Available online at
http://journal.uitm.edu.my/ojs/index.php/BEJ

Built Environment Journal

e-ISSN: 2637-0395

Built Environment Journal 22(Special Issue) 2025, 154 – 170.

Evaluation of Air Quality in The Surrounding Community Due to Limestone Blasting

Emma Marinie Ahmad Zawawi[1*], Wan Hasmirah Wan Ibrahim[1], Naziah Muhammad Salleh[2], Badrul Hisham Daud[3]

[1]*School of Construction and Quantity Surveying, College of Built Environment, Universiti Teknologi MARA, Shah Alam, 40450 Selangor, Malaysia*
[2]*Department of Building Surveying, School of Housing, Building and Planning, Universiti Sains Malaysia, 11800 Penang, Malaysia*
[3]*Bina Pragmatik Sdn Bhd, A-10-1, Block A, Bistari De Kota, Jalan Teknologi 3/9, Kota Damansara,47810 Petaling Jaya, Selangor, Malaysia*

ARTICLE INFO

Article history:
Received 1 November 2024
Revised 24 April 2025
Accepted 16 May 2025
Online first
Published 31 July 2025

Keywords:
Quarry
Blasting
Indoor Air Quality
Particulate Matters
Environment
Construction

DOI:
10.24191/bej.v22iSI.6499

ABSTRACT

Air quality is very important in the people's lives. In Malaysia, the quality of air needs to be monitored as the level is getting worst day by day. This is especially the case in areas where activities such as construction and quarry mining operate actively. This paper presents the findings of an investigation into air quality status in a community adjacent to a quarry. Air pollutants were monitored according to PM2.5 and PM10, using the TSI 8533 DustTrak, DRX Desktop Aerosol Monitor. The data were used to examine the influence of mining activities (blasting and non-blasting) within variability of PM2.5 and PM10 concentrations inside residential buildings. Indoor dust was collected manually to be tested in the lab to identify the chemical composition. The result indicates that within-day variability of indoor PM2.5 and PM10 was influenced by the occupant's activities and surrounding outdoor activities such as blasting and vehicle movements. Mitigation measures are proposed to ensure the achievement of sustainable development and indirectly improve the quality of air around the nearby residential area. It is anticipated that both residents and the quarry management are aware of the importance of monitoring air quality towards sustainable life in the future.

INTRODUCTION

The construction industry is one of the main contributors to quarry mining in Malaysia. The higher demand for new developments results in the increase in construction activities, which have a significant impact on the environment. Therefore, residential areas near the quarrying industry are currently facing problems of

[1*] Corresponding author. *E-mail address*: emmamarinie@uitm.edu.my

air quality. Thus, the impact of quarrying on the air quality level needs to be identified. Quarrying activities have increased to supply the raw materials for building construction, industry and other purposes, using explosives for blasting. This inevitably leads to concern over the effect on the environment, especially in the vicinity of quarry mining. These effects are normally a nuisance to the neighbouring residential areas, in the form of dust, toxic gases, noise, flying rocks, air blasts and ground vibrations. Therefore, there are many complaints from residents near quarry mining. For example, limestone dust consists of many elements which affect human health, such as magnesium (Mg) and calcium (Ca). The finest particulates of Ca and Mg can damage the human lung and respiratory system (Drain et al., 2015).

The major source of air pollution is this dust, and its impact depends on factors like the local conditions, the saturation of dust particles in the air, the size of the dust particles and their chemistry. Limestone quarries produce a high level of alkaline dust. Air pollution is caused when air contains substances or particles that can affect humans, animals and plants. The air quality becomes poorer, and if the pollution continues, it will increase negative effects on the health of residents near the quarry. This study was conducted to investigate the effect of dust from the blasting activity of quarry mining.

According to Branquinho (2008), when the mineral mass is fragmented and released through blasting, it is loaded onto haulage trucks. Haulage trucks of up to 100 tonne volume are frequently used to remove the mined mineral out of the open pit to the downstream dispensation plant. These procedures cause dust emissions throughout loading, unloading and throughout the conveyance of the components out of the quarry. The crushing and screening of the mineral into smaller dimensions causes dust emanations. A loader and gyratory crusher are constantly applied for the initial crushing of the mineral, mechanically producing dust and fines. The crushing and screening of the rock and its following transmission by belt conveyor to main stockpiles are similarly a possible basis of dust creation (Raisian & Yahaya, 2015). The pollution is caused by emissions of air that contains substances or particles that can affect humans, animals, plants and other materials. If this air pollution is not controlled, the air quality will become increasingly worse, affecting the quality of life of the residents near the quarry mining. In addition, the biodiversity, of fish, insects, reptiles, birds, mammals, plants, fungi and microorganisms will be affected as the quarry is likely to destroy their habitat. It is clearly important to investigate blasting as one of the factors contributing to poor indoor air quality.

LIMESTONE QUARRYING

Quarrying is one of the most important industries in the development of a country's economy, providing a continuous supply of raw materials for construction, building and manufacturing. In support, both industry and government agencies must take responsibility for regulating it. The increase in population has led to an increase in the demand for residential land, which explains why housing developments are situated near quarry mining. This will cause the level of the Air Quality Index (AQI) to deteriorate. Laws must manage the balance between the environment and economic development, by providing preventive measures to preserve the environment. In line with the current legislation (Section 34A of the Environmental Quality Act, 1974, Amendment 1985) a 1990 report requires an Environmental Impact Assessment (EIA), which includes an assessment of the mitigation, prevention and reduction of environmental impact. Wahid (2016) studied 49 EIA reports from 1995 to 2002 on housing construction, with proposals to place the mine processing or any industry at least three kilometres away from the mine site. However, many of the dwellings near the mine experience negative effects caused by construction sites and mining.

Quarrying is the process of obtaining stone from the ground. The methods and equipment utilised in quarries depend on the purpose for which the stone is extracted. Different quarrying activities have different impacts on air quality, as the drilling and blasting process is considered a source of pollutant emission.

