/kg, and pine tree branches exhibit 3500 mg/kg. Eucalyptus leaf samples have 3125 mg/kg, and wild thistle records 2925 mg/kg. Even the olive tree branch, situated farthest from the pollution source, demonstrates a CaO mineral concentration of 2500 mg/kg. The dust covering these plants, leaves, and tree branches contains heavy metals, including aluminum. The concentration of aluminum in the olive tree branch is 80 mg/kg, in the laurel is 75 mg/kg, and in the Eucalyptus leaves is 70 mg/kg. Mallow shows a concentration of 62.5 mg/kg, wild thistle has 25 mg/kg, and the pine branch records 22 mg/kg. Numerous significant studies have emphasized the risks associated with plants' exposure to Al_2O_3, which can lead to DNA fragmentation and subsequent cell death. Additionally, it has been established that Al_2O_3 causes phytotoxicity in plant roots (Yanık & Vardar, 2015).

Regarding silicon dioxide (SiO_2), mallows exhibit the highest concentration at 525 mg/kg, followed by olive tree branches at 375 mg/kg. Then, the silicon dioxide (SiO_2) content of laurel plants was at 225 mg/kg, eucalyptus leaves (175 mg/kg), wild thistle (50 mg/kg), and pine tree branch (30 mg/kg).

Plant physiology hinges on various physiological processes crucial for growth and development, with photosynthesis standing out as the most vital. Photosynthesis entails the conversion of light energy into chemical energy, a fundamental task for the growth and survival of plants (Bhatla & Lal, 2018). The accumulation of quarry dust on plant surfaces hampers this process as the tiny particles obstruct the penetration of light, thereby blocking the stomata, small pores on the leaves responsible for gas exchange. This interference leads to a decline in plant development and a decrease in crop quality (Meravi, Singh, & Prajapati, 2021).

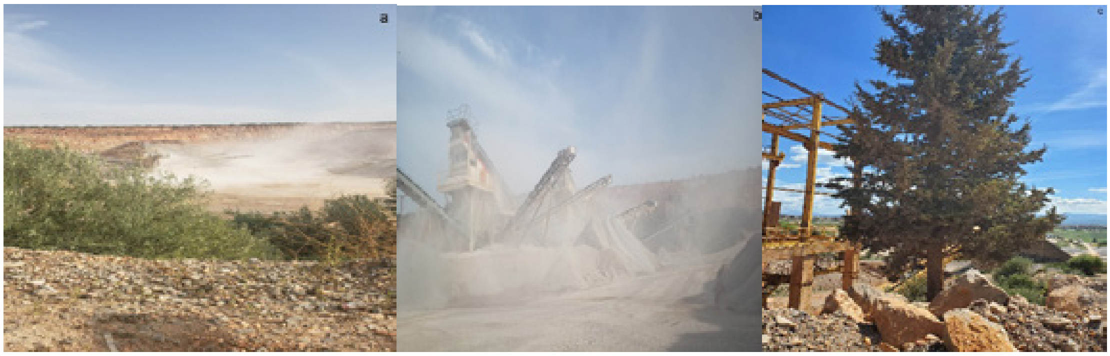

Figure 11. Dust emissions from gravel preparation operations in Heliopolis quarry (a: Air pollution caused by rock extraction and transportation; b: Dust emission from the grinding station; c: Pine tree covered by mineral dust near the crushing station)

Air pollution resulting from various gravel-processing operations in the Heliopolis aggregates quarry as we see in Figure 11a and Figure 11b has extended to neighboring plants and trees, causing a change in color and a reduction in productivity. Physical and chemical analyses have confirmed that the mineral dust covering the plants and trees in this area hinders their natural development and obstructs sunlight, significantly affecting the process of photosynthesis.

We can observe the visible impact of quarry dust on the pine tree with the naked eye in the attached picture in Figure 11c.

