Introduction to Air Pollution: Resources for Schools (KS3-4)

This resource was prepared by the University of Birmingham WM-Air team.

Acknowledgements: WM-Air (wm-air.org.uk/) Team: Clarissa Baldo, Catherine Muller, Nicole Cowell, Suzanne Bartington, Jian Zhong, William Bloss. Original air pollution Independent Project by Georgina Smellie and Prof. Sophie Hadfield-Hill (University of Birmingham). Schools resource reviewed by Pete Mackintosh and Mandi Slater (Birmingham City Council), Prof Sylvia Knight (RMetS) and Dr Sam Dobbie (BiFOR).

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Curriculum map

This series of lesson plans - which can either be used as stand-alone modules or followed sequentially - are designed to align with the key skills required of KS3-4 geography students, including mapwork, data skills and fieldwork within the context of air pollution. Each lesson can be used as an independent resource or followed as a part of longer lesson series around air pollution. The material is adaptable to suit KS3-4 and aligns with the curriculum at the following points:

- KS3: Urbanisation, challenges of urban environments, understanding of the interaction of human and physical processes to influence and change landscapes and environments, map work, data skills.
- GCSE: Human and Physical field work, urbanisation, fieldwork skills, data skills.

Although designed for KS3-4, this resource also crosses over with aspects of the KS5 A-level curriculum:

- OCR: 2d. Investigative geography (H481/04, 05)
- AQA: Component 3.3 - Geography fieldwork investigation (7037/03)
- Edexcel: Independent Investigation (9GE0/04)
- WJEC: A2 Unit 5 - Independent Investigation

Aim and objectives

This resource can be used as lesson plans for staff and students, or for awareness building with families and the wider communities around the main sources and health effects of air pollutant emissions and to encourage action for clean air.

In this lesson plan, students will learn to:

- List key air pollutants and their sources.
- Explain the negative health effects of air pollution.
- Describe methods to reduce air pollution.
- Use different data collection methods to understand air pollution.
- Record and report results using appropriate tables and graphs.
- Use results to draw conclusions.
- Use established scientific knowledge to answer questions.
- Write a formal scientific report.

Structure

The material is structured into three main sections, each of which comprises multiple lessons with various tasks and exercises. Importantly, teachers can select individual lessons to use as stand-alone modules or follow the lessons in order. Below is a brief description of each section and its lessons.

- Section 1 includes several introductory lessons on air pollution:
  - Lessons 1 and 2 introduce key air pollutants, their sources, and health impacts.
  - Lesson 3 illustrates the units that are used to measure air pollution.
  - Lessons 4 explains how air pollution changes in different settings and over time.
  - Lesson 5 discusses common myths related to air pollution.
  - Lesson 6 introduces actions to reduce air pollution.
  - Lesson 7 describes the Birmingham case study.
- Section 2 contains practical exercises for understanding local air pollution:
  - Lesson 8 summarises data types and sampling methods.
  - Practical exercises 1-4.
- Section 3 provides detailed instructions for writing the final report.

Contents

Section 1: Introduction to air pollution

Lesson 1: Understanding air pollution

What is air pollution?

Read the text and search keywords. Some examples of keywords are highlighted in blue.

Air pollution is made up of harmful gases and tiny particles that are found in the air we breathe. These pollutants can cause health problems for people and can also harm the environment. The two main pollutants in the UK are called **Particulate Matter (PM)** and **Nitrogen Dioxide (NO_2)**.

What is Particulate Matter (PM)?

PM is a mixture of tiny particles and droplets with different sizes and shapes. These particles can be made up of various chemicals and come from many different sources.

Where does PM come from?

Some particles come from nature, like desert dust, sea salt, and pollen. In city areas, the main sources of PM are from human activities such as burning fossil fuels in cars, industries, and homes. PM can also form from chemical reactions in the air.

What are the harmful effects of PM?

$PM_{2.5}$ are the tiniest and most dangerous particles. They are called $PM_{2.5}$ because they are smaller than 2.5 micrometres in diameter (1 micrometre equals 1 millionth of a meter or 1 thousandth of a millimetre). These particles are around 30 times thinner than a human hair (Figure 1.1). Because they are so small, they can get deep into the lungs and blood system, which can cause health problems like **hearth and lung diseases** and even **early death**.

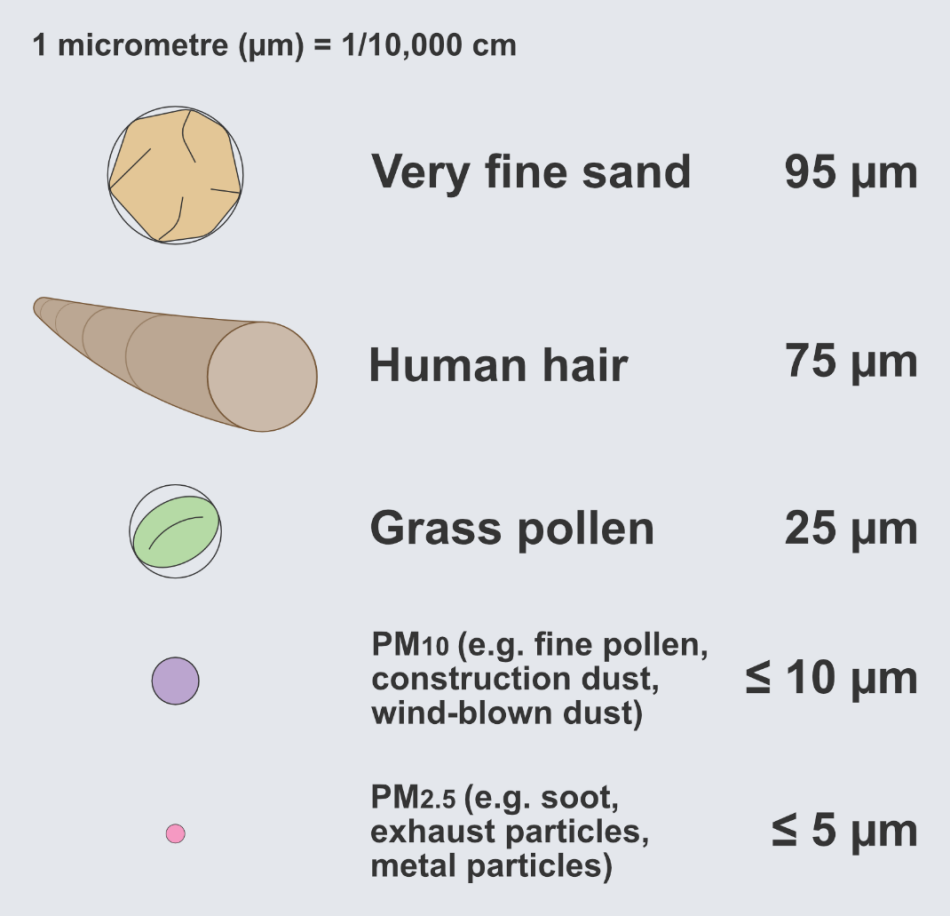


Figure 1.1: Particulate matter (PM) are small harmful pollutants in the air we breathe. $PM_{2.5}$ is smaller and more harmful than PM_{10} as it can penetrate deeper into the lungs and enter the bloodstream.