Furthermore, elements such as arsenic, lead and nickel may be found in some mining operations, having an impact on ecology through habitat loss and fragmentation (Hayyat et al., 2021). Shattering the drilled limestone or overburden to produce smaller fragments is also an instantaneous source of suspended particulates. The loading and movement of dumper trucks to move material generates suspended particulates, and the crushing of rock and transferring it to a belt conveyor is a possible source of dust generation (Wan Ibrahim et al., 2018). Mineral exploration, mining and processing have resulted in environmental damage together with ecological disturbance, destruction of natural flora, the pollution of air, land, and water, instability of soil and rock masses, landscape degradation and radiation hazards. A review of mining practice is important to know where dust originates in mining operations, and therefore the environmental factors affecting dust emissions (Norgate, 2010).

In general, the process of quarrying starts with the removal of topsoil, drilling and blasting of overburden, removal of overburden, removal of material containing the mineral, processing of material containing the mineral, continuing to the reclamation of the mined-out area. Once the mineral has been extracted and removed from the working area, some processing is normally carried out on site. Some materials might have to be crushed to reduce individual pieces to a manageable size. Crushing plants can also be noisy, and for hard rock it is sometimes necessary to use a pecker on the largest rocks before loading on to the dump truck, or a hydraulic breaker at the crush feed. Dust is thus produced through a wide variety of processes including blasting and crushing of the rock (Raisian & Yahaya, 2015).

Blasting also has a major impact on poor air quality. It breaks the rock into pieces suitable for crushing. A bursting charge is detonated in a shot hole and a rapid discharge of energy takes place within a brief duration causing a tremendous rise in pressure and temperature. The majority of energy released is used in breaking the rock, but a significant percentage is wasted. This wasted energy is dissipated through noise, dust, heat and noxious gases along with the formation of a number of more significant environmental impacts. According to Jain et al. (2016), quarry blocks are then transported with bulldozers or caterpillars. The basic process of the quarry begins with drilling large boreholes for the entire length of the high wall, followed by blasting used to break the rock from the high wall. After the rock falls to the bottom of the pit, it is loaded into haulage trucks and driven to the crusher. Each crusher progressively reduces the rock into smaller pieces and screens out the dust. The last part of the method is the processing plant or mill. At the processing plant, stone is washed, sized and sent to the kiln system to burn off impurities. The drilling, blasting, and crushing of the rock creates dust at many different steps within the process. This dust easily floats and can move throughout the facility contributing to the concentration of particulate matter. However, most dust is relatively large and is readily deposited on flat surfaces or on the ground. The dust is more likely to become airborne when vibration, wind, or other motion disturbs the settling process (Adinkrah-Appiah et al., 2016). According to Nartey et al. (2012), the operation of quarry mining produces dust by the process of removing blocks or pieces of stone from an identified geologic deposit. Lameed and Ayodele (2010) stated that the major source of air pollution is dust from the quarry, influenced by local conditions, the saturation of dust particles in the air, size of the dust particles and their chemistry, a high alkaline level in limestone.

Dust is the main source of air pollution from the quarry industry, affecting both human health and the natural environment. Long-term exposure to toxic air pollutants can lead to chronic health problems, for instance decreased lung capacity and lung cancer (Bada, Kofoworola and Babarinde, 2013). According to Olusegun et al. (2009), the respiratory system is harmed when any component of chemical compounds is inhaled into the lungs; for example, the dust may cause silicosis, impairing health and other related cases that lead to death. Suspended particulate dust also causes asthma, lung cancer, and cardiovascular issues and may result in early death. Respiratory illnesses such as asthma are caused by very fine dust, and even arthritis sufferers are affected. Dust from tin mining has a high silica content and increases the incidence of silicosis and silico-tuberculosis in the region, as well as lung cancer and non-malignant respiratory

https://doi.org/10.24191/bej.v22iSI.6499

infections. A high arsenic content in dust and smoke appears to have a more critical influence than crystalline silica in raising the mortality rate from lung cancer. Non-poisonous gases have an unpleasant impact, especially those that reduce the oxygen content (Bluvshtein et al., 2011).

Blasting is considered as a vital component of surface mining, the main force in breaking up the overburden and revealing limestone and related mineral deposits (Afeni & Osasan, 2009). Serious structural damage and personal injury can be caused by ground vibration from blasting. People notice vibration at levels much lower than those needed for even superficial injury to the most susceptible constructions. Ground vibration, air blasts and flying rocks are considered as side effects of badly planned blasting operations. Emissions result from the mechanics of quarrying and are windblown. According to Branquinho (2008), when the mineral mass has been fragmented and released through blasting, it is loaded into giant haulage trucks for removal from the open pit to the downstream dispensation plant. These procedures will cause dust emissions throughout loading, unloading and throughout the conveyance of the component material out of the pit.

GOVERNMENT ENFORCEMENT TO REDUCE ENVIRONMENTAL IMPACT OF QUARRY ACTIVITIES

The Environmental Quality Act 1974 (EQA) set the standard for environmental protection and pollution control. This law and regulations are enforced by the Department of the Environment. In addition to the national legislation, some states such as Selangor, Perak, Kelantan, Pahang and Terengganu have adopted Quarry Rules, which focused on operational safety as well as pollution control and occupational health and safety. A baseline study examining the noise, dust, erosion and social impact and traffic conditions was carried out in residential areas close to quarries, where these problems were already known to exist. As a recommendation, the government needed to find suitable and practicable mitigation measures to reduce the environmental impact and improve the quality of life for residents (Chooi & Yong, 2016). EIA monitoring and managing natural resources reports show that the assessment does not always follow the correct guidelines, and mitigation will not be useful in protecting natural resources, insulating projects, or minimising environmental damage (Wahid, 2016).

