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Research Article

The Impact of Quarrying Activities on Air Quality and Public Health: A Case Study in Warwickshire

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Abstract

Poor air quality is well-documented for its links to health issues such as asthma, cancer, and autoimmune diseases, posing particularly high risks to children and vulnerable populations. This study utilizes a mixed-methods approach to evaluate the air pollution levels that school students and local residents are currently exposed to, along with the potential impact of a proposed 220-acre sand and gravel quarry, which would increase heavy goods vehicle (HGV) traffic near the community. Monitoring was conducted in multiple locations, including the village High Street, a 250-student primary school, a private residence opposite the school, and 350 meters from an active quarry site. Results indicate that levels of particulate matter (PM_{10} and $PM_{2.5}$) frequently exceeded both national and WHO safety thresholds, particularly during peak traffic hours, which exacerbated the decline in air quality. If the new quarry is approved, air pollution levels are expected to further increase due to intensified HGV traffic and additional emissions from quarry activities, raising serious concerns about potential health impacts on local residents. For over twenty years, planning officers, regulatory bodies, and developers have relied predominantly on desktop modelling to assess the health risks associated with quarry activities, often using outdated and limited data that fail to capture the current conditions and real-world risks. Authorities maintain that there is "no evidence" of health risks for residents near quarries, a claim based on the absence of direct scientific studies rather than conclusive safety. This research underscores the urgent need for robust, ground-level data to inform decision-making and safeguard public health, particularly given the increased exposure risks to children attending school within the impact zone. The study's findings strongly suggest that new quarrying activities could significantly compromise local air quality and increase health risks, highlighting the inadequacies of current regulatory assessments.

Keywords

Air Pollution, Quarrying, Public Health, Traffic Emissions, Air Quality Monitoring

1. Introduction

The quarrying sector plays a crucial role in supporting infrastructure development by providing a stable and abundant supply of raw materials. However, quarrying activities pose significant environmental and health risks to nearby communities. The environmental impacts of quarrying encompass a range of air pollutants, including

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sulphur oxides (SOx), nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), ammonia (NH_3), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), and fine particulate matter (PM_{10} and $PM_{2.5}$), depending on the quarry type [1].

In Europe, around 2.7 billion tons of aggregates are produced annually across approximately 25,000 quarries, with substantial environmental impacts on vegetation and soil in the areas surrounding these quarries due to the large-scale nature of open-cast mining [2]. The UK ranks high in Europe for particulate and gas emissions from quarrying and mining sectors [1]. Dust generated from these activities can significantly affect air quality, influenced by factors like dust particle concentration, particle size, and chemical properties. For instance, limestone quarries produce highly alkaline dust, while coal mining yields acidic dust. Such dust emissions are not only nuisances—coating surfaces and affecting visibility—but also present health risks, particularly for individuals with respiratory issues. They also have physical and chemical effects on vegetation, blocking internal plant structures, which may compromise plant survival [2].

Key environmental concerns associated with quarrying include negative impact on the environment especially [3], biodiversity loss, waste generation, noise pollution, and transportation impacts. Quarrying can disrupt biodiversity by disturbing various species, including plants, animals, and microorganisms [4]. Additionally, quarry waste varies across different types of quarries; sand and gravel quarries typically generate less waste than those that extract materials like clay and silt [2]. Noise pollution from quarry activities, including excavation, transport, and processing, also significantly impacts the surrounding environment [2]. The transportation of quarry products further exacerbates dust pollution, posing risks to local communities [1].

Quarry dust impacts vegetation both physically and chemically. Physically, it can cover leaf surfaces and obstruct light necessary for photosynthesis, or block stomata, resulting in water stress. Chemically, dust may vary in reactivity based on its composition; for example, alkaline dust from limestone quarries can alter soil pH and nutrient content, potentially affecting vegetation and invertebrate communities. For unmanaged ecosystems that have been acidified by atmospheric pollutants like sulphuric and nitric acids, alkaline dust might even offer local benefits by adding essential minerals [2].