What is Nitrogen Dioxide (NO_2)?
NO_2 is a gas made up of nitrogen and oxygen that is found in the air (Figure 1.2).

Where does NO_2 come from?
NO_2 is released into the air when fossil fuels are burned, such as in cars that use petrol or diesel. In cities, most of the NO_2 comes from **vehicles** on the road. Other important sources are **power stations**, **industries**, and **home heating systems**.

What are the harmful effects of NO_2?
NO_2 can make it harder to breathe and can cause **asthma** attacks. It can also increase the risk of **respiratory infections**, which can make people sick.

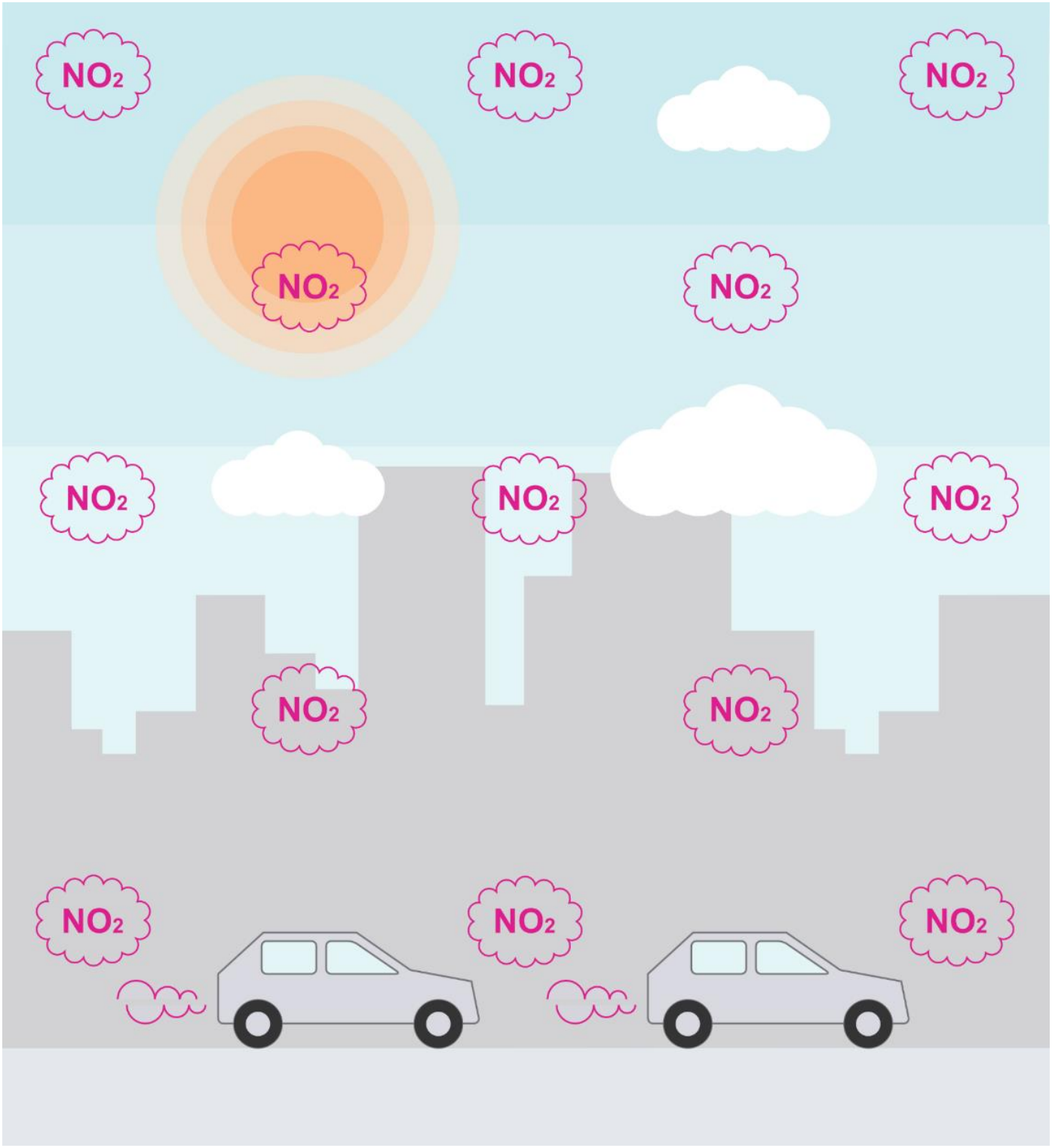


Figure 1.2: Nitrogen dioxide (NO_2) is a toxic gas present in the air we breathe.

Task 1.1: Reading Quiz 1

After reading the text, answer the questions below to check your understanding of the topic.

1) What is air pollution, and how can it affect people's health?

Students should explain that air pollution consists of harmful gases and particles that can be breathed in and cause a variety of health problems.

2) What are the two main pollutants in the UK, and what are their sources?

Students should explain that NO_2 and $PM_{2.5}$ are the main pollutants in UK cities and that are primarily released by transport, industries, and households.

3) What is PM, and how can it affect people's health?

Students should explain that PM is a mixture of small particles and liquid droplets with different sizes and shapes. The smaller particles, $PM_{2.5}$, are more harmful as they can penetrate deeper into the lungs and enter the bloodstream, which can cause health problems like hearth and lung diseases and even early death.

4) What is NO_2, and how can it affect people's health?

Students should explain that NO_2 is a gas made up of nitrogen and oxygen. Exposure to NO_2 pollution can cause health problems like breathing difficulty, respiratory infections, and asthma.

Resources

[1] Public Health England: Health matters: air pollution. Public Health England, 2018. Accessed 31/01/2023. Available at: https://www.gov.uk/government/publications/health-matters-air-pollution/health-matters-air-pollution

[2] Global Action Plan: Air pollution Facts. Global Action Plan, 2022. Accessed 31/01/2023. Available at: https://www.cleanairhub.org.uk/clean-air-information/the-basic-information

[3] EPA: Particulate Matter (PM) Basics. United States Environmental Protection Agency, 2022. Accessed 31/01/2023. Available at: https://www.epa.gov/pm-pollution/particulate-matter-pm-basics

[4] RCP: Every breath we take: the lifelong impact of air pollution. Royal College of Physicians, 2016. Available at: https://www.rcplondon.ac.uk/projects/outputs/every-breath-we-take-lifelong-impact-air-pollution

[5] DHSC: Chief Medical Officer's Annual Report 2022: Air pollution. Department of Health and Social Care, 2022. Available at: https://www.gov.uk/government/publications/chief-medical-officers-annual-report-2022-air-pollution

[6] WHO: WHO Global Air Quality Guidelines. World Health Organization, 2021. Available at: https://www.who.int/publications/i/item/9789240034433

[7] Acton, WJF et al., 2023: What is $PM_{2.5}$? An Introduction to Particulate Matter in the Atmosphere: A Briefing Note. WM-Air Project, University of Birmingham. Available at: https://doi.org/10.25500/epapers.bham.00004241

Lesson 2: Sources of air pollution

What are fossil fuels?