According to Wan Ibrahim (2009), the quarry management needs to consider the Occupational Safety, Health and Environmental (OSHE) issues. The environment has been a major issue for the quarrying industry for many years and its profile is increasing. This is because of the long overdue need to identify the problem of enforcing the law and regulations pertaining to quarry management and quarry dust management. It is important to have good management of quarry operations. Activities such as drilling and blasting, and transport in and out of the quarry area have an impact on air quality. A report by the residents themselves indicates their problems resulting from quarrying activities, including dust pollution, soil erosion, cracking and noise disturbance from blasting. However, awareness on the importance of air quality to human life is still low, with no action taken despite the many complaints that have been submitted. Hence, this problem needs to be fully investigated to make sure the enforcement by the government will be effective in reducing the impact of quarrying activities.

https://doi.org/10.24191/bej.v22iSI.6499

METHODOLOGY

Area of Study

This study involved a quantitative method of data collection, measuring the particulate matter in situ and also by experimental procedures in the lab. Aware of the problems and issues of dust from quarrying for nearby residential areas, the researcher chose Bandar Saujana Putra. located in Tanjung Dua Belas sub-district, Kuala Langat District, Selangor to conduct the study. Bandar Saujana Putra is an 850-acre township developed by LBS Bina Berhad in 2003, with an estimated 20,000 residents following the completion of 6,000 units. The township is located south of Putra Heights, UEP Subang Jaya and Puchong, along the North–South Expressway Central Link. Cyberjaya, Putrajaya and Kuala Lumpur International Airport (KLIA) are to the east and south, and Jenjarom and Teluk Panglima Garang to the west. Bandar Saujana Putra grew rapidly and this growth put pressure on the city's infrastructure; it consists of residential areas, a university and schools, with the limestone quarry nearby. The great influx of people into the city without matching urban planning has continued to result in a wide variety of environmental problems. Due to economic and political pressures, the city has continued to grow without integrating environmental considerations. The resulting poorly managed environment is now a major impediment to economic growth and is already impacting adversely on the health and livelihoods of residents and the long-term sustainability of the city's natural resources such as the quarry mining area.

The criteria justifying the choice of this area included the distance of the residential area from the highway (Elite Highway Express), its location close to the quarry mining area, and the lack of obstacles to taking measurements of dust. To achieve the objective of this study, information on the air quality index has been obtained from surveys and air quality measurements in houses.

Evaluation of Particular Matter

Figure 1 shows the location of the case study and the distance between the quarry and housing. The selection of 15 residences was determined based on their distance (200m, 400m, 600m, 800m and 1000m) from the nearby limestone quarry. Using a TSI 8533 Dust-track DRX Desktop Aerosol Monitor, particulate matter was measured inside of the houses. The aerosol monitor is a battery-operated, data-logging, light-scattering laser photometer that gives real-time aerosol mass readings. It uses a sheath air system that isolates the aerosol in the optics chamber to keep the optics clean for improved reliability and low maintenance. It is suitable for clean office settings as well as harsh industrial workplaces, construction and environmental sites and other outdoor applications. It is capable of simultaneously measuring size-segregated mass fraction concentrations corresponding to PM1, PM2.5, PM10 and total PM size fractions, present in dust, smoke, fumes and mist. That is, the monitor was suitable for measuring indoor dust, especially particulate matter (PM2.5 and PM10). The equipment was placed in the living room for eight hours, between 9am and 5pm on selected days. Measurements were taken every ten minutes throughout the eight hours. The measurements of particulate matter PM2.5 and PM10 were held on blasting days and non-blasting days.

https://doi.org/10.24191/bej.v22iSI.6499

Fig. 1. Aerial View of the Distance from the Housing to The Quarry

Source: Authors (2024)

(a) (b) (c)

Fig. 2. (a) Collection of the Indoor Dust, (b) Samples of Indoor Dust, (c) Digestion Process

Source: Authors (2024)

Evaluation of the Dust Content

The dust from the house was collected manually Figure 2(a) and Figure 2(b) shows the samples of collected dust to be taken to the lab for testing. Indoor dust was collected using a plastic brush. 0.2g dust were collected from each of 15 houses, from surface areas of the living room like cabinets, floors and windows. The sampling was done three times for all the houses on different days, giving a total of 15 samples. After collection, the dust was transferred to a sealed bag and taken to the laboratory for analysis. The 0.2g of dust was dissolved in a 9 mL mixture of 65% nitric acid and a 3mL mixture of 37% hydrochloric acid on a hot plate for an hour. The digestion extract as in Figure 2(c) was let to cool, and then filtered through a small filter funnel. The filtrates were transferred carefully to a 25 cm3 volumetric flask and were diluted up to the graduation mark with distilled water; analysis was by Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) to determine the concentration of Ca, Mg, Fe, Ni, Pb and Zn (Chakraborty & Gupta, 2010). The blank experiment was carried out by repeating the procedure for sample preparation without the sample. The composition of the blank solution was compared with the sample solution to identify the elemental composition in the dust.

RESULTS AND DISCUSSION

From the analysis of concentration of particulate matter on blasting and non-blasting days, the average of mass concentration PM2.5 and PM10 for eight hours and the distance of houses from the quarry are shown in Figures 3 and 4 respectively.

