

Article

Marble Dust Effect on the Air Quality: An Environmental Assessment Approach

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Abstract: All over the world, increasing anthropogenic activities, industrialization, and urbanization have intensified the emissions of various pollutants that cause air pollution. Marble quarries in Pakistan are abundant and there is a plethora of small- and large-scale industries, including mining and marble-based industries. The air pollution caused by the dust generated in the process of crushing and extracting marble can cause serious problems to the general physiological functions of plants and it affects human life as well. Therefore, the objectives of this study were to assess the air quality of areas with marble factories and areas without marble factories, where the concentration of particulate matter in terms of total suspended particles (TSP) was determined. For this purpose, EPAM-5000 equipment was used to measure the particulate levels. Besides this, a spectrophotometer was used to analyze the presence of PM_{2.5} and PM₁₀ in the chemical composition of marble dust. It was observed that the TSP concentrations in Darmangi and Malagori areas of Peshawar, Pakistan—having marble factories—were 626 µg/m³ and 5321 µg/m³ respectively. The (PM_{2.5}, PM₁₀) concentration in Darmangi was (189 µg/m³, 520 µg/m³) and in Malagori, it was recorded as (195 µg/m³, 631 µg/m³), which was significantly higher than the non-marble dust areas and also exceeded WHO recommended standards. It was concluded that the areas with the marble factories were more susceptible to air pollution as the concentration of TSP was significantly higher than the recommended TSP levels. It is recommended that marble factories should be shifted away from residential areas along with strict enforcement. People should be instructed to use protective equipment and waste management should be ensured along with control mechanisms to monitor particulate levels.

Keywords: marble dust; air pollution; health hazards; environmental pollution



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1. Introduction

Due to extensive urbanization, more than 90% of the world's population is at risk of being affected by air pollution [1,2]. Air pollution occurs when gas, dust particles, and smoke mix with the atmosphere in a harmful way that is toxic to every living organism [3]. The combination of suspended organic and inorganic particles emit various precursors—such as nitrogen oxides (NO_x), sulphur dioxide (SO₂), ozone (O₃), carbon monoxide (CO), lead, and volatile organic chemical compounds—which is a serious problem faced by developing as well as developed countries [2,4]. According to the World Health Organization (WHO), it is estimated that the presence of the most dangerous particulate matter (PM)—that is particles having a 2.5-micrometre diameter (PM)_{2.5}—in the

air causes approximately 800,000 premature deaths each year and ranks it as the 13th leading cause of death in the world [5]. In the absence of strict controlling measures for air pollution, the number of deaths due to air pollution is expected to rise to 6–9 million deaths per year by 2060 [6]. The number of deaths from air pollution along with a comparison to other reasons for deaths is shown in Table 1.

Table 1. Number of deaths due to various reasons in 2015.

S. No	Reason of Deaths	Number of Deaths (Million)	Source
1	Polluted air	6.4	[7,8]
2	Household air pollution	2.8	
3	Ambient air pollution	4.2	
4	Tobacco	7.0	[9]
5	Acute immunity deficiency syndrome (AIDS)	1.2	
6	Tuberculosis	1.1	
7	Malaria	0.7	

The unwanted gift of the industrial revolution, population explosion, and the rapid expansion of metropolitan areas is air pollution, which is a problem being faced globally, especially in developing countries [10]. Air pollution produces smog and acid rain, which depletes the ozone layer of the atmosphere causes global warming [11]. Polluted air is a perpetual threat and its mitigation is a colossal challenge in terms of achieving sustainability [12]. Moreover, air pollutants have harmful effects on plant life—such as stomata movement, foliar geometry, photosynthesis, membrane permeability, and nutrient transport—which leads to plant growth retardation, low yield, and premature senescence in highly susceptible plants [13]. In a study to evaluate the effect of marble dust on plants, the chlorophyll content of different species of trees was measured. It was found that chlorophyll content was reduced significantly in trees near marble industries [14]. Similarly, poor air quality harms human health [15]. Evidence suggests that these suspended particles are generated by the burning of biomass for energy conversion and fossil fuel combustion, which enter the human body and affect the alveoli of the lungs [16]. Other epidemiological studies revealed that poor air quality is a leading factor in the increase in mortality and causes various cardiovascular and respiratory diseases [17]. The assessment of the diseases caused by air pollution illustrates that more than 2 million premature deaths occur each year that could be attributed to the effects of urban outdoor and indoor air pollution [18]. Medical expenditures are increased significantly due to air-pollution related-diseases, as in 2015, the global economy suffered a loss of USD 21 billion due to air-borne diseases [19].

Dust is regarded as an omnipresent air pollutant [20]. Dust can exist in natural and artificial forms. The natural sources of dust are food and chemical industries, animal debris, the earth's surface, and volcanic eruption, while anthropogenic sources are fossil fuel, factories, mining and quarrying, and stone-working [21]. Besides PM_{2.5}, PM₁₀ is another highly significant air-pollutant that is generated in the form of dust from road construction activities, mining dust, and manufacturing plants [22]. Dust is produced as a result of a variety of processes such as handling and manufacturing of materials, which consists of transferring, dropping, weighing, and conveying [23].

The marble industry is also one form of construction activity, and it consists of processes and operations—namely cutting, buffing, and polishing—which generate a considerable amount of dust particles [24]. The particulate matter produced in the process of crushing and cutting marble used to make statues is usually larger. Large-scale mining processes also produce many particulate emissions [14]. During marble manufacturing, 40% of the marble waste is equal to consists of the manufactured volume, which is generated when the rock debris is dumped in nearby fields, agricultural lands, and river beds,

which produces environmental hazards [25]. The resulting dust particles from marble factories have high levels of toxic PM particles and its exposure is a root cause of many fatal respiratory and carcinogenic diseases—such as nasal cancer, bronchitis, asthma, and lung infection—in marble workers [14]. A similar study was conducted in the Hayatabad residential area in Peshawar, Pakistan that performed the air pollution analysis and its air quality assessment. Based on the results, it was found that the air near the residential area had higher TSP, PM_{2.5}, and PM₁₀ levels than the WHO recommended guidelines [26]. Iran, a neighboring country of Pakistan, also faces mining and quarrying health hazards. A methodology was developed to rank the mines according to safety and sustainable production. A “Multi-Attribute Decision Making” could be used to rank the quarrying and mining factories per safety and environmental standards [27]. Since Iran is one of the main producers of marble all over the globe, the mining industry is in abundance and faces health and occupational issues. To study the environmental and safety of the mining industry, a risk breakdown structure was applied in Fars province due to the high production of marble. Based on the methodology of the analytical hierarchical process, it was found that the employer is at higher risk of health followed by the financial risk in the quarrying sector [28].