Quarry dust also impacts local plant biodiversity and reduces crop yields, with vegetables being the most affected. This underscores the need for establishing green belts of pollutant-tolerant trees around quarries and implementing self-regulation in the industry to control dust spread [4]. A study in South-Eastern Nigeria, where quarrying contributes 8.7% of the regional GDP, measured high levels of particulate matter (PM10 and PM2.5) around quarries and found that temperature strongly correlated with particulate levels [5].

Wang's research on environmental impact assessments emphasizes the importance of adopting best practices in evaluating quarry impacts, recommending a careful and comprehensive approach to mitigate adverse outcomes. His work advocates for improved regulatory measures to prevent long-term environmental degradation and protect local ecosystems [6].

In the UK, the mining and quarrying sectors contribute to particulate and gas emissions, particularly PM_{10}, $PM_{2.5}$, and nitrogen dioxide (NO_2) [7, 8], which are significant health risks for nearby communities. Concerns about NO_2 emissions, largely from diesel vehicles, have intensified, with many urban areas in the UK reporting illegal levels of NO_2 since 2010. The European Court of Justice has intervened, compelling the UK to take stronger measures to address these air quality issues. The proposed sand and gravel quarry near Wasperton, Warwickshire, raises additional concerns for residents, particularly given its proximity to schools and residential areas, due to NO_2 and particulate emissions from heavy vehicle traffic. Previous studies on emissions from diesel engines underscore the need for a strategic shift towards hybrid and electric vehicles to mitigate environmental impact, highlighting a pressing need for sustainable transportation solutions [9]. Furthermore, there is a growing push to develop smart and NetZero cities to reduce carbon emissions through the use of electric transportation technologies [10] and surveys have been taken place to assess the physical and air quality risks associated with these technologies as well [11]

2. Methodology

2.1. Air Quality Data Collection

Al-Habaibeh et al. (2021) have monitored the real-time air quality at various locations in Barford, including a primary school and an existing quarry site, to capture realistic air pollution levels [12]. For this experiment, Aeroqual devices are utilized, each comprising a logger and a monitoring head. A total of four devices were used, with two dedicated to monitoring PM_{10} and $PM_{2.5}$ levels. To ensure a comprehensive data collection, the loggers were programmed to record readings at intervals of every 2 minutes. This setup allowed for the continues collection of data over a span of several days, ensuring a robust dataset for analysis.

2.2. Meteorological Data

Meteorological data (see Figure 1) has been provided by the Barford Residents Association from the nearest station is Wellesbourne Airfield [13], located about 6 km from the site. The data shows prevailing wind towards Barford and Wasperton villages.