Table 4 presents the findings of the physicochemical analysis, and it reveals an aluminum concentration in the water samples of 0.50 mg/l while the World Health Organization has set a limit of 0.05 mg/l to 0.2 mg/l for aluminum in drinking water.

Table 4. Water sample physicochemical examination results

Parameters	Values	Method norms
PH at 25°C	7.74	NF T 90-008
Conductivity (CE) µS/cm at 20°C	749	NF T 90-031
Salinity mg/l at 20°C	334	NF T 90-031
Aluminum (Al) mg/l	0.50	APHA 3500 AL D
Silica (SiO_2) mg/l	0.30	DIN EN ISO 16264-H57
Calcium oxide (CaO) mg/l	170	Volumetric NFT 90 005

Health studies underscore the dangers associated with the presence of this chemical element (Al) in water, linking it to various incurable diseases such as Alzheimer's and other neurological disorders (Hızlı, Karaoğlu, Gören, & Kobya, 2023). Exposure to aluminum poses health risks for individuals across age groups, including children, adults, and the elderly and even animals. (Niu, 2023). A 15-year study conducted in the south of France found a correlation between the consumption of water containing aluminum at concentrations greater than or equal to 0.1 mg/day and the onset of dementia. Additionally, the analysis in Table 4 reveals the presence of silicate at 0.30 mg/l and a significant amount of CaO at 170 mg/l.

Table 5. Physicochemical Analysis Results of Soil Samples

Parameters	Values	Method norms
pH at 25°C	9.51	AFNOR : X 31--103
Conductivity (EC) µS/cm at 20°C	457	ISO : 11265
Salinity mg/l at 20°C	217	ISO : 11265
Calcium oxide (CaO) mg/kg	9350	Volumetric NFT 90 005
Aluminum (Al) mg/l	82.02	APHA 3500 AL D
Silica (SiO_2) mg/l	175.18	DIN EN ISO 16264-H57

According to the physicochemical analysis of soil samples presented in Table 5, it is evident that the soil contains significant concentrations of CaO mineral (9350 mg/kg), aluminum (Al) with a concentration of 82.02 mg/kg, and silicon dioxide (SiO_2) with 175.18 mg/kg.

The scarcity of water, amidst global water shortages, combined with the presence of aluminum in the soil, contributes to environmental contamination, ultimately causing stress for plants and leading to a decline in their growth (José Rodrigues Cruz, 2023).

Land degradation and loss of vegetation cover are some of the harmful effects of quarrying activities. Plants are crucial in stabilizing soil and supporting ecological life (Opondo, Ajayi, & Makindi, 2022), which is vital for robust food production. Unpolluted soil plays a significant role as a preserver of water and life. However, soil contamination by substances like heavy metals and industrial waste leads to premature deaths and the transmission of diseases. Soil pollution also restricts the presence of microorganisms, leading to increased toxicity. Hence, contaminated soil is likely to cause groundwater contamination in the future (Münzel, Hahad, Daiber, & Landrigan, 2022).

CONCLUSION

Our research revealed that various methods of preparing gravel adversely affect air quality, leading to pollution. Monitoring of air quality indicated that particulate matter emissions from gravel extraction activities exceeded the maximum limits set by the World Health Organization for PM2.5 and PM10, with readings of PM2.5 at 520 µg/m^3 and PM10 at 684 µg/m^3 in S2. Inhaling fine mineral particles like PM2.5 heightens the risk of lung cancer and respiratory ailments such as asthma, whereas PM10 can cause skin irritation, conjunctivitis, and eye infections. The wind transports these tiny particles that contain a variety of minerals such as calcite, dolomite, quartz, aluminum oxide, iron oxide, silicon dioxide, and other mineral oxides, posing significant risks to local populations, particularly vulnerable groups like the elderly and pregnant women. The physicochemical analysis conducted on water, soil, and flora samples validates the transportation of these particles by wind to neighboring regions, potentially leading to damage and a reduction in crop quality. In summary, quarrying activities must take proactive measures to mitigate various forms of pollution. Emphasizing the significance of incorporating these findings is crucial for protecting the environment and fostering cleaner production practices for aggregates in the future.