Urbanization has increased the demand for construction, which has led to a manifold increase in mineral extraction in many countries [29]. Urban air pollution is associated with inflammation, oxidative stress, blood coagulation, and autonomic dysfunction simultaneously in healthy young humans, with sulfate and O₃ as two major traffic-related pollutants contributing to such effects [30]. According to Environmental Protection Agency (EPA), particles can be carried over long distances by wind and then settle on ground or water [31]. The chemical composition of marble dust is shown in Table 2 [32].

Table 2. Chemical composition of marble dust by percentage.

S. No	Chemical Compounds	Percentage of Marble Dust
1	Calcium carbonate	94.30
2	Lime	50.10
3	Alumina	1.38
4	Silica	1.28
5	Magnesia	1.72
6	Iron oxide	0.54
7	Sulphur trioxide	0.21
8	Alkaline	0.29
9	Loss of ignition	0.39

The marble reserves in Pakistan are estimated to be above 297 billion tons [33]. There are more than 100 different types of marbles available [34]. Marble deposits are present in large quantities in the Khyber Pakhtunkhwa region, Baluchistan region, and Azad Kashmir region [35]. Due to such an abundance of natural deposits of marbles, there is an innumerable number of marble factories in Pakistan and currently, there is no law for proper license and dumping of marble waste [36]. People living nearby marble factories are suffering from polluted water [37], kidney stones [38], radioactive diseases [39], occupational health hazards [40,41], sediment deposition in rivers [42], and polluted landfills [36] due to the marble dust. Besides this, the air quality has worsened due to anthropogenic emissions from these factories [43]. All industrial processes ultimately lead to a decline in air quality standards, which poses health risks in most developing countries such as Pakistan [44]. Table 3 shows the list of most polluted countries based on a dataset containing over 80,000 data points [45].

Table 3. World's most polluted countries 2020 (PM_{2.5}) [45].

Rank	Country	2020 Emission (µg/m ³)	2019 Emission (µg/m ³)	Population (2020)
1	Bangladesh	77.10	83.30	164,689,383
2	Pakistan	59.00	65.80	220,892,331
3	India	51.90	58.10	1,380,004,385
4	Mongolia	46.60	62.00	3,278,292
5	Afghanistan	46.50	58.80	38,928,341

Currently, Pakistan is one of the most air-polluted countries in the world [45]. The WHO standard of PM_{2.5} and PM₁₀ concentrations are 25 µg/m³ and 50 µg/m³ respectively [46]. According to various studies, PM₁₀ for Peshawar was calculated as 219 µg/m³ [47], 540 µg/m³ for PM₁₀, and 160 µg/m³ for PM_{2.5}. The high concentration of PM_{2.5} and PM₁₀ in the Peshawar region is due to the dust particles that reach from Afghanistan, which adds air pollution to the local region [48]. The prevalence of air pollution levels surpassing the WHO guidelines beyond the acceptable levels of PM concentration accounts for environmental degradation and health deterioration of people.

In Pakistan, a large number of marble processing units dump their marble waste directly into streams, rivers, and fertile lowlands, which cover the soil pores because there is an absence of awareness and no law about the disposal of waste material [49]. Consequently, soil permeability is reduced, which increases the alkalinity of the soil. Since Pakistan is an agricultural country and most people are dependent on agriculture for their livelihood, losing fertile soil would be disastrous for the people and the national economy. The objectives of the study were to environmentally evaluate the air quality and to investigate the concentration of marble dust in the air of the Peshawar area in the Khyber Pakhtunkhwa region of Pakistan. The outcomes of the study would enable the local communities and the government to know the current levels of harmful particulate matter in the air. This study also proposes mitigation strategies for local decision-makers that could improve the air quality to ensure clean air for living organisms.

2. Methodology

Based on the objectives, various areas of Marble Dust (MD) and Non-Marble Dust (NMD) were selected to measure the air quality using PM concentrations. The air quality was investigated in the Peshawar area of Mattani and Jalozi for marble factories for NMD areas and Warsak road, and Alazizi road for MD having marble factories. For this study, the data were collected for 6 months, from March 2021 to September 2021. The reason for selecting this time for analysis was because the wind speed is dominant at this time; hence, adding the wind factor was considered, which is a crucial parameter for counting the particulate matter. During this time, a fresh supply of marble raw material got supplied to the respective factories; thus, most of the marble factories were operational. By selecting this time for analysis, the highest possible concentration of air particles was captured. The weather condition during this time ranged from a sunny day to broken clouds, wind speed from 10 km/h to 30 km/h, and temperature ranging from 29 °C to 42 °C. The black arrow in Figure 1 indicates the analysis location.

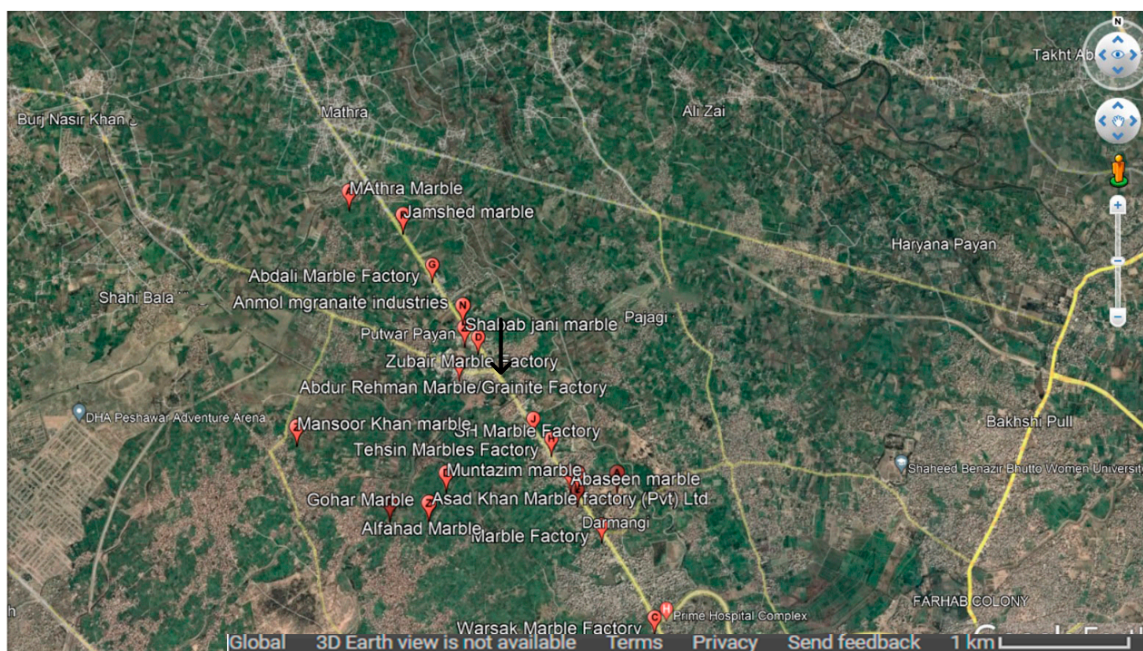


Figure 1. Marble factories in the Darmangi region (Google Earth).