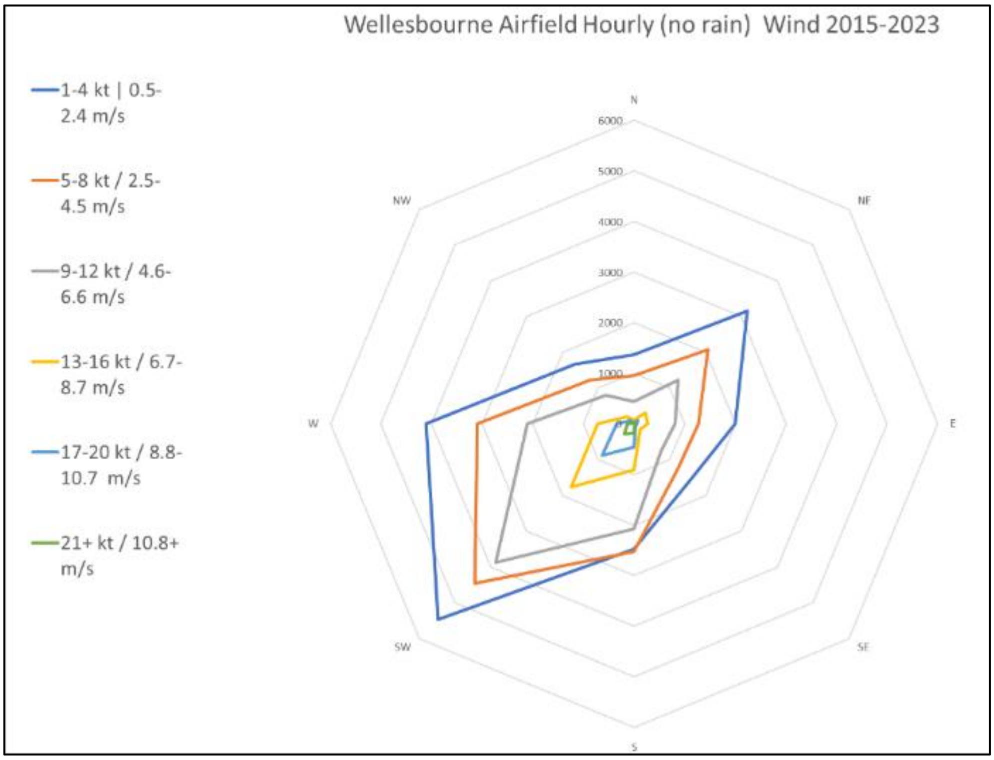

Figure 1. *Wind rose diagram for Wellesbourne Airfield (2015-2023), showing prevailing wind directions (data excludes rainy periods).*

2.3. Traffic Impact and Emission Analysis

Data from Department for Transport (DfT) has been utilised on the number of vehicles that travel past the count point (in both directions) on an average day of the year on A429 road. The

The specific dataset is accessible from the local authorities' section for Warwickshire on the DfT's Road Traffic Statistics website [14]. The dataset includes comprehensive details on vehicle counts, including cars, taxis, buses, light goods vehicles (LGVs), and various categories of heavy vehicles (HGVs) [15].

Table 1 shows the sample data has been taken to provide an overview of traffic on a specific major road A429 in Warwickshire providing a representative snapshot of traffic conditions in the area.

Table 1. *Sample data taken for Road A429.*

Year	2021	2022	2023
Road Name	A429		
Cars and Taxis	10812	11605	11892
Buses and Coaches	45	48	48
Light Good Vehicles (LGVs)	1812	2019	2059
HGVs 4 or more rigid axles	69	71	66
All HGVs	1031	1061	1035

A429 passes by Barford and Wasperton Village and it will be the main route used by lorries to transport the extracted minerals.

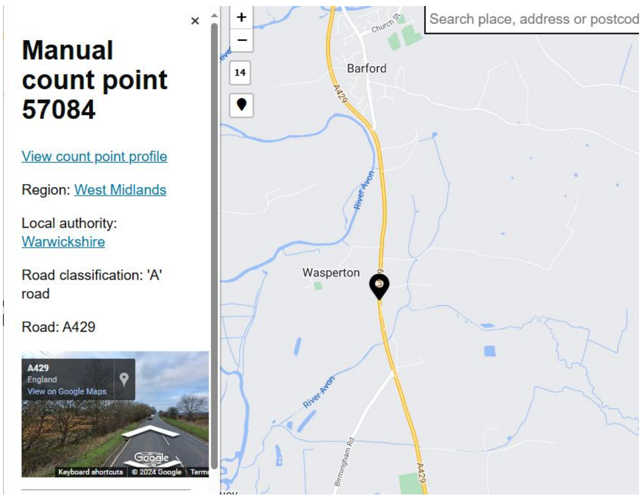

Figure 2. *Location of Road A429 (Source: Road Traffic Statistics).*

To understand the logistical impact of the proposed development, the number of lorry trips required to transport the annual production output. The site is expected to produce 200,000 tonnes of material per annum. Assuming the use of 30-tone lorries (HGVs 3 rigid axle), a sample calculation is as follows:

$$\text{Annual Trips: } \frac{200{,}000\ tonnes}{30\ tonnes\ per\ lorry} = 6{,}667\ trips$$

$$\text{Daily trips: } \frac{6{,}667\ trips}{300\ days} \approx 22\ trips\ pers\ day$$