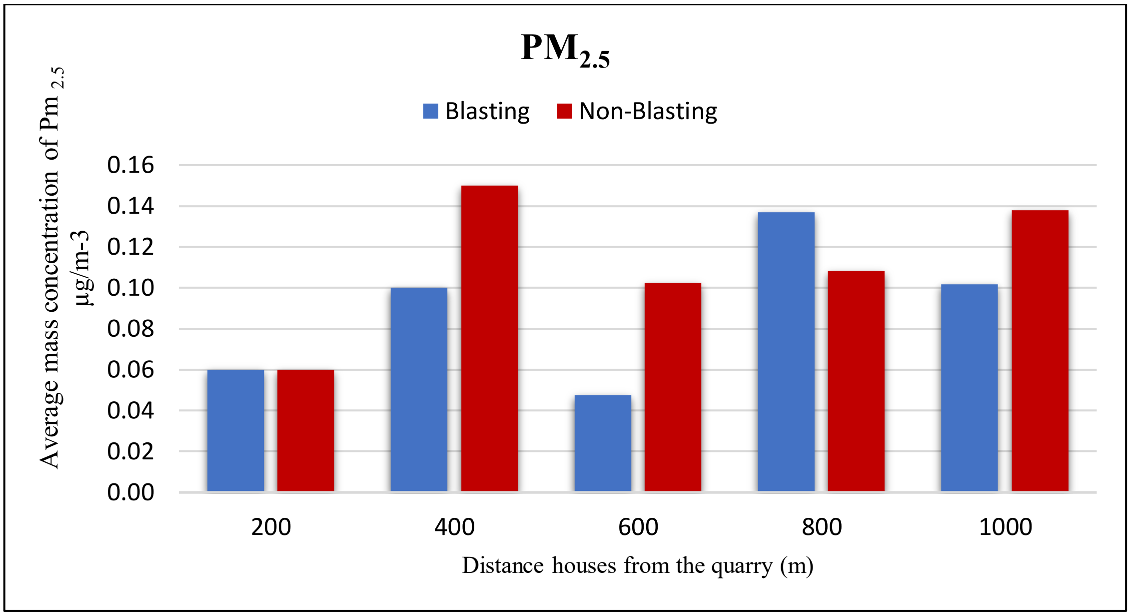

Fig. 3. The Average Over Eight Hours for Concentration of PM2.5 and Distance of Houses from the Quarry

Source: Authors (2024)

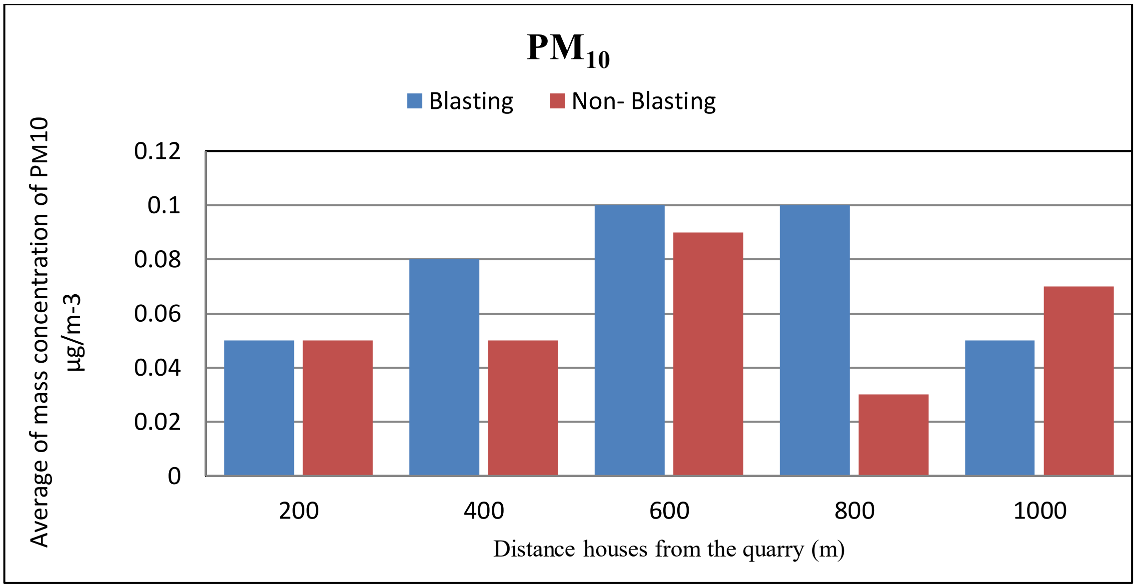

Fig. 4. The Average Over Eight Hours for Concentration of PM2.5 and Distance of Houses from The Quarry

Source: Authors (2024)

Figure 3 represents the mean concentration of PM2.5 during the blasting and non-blasting days. Figure 5 indicates that PM10 also has a higher mean concentration during non-blasting days except at 800m distance. The suspension of PM2.5 is longer in the air because it is physically lightest than PM10. Nartey et al. (2012) proved that quarrying will generate a lot of particulate matter with a micron size that will be suspended in the atmosphere; particles with an aerodynamic diameter of less than 10µm can be transported over long distances, influenced by weather conditions on the monitoring day. This is related to the work of Kapwata et al. (2018) who found that rainfall and humidity do affect the concentration of particulate matter.

On the other hand, 400 metres from the quarry area shows the highest mean concentration of PM2.5 during the non-blasting day, 102.5µg/m3. The two houses located nearer the quarry show a slightly higher mean concentration; as they are located next to a busy highway, vehicle emissions are another influencing factor. Darus et. al. (2012) relates that main city roads with a high volume of traffic increase the concentration of particulate matter.

The bar chart in Figure 4 indicates that the mean concentration of PM10 is during blasting days, with the highest at 800 metres from the quarry area. However, the distance may not be the only factor influencing the mean concentration; vehicle emissions and construction activities may also have an effect. Azarmi et al. (2014) stated that the potential generation of particulate matter includes coarse, fine, very fine and ultrafine particles from construction activities. The level of indoor concentration is mainly related to the outdoor concentration that penetrates indoors, requiring preventive measures. In conclusion, the activities of quarrying, blasting and non-blasting, and the distance of the house to the quarry may be the main factors influencing the mean concentration of particulate matter (PM2.5 and PM10).

Dust can be found in sizes ranging from sub-microns to more than 100µm. Fog or mist generally ranges between sub-micronic and 200µm (Dibble, 2002). Dust tends to create health problems in the respective size range; from 10µm or less. For comparison purposes, the human hair is approximately 60µm in diameter (NIOSH, 2019). Small dust particles are capable of being transported over long distances.