At normal capacity, the marble factories operate from 9 a.m. to 7 p.m. with 40–50 workers. However, due to COVID-19, the operation was being performed below the normal capacity with the restriction of 15 workers with variable shifts. Secondly, the power outages in this study area were also the main factor that was taken into consideration. The power outage was scheduled for three times a day by the electric supply company. Considering this factor, the analysis was stopped when the factories cease to operate.

The dust concentration in the air was measured with HAZ-DUST EPAM-5000 as shown in Figure 2. This apparatus has a size selectable impactor for particulate matter, $PM_{1.0}$, and total suspended particles (TSP). In this research, PM_{10} , $PM_{2.5}$, and TSP were used to analyze the suspended marble particles in areas having marble factories and non-marble factories. A detailed overview of this device is shown in Figure 2.



Figure 2. EPAM-5000.

This device works on the principle of light scattering of infrared radiation using the near forward technique to detect the concentration in mg/m^3 . The infrared light is measured in a photodetector at a 90° angle. The light is dispersed when the dust is entered into an infrared beam. The amount of aerosol concentration depends on the amount of light detected by the photodetector. As a result, the noise and drift of the light are removed using signal processing, which allows for high stability and accuracy of the baseline results. The schematic principle is shown in Figure 3.

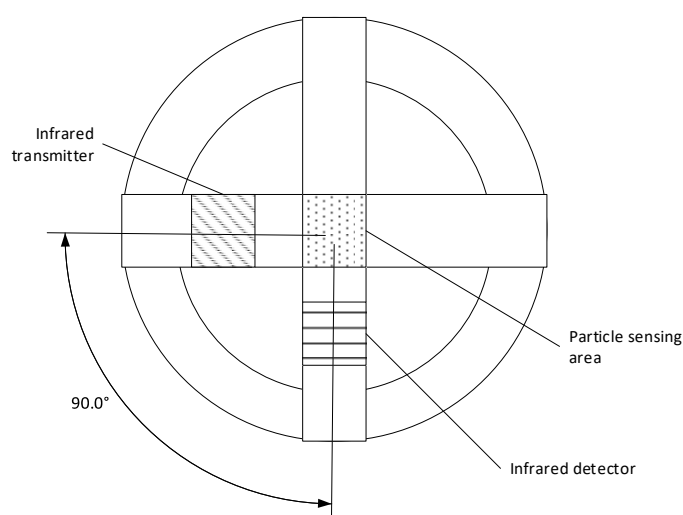


Figure 3. Principle of near forward light scattering.

This device overcomes the limitation of other methods and combines the filter techniques of traditional methods along with real-time monitoring. The advantages of using this unit are that it provides immediate readings, 24 h continuous determination of concentration, and an alarm sound when approaching the hazardous range. Therefore, it is a considerably cheaper and time-saving device as compared to the traditional method of measuring dust particles [50]. EPAM-5000 is calibrated based on the standard protocols of the National Institute for Occupational Safety and Health (NIOSH) for Arizona road dust (ARD) that measures the quality of respiratory air ($\text{PM}_{2.5}$) with $\pm 10\%$ accuracy [51]. The readings obtained from this unit are converted using DustComm Pro software that could provide mathematical readings, create graphs, and correct statistical differences between aerosol and calibrated models.

Spectrophotometer

As it uses the combination of concepts of spectrometry and photometry, it is therefore called a spectrophotometer. This instrument measures the optical density of suspension material. Where optical density is defined as the ratio of light-receiving by the material (I_o) to the light transmitted across the material (I_t). Mathematically, it is expressed as I_o/I_t . If the value of this ratio is high, it means that a higher concentration of particles is present in the material and lower values indicate the weak concentration of the particles.

This instrument works on the principle of Beer-Lambert Law, which states that the amount of light absorbed is directly proportional to the concentration and thickness of the solution. The Beer-Lambert law can be expressed as

$$A = \epsilon bc \quad (1)$$

where “A” means absorbance, “ ϵ ” stands for molar absorptivity, which is the strength of a compound that absorbs the light at a given wavelength, “b” shows the path length, and “c” is the concentration of the sample. Hence, Equation (1) becomes

$$-\log \frac{I_t}{I_0} = \epsilon bc \quad (2)$$

$$I_t = I_0 e^{-\epsilon bc} \quad (3)$$

The advantage of this technique is that the rate of reaction could be measured directly by measuring the light interacting with the components of the solution rather than stopping the reaction and measuring its rate.

3. Results and Discussion

For investigating air quality, marble dust, and non-marble dust areas were visited and measured the concentration of marble dust in the air by using EPAM-5000. The areas of non-marble dust (NMD) and marble dust (MD) areas are mentioned in Figures 4 and 5 respectively.

Figure 4a,b shows that the area is in its natural soil color because of the absence of any marble factory in the vicinity. However, Figure 5a,b clearly shows that a white residue is left untreated near the marble factories. This means that the lighter marble dust particles such as $PM_{2.5}$ and PM_{10} were transported along with the wind, thereby polluting the air and leaving behind the hardened marble sludge.

The details of the results of different areas with coordinates are mentioned in Table 4. The result shows that areas having marble factories have greater marble dust (MD) levels in the air as compared to non-marble dust (NMD) areas. As per the authors' study, there are 26 marbles factories in the Malagori area, and it is the heart of marble production. While Darmangi area is the neighboring area with adequate plantations and there are less than 10 factories in this area, due to which, the Darmangi area has less concentration than the Malagori area.