To assess the potential impact of heavy goods vehicles (HGVs) on air quality, a proxy methodology was employed due to the limited availability of direct HGV emissions data. Air quality measurement equipment was attached to a car following a bus to measure its nitric oxide (NO) emissions during stop-and-start patterns similar to those expected of HGVs used in quarry operations. Nitric oxide (NO) emissions were measured using a Chemi Luminescence Detector (CLD), the industry-standard method for quantifying NO concentrations in engine exhaust. The CLD500, manufactured by Cambustion [16], was employed in this experiment, offering a more advanced 2-millisecond response time compared to conventional CLDs, which have response times of 1-2 seconds and are typically used to measure bag emissions where the concentration changes very slowly. The collected NO emissions data were then converted to nitrogen dioxide (NO_2) using conversion factors provided by DEFRA and compared to UK government air quality standards to assess potential exceedances.

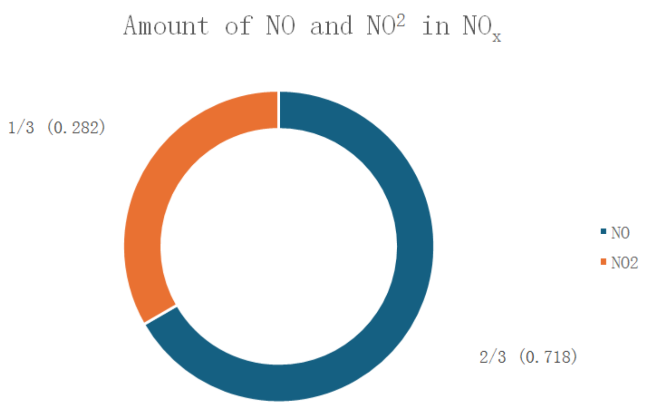

Figure 3. Amount of NO and NO2 in NOx (Source: NOx to NO2 Calculator | LAQM (defra.gov.uk)).

As Figure 3 illustrates, according to the Department for Environment Food & Rural Affairs [17], non-urban UK traffic in 2024 consists of approximately one-third NO_2 and two-thirds NO within the total NO_x emissions. This data underscores the importance of monitoring and mitigating NO_2 emissions, particularly in areas with significant quarrying activities or heavy vehicle traffic.

3. Results and Discussion

3.1. NTU Air Quality Monitoring Results

Air quality readings, specifically for PM_{10} and $PM_{2.5}$, were collected inside a school in Barford Village, with findings indicating elevated particulate matter levels during school hours compared to non-school hours (Figure 4). This increase is likely due to greater occupancy and activity during school hours.

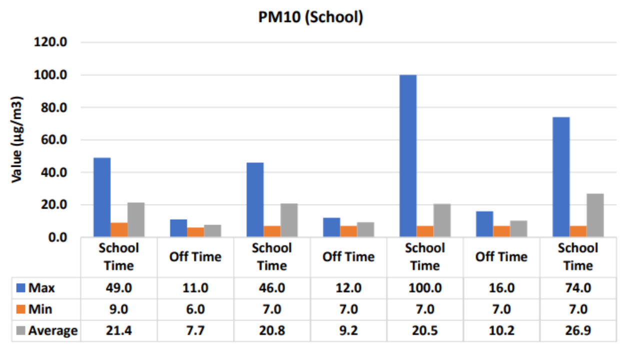

Figure 4. Data analysis for PM10 at the school at Barford village.

Additionally, data recorded at a house on Barford Road, close to the proposed quarry site, mirrored the trend observed at the school. Daytime measurements were consistently higher, likely influenced by traffic. Interestingly, an unusual spike was observed on the third day, with daily averages peaking on the fourth day.