The linear regression analysis of the relationship between distance from the quarry and each of the elements found in dust was analysed. In every case, the analysis reveals the range of the correlation coefficient (R2 is greater than 0.50) for this relationship. According to Awang (2010), when a correlation is close or equal to zero there is no linear relationship between the two variables, although this does not necessarily mean that the two variables are totally unrelated; they could be connected in a non-linear relationship. Figures 7 to 12 illustrate the relationship between the concentration of each element and the distance of the houses from the quarry at 200m, 400m, 600m, 800m and 1000m; in every case, the regression analysis indicates a linear trend with the compressive strength showing a negative relationship between concentration of the element and distance from the quarry; that is, there was a decline in the compressive strength with the increase in distance.

https://doi.org/10.24191/bej.v22iSI.6499

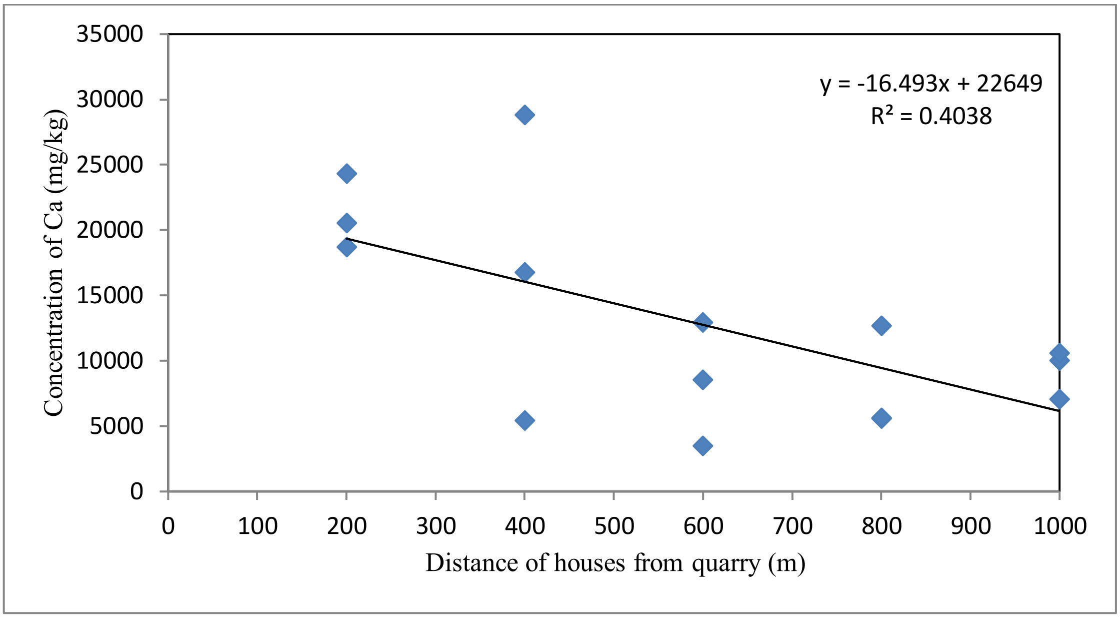

Fig. 5. Concentration of Calcium and Distance of Houses from The Quarry (m)

Source: Authors (2024)

Fig. 6. Concentration of Magnesium and Distance from The Quarry (m)

Source: Authors (2024)

Fig. 7. Concentration of Iron and Distance from The Quarry (m)

Source: Authors (2024)

Fig. 8. Concentration of Nickel and Distance from The Quarry (m)

Source: Authors (2024)

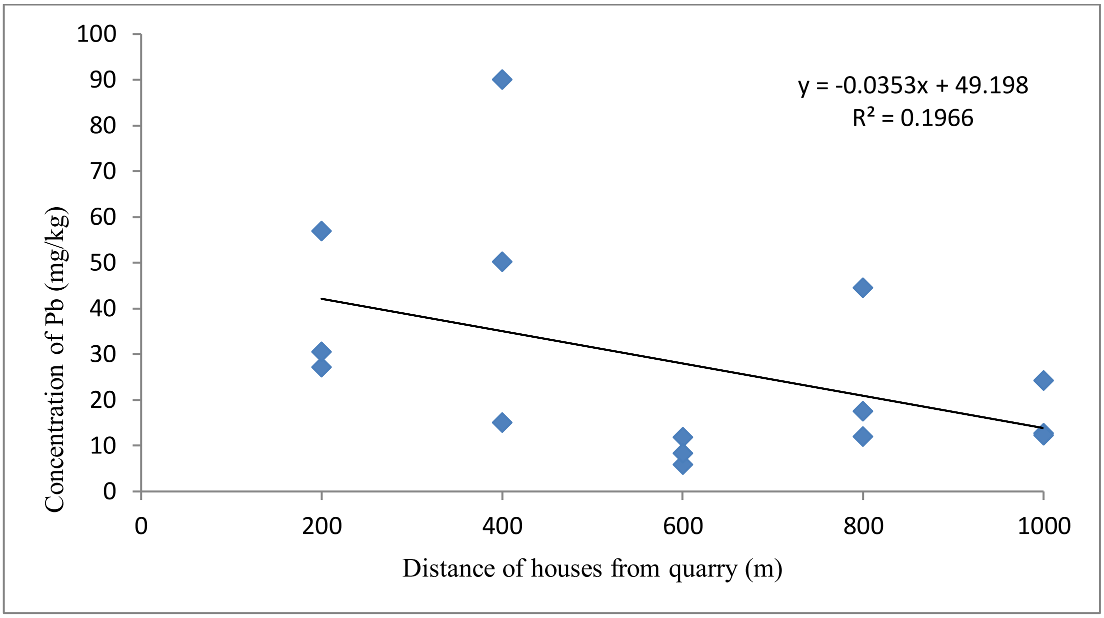

Fig. 9. Concentration of Lead and Distance from The Quarry (m)

Source: Authors (2024)