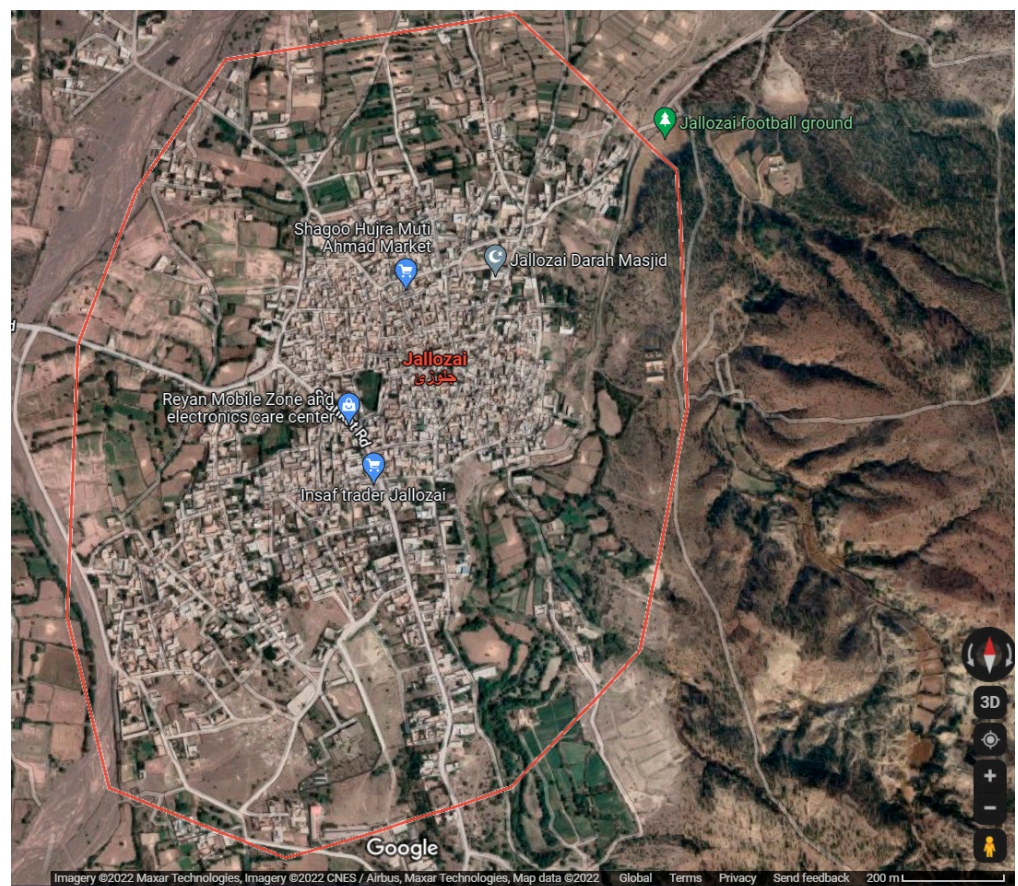
Similarly, the $PM_{2.5}$ concentration for marble dust areas (Darmangi and Malagori) are $189 \mu\text{g}/\text{m}^3$ and $195 \mu\text{g}/\text{m}^3$, which exceeds the WHO standard limits of $25 \mu\text{g}/\text{m}^3$. Additionally, the PM_{10} concentration values for the same marble dust areas were calculated as $620 \mu\text{g}/\text{m}^3$ and $730 \mu\text{g}/\text{m}^3$ as compared to $50 \mu\text{g}/\text{m}^3$ recommended values of PM_{10} . While the NMD areas (Mattani and Jalozei) were not quite so affected. Hence, it is evident that the residential areas located near marble factories are at higher risk of exposing people to breathing polluted air. The results are shown in Table 5.

The marble industry is one of the most important industrial sectors that contributes to the socio-economic development of Peshawar residents. This sector adds yields its fair share to the national economy because of the diverse processes of marble factories. Despite having such a crucial role, the dust generated from this sector has had adverse effects on plants, humans, and the environment and poses a potential risk to the living organisms because of polluted water quality and air quality.

The analysis of suspension material of marble dust particles indicates higher absorbance and less transmission of the light, which means that the solution has higher optical density. The lower values of absorbance indicate that there was little concentration of mentioned particles. The concentration of the dust sample is changing over time due to a variety of particulate matters as shown in Table 6.

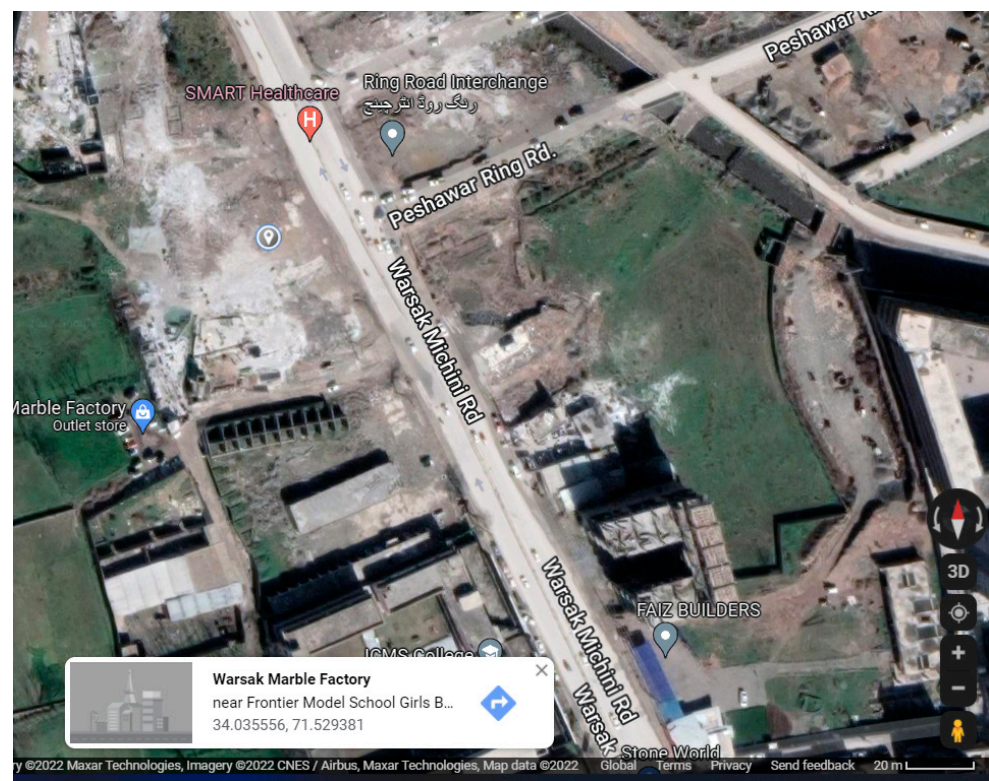


(a)