Acknowledgement
I extend my heartfelt gratitude to my supervisor and the director of the Mineral Processing and Environmental Laboratory (LAVAMINE), Professor Mohamed Bounouala, for their unwavering encouragement and invaluable guidance throughout this journey. I am also deeply thankful to Dr. Benselhoub Aissa for his significant contributions to this research endeavor.
Furthermore, I express my sincere appreciation to all the engineers at the Heliopolis and El Fedjoudj aggregates quarries in Guelma, Algeria, for their collaboration, which was instrumental in the successful completion of this scientific work.
I am profoundly grateful to my parents for their unwavering support and encouragement during my doctoral preparation. Their constant belief in me has been a source of strength and motivation.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors have no relevant financial or non-financial interests to disclose.

Funding Statement

No funding was received for the preparation of this manuscript.

Ethics Statement

Our research preparation did not involve human or animal experiments.

All authors have read and approved the final version of the manuscript and agree with its submission to the journal: Quality of life.

REFERENCES

Ajibade, O. M., Olisa, O. G., Oladipupo, S. D., Adegoke, C. B., & Adebayo, O. H. (2022). Health impact assessment of quarrying in some parts of southwestern Nigeria. Arabian Journal of Geosciences, 15(8). https://doi.org/10.1007/s12517-021-08391-7.

Argacha, J. (2023). Effets de la pollution de l'air sur les évènements cardiovasculaires en unité de soins intensifs cardiologiques. Annales De Cardiologie Et D'Angéiologie, 72(5), 101663. https://doi.org/10.1016/j.ancard.2023.101663.

Bascompta, M., Sanmiquel, L., Gangolells, M., & Sidki, N. (2022). LCA analysis and comparison in quarrying: Drill and blast vs mechanical extraction. Journal of Cleaner Production, 369, 133042. https://doi.org/10.1016/j.jclepro.2022.133042.

Bhatla, S. C., & Lal, M. A. (2018). Plant Physiology, Development and Metabolism.Springer.

Boutemedjet, A., Bounouala, M., Idres, A., & Benselhoub, A. (2019). Assessment of dust pollution related to granite quarry operations in Kef Bouacida, Annaba (Algeria). Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 1, 117–124. https://doi.org/10.29202/nvngu/2019-1/13.

Danielsen, S. W., & Kuznetsova, E. (2014). Environmental Impact and Sustainability in Aggregate Production and Use. Engineering Geology for Society and Territory - Volume 5, 41–44. https://doi.org/10.1007/978-3-319-09048-1_7.

Dong, X., Yu, B., Brown, M., Zhang, Y., Kang, M., Jin, Y., Zhang, X., & Ulgiati, S. (2014). Environmental and economic consequences of the overexploitation of natural capital and ecosystem services in Xilinguole League, China. Energy Policy, 67, 767–780. https://doi.org/10.1016/j.enpol.2013.11.038.

Ferreira, A., Fernandes, D., de Figueiredo, J. P., Loureiro, A., Seco, S., & Moreira, F. (2023). Occupational Exposure to Particles in Quarries and Its Effects on worker's Health. Occupational and Environmental Safety and Health V, 373–388. https://doi.org/10.1007/978-3-031-38277-2_30.

Foued, B., Hénia, D., Lazhar, B., Nabil, M., & Nabil, C. (2017). Hydrogeochemistry and geothermometry of thermal springs from the Guelma region, Algeria. Journal of the Geological Society of India, 90(2), 226–232. https://doi.org/10.1007/s12594-017-0703-y.

Geng, G., Xiao, Q., Zheng, Y., Tong, D., Zhang, Y., Zhang, X., Zhang, Q., He, K., & Liu, Y. (2019). Impact of China's Air Pollution Prevention and Control Action Plan on PM2.5 chemical composition over eastern China. Science China Earth Sciences, 62(12), 1872–1884. https://doi.org/10.1007/s11430-018-9353-x.