Read the text and search keywords. Some examples of keywords are highlighted in blue.

Human activities are a major cause of air pollution, especially in large cities. These include **burning of fossil fuels** by vehicles (e.g. cars, buses, trucks), industries, and homes.

Fossil fuels are formed over millions of years from the remains of dead plants and animals buried under many layers of rocks. **Coal**, **oil**, and **natural gas** are examples of fossil fuels. Fossil fuels are burnt to **produce energy**. They are used to power everything from airplanes to gas cookers. Fossil fuels are non-renewable energy resources because they will run out one day.

Burning of fossil fuels is a source of **air pollutants**, including PM like soot and fly ash and NO_2. Burning fossil fuels also creates **greenhouse gases** like **carbon dioxide** (CO_2), which are damaging to the environment and are making the **Earth warmer** than it should be. Note that climate change is a separate topic, and not covered in this booklet, for more info please see for examples the resources by the Royal Meteorological Society, you can visit their website at https://www.metlink.org/resource/14-changing-uk-climate/.

Using **renewable energy** like hydropower, solar energy, wind energy, and geothermal energy is much cleaner than using fossil fuels because they do not produce harmful gases and particles that cause air pollution and climate change.

Task 2.1: Sorting energy sources

Figure 2.1: Examples of fossil fuels and renewable energy sources

Figure 2.1 provides some examples of fossil fuels and renewable energy sources. In the boxes below, write down at least five things that burn fossil fuels and five things that do not burn fossil fuels. Then, as a class, discuss why it is important to be mindful of what burns fossil fuels and what does not. Brainstorm ways to reduce the use of fossil fuels in our daily lives and share your ideas with the class.

Burns Fossil Fuels	Does Not Burn Fossil Fuels
1) Vehicles 2) Airplanes 3) Home heating 4) Power plants 5) Industrial processes	1) Solar energy 2) Wind energy 3) Bicycle 4) Electric vehicles 5) Geothermal energy

Task 2.2: Describing sources of air pollution in the West Midlands

Figure 2.2 shows two common pollutants, $PM_{2.5}$ and NO_2, and where they come from in the West Midlands. Air pollution can come from different sources. These sources include cars, buses, trains, lorries, and industries that burn fossil fuels for energy. Other sources of air pollution are homes where people burn fossil fuels for heating or cooking, waste that are burnt in incinerators, and farms using chemicals and fertilizers.

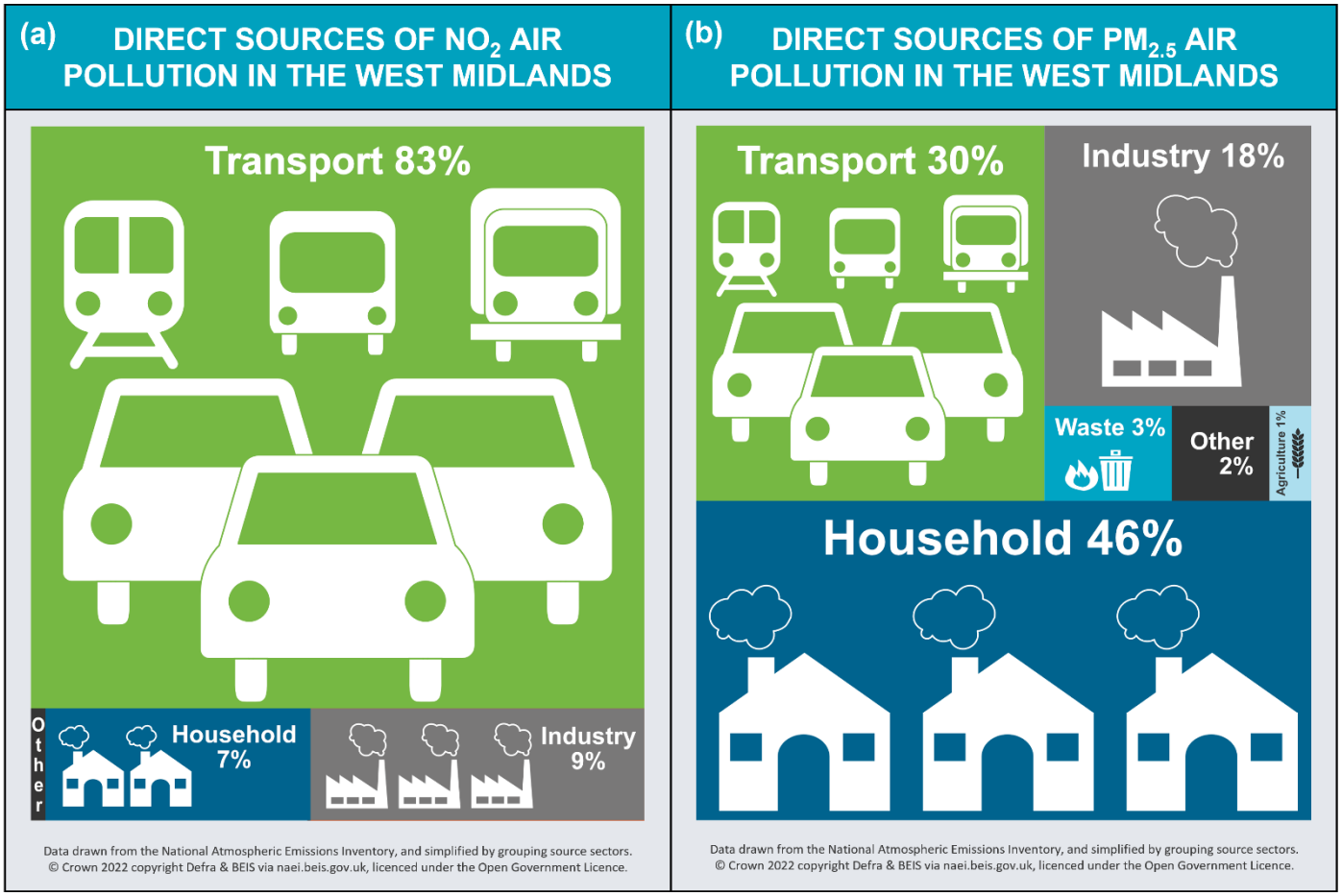


Figure 2.2: Direct contributions of air pollution sources in the West Midlands. Air pollutant emission data © Crown 2022 copyright Department for Environment, Food and Rural Affairs (Defra) & Department for

Business, Energy & Industrial Strategy (BEIS) via naei.beis.gov.uk, licenced under the Open Government Licence (OGL).