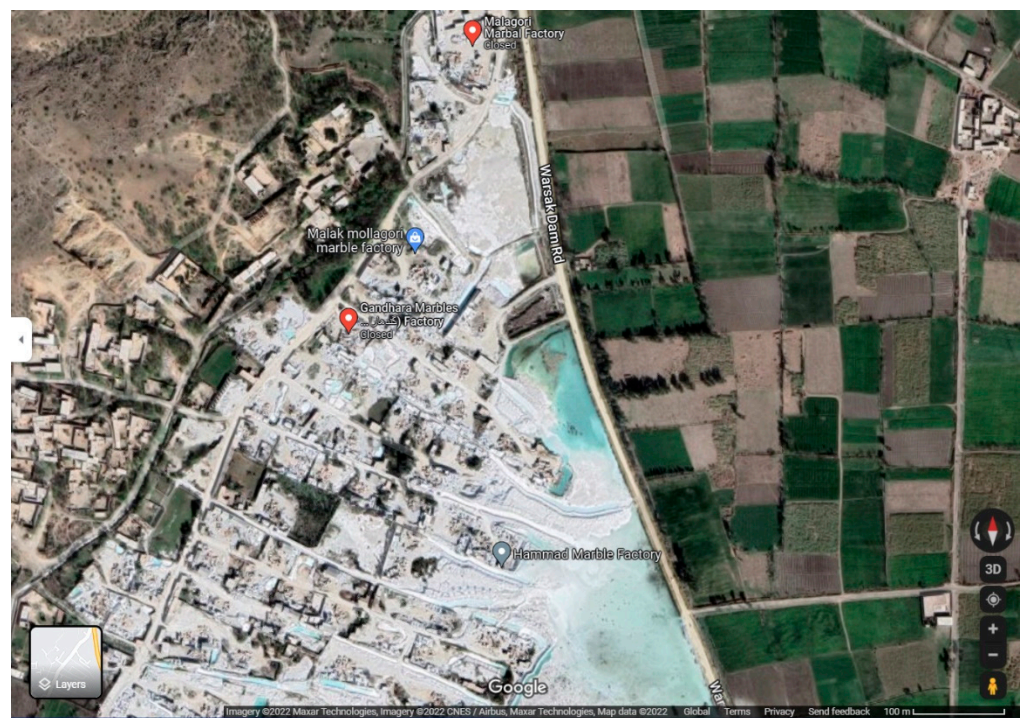


(b)

Figure 4. Non-marble dust areas (Google Maps). (a) Mattani area. (b) Jallozai area.



(a)



(b)

Figure 5. Marble dust area (Google Maps). (a) Darmangi Warsak road area. (b) Malagori area.

Table 4. Results of marble dust (MD) in air.

S. No	Location	Concentration of TSP ($\mu\text{g}/\text{m}^3$)	Coordinates	MD/NMD	WHO Guidelines
1	Mattani Kohat Road	2	N: 33.832953° E: 71.565458°	NMD	120 $\mu\text{g}/\text{m}^3$
2	Jalozai	26	N: 33.914888° E: 71.815810°	NMD	
3	Darmangi Warsak Road	626	N: 34.0484206° E: 71.5205146°	MD	
4	Malagori	5321	N 34.135703° E 71.403719°	MD	

Table 5. Results of PM_{2.5} and PM₁₀ in the selected areas of Peshawar.

Description	Mattani $\mu\text{g}/\text{m}^3$ (NMD)	Jalozai $\mu\text{g}/\text{m}^3$ (NMD)	Darmangi $\mu\text{g}/\text{m}^3$ (MD)	Malagori $\mu\text{g}/\text{m}^3$ (MD)	WHO Guidelines $\mu\text{g}/\text{m}^3$
Concentration of PM _{2.5} ($\mu\text{g}/\text{m}^3$)	33	42	189	195	25
Concentration of PM ₁₀ ($\mu\text{g}/\text{m}^3$)	109	214	620	730	50

Table 6. Spectrophotometry results.

PM _{2.5} /PM ₁₀	Absorbance	Transmittance	Wavelength (nm)
NO	0.230	14.2	380
Cu	0.365	7.4	405
Zn	0.415	5.0	430
SO ₂	1.130	6.8	530
Mg	1.320	10.7	580
Al	1.590	5.4	630
Fe	1.800	2.7	655
Ca	2.130	19.6	680

The medical records from the last two-year period, indicating 1543 patients with breathing problems, were analyzed. It was found that the highest cases originated from the Malagori area and its neighboring areas. The recorded patient history showed that the breathing problems were not genetic and only male members with ages from 18–57 years of the family were suffering. These people were either worker in the marble factory or were living in the vicinity of these factories. The wages of these factory workers were below USD 100, and they could not afford to pursue other professions and were unable to pay medical bills, which indicates that these people were doing jobs in these factories due to the absence of other skills and were forced to pursue physical jobs.

The water polluted with toxic elements contaminates the pH of water, which in turn affects the turbidity in the water [52]. The turbidity is changed by suspended matter such as silts and organic chemical compounds from these factories. This turbid water enters into the river which makes the water translucent; which consequently blocks the sunlight penetration in bodies of water; hence, the survival of aquatic organisms and algae is compromised [53]. Sodium is another waste generated by marble dust. The excess addition of sodium affects plants and would disrupt the chemical balance in the water, animals, and humans affecting plant life, animal survival, and heart disease among humans respectively [54]. Magnesium is also an important constituent of seafood and vegetables. Magnesium intake is often blocked by the accumulation of marble dust in the soil,

which reduced the required magnesium concentration; this lack of magnesium can cause hypomagnesemia, leading to diabetes, low blood pressure, and cardiac arrests [55].

Similarly, the marble dust alters the air quality such as calcium carbonate upon heating releases carbon dioxide from the marble powder, which is released into the atmosphere, thus making the air unfit for the environment. This process is regarded as an important factor in increasing carbon emissions each year [56]. Copper is also released in marble dust and its high concentration in water is dangerous to both humans and crops, which can harm kidneys and can cause cancer in people living and working in marble factories [57]. Zinc is another necessary element, which prevents heart diseases, acts as an anti-inflammatory agent, and helps in connective tissue formation. Traces of a high amount of zinc were found in marble workers' blood, any amount higher than the necessary intake is harmful [58]. Manganese is also released in dust emanating from steel, marble, and fossil fuel combustion [59]. Higher exposure to manganese especially in marble workers generates strong signals in the human body, triggering liver diseases. Arsenic is a major constituent of dust particles [60]. The emission of CaCO_3 produces white dust that reduces visibility and produces asthma problems in people in the vicinity of marble dust [61]. Arsenic pollution is a global dust problem—especially in South Asian countries such as Pakistan, India, and Bangladesh—which can cause hyperkeratosis as well as kidney, liver, cardiovascular, and neurological disorders [62]. Areas with increased concentration of $\text{PM}_{2.5}$ also recorded higher rates of casualties due to COVID-19 [63].

This study shows that the areas in the vicinity of the marble factories have reduced air quality due to the presence of a high concentration of particulate matter. However, the absence of marble factories has little to no effect on improving the air quality as the dust from marble factories traveled to NMD areas. To elaborate, $\text{PM}_{2.5}$ and PM_{10} concentration levels are higher even in NMD areas due to the abundance of marble activities in the MD areas.

The problem of polluted air is widespread. With industrialization, air pollution has become a global issue. It is estimated that 1 m^3 of marble, when cut into 2 cm thick slabs, produces 25% marble dust [64]. In the United States of America, there was a 173% increase in gross domestic product, 85% vehicle emissions, energy consumption soared by 19% from 1980 to 2020 along with the addition of 68 million tons of pollutants [65]. In India, marble and mining dust have adverse effects on plants and vegetation near marble industries. Due to the reduced amount of chlorophyll, the trees and plants suffered biochemical, physiological, and morphological changes resulting in 20% reduced growth [66]. The extraction and energy emissions of the marble industry in Italy produce large amounts of marble mining dust during quarrying. The pollution is increased with the number of processes associated with marble production [67]. Turkey's marble production generates dust of 40–60% of the overall manufacturing volume. The mining and quarrying processes involved in marble processing in the Afyon region generate 340,000 tonnes of marble waste [68]. Egypt, being the fifth largest producer of marble, generated 3.5 million tonnes of marble. The Shaq El-Thouban region is suffering from soil alkalinity, airborne diseases, and reduced plant productivity due to the presence of 400 marble factories [69]. The Skikda region in Algeria has cement factories and aggregate manufacturing industries that utilized various processes for marble stone production, which generates harmful particles in the atmosphere. The use of marble in cement preparation is damaging to the air quality; therefore, marble dust recycling is performed at low temperature and reduced humidity [70].