Two trials were also conducted to measure air quality near an active quarry. The first trial, which focused on short-term (1-hour) monitoring of PM_{10}, $PM_{2.5}$, and NO2 levels, showed increased particulate matter readings as the monitoring devices moved closer to the quarry (Figure 5).

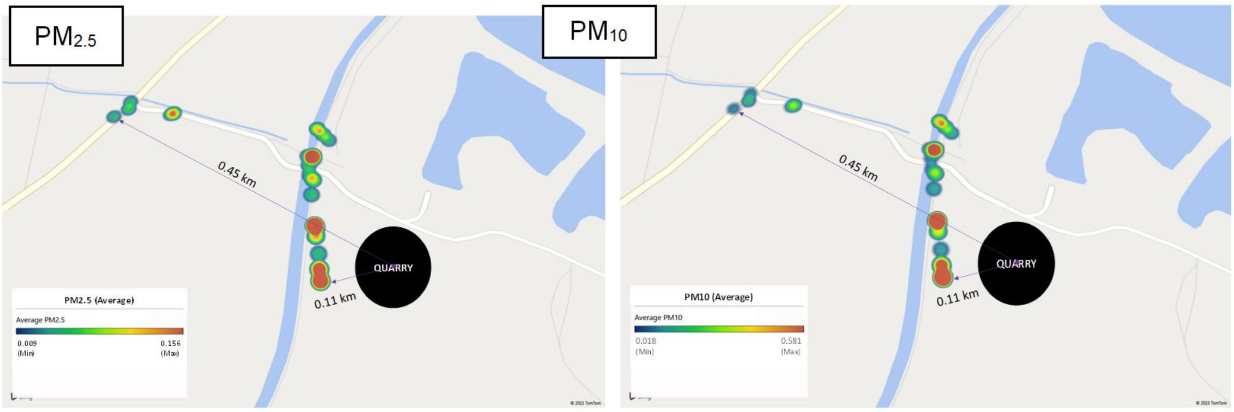

Figure 5. *A map shows the location of the average PM_{10} and $PM_{2.5}$ readings taken by devices.*

The second trial, lasting longer and considering variables such as wind direction, reaffirmed the presence of higher PM levels closer to the quarry. Farming activities in the vicinity also contributed to elevated PM levels, particularly in the second trial (Figure 6).

Figure 6. *This map shows the fixed point in yellow circle and the path used to collect data in the last hour.*

Fixed-point measurements taken 0.65 km from the quarry under low wind conditions revealed relatively stable concentrations of PM_{10}, $PM_{2.5}$, and NO_2. However, as mobile monitoring moved closer to the quarry, particulate matter levels increased, indicating a direct impact from the quarry's operations (Figure 7).