Look at the treemaps in Figure 2.2, which show where $PM_{2.5}$ and NO_2 come from in the West Midlands. In the treemaps, each rectangle represents a different source of these pollutants. The larger the rectangle, the larger the source of the pollutants.

Use the information in the treemaps to describe the biggest sources of $PM_{2.5}$ and NO_2 in the region.

Students should explain that the treemaps report contributions from direct sources of $PM_{2.5}$ and NO_2 in the West Midlands. For each pollutant, students should describe the type of sources and their percentage contribution as shown in the graph.

Resources

[1] BBC: Energy generation and storage. British Broadcasting Corporation, 2020. Accessed 31/01/2023. Available at: https://www.bbc.co.uk/bitesize/guides/zf8ck2p/revision/1

[2] UN: What is renewable energy. United Nations, 2018. Accessed 31/01/2023. Available at: https://www.un.org/en/climatechange/what-is-renewable-energy

[3] EPA: Renewable Energy at EPA. United States Environmental Protection Agency, 2023. Accessed 31/01/2023. Available at: https://www.epa.gov/greeningepa/renewable-energy-epa

Lesson 3: Measuring pollutants in the air

How is air pollution measured?

The levels of harmful gases and particles in the air are measured to check whether the air is polluted or clean. The amount of pollutants in the air is usually measured in micrograms per cubic meter of air or "µg/m^3", which is one millionth of a gram in each cubic meter of air. For example, if the level of a pollutant is 5 µg/m^3, it means that in one cubic metre of air, there are 5 micrograms of that pollutant.

Task 3.1: Calculating the amount of pollutants in the air

If the level of a pollutant is 10 µg/m^3 and the volume of air in a room is 100 cubic meters (m^3), how many micrograms (µg) of that pollutant are in the room?

Students should calculate as follows:

10 (µg/m^3) X 100 m^3 = 1000 ug or 1 mg

Task 3.2: Creating an air pollution map

The **annual mean concentration is the average amount of pollution in the air for a whole year**. This is important because pollution levels can change depending on factors like weather, seasons, and location. Looking at the average pollution over a year gives a better idea of how polluted an area is.

Figure 3.1 is a map of the West Midlands. The map shows different areas of this region, each with a number that represents the average level of an air pollutant in that area for one year.

Use the legend provided to colour each area based on its level of air pollution.

Legend
Region with a level of air pollution between 14 and 18: Leave the region white *(shown as pale yellow in example below)*
Region with a level of air pollution between 18 and 22: Colour the region yellow
Region with a level of air pollution between 22 and 26: Colour the region orange
Region with a level of air pollution greater than 26 and 30: Colour the region red

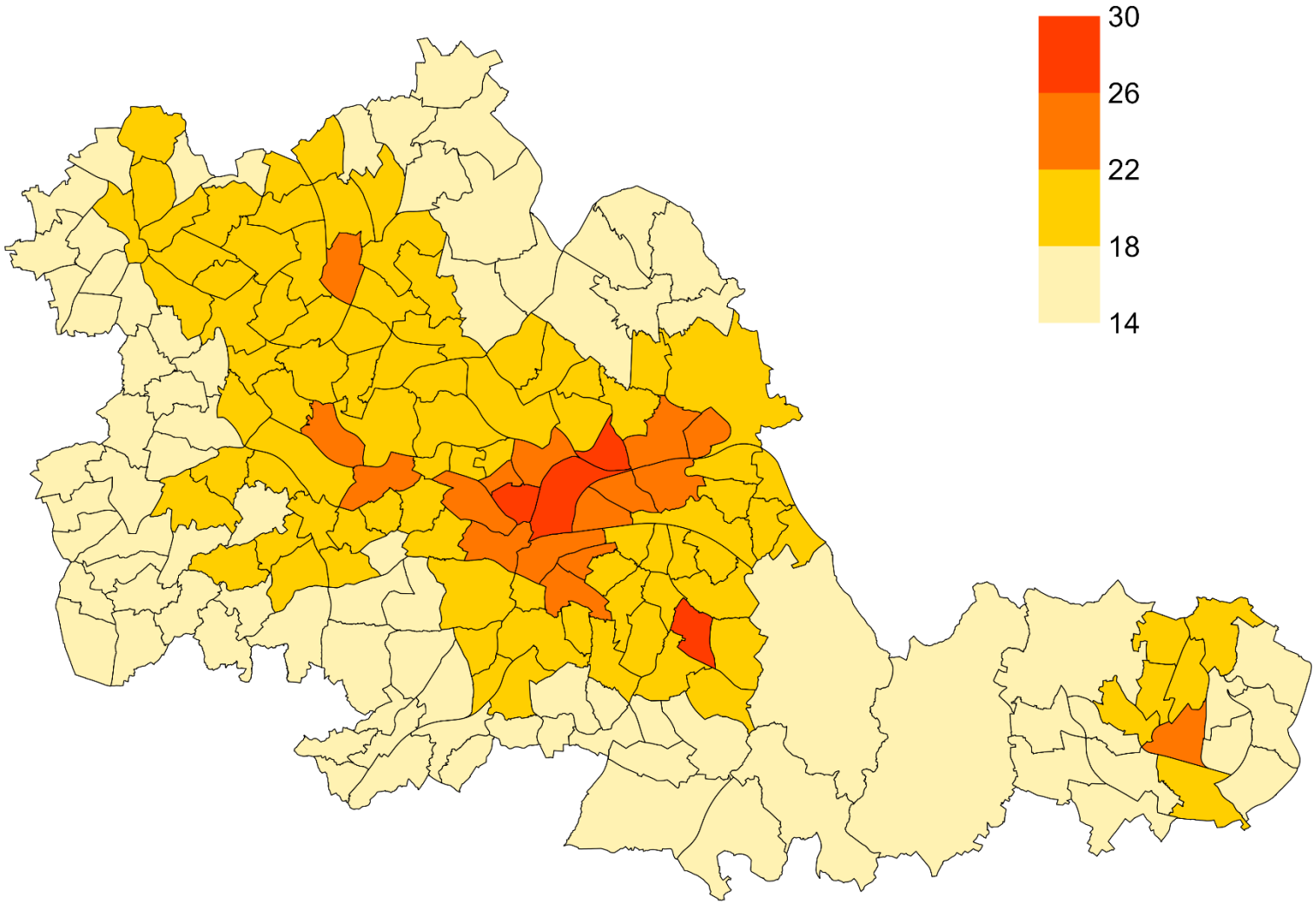


Figure 3.1: Air pollution level map exercise. Annual mean levels of NO_2 in the West Midlands region.

Once you have finished colouring the air pollution map in Figure 3.1, take a look at the geographical map of the West Midlands in Figure 3.2. Compare the two maps and discuss any differences and patterns you observe as a class. Is the pollution higher in countryside areas or around large cities? What could be the possible reasons for these differences?