The problem of polluted air can be reduced globally when each country introduces interventions to deal with the pollution of their respective countries. In this regard, sustainable processes, waste treatment, and strict legislation for collective recycling could be utilized. Moreover, awareness campaigns, relocation of marble factories, treatment of wastewater, disposal of effluents away from residential areas, filtering dust and smoke generated, pre-defined schedule of factory operation, using marble dust as admixtures, controlled expansion of factories, action against illegal marble factories, limiting socioeconomic activities in a polluted area, and use of personal protective equipment are some of

the preventive measures that could prove helpful to make the air, water, and environment suitable for human existence concerning marble quarrying.

4. Conclusions

This study was conducted in the Peshawar region of Pakistan with marble dust (MD) and non-marble dust (NMD) areas to analyze the air quality based on the readings of PM_{2.5}, PM₁₀, and TSP. For the determination of air pollution, the areas near marble factories and non-marble factories were compared and it was found that people living near marble factories are more prone to diseases associated with dust inhalation. Based on the results of the air pollution test, the Peshawar area air is unfit to breathe, and it would worsen with time due to the unlicensed and haphazard location of factories because of the absence of regulation. There is a strong need for legislation of establishment of factories in the industrial zone only. Therefore, it is recommended that awareness must be ensured for marble workers and owners about the hazardous results of marble dust. Local communities and stakeholders should be educated about the presence of factories in residential areas. Preventive measures such as using wet processes, dust collection, use of safety gear, avoiding direct skin contact, ventilation systems, using of marble dust as an admixture, and city planning should be implemented.

5. Limitations

The results are limited based on the tenure of the data collected. As monitoring points are random—having diverse localities—it may be possible that the readings of one area differ from the other area. Moreover, the readings can be affected by various factors in settings, such as unpaved roads dust and residential dust, that can interfere with the actual marble dust concentration.

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References

1. World Health Organisation (WHO). Ambient (Outdoor) Air Pollution. 2018. Available online: [https://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health) (accessed on 27 January 2022).
2. Alaloul, W.S.; Musarat, M.A. Impact of Zero Energy Building: Sustainability Perspective. In *Sustainable Sewage Sludge Management and Resource Efficiency*; InTech: London, UK, 2020.
3. Pénard-Morand, C.; Annesi-Maesano, I. Air pollution: From sources of emissions to health effects. *Breathe* **2004**, *1*, 108–119. [CrossRef]
4. Combes, A.; Franchineau, G. Fine particle environmental pollution and cardiovascular diseases. *Metabolism* **2019**, *100*, 153944. [CrossRef] [PubMed]
5. World Health Organisation (WHO). *The World Health Report 2002: Reducing Risks, Promoting Healthy Life*; World Health Organization: Geneva, Switzerland, 2002.
6. Organisation for Economic Cooperation and Development (OECD). 2016. Available online: <https://www.oecd.org/env/air-pollution-to-cause-6-9-million-premature-deaths-and-cost-1-gdp-by-2060.htm> (accessed on 8 September 2021).
7. GBD. Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: A systematic analysis for the Global Burden of Disease Study 2017. *Lancet* **2018**, *392*, 1923–1994. [CrossRef]