Hızlı, S., Karaoğlu, A. G., Gören, A. Y., & Kobya, M. (2023). Identifying Geogenic and Anthropogenic Aluminum Pollution on Different Spatial Distributions and Removal of Natural Waters and Soil in Çanakkale, Turkey. ACS Omega, 8(9), 8557–8568. https://doi.org/10.1021/acsomega.2c07707.

José Rodrigues Cruz, F. (2023). Toxic Aluminum and Water Deficit Interaction in Plants: Physiological Aspects and Chemical Soil Management to Improve Root Environment in the Context of Global Climate Change. Abiotic Stress in Plants - Adaptations to Climate Change. https://doi.org/10.5772/intechopen.111418.

Kerbachi, R., Boumechhour, F., Arrar, J., & Boughedaoui, M. (2009). Pollution de l'air par les particules acides à Alger et influence de l'aérosol marin. Pollution Atmosphérique, N°204. https://doi.org/10.4267/pollution-atmospherique.1220.

Li, C., & Zhu, Z. (2018). Research and application of a novel hybrid air quality early-warning system: A case study in China. Science of the Total Environment, 626, 1421–1438. https://doi.org/10.1016/j.scitotenv.2018.01.195.

Liang, Y., McCoy, K. E., Tomasallo, C. D., & Meiman, J. G. (2023). Social determinants of an occupational lung disease: Workers' narratives on silicosis. SSM - Qualitative Research in Health, 3, 100290. https://doi.org/10.1016/j.ssmqr.2023.100290.

Liu, Z., Ao, Z., Zhou, W., Zhang, B., Niu, J., Wang, Z., Liu, L., Yang, Z., Xu, K., Lu, W., & Zhu, L. (2023). Research on the Physical and Chemical Characteristics of Dust in Open Pit Coal Mine Crushing Stations and Closed Dust Reduction Methods. Sustainability, 15(16), 12202. https://doi.org/10.3390/su151612202 .

Lyu, Y., Zhang, Q., Liu, Y., Zhang, W. P., Tian, F. J., Zhang, H. F., Hu, B. H., Feng, J., Qian, Y., Jiang, Y., Zhang, P. H., Ma, N., Tang, S. C., Zheng, J. P., & Qiu, Y. L. (2022). Nano–Calcium Carbonate Affect the Respiratory and Function Through Inducing Oxidative Stress. Journal of Occupational & Environmental Medicine, 65(2), 184–191. https://doi.org/10.1097/jom.0000000000002713.

Materu, S. F., Sway, G. G., & Mussa, B. S. (2023). Workplace concentrations of particulate matter and noise levels among stone quarry and soil brick-making workers in Tanzania. Journal of Occupational and Environmental Hygiene, 20(12), 563–573. https://doi.org/10.1080/15459624.2023.2249520.

Meravi, N., Singh, P. K., & Prajapati, S. K. (2021). Seasonal variation of dust deposition on plant leaves and its impact on various photochemical yields of plants. Environmental Challenges, 4, 100166. https://doi.org/10.1016/j.envc.2021.100166.

Münzel, T., Hahad, O., Daiber, A., & Landrigan, P. J. (2022). Soil and water pollution and human health: what should cardiologists worry about? Cardiovascular Research, 119(2), 440–449. https://doi.org/10.1093/cvr/cvac082.

Najafi, Hamzeh, & Moqimi. (2014). The contribution of „Kimberley" as a rehabilitated mine to South Africa`s tourism income. African Journal of Hospitality, Tourism and Leisure.

Neghab, Abedini, Soltanzadeh, Kashkooli, & Ghayoomi. (2012). Respiratory disorders associated with heavy inhalation exposure to dolomite dust. Iran Red Crescent Medical Journal, 14(09). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3482327/.