Students can explain that the air is dirtier in large cities than in the countryside areas. This is because usually there are more cars, industries, and people living in cities, which creates more pollution.

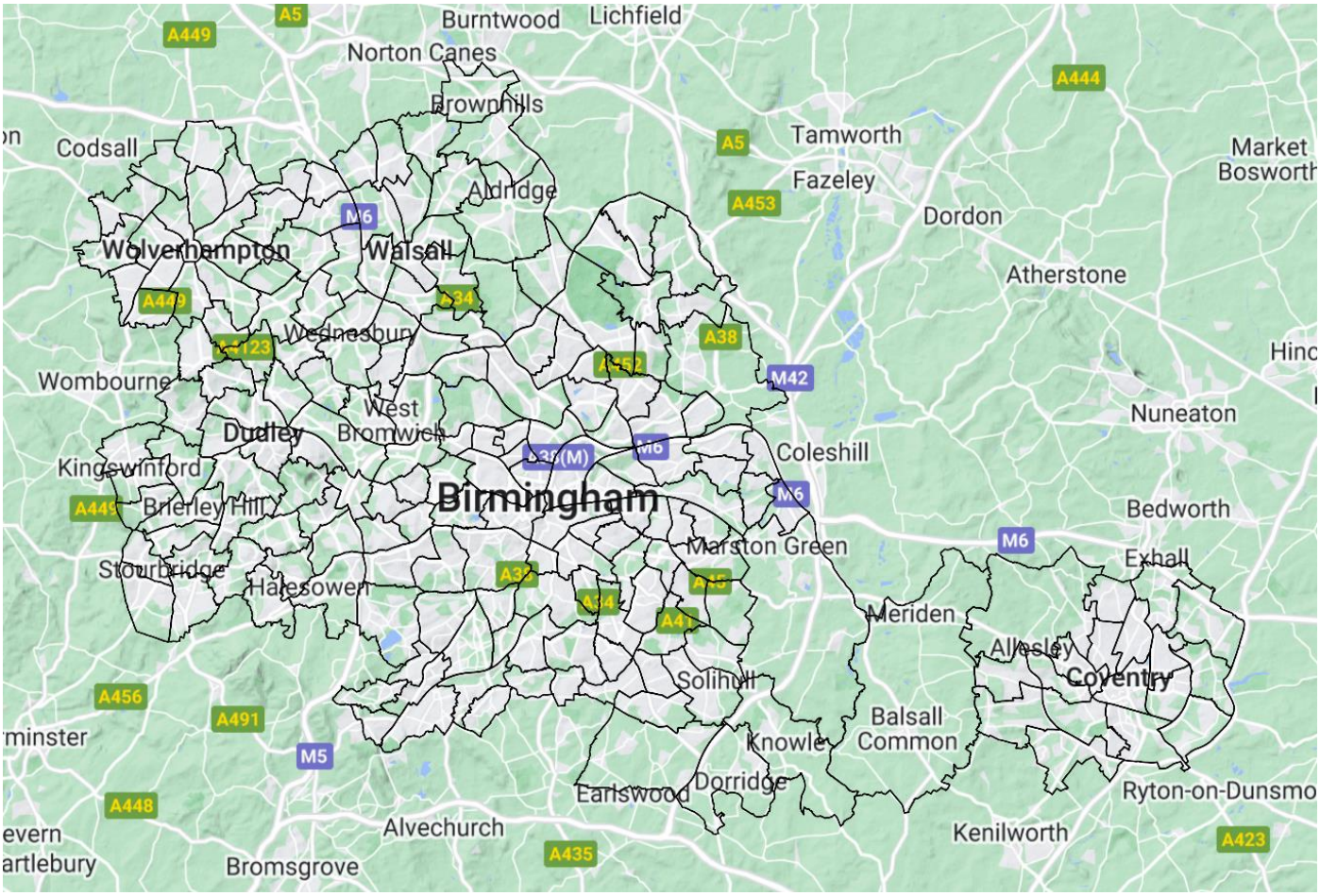


Figure 3.2: Geographical map of the West Midlands region, UK, showing its major cities and surrounding terrain. The black lines denote the administrative boundaries of local authority districts. Map data ©2023 Google. Created with ggmap and openair R packages.

Task 3.3: Matching exercise

Match with a line the terms to the correct definitions.

Terms	Correct Definitions
µg/m^3	The amount of pollutants in the air is usually measured in this
Annual mean concentration	The average amount of pollution in the air for a whole year
Air pollution levels	Refers to the amount of harmful gases and particles in the air
Weather	Air pollution levels can change depending on factors like this

Lesson 4: Describing air pollution levels

Task 4.1: Air pollution True or False

Read the following paragraph about air pollution levels and determine whether the statements that follow are true or false. Write "T" for true and "F" for false.

The level of pollution can vary depending on location and time of year. In large cities, the air is often dirtier than in the countryside areas. This is because usually there are more cars, industries, and people living in cities, which creates more pollution. Figure 4.1 shows how air pollution levels change during the year.

The graph has two lines, one representing a large city and the other representing a countryside area. The x-axis of the graph represents the months of the year, from January to December, and the y-axis represents the level of air pollution, measured in units of µg/m³. The graph shows that the level of air pollution is generally higher in cities than in countryside areas. In both settings, the level of pollution is highest in the cold months, particularly between November and February, and lowest in the warm months, especially between June and August.

Statement	T/F
The graph in Figure 4.1 shows how the level of air pollution changes during the day	F
The graph has one line representing a city area and another line representing a countryside area	T
The x-axis of the graph represents the months of the year	T
The level of air pollution is generally higher in city than in the countryside area	T
The level of pollution is highest in the warm months and lowest in the cold months	F

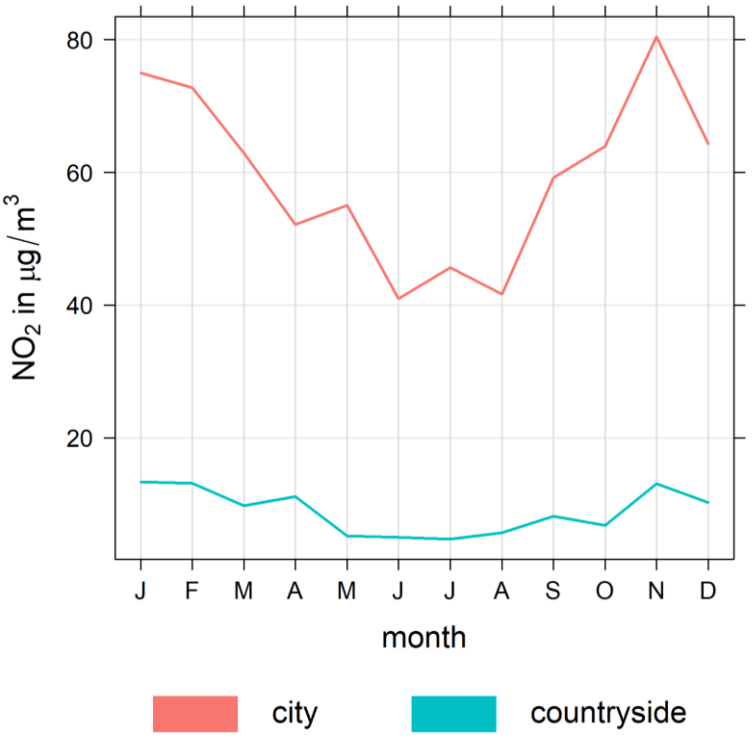


Figure 4.1: Changes of air pollution levels in the countryside and city areas of the West Midlands during a year. Air quality data ©2023 AURN.