8. Prüss-Ustün, A.; Wolf, J.; Corvalán, C.; Neville, T.; Bos, R.; Neira, M. Diseases due to unhealthy environments: An updated estimate of the global burden of disease attributable to environmental determinants of health. *J. Public Health* **2017**, *39*, 464–475. [CrossRef] [PubMed]
9. França, E.B.; Passos, V.M.D.A.; Malta, D.C.; Duncan, B.B.; Ribeiro, A.L.P.; Guimarães, M.D.C.; Abreu, D.M.; Vasconcelos, A.M.N.; Carneiro, M.; Teixeira, R.; et al. Cause-specific mortality for 249 causes in Brazil and states during 1990–2015: A systematic analysis for the global burden of disease study 2015. *Popul. Health Metr.* **2017**, *15*, 39. [CrossRef] [PubMed]
10. Arbex, M.A.; Santos, U.d.P.; Martins, L.C.; Saldiva, P.H.N.; Pereira, L.A.A.; Braga, A.L.F. Air pollution and the respiratory system. *J. Bras. Pneumol.* **2012**, *38*, 643–655. [CrossRef]
11. Choudhary, M.P.; Garg, V. Causes, consequences and control of air pollution. In *All India Seminar on Methodologies for Air Pollution Control*; MNIT: Jaipur, India, 2013.
12. Moraga, R.; Hosseinabad, E.R. A system dynamics approach in air pollution mitigation of metropolitan areas with sustainable development perspective: A case study of Mexico City. *J. Appl. Environ. Biol. Sci.* **2017**, *12*, 164–174.
13. Tripathi, A.K.; Gautam, M.K. Biochemical parameters of plants as indicators of air pollution. *J. Environ. Biol.* **2007**, *28*, 127.
14. Saini, Y.; Bhardwaj, N.; Gautam, R. Effect of marble dust on plants around Vishwakarma Industrial Area (VKIA) in Jaipur, India. *J. Environ. Biol.* **2011**, *32*, 209–212.
15. Quarmby, S.; Santos, G.; Mathias, M. Air Quality Strategies and Technologies: A Rapid Review of the International Evidence. *Sustainability* **2019**, *11*, 2757. [CrossRef]
16. Brook, R.D.; Rajagopalan, S.; Pope III, C.A.; Brook, J.R.; Bhatnagar, A.; Diez-Roux, A.V.; Holguin, F.; Hong, Y.; Luepker, R.V.; Mittleman, M.A.; et al. Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. *Circulation* **2010**, *121*, 2331–2378. [CrossRef]
17. Heft-Neal, S.; Burney, J.; Bendavid, E.; Burke, M. Robust relationship between air quality and infant mortality in Africa. *Nature* **2018**, *559*, 254–258. [CrossRef] [PubMed]
18. Jerrett, M. The death toll from air-pollution sources. *Nature* **2015**, *525*, 330–331. [CrossRef] [PubMed]
19. The Vegetarian Resource Group. How Many Youth Are Vegetarian? Available online: http://www.vrg.org/press/youth_poll_2010.php (accessed on 9 December 2018).
20. Andersen, A.C. In the beginning: The origin of dust. *AIP Conf. Proc.* **2009**, *1094*, 254. [CrossRef]
21. Popescu, F.; Ionel, I. Anthropogenic Air Pollution Sources. In *Air Quality*; InTech: London, UK, 2010; pp. 1–22. [CrossRef]
22. Yan, H.; Ding, G.; Li, H.; Wang, Y.; Zhang, L.; Shen, Q.; Feng, K. Field Evaluation of the Dust Impacts from Construction Sites on Surrounding Areas: A City Case Study in China. *Sustainability* **2019**, *11*, 1906. [CrossRef]
23. Darren, M.; Technikon, M. Hazard Prevention and Control in the Work Environment: Airborne Dust WHO/SDE/OEH/99.14. 2000. Available online: <https://apps.who.int/iris/handle/10665/66147> (accessed on 22 September 2021).
24. El-Gammal, M.; Ibrahim, M.; Badr, E.; Asker, S.A.; El-Galad, N.M. Health risk assessment of marble dust at marble workshops. *Nat. Sci.* **2011**, *9*, 144–154.
25. Akbulut, H.; Güner, C. The environmental effects of waste marble and possibilities of utilization and waste minimization by using in the road layers. In *Proceedings of the Fourth National Marble Symposium, Afyonkarahisar, Turkey, 18–19 December 2003*; pp. 371–378.
26. Rabbani, M.B.A.; Khan, Q.Z.; Usama, U. Determination of Air Pollutants and Its Modeling: A Machine Learning Approach for Assessment of Air Quality in Industrial Estate, Hayatabad. Presented at the 1st International Conference on Recent Advances in Civil and Earthquake Engineering, Peshawar, Pakistan, 8 October 2021. Available online: <https://drive.google.com/file/d/1P7J8oR1mHm2a0f0J4l0q62dKksrj-fh1/view> (accessed on 1 December 2021).
27. Yari, M.; Bagherpour, R.; Almasi, N. An approach to the evaluation and classification of dimensional stone quarries with an emphasis on safety parameters. *Rud. Zb.* **2016**, *31*, 15–26. [CrossRef]
28. Yari, M.; Bagherpour, R.; Khoshouei, M.; Pedram, H. Investigating a comprehensive model for evaluating occupational and environmental risks of dimensional stone mining. *Rud. Zb.* **2020**, *35*, 101–109. [CrossRef]
29. Kumar, N. Effect of different mining dust on the vegetation of district balaghat, MP-A critical review. *Int. J. Sci. Res.* **2015**, *4*, 603–607.
30. Chuang, K.-J.; Chan, C.-C.; Su, T.-C.; Lee, C.-T.; Tang, C.-S. The Effect of Urban Air Pollution on Inflammation, Oxidative Stress, Coagulation, and Autonomic Dysfunction in Young Adults. *Am. J. Respir. Crit. Care Med.* **2007**, *176*, 370–376. [CrossRef]
31. EPA, U.; United States Environmental Protection Agency. Quality Assurance Guidance Document-Model Quality Assurance Project Plan for the PM Ambient Air, Volume 2. 2001. Available online: <https://swap.stanford.edu/20131015080356/> (accessed on 30 November 2021).
32. Raghunath, P.; Suguna, K.; Karthick, J.; Sarathkumar, B. Mechanical and durability characteristics of marble-powder-based high-strength concrete. *Sci. Iran.* **2019**, *26*, 3159–3164.
33. Sarkar, R.; Das, S.K.; Mandal, P.K.; Maiti, H.S. Phase and microstructure evolution during hydrothermal solidification of clay-quartz mixture with marble dust source of reactive lime. *J. Eur. Ceram. Soc.* **2006**, *26*, 297–304. [CrossRef]
34. Pre-Feasibility Study—Marble Quarry Project. 2010. Available online: <https://www.yumpu.com/en/document/read/11352777/pre-feasibility-study-marble-quarry-project-sbi-sindh-board-of> (accessed on 22 November 2021).
35. Manan, A.; Iqbal, Y. Phase, Microstructure and Mechanical Properties of Marble in North-Western Part of Pakistan: Preliminary Findings. *J. Pak. Mater. Soc.* **2007**, *1*, 68–71.