Niu, Q. (2023). Neurotoxicity of Aluminum (pp.323 *-324)*.Department of Occupational Health, School of Public Health, Shanxi Medical University. Taiyuan, China. Springer Nature.

Opondo, E. O., Ajayi, D. D., & Makindi, S. M. (2022). Impacts of quarrying activities on the environment and livelihood of people in Border II sub-location, Nyando sub-county, Kisumu County, Kenya. Environmental Quality Management, 32(3), 147–160. https://doi.org/10.1002/tqem.21881.

Rentschler, J., & Leonova, N. (2023). Global air pollution exposure and poverty. Nature Communications, 14(1). https://doi.org/10.1038/s41467-023-39797-4.

Secchi, M., Zanatta, M., Borovin, E., Bortolotti, M., Kumar, A., Giarola, M., Sanson, A., Orberger, B., Daldosso, N., Gialanella, S., Mariotto, G., Montagna, M., & Lutterotti, L. (2018). Mineralogical investigations using XRD, XRF, and Raman spectroscopy in a combined approach. Journal of Raman Spectroscopy, 49(6), 1023–1030. https://doi.org/10.1002/jrs.5386.

Semmeq, A., Foucaud, Y., El Yamami, N., Michailovski, A., Lebègue, S., & Badawi, M. (2021). Hydration of magnesite and dolomite minerals: new insights from ab initio molecular dynamics. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 631, 127697. https://doi.org/10.1016/j.colsurfa.2021.127697.

Yanık, F., & Vardar, F. (2015). Toxic Effects of Aluminum Oxide (Al2O3) Nanoparticles on Root Growth and Development in Triticum aestivum. Water, Air, & Soil Pollution, 226(9). https://doi.org/10.1007/s11270-015-2566-4.

Yu, H., & Zahidi, I. (2023). Spatial and temporal variation of vegetation cover in the main mining area of Qibaoshan Town, China: Potential impacts from mining damage, solid waste discharge and land reclamation. Science of the Total Environment, 859, 160392. https://doi.org/10.1016/j.scitotenv.2022.160392.

Zhou, S., Wang, J., Wang, W., & Liao, S. (2023, January 24). Evaluation of Portable X-ray Fluorescence Analysis and Its Applicability As a Tool in Geochemical Exploration. *Minerals*, *13*(2), 166. https://doi.org/10.3390/min13020166.

WEB REFERENCES:

FILAB, laboratoire d`analyses et d`expertise. (2023). Analyse de matériaux par DRX (Diffraction des Rayons X). Available at: <https://filab.fr/nos-moyens-techniques/analyse-et-caracterisation-des-materiaux-par-diffraction-des-rayons-x-drx-en-laboratoire/filab-caracterise-vos-mineraux-par-drx/#:~:text=L'%C3%A9tude%20par%20diffraction%20des,les%20s%C3%A9diments%20et%20les%20poussi%C3%A8res> [Accessed 19.01.2024].

Google Maps. Données cartographiques (2024). Available at: < https://www.google.com/maps/@36.5185508,7.4192043,297m/data=!3m1!1e3?entry=ttu> [Accessed 23.03.2024].

Meteoblue. (2024). Météo Guelma. Available at: <https://www.meteoblue.com/fr/meteo/semaine/guelma_alg%C3%A9rie_2495662> [Accessed: 11.04.2024].

World Health Organization. (2021). WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geniva: WHO. Available at: <https://www.who.int/publications/i/item/9789240034228>. Accessed: 18.08.2023.

World Health Organization. (2022). Air quality database. Air quality data portal. Geneva: WHO. Available at: <https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database/2022>. Accessed 19.12.2022.

World Health Organization. (2024). Air Quality. Energy and Health. Geneva: WHO. Available at: <https://www.who.int/teams/environment-climate-change-and-health/air-quality-energy-and-health>. Accessed 18.03.2024.

Recived: March 26, 2024

Accepted: May 31, 2024