Task 4.2: Can you hear what's in the air?

The following videos created by WM-Air (www.wm-air.org.uk) describe with the aid of music how air pollution levels change in the countryside and in towns and cities, at difference times of the day, and across Birmingham and the UK. The online audience guide by WM-Air is available at following link: https://wm-air.org.uk/wp-content/uploads/2022/02/Audience-Guide-by-Robert-Jarvis.pdf

Watch the videos by WM-Air and try to answer the questions listed below.

Video 1: Location matters - The importance of place

Listen to how air pollution changes for different settings:
https://www.youtube.com/watch?v=4Rv7j2Bkm0Q&t=3s

1) What is the NO_2 concentration in Aston Hill Shropshire?

Students should answer that NO_2 concentration in Aston Hill Shropshire is 4 µg/m^3.

2) Where in the video has the highest NO_2 concentration in the UK?

Students should answer that the highest NO_2 concentration shown in the video is 64 µg/m^3 at Hafod-Yr-Ynys, Caerphilly.

3) Describe what happened to the sound as concentrations increased.

Students should explain that deep tones are used for lower air pollutant concentrations, while higher tones are used when concentrations increase.

Video 2: Pick your moment - The difference the time of day makes

Listen to the changes in pollution across the West Midlands, hour by hour, expressed as sound:
https://www.youtube.com/watch?v=Z5C2p509thc&list=PLK1fJ0SUly2h2lFIabJE1nuKxnJXIxlVu&t=5s

4) At what times of day does NO_2 concentrations increase across Birmingham?

Students should answer that NO_2 concentrations increases in the morning between 6 am and 10 am, and in the evening between 4 pm and 10 pm.

5) Describe any patterns you see on the map.

Students should explain that NO_2 concentrations increase in the city centre and along main roads.

6) What can make NO_2 concentrations increase at certain times?

Students can answer that peak traffic hours can explain the higher pollution at certain times.

Video 3: Choose your path carefully - Taking the scenic route

Listen to the changes in pollutant levels along a route across Birmingham, from the rural outskirts through the city centre: https://www.youtube.com/watch?v=X0nMgM8QgkA&t=2s ##

7) What is the NO_2 and $PM_{2.5}$ maximum concentrations at Spaghetti Junction?

Students should answer that at Spaghetti Junction the maximum concentration of NO_2 is 201.9 µg/m^3 while the maximum concentration of $PM_{2.5}$ is 107.5 µg/m^3

8) Describe how NO_2 and PM levels change across Birmingham following the route from Lickey Hills Park to Sutton Park passing through the Birmingham city centre.

Students should explain that air pollution levels increase travelling from Lickey Hills Park to central Birmingham and decrease from central Birmingham to Sutton Park.

9) Where in the video air pollution levels are highest across Birmingham? What can make air pollution increase in these areas?

Students can explain that central Birmingham areas can be more polluted because there is more traffic with many cars and buses, more people living and working there, factories and companies releasing pollutants and fewer parks and trees to clean the air.

Lesson 5: Myths about air pollution

Are you more exposed to air pollution in your car, or on your bike?

Watch the following video by Sustrans (www.sustrans.org.uk) and answer the questions below.

Video link: https://www.youtube.com/watch?v=_Fh5pAiaTj4

1) Before the video, what did you think exposed you more to air pollution: car or bike? Did this video change your opinion?

Before watching the video, students can discuss which type of transport they think will reduce their exposure to air pollution and share their revised opinions after watching the video.

2) How can choosing to travel by bike instead of by car help to reduce air pollution?

Students can answer that traveling by bicycle instead of by car helps reduce air pollution because bicycles produce zero emissions and also reduce traffic congestion.

3) What are some other benefits of cycling for both individuals and the environment that were mentioned in the video?

Students can answer that cycling reduces the amount of air pollutants released in the air (e.g. fewer cars, less traffic), but it also reduces exposure to air pollution, since in a car you are exposed to a higher level of air pollution that gets trapped inside; moreover, cycling allows you to avoid busy roads. In addition, cycling keeps you fit and healthy.

Can you see all types of air pollution?

Watch the following video by Sustrans (www.sustrans.org.uk) and answer the questions below.

Video link: https://www.youtube.com/watch?v=usi5ueKw8sI

4) What did you learn about air pollution that you did not know before watching the video?

Before watching the video, students can discuss what they know about air pollution and share their revised opinions after watching the video.

5) Can you name some big sources of invisible air pollutants?

Students can answer that sources of air pollutants include for example transport (e.g. cars, trains, lorries, buses), industries, heating at home, cooking activities, bonfires, fireworks, airplane, shipping etc… Students can also refer to lesson 2 of this booklet “Sources of air pollution”.

6) Why $PM_{2.5}$ is more dangerous than PM_{10}?

Students should answer that $PM_{2.5}$ is smaller and more harmful than PM_{10} because it can penetrate deeper into the lungs and enter the bloodstream causing a variety of health problems.

Lesson 6: Actions for cleaner air

What are we doing to reduce air pollution?

Read the text and search keywords. Some examples of keywords were highlighted in bold.

Strategy to reduce air pollution in cities in the UK

Some cities in the UK have created **Clean Air Zones** to decrease the amount of harmful NO_2 in the air (see the example from Birmingham below). They want to reduce NO_2 levels to below the **legal limit** (**40 µg/m^3**, **annual mean concentration**). However, it is important to remember that NO_2, like many other pollutants including $PM_{2.5}$, can still be harmful to health even if it is below this limit. To help reduce pollution and improve health, some cities have also launched public campaigns encouraging people to **walk, cycle,** or **use public transport** instead of driving.

WHO Global Air Quality guidelines

To protect our health, it is important to continue improving air quality in the UK, even though there has been some progress in recent years. The World Health Organization (WHO) recommends air quality guideline levels which are based on scientific evidence on air pollution's health impacts. The WHO Global Air Quality guidelines indicate that annual mean concentration should not exceed 5 µg/m^3 for $PM_{2.5}$ and 10 µg/m^3 for NO_2 (Table 6.1).

Table 6.1: Annual mean $PM_{2.5}$ and NO_2 legal limits for England and WHO health guidelines.