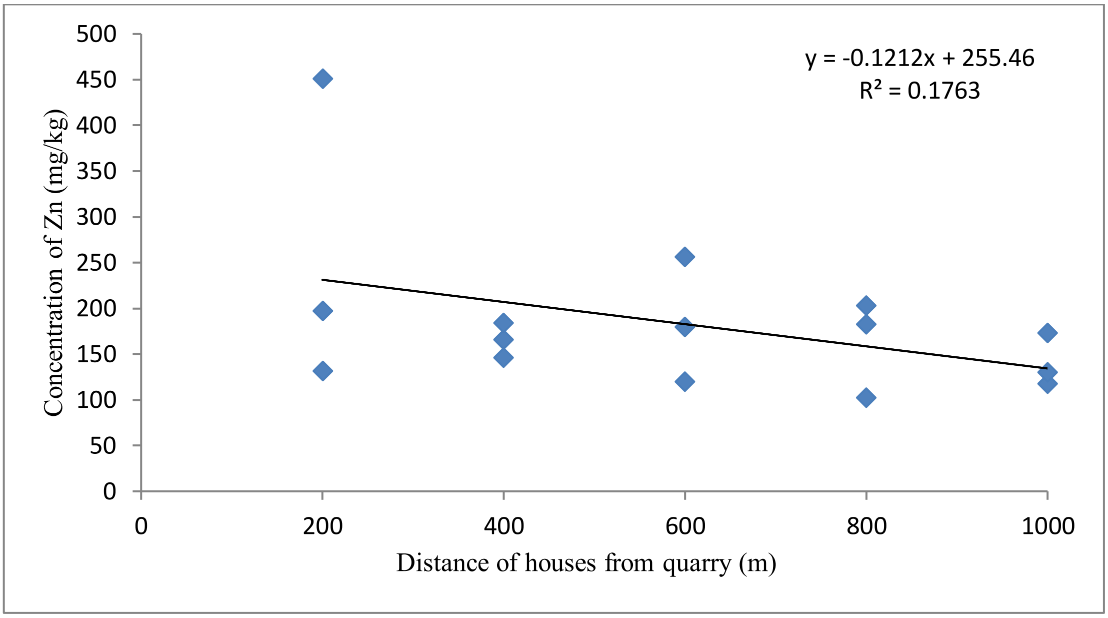

Fig. 10. Concentration of Zinc and Distance from The Quarry (m)

Source: Authors (2024)

Figures 5 to 10 illustrate the relationship between the concentration of each element and the distance of the houses from the quarry at 200m, 400m, 600m, 800m and 1000m. In every case, the regression analysis indicates a linear trend with the distance for each element. The result shows the correlation does not decrease the linear trend and slightly affects residents within a one-kilometer radius. It shows that the concentration of elements reduces with distance, concluding that the greater the distance, the lower is the concentration of elements.

The Geo-accumulation Index (Igeo) can be used to determine whether or not the dust is at a polluted level according to the elements it contains. There are six classifications of Igeo. The elements in indoor dust are shown in Table 1 and the classification of the Geo-accumulation Index in Table 2.

The data gained are used to calculate the concentration of each element (mg/kg) using this formula:

$$Cs = \frac{CSOL \times V}{W} \qquad \text{Equation 1}$$

W = Weight of dust
CSOL = Concentration in solution
V = Volume in dilution

The Geo-accumulation Index I_{geo} formula was then used to calculate the value of elements in indoor dust:

$$\text{Geo-accumulation index } (I_{geo}) = \log 2\ [Cn / 1.5Bn] \qquad \text{Equation 2}$$

Cn = Concentration of metal
Bn = Background value of metal

Table 1. Geo-accumulation Index (Igeo) of Elements in Indoor Dust

Sample code	Ca	Mg	Fe	Ni	Pb	Zn
200 m	13.2	10.11	9.57	-1.46	-0.46	0.95
400 m	12.89	9.84	8.59	-2.92	-0.02	0.29
600 m	11.86	8.16	7.75	-2.74	-2.58	1.37
800 m	11.79	8.79	8.78	-2.44	-1.09	1.21
1000 m	12	9.28	8.39	0.3	-1.37	0.05

Source: Authors (2024)

Table 2. The Geo-accumulation Index Classification[21]

Igeo	Igeo Class	Pollution Intensity
>5	6	Very highly polluted
4< Igeo <5	5	Highly polluted to very highly polluted
3< Igeo <4	4	Highly polluted
2< Igeo <3	3	Moderately polluted to highly polluted
1< Igeo <2	2	Moderately polluted

https://doi.org/10.24191/bej.v22iSI.6499

0< Igeo <1	1	Unpolluted to moderately polluted
<0	0	Unpolluted

Source: Authors (2024)

Geo-accumulation Index (Igeo) ratings are presented in Table 2. Here, the content accepted as background is multiplied in each case by a factor of 1.5 in order to account for natural fluctuations of given elements in the environment as well as small anthropogenic influences (Loska, Wiechuła & Korus, 2004). Table 1 shows the mean Igeo ratings in indoor dust for Ca, Fe, Mg (the three highest), and Ni, Pb, Zn (the three lowest). Two elements, Ca and Mg, show varying enrichment from the limestone quarry since the indoor dust is classified as very strongly contaminated by these elements shown in Table 1 (Bluvshtein et al., 2011). Zn is classified as uncontaminated to slightly contaminated, influenced by human habits such as smoking (Bohlandt et al., 2012). The pollution intensity is practically uncontaminated by Ni and Pb, resulting from emissions from residents' vehicle (Mouli et al., 2006; Pourkhabaz & Pourkhabaz, 2012; and Yuen et al., 2012).

Overall, the strongest contamination of indoor dust by Ca, Mg and Fe in houses adjacent to the quarry may result from the quarrying of limestone. Similar findings were reported by Bluvshtein et al. (2011) who found that the enrichment of Ca and Mg was anticipated because of contributions from the limestone quarry nearby. The elements analysis of indoor dust samples from selected residential buildings in this study helps to explain the influence of nearby quarry activities on the concentration of elements of indoor dust.