36. Fawad, M.; Ullah, F.; Irshad, M.; Shah, W.; Tahir, A.A.; Mehmood, Q.; Ahmed, T. Pollution hotspots and potential impacts on land use in the Mohmand Marble Zone, Pakistan. *Environ. Earth Sci.* **2021**, *80*, 372. [\[CrossRef\]](#)
37. Iqbal, M.; Akbar, F.; Ullah, S.; Anwar, I.; Khan, M.T.; Nawab, A.; Bacha, M.S.; Rashid, W. The effects of marble industries effluents on water quality in Swat, Northern Pakistan. *J. Biodivers. Environ. Sci.* **2018**, *13*, 34–42.
38. Jehangir, K.; Zeshan, A.; Bakht, T.; Faiz, U. Burden of marble factories and health risk assessment of kidney (renal) stones development in district Buner, Khyber Pakhtunkhwa, Pakistan. *Expert Opin. Environ. Biol.* **2015**, *2*, 2.
39. Iqbal, M.; Tufail, M.; Mirza, S.M. Measurement of natural radioactivity in marble found in Pakistan using a NaI (TI) gamma-ray spectrometer. *J. Environ. Radioact.* **2000**, *51*, 255–265. [\[CrossRef\]](#)
40. Khan, Q.; Maqsood, S.; Khattak, S.B.; Omair, M.; Hussain, A. Evaluation of Activity Hazards in Marble Industry of Pakistan. *Int. J. Eng. Technol.* **2015**, *15*, 73–78.
41. Noreen, U.; Ahmed, Z.; Khalid, A.; Di Serafino, A.; Habiba, U.; Ali, F.; Hussain, M. Water pollution and occupational health hazards caused by the marble industries in district Mardan, Pakistan. *Environ. Technol. Innov.* **2019**, *16*, 100470. [\[CrossRef\]](#)
42. Mulk, S.; Azizullah, A.; Korai, A.L.; Khattak, M.N.K. Impact of marble industry effluents on water and sediment quality of Barandu River in Buner District, Pakistan. *Environ. Monit. Assess.* **2015**, *187*, 8. [\[CrossRef\]](#)
43. Raza, W.; Saeed, S.; Saulat, H.; Gul, H.; Sarfraz, M.; Sonne, C.; Sohn, Z.-H.; Brown, R.J.; Kim, K.-H. A review on the deteriorating situation of smog and its preventive measures in Pakistan. *J. Clean. Prod.* **2021**, *279*, 123676. [\[CrossRef\]](#)
44. Majid, H.; Madl, P.; Alam, K. Ambient air quality with emphasis on roadside junctions in metropolitan cities of Pakistan and its potential health effects. *Health* **2012**, *3*, 79–85.
45. IQAir. World's Most Polluted Countries 2020 (PM2.5). Available online: <https://www.iqair.com/world-most-polluted-countries> (accessed on 20 September 2021).
46. World Health Organization (WHO). A Prüss-Ustün, J Wolf, C Corvalán, R Bos and M Neira. Preventing Disease through Healthy Environments, A Global Assessment of the Burden of Disease from Environmental Risks. 2018. Available online: <https://apps.who.int/iris/rest/bitstreams/908623/retrieve> (accessed on 20 December 2021).
47. Ghauri, B.; Lodhi, A.; Mansha, M. Development of baseline (air quality) data in Pakistan. *Environ. Monit. Assess.* **2006**, *127*, 237–252. [\[CrossRef\]](#) [\[PubMed\]](#)
48. Alam, K.; Blaschke, T.; Madl, P.; Mukhtar, A.; Hussain, M.; Trautmann, T.; Rahman, S. Aerosol size distribution and mass concentration measurements in various cities of Pakistan. *J. Environ. Monit.* **2011**, *13*, 1944–1952. [\[CrossRef\]](#) [\[PubMed\]](#)
49. Haider, A.; Amber, A.; Ammara, S.; Mahrukh, K.S.; Aisha, B. Knowledge, perception and attitude of common people towards solid waste management—A case study of Lahore, Pakistan. *Int. Res. J. Environ. Sci.* **2015**, *4*, 100–107.
50. National Institute for Occupational Safety and Health. *The Industrial Environment—Its Evaluation & Control*; US Government Printing Office: Washington, DC, USA, 1973.
51. SKC. Environmental Particulate air Monitor. 1999. Available online: <https://www.skcltd.com/images/pdfs/EPAM-5000-manual.pdf> (accessed on 23 September 2021).
52. Sabouri, R.; Afkhami, M.; Zarasvandi, A.; Khodadadi, M. Correlation Analysis of Dust Concentration and Water Quality Indicators. *Int. J. Environ. Sci. Dev.* **2011**, *2*, 91–97. [\[CrossRef\]](#)
53. Davies-Colley, R.J.; Smith, D.G. Turbidity suspended sediment, and water clarity: A review. *Jawra J. Am. Water Resour. Assoc.* **2001**, *37*, 1085–1101. [\[CrossRef\]](#)
54. Kazi, T.G.; Arain, M.B.; Baig, J.A.; Jamali, M.K.; Afridi, H.I.; Jalbani, N.; Sarfraz, R.A.; Shah, A.Q.; Niaz, A. The correlation of arsenic levels in drinking water with the biological samples of skin disorders. *Sci. Total Environ.* **2009**, *407*, 1019–1026. [\[CrossRef\]](#)
55. Smedley, P.L.; Kinniburgh, D.G. A review of the source, behaviour and distribution of arsenic in natural waters. *Appl. Geochem.* **2002**, *17*, 517–568. [\[CrossRef\]](#)
56. Sütçü, M.; Alptekin, H.; Erdogmus, E.; Er, Y.; Gencel, O. Characteristics of fired clay bricks with waste marble powder addition as building materials. *Constr. Build. Mater.* **2015**, *82*, 1–8. [\[CrossRef\]](#)
57. Martin, S.; Griswold, W. Human health effects of heavy metals. *Environ. Sci. Technol. Briefs Citiz.* **2009**, *15*, 1–6.
58. James, W.D.; Elston, D.; Berger, T. *Andrew's Diseases of the Skin E-book: Clinical Dermatology*; Elsevier Health Science: Amsterdam, The Netherlands, 2011; pp. 1–900.
59. Harding, A.K.; Daston, G.P.; Boyd, G.R.; Lucier, G.W.; Safe, S.H.; Stewart, J.; Tillitt, D.E.; Van Der Kraak, G. Endocrine Disrupting Chemicals Research Program of the U.S. Environmental Protection Agency: Summary of a Peer-Review Report. *Environ. Health Perspect.* **2006**, *114*, 1276–1282. [\[CrossRef\]](#)
60. Bhattacharyya, R.; Jana, J.; Nath, B.; Sahu, S.; Chatterjee, D.; Jacks, G. Groundwater As mobilization in the Bengal Delta Plain, the use of ferralite as a possible remedial measure—A case study. *Appl. Geochem.* **2003**, *18*, 1435–1451. [\[CrossRef\]](#)
61. Çelik, M.Y.; Sabah, E. Geological and technical characterisation of Iscehisar (Afyon-Turkey) marble deposits and the impact of marble waste on environmental pollution. *J. Environ. Manag.* **2008**, *87*, 106–116. [\[CrossRef\]](#)
62. Mosley, L.; Singh, S.; Aalbersberg, B. Water quality monitoring in Pacific Island countries. *SOPAC Tech. Rep.* **2005**, *381*, 42.
63. Ali, S.M.; Malik, F.; Anjum, M.S.; Siddiqui, G.F.; Anwar, M.N.; Lam, S.S.; Nizami, A.-S.; Khokhar, M.F. Exploring the linkage between PM2.5 levels and COVID-19 spread and its implications for socio-economic circles. *Environ. Res.* **2021**, *193*, 110421. [\[CrossRef\]](#)
64. Kun, N. *Mermer Jeolojisi ve Teknolojisi*. Tezer Printing House. İzmir **2000**, *1*, 1–149.

65. Environmental Protection Agency. Air Quality—National Summary. 2021. Available online: <https://www.epa.gov/air-trends/air-quality-national-summary> (accessed on 26 September 2021).
66. Soni, A.; Aseri, G.; Jain, N. Impact of Air Pollution caused by Mining and Marble Dust on Foliar Sensitivity through Biochemical Changes. *Int. J. Eng. Res. Technol.* **2017**, *5*, 1–4.
67. Liguori, V.; Rizzo, G.; Traverso, M. Marble quarrying: An energy and waste intensive activity in the production of building materials. *Wit Trans. Ecol. Environ.* **2008**, *108*, 197–207. [[CrossRef](#)]
68. Sabah, E.; Çelik, M. İscehisar (Afyon) Mermer Artıklarının Hayvan Yemi Katkı Maddesi Olarak Kullanılabilirliğinin Araştırılması. In Proceedings of the Türkiye III Mermer Sempozyumu (Mersem '2001) Bildiriler Kitabı, Afyonkarahisar, Turkey, 3 May 2001; pp. 3–5.
69. Abdelkader, H.A.M.; Hussein, M.M.A.; Ye, H. Influence of Waste Marble Dust on the Improvement of Expansive Clay Soils. *Adv. Civ. Eng.* **2021**, *2021*, 3192122. [[CrossRef](#)]
70. Seghir, N.T.; Mellas, M.; Sadowski, Ł.; Krolicka, A.; Żak, A.; Ostrowski, K. The Utilization of Waste Marble Dust as a Cement Replacement in Air-Cured Mortar. *Sustainability* **2019**, *11*, 2215. [[CrossRef](#)]