Pollutants	Legal limits for England (µg/m^3)	WHO 2021 Global Air Quality (health-based) guidelines (µg/m^3)
$PM_{2.5}$	20 (current limit) 10 (new limit by 2040)	5
NO_2	40	10

Resources

[1] WHO: WHO Global Air Quality Guidelines. World Health Organization, 2021. Available at: https://www.who.int/publications/i/item/9789240034433

[2] DEFRA: Environmental Improvement Plan 2023. Department for Environment, Food and Rural Affairs, 2023. Available at: https://www.gov.uk/government/publications/environmental-improvement-plan

[3] DEFRA: National Air Quality Objectives. Department for Environment, Food and Rural Affairs, 2005. Accessed 31/01/2023. Available at: https://uk-air.defra.gov.uk/assets/documents/ Air_Quality_Objectives_Update.pdf

[4] DEFRA: Clean air zones. Department for Environment, Food and Rural Affairs, 2023. Accessed 31/01/2023. Available at: https://www.gov.uk/guidance/driving-in-a-clean-air-zone

Task 6.1: Reading Quiz 2

After reading the text, answer the questions below to check your understanding of the topics.

1) What are some strategies that cities in the UK are using to reduce air pollution?

Students should answer that some cities have introduced Clean Air Zones to reduce NO_2 pollution released by vehicles. But there are also public campaigns to encourage people to walk, cycle or use public transport instead of driving.

2) What are the legal limits for $PM_{2.5}$ and NO_2 in the air for England?

Students should report the current legal limits for annual mean concentrations of $PM_{2.5}$ (20 µg/m^3) and NO_2 (40 µg/m^3) in England. Students should also include the new legal limits for $PM_{2.5}$ annual mean concentrations (10 µg/m^3) to be achieved by 2040.

3) What is the WHO Global Air Quality guidelines, and why are they important?

Students should answer that World Health Organization (WHO) recommends air quality guideline levels to protect people health. The WHO global air quality guidelines are important because they are based on scientific evidence of the impact of air pollution on health.

Task 6.2: Personal pledges for clean air

Create a list of actions that you and your family can take to reduce air pollution. Refer to the extra three resources below for ideas and inspiration.

Students can brainstorm ideas for pledges and, as a class, create a board to keep track of pledges and progress towards reducing air pollution.

Extra Resources

[1] Global Action Plan: School actions for clean air. Global Action Plan, 2023. Accessed 31/01/2023. Available at: https://www.actionforcleanair.org.uk/schools

[2] Sustrans: 10 things you can do to help reduce air pollution today. Sustrans, 2023. Accessed 31/01/2023. Available at: https://www.sustrans.org.uk/our-blog/get-active/2020/in-your-community/10-things-you-can-do-to-help-reduce-air-pollution-today

[3] WHO: 10 ways you can fight air pollution. World Health Organization, 2023. Accessed 31/01/2023. Available at: https://www.who.int/news-room/spotlight/how-air-pollution-is-destroying-our-health/10-ways-you-can-fight-air-pollution

Lesson 7: Air pollution case study

Air pollution in Birmingham

Read the text and fill in the gaps with the appropriate words from the three options.

What is air quality like in Birmingham?

Air pollution is a major problem in big cities like Birmingham. The main air pollutants in Birmingham are nitrogen dioxide (NO_2) and _____ ($PM_{2.5}$). They come from various sources like cars, industries, and homes.

a) small particles less than 2.5 µm in diameter
b) particles larger than 2.5 µm in diameter
c) small particles less than 1 µm in diameter

$PM_{2.5}$ and NO_2 levels in Birmingham are higher than what the _____ (WHO) recommends for good air quality and to protect people's health.

a) World Health Organization
b) World Heart Organization
c) Water Help Organization

The average amount of $PM_{2.5}$ throughout the year (annual mean $PM_{2.5}$ concentrations) across Birmingham varies between 8 and 20 _____. Higher $PM_{2.5}$ pollution is found in the city centre compared to countryside areas (Figure 7.1).

a) milligram per cubic meter (µg/m^3)
b) microgram per cubic meter (mg/m^3)
c) microgram per cubic meter (µg/m^3)

Annual mean $PM_{2.5}$ levels in Birmingham are well above the 2021 WHO guidelines of _____. Most places exceed the new air quality target of 10 µg/m^3 set for England to achieve by 2040 (Table 6.1).

a) 15 µg/m^3
b) 5 µg/m^3
c) 100 µg/m^3

Annual mean NO_2 levels in Birmingham range from around 14 to 84 µg/m^3 (Figure 7.2). These concentrations are well above the 2021 WHO guidelines of _____. But only areas near major roads exceed the legal limit for England of 40 µg/m^3 (Table 6.1).

a) 40 µg/m^3
b) 5 µg/m^3
c) 10 µg/m^3

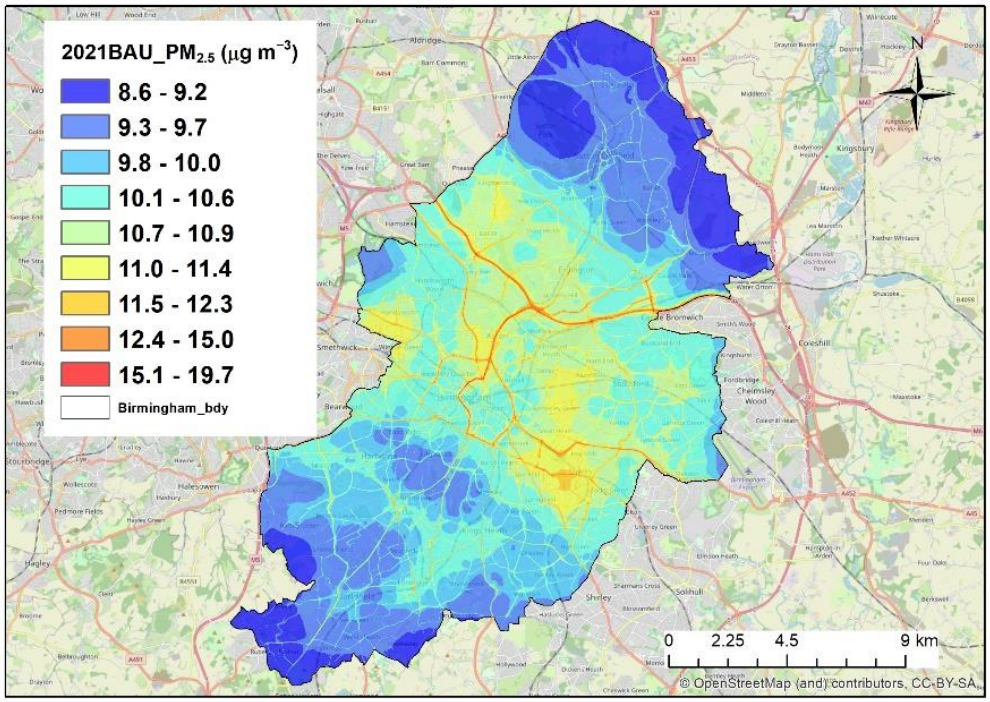


Figure 3.1: Annual mean concentration of $PM_{2.5}$ in Birmingham. Map and modelling undertaken by Dr Jian Zhong as part of the WM-Air Project, University of Birmingham.