Table 3. The Geo-accumulation Index Classification of Each Element

Elements	Distance (m)				
	200	400	600	800	1000
Calcium (Ca)	Very highly polluted				
Magnesium (Mg)	Very highly polluted				
Iron (Fe)	Very highly polluted				
Nickel (Ni)	Unpolluted				
Lead (Pb)	Unpolluted				
Zinc (Zn)	Unpolluted		Moderately polluted	Unpolluted	

Source: Authors (2024)

Table 3 show the results of the concentration of indoor dust at different distances ranging from 7961.70 to 21189.58, 214.91 to 830.69, 1288.57 to 4569.64, 140.2 to 260.03, 8.76 to 51.83 and 9.91 to 27.31 mg/kg for Ca, Mg, Fe, Ni, Pb and Zn respectively. The result of indoor dust concentrations is in the order Ca > Mg > Fe > Zn > Pb > Ni. The elements of indoor dust concentrations in all the investigated areas indicated the major sources of indoor dust pollutants are from outdoor anthropogenic activities, mainly through nearby quarrying activities and vehicular movements. The Igeo results also reveal that indoor dust in residential buildings was strongly polluted (Igeo > 5) with Ca, Mg and Fe. on the concentration of elements of indoor dust.

https://doi.org/10.24191/bej.v22iSI.6499

CONCLUSION

The analysis of indoor dust samples showed the distribution and concentration of elements within the area of study, in the order Ca > Fe > Mg > Zn > Ni > Pb. The assessments of the Igeo index reveal that indoor dust was strongly polluted (Igeo > 5) with Ca, Mg and Fe. The concentrations of elements in residential houses were influenced by their surrounding environment including the limestone quarry. From this study, several recommendations for reducing the effects of quarry activities are proposed:

(i) The residents should take more preventive actions to against exposure to the harmful impacts of PM10 and PM2.5. The indoor concentration is strongly influenced by the outdoor concentration, so an effective way to reduce indoor concentration is by preventing the outdoor particulate from penetrating inside the house.

(ii) Preventive measures include sealing the opening of windows and doors using rubber strips to prevent the infiltration of particulate matter indoors. Residents could also use air purifiers to make the indoor air cleaner.

(iii) The preventive measures should not be limited to those of the residents. The quarry management should also play a role in reducing the effects of their quarrying activities.

(iv) Some mitigation measures can be taken, such as by planting more vegetation to act as a barrier between the quarry and the residential areas.

(v) The quarry management should consider minimising their operation hours in consideration of the effects on the people in surrounding areas.

From the encouraging results of the current work, it is of the author's opinion that an in-dept investigation should be carried out so that every technical aspect can be further identified in the future. Following the research findings, additional studies on the indoor air quality (IAQ) of houses near the quarry mining need to be undertaken, as the quarry industry is particularly influential in the economic development of Malaysia. The key areas of recommended research are:

(i) Research on the existing quarry mining guidelines in Malaysia, to find the success factors in controlling environmental issues, especially air pollution, with advanced technology; comparison with other developed countries (e.g. Italy and Canada) is also recommended.

(ii) Research on the roles of the Department of Environmental (DOE) and local authorities in monitoring the quarrying activities and how their impact can be reduced. To construct the mitigation strategies, the government needs to take part in the responsibilities in managing in the quarrying mining activities toward air quality level.

(iii) A comprehensive study on the Environmental Quality Act 1974 in Malaysia is needed to upgrade and revisit the elements of specific regulations, especially regarding the air quality from industrial pollution.

https://doi.org/10.24191/bej.v22iSI.6499

ACKNOWLEDGEMENTS

The authors would like to thank the residents of Bandar Saujana Putra, Hulu Langat, Selangor for their technical support and information regarding the permission to enter their houses to measure the air quality. They would also like to thank all the anonymous reviewers and the editorial board of Indoor and Built Environment for their constructive comments during the review process. This research is supported by BESTARI grant, 600-IRMI/PERDANA 5/3 BESTARI (089/2018). The authors fully acknowledged Universiti Teknologi MARA (UiTM) for the approved fund which makes this important research viable and effective.

CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial, or financial conflicts and declare the absence of any conflicting interests.

AUTHORS' CONTRIBUTIONS

Wan Hasmirah Wan Ibrahim carried out the data collection and analysing the data. Emma Marinie wrote the article based on data gathered and data analysed, as well as designed the research, and supervised the research progress. Naziah Muhammad Salleh revised the article. Badrul Hisyam conceptualised the central research idea and recommended for future research direction.

REFERENCES

Afeni, T. B. (2009). Assessment of Noise and Ground Vibration Induced During Blasting Operations in An Open Pit Mine. A Case Study on Ewekoro Limestone Quarry, Nigeria. Mining Science and Technology (China) 19, 420-424. https://doi.org/10.1016/S1674-5264(09)60078-8

Adinkrah-Appiah, K., Kpamma, E. Z., Nimo-Boakye, A., Asumadu, K. T., & Obeng-Ankamah, N. (2016). Annual Consumption of Crushed Stone Aggregates in Ghana. Journal of Civil Engineering and Architecture Research. 3. 1729-1737.

Awang, Z. (2010). Research Methodology for Business and Social Science (1st Ed.). Shah Alam: University Publication Centre (UPENA).

Azarmi, F., Kumar, P., & Mulheron, M. (2014). The exposure to coarse, fine and ultrafine particle emissions from concrete mixing, drilling and cutting activities. Journal of Hazardous Materials, 279, 268-279. https://doi.org/10.1016/j.jhazmat.2014.07.003

Bada, B.S., Olatunde, K.A. & Akande, O.A. (2013). Air Quality Assessment in the Vicinity of Quarry Site. Environment and Natural Resources Research. Vol. 3, No. 2. http://dx.doi.org/10.5539/enrr.v3n2p111

Bluvshtein, N., Mahrer, Y., Sandler, A., & Rytwo, G. (2011). Evaluating the Impact of a Limestone Quarry on Suspended and Accumulated Dust. Atmospheric Environment 45(9): 1732-1739. https://doi.org/10.1016/j.atmosenv.2010.12.055

Bohlandt, A., Schierl, R., & Diemer, J. (2012). High concentrations of cadmium, cerium and lanthanum in indoor air due to environmental tobacco smoke. Science of The Total Environment, 414, 738-741. http://dx.doi.org/10.1016/j.scitotenv.2011.11.017

Branquinho, C. G. O. (2008). Bio-monitoring Spatial and Temporal Impact of Atmospheric Dust from a Cement Industry. Environmental Pollution 151, No. 2, 292-299. https://doi.org/10.1016/j.envpol.2007.06.014

Chakraborty, A., & Gupta, T. (2010) Chemical characterization and source apportionment of submicron (PM) aerosol in Kanpur region. Aerosol and Air Quality Research 10, 433-445. https://doi.org/10.4209/aaqr.2009.11.0071

Chooi, Y.H., & Yong, E. L. (2016). The Influence of PM2.5 and PM10 on Air Pollution Index (API). Environmental Engineering, Hydraulics and Hydrology: Proceeding of Civil Engineering. 3: 132-143. Johor: Universiti Teknologi Malaysia.