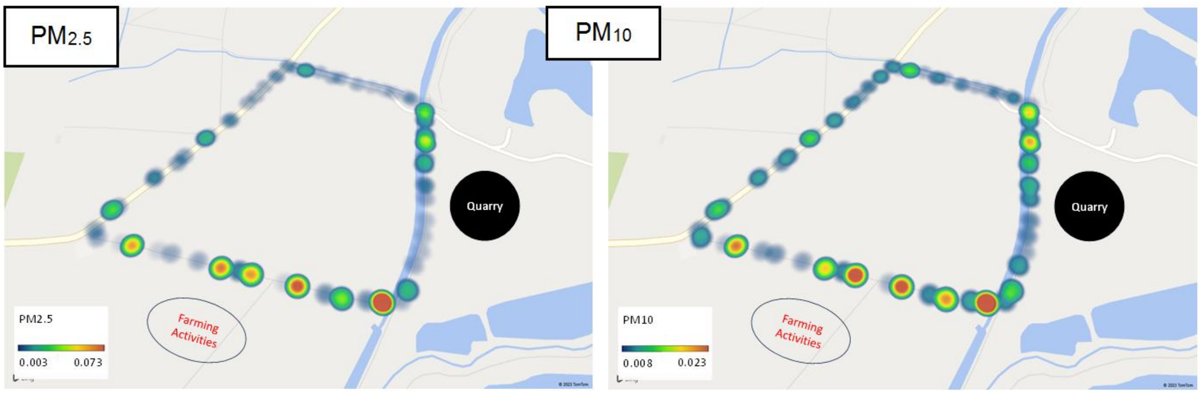

Figure 7. *PM_{10} and $PM_{2.5}$ colour map.*

3.2. Impacts of the HGVs

Based on the calculations earlier in the report, it is estimated to have 22 trips per day (44 trips including the return journey) over 12 hours of operation, across 300 working days per year (Monday to Saturday). However, water abstraction restrictions—such as those limiting operations when the flow of the River Avon falls below a certain threshold—might reduce the number of operational days if water needs to be pumped from the excavation pits. If standard lorries are being used, it would be necessary to complete up to 200 trips per day to fulfil the project's objectives.

Alternatively, 1.8 million tonnes are to be extracted over 15 years, equating to 120,000 tonnes per year. Assuming a maximum of 320 working days, 375 tonnes per day need to be transported. This number is doubled for infill importation, resulting in 750 tonnes per day. If 25-tonne lorries are utilized, 30 trips per day (60 trips including the return journey) will be required. If 18-tonne lorries are used, 40 trips per day (80 trips including the return journey) will be necessary.

The results from emissions of the bus clearly shows the start and stop results in spikes equate to 5,000 μg/m^3 of NO_2, while the average during travel is 1,000 μg/m^3.Table shows the assumptions made for different scenarios with estimated trips per hours, hourly emissions and number of daily exceedances.

Table 2. Emissions and exceedances considering different Scenarios.

Lorries tonne	Number of lorries	Trips per hour	Hourly NO_2 during stop and start (μg/m^3)	Number of daily exceedances (limit ×18 per year)	Hourly NO_2 during travel (μg/m^3)	Number of daily exceedances (limit ×18 per year)
30	22	3	15,000	90	3,000	15
25	30	4	20,000	100	4,000	20
18	40	5	25,000	125	5,000	25
Standard	200	25	125,000	625	25,000	125

The numbers in table 1 are concerning after realizing that the government target for NO_2 is 200 μg/m^3 which can only be exceeded 18 times a year. However, the target will be exceeded at least 15 times a day which is equivalent to 180 times a year.

The limitations of using bus emissions as a proxy for HGV data are acknowledged, as HGVs typically produce higher levels of NO_2. Therefore, the actual air quality impacts of the proposed development would be probably greater than that estimated in this report. Further research with direct measurement of HGV emissions would be beneficial for a more comprehensive understanding.

4. Conclusion

This study highlights the significant environmental and public health risks associated with increased quarrying activities and HGV traffic in the Wasperton and Barford areas. The analysis reveals that the proposed quarry, alongside the rise in heavy vehicle traffic, would lead to a considerable increase in harmful pollutants such as NO_2, $PM_{2.5}$ and PM_{10}. Air quality monitoring data from local schools and residential areas already indicate elevated pollution levels during peak traffic times, particularly affecting children. The projected number of HGV per day significantly exceeds safe NO_2 concentration limits set by government standards, implying frequent and severe air quality exceedances. These results emphasize the need for stricter regulation and alternative transport methods to mitigate the environmental impact [18]. Without appropriate intervention, the local population, especially schoolchildren, faces heightened exposure to air pollutants, increasing the risk of long-term health issues such as respiratory and cardiovascular diseases. This underscores the necessity for further, more precise research and comprehensive environmental impact assessments before proceeding with the quarrying project.

Abbreviations

CLD	Chemi Luminescence Detector
DfT	Department for Transport
HGV	Heavy Goods Vehicle
LGV	Light Goods Vehicle
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
PM_{10}	Particulate Matter 10 (Micrometers or Less in Diameter)

$PM_{2.5}$	Particulate Matter 2.5 (Micrometers or Less in Diameter)
WHO	World Health Organization

Conflicts of Interest

The authors declare no conflicts of interest.

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