Darus, F. M., Nasir, R. A., Sumari, S. M., Ismail, Z. S., & Omar, N. A. (2012). Heavy Metals Composition of Indoor Dust in Nursery Schools Building. Procedia - Social and Behavioral Sciences 38: 169-175. http://dx.doi.org/10.1016/j.sbspro.2012.03.337

Drain, M. M., Ben-Elhaj, K. M., Ali, A. M., Schmid, K. K, & Gibb, S. G. (2015). Lung Function Impact from Working in the Pre-Revolution Libyan Quarry Industry. Environmental Research and Public Health, 12(5): 5006–5012. https://doi.org/10.3390/ijerph120505006

Hayyat, M., Siddiq, Z., Mahmood, R., Khan, A., & Cao, K. (2021). Limestone Quarry Waste Promotes the Growth of Two Native Woody Angiosperms. Frontiers in Ecology and Evolution, 9. https://doi.org/10.3389/fevo.2021.637833

Dibble, A. C. (2002). Flora of New Brunswick, Second Edition: A Manual for Identification of the Vascular Plants of New Brunswick by Harold R. Hinds. Rhodora, 104, 312--315. https://www.biodiversitylibrary.org/part/189722

Jain, R. K., Zengdi, P. E., & Domen, J. K. (2016). Chapter 4: Environmental Impacts of Mining. Environmental Impact of Mining and Mineral Processing: 53-157. https://searchworks.stanford.edu/view/11640694

Kapwata, T., Language, B., Piketh, S., & Wright, C. (2018). Variation of Indoor Particulate Matter Concentrations and Association with Indoor/Outdoor Temperature: A Case Study in Rural Limpopo, South Africa. Atmosphere, 9(4), 124. https://doi.org/10.3390/atmos9040124

Lameed, G. A., & Ayodele A. E. (2010). Effect of Quarry Activity on Biodiversity: Case Study of Ogere Site, Ogun State Nigeri, African Journal of Science and Technology, 4(11): 740-750. http://dx.doi.org/10.4314/ajest.v4i11.71340

Loska, K., Wiechuła, D., & Korus, I. (2004). Metal contamination of farming soils affected by industry. Environment International, 30(2), 159-165. https://doi.org/10.1016/s0160-4120(03)00157-0

Mouli, P.C., Mohan, S. V., Balaram, V., Kumar, M. P., & Reddy, S. J. (2006). A Study on Trace Elemental Composition of Atmospheric Aerosols at a Semi-Arid Urban Site Using ICP-Ms Technique. Atmos.

Environment., 40:136-146. http://dx.doi.org/10.1016/j.atmosenv.2005.09.028

Nartey, V. K., Nanor, J. N., & Klake, R. K. (2012). Effects of Quarry Activities on Some Selected Communities in the Lower Manya Krobo District of the Eastern Region of Ghana 362. http://dx.doi.org/10.4236/acs.2012.23032

NIOSH. (2019). Dust Control Handbook for Industrial Minerals Mining and Processing. Second edition. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2019–124, RI 9701. https://doi.org/10.26616/NIOSHPUB2019124

Norgate, T. A. (2010). Energy and Greenhouse Gas Impacts of Mining and Mineral Processing Operations. Journal of Cleaner Production, 266-274. https://doi.org/10.1016/j.jclepro.2010.06.011

Olusegun, Oguntoke, Aboaba Adeniyi & Gbadebo T. Adeola (2009), Impact of Granite Quarrying on the Health of Workers and Nearby Residents in Abeokuta Ogun State, Nigeria. Ethiopian Journal of Environmental Studies and Management. Vol.2 No.1. PMID: 23493960; PMCID: PMC3586865. http://dx.doi.org/10.4314/ejesm.v2i1.43497

Pourkhabaz, A., & Pourkhabaz, H. (2011). Investigation of Toxic Metals in the Tobacco of Different Iranian Cigarette Brands and Related Health Issues. Iran J Basic Med Science 15(1): 636-644.

Raisian, K., & Yahaya, J. (2015). A Research Framework for Environmental Quarry System. International Research Management and Innovation Conference. http://rmc.kuis.edu.my/irmic/e-proceedings/e-proceeding-irmic-2015/. eISBN. 978 – 967 – 0850 – 37 – 5

Wahid, R. (2016). Input Assessment and EIA: A Study on EIA Report for Quarry Projects. Journal of Arts and Humanities, 5 (12), 48-57. https://doi.org/10.18533/journal.v5i12.1029

Wan Ibrahim, W. H., Ahmad Zawawi, E. M., Yunus, J., Asra, N. ,& Sukor, K. (2018). Air quality assessment on human well-being in the vicinity of quarry site. IOP Conference Series: Earth and Environmental Science, 117, p.012010. http://dx.doi.org/10.1088/1755-1315/117/1/012010

Wan Ibrahim, W. Z. (2009). Towards Sustainable Quarry Industry in Malaysia. Malaysia: JURUTERA. https://spaj.ukm.my/jsb/index.php/jbp/article/view/378/pdf

Yuen, J. Q., Olin, P. H., Lim, H. S, Benner, S. G., Sutherland, R. A., & Ziegler, A. D. (2012). Accumulation of Potentially Toxic Elements in Road Deposited Sediments in Residential and Light Industrial Neighbourhoods of Singapore. Journal of Environmental Management 101; 151-163. https://doi.org/10.1016/j.jenvman.2011.11.017