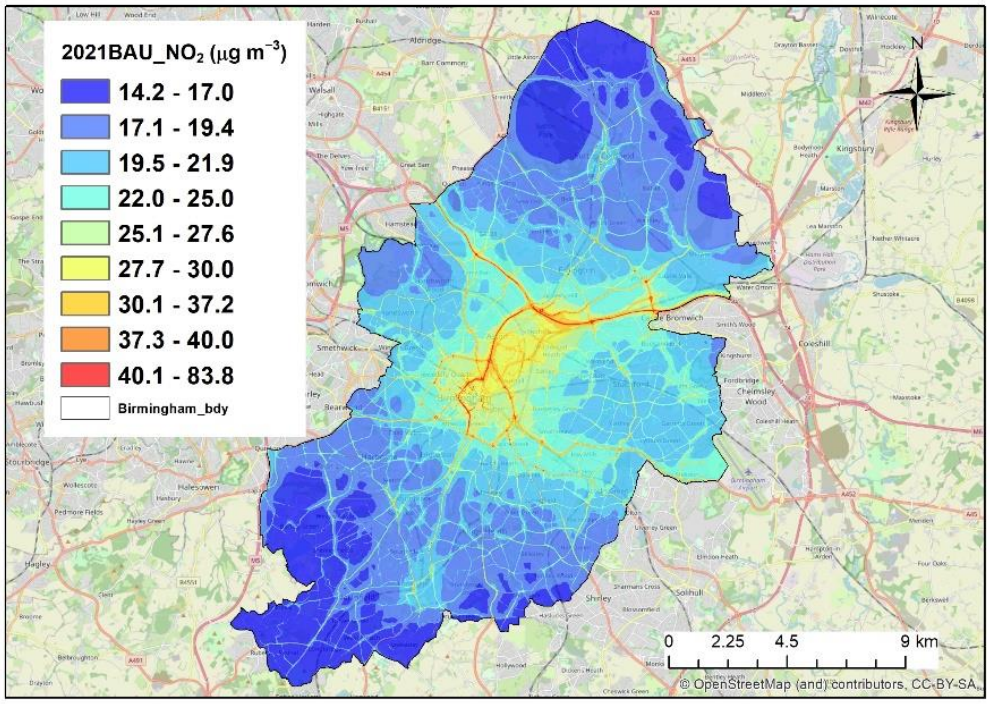


Figure 7.2: Annual mean concentration of NO_2 in Birmingham. Map and modelling undertaken by Dr Jian Zhong as part of the WM-Air Project, University of Birmingham.

What is Birmingham doing to reduce air pollution?

Birmingham Clean Air Zone: Birmingham City Council has introduced the **Clean Air Zone** in June 2021. This was done to reduce NO_2 concentrations to within legal limits by charging _____ that produce a high level of pollutants a fee (e.g. £8 daily for higher emission cars) to enter a specific zone around the city centre (see link below for more info).

a) bikes
b) vehicles
c) trains

This encourages the shift to cleaner vehicles and _____ (e.g. walking, cycling, public transportation).

a) industries
b) alternative modes of transport
c) heating system

Commonwealth Games Sustainability: During the **Commonwealth Games 2022** in Birmingham**,** the West Midlands Combined Authority agreed with the organisers to include bus, tram and train travel for ticket holders, and direct people towards green routes for walking and cycling short journeys. This is in an attempt to reduce the amount of _____ caused by the high volume of people using transport during the games (see link below for more info).

a) air pollution
b) noise pollution
c) water pollution

Organizations that work to combat air pollution in Birmingham: There are many organisations within Birmingham trying to combat air pollution. **WM-Air** (www.wm-air.org.uk**)** is a scheme led by the University of Birmingham which uses science to support the improvement of air quality in the area (see link below for more info). **Sustrans** (www.sustrans.org.uk) is a nationwide group who encourages sustainable travel and have worked on the citizen project **BrumBreathes (**www.brumbreathes.co.uk**)** to combat air pollution in the city and educate local people about actions they can take to achieve cleaner air.

Resources

[1] BCC: Birmingham Clean Air Zone. Birmingham City Council, 2023. Accessed 31/01/2023. Available at: https://www.birmingham.gov.uk/info/20076/pollution/1763/a_clean_air_zone_for_birmingham

[2] WMCA: Commonwealth Games and Travel. West Midlands Combined Authority, 2021. Accessed 31/01/2023. Available at: https://www.wmca.org.uk/news/local-public-transport-included-in-birmingham-2022-tickets-as-plans-for-greenest-ever-commonwealth-games-unveiled/

Task 7.1: Reading Quiz 3

After reading the case study of Birmingham and learning about air pollution, answer the following questions about air pollution in Birmingham.

1) Describe the main sources of air pollutants in Birmingham.

Students should explain that in Birmingham and other UK cities, air pollutants are released mainly from burning fossil fuels in vehicles, industries and homes.

2) Explain the health impacts of $PM_{2.5}$ and NO_2.

Students should explain that $PM_{2.5}$ can penetrate deep into the lungs and enter the bloodstream, causing health problems like hearth and lung diseases and even early death. Exposure to NO_2 pollution can cause health problems such as breathing difficulties, respiratory infections, and asthma.

3) Describe and contrast where the areas of high pollution are in Birmingham compared to area of low pollution

Students should explain that in Birmingham the area around the city centre and places near the main roads are the most polluted. Whereas the country areas have cleaner air.

4) Where do $PM_{2.5}$ levels exceed the WHO health guidelines? What about NO_2 levels?

Students should answer that $PM_{2.5}$ and NO_2 levels in Birmingham exceed WHO global health-based guidelines.

5) Evaluate the $PM_{2.5}$ and NO_2 concentrations in Birmingham against the UK legal limits. Are $PM_{2.5}$ and NO_2 levels within legal limits for England?

Students should explain that in Birmingham most locations exceed the 2040 air quality target of 10 $\mu g/m^3$ for annual mean $PM_{2.5}$ concentrations, while only areas close to major roads exceed the legal limit for England of 40 $\mu g/m^3$ for annual mean NO_2 concentrations.

Task 7.2: Air pollution level contour drawing exercise

Create a map to show how air pollution varies in Birmingham. Figure 7.3 shows the annual mean concentrations of NO_2 at different locations in Birmingham. Draw lines to connect points with the same annual mean concentrations in Figure 7.3. Colour the areas between the different contour lines using shades of red for more polluted areas and shades of blue for less polluted areas (you can use the legend below as a reference). Compare the final map with Figure 7.2. Are they similar?

Legend
Area between contour lines 14 and 18: blue
Area between contour lines 18 and 22: azure
Area between contour lines 22 and 26: orange
Area between contour lines 26 and 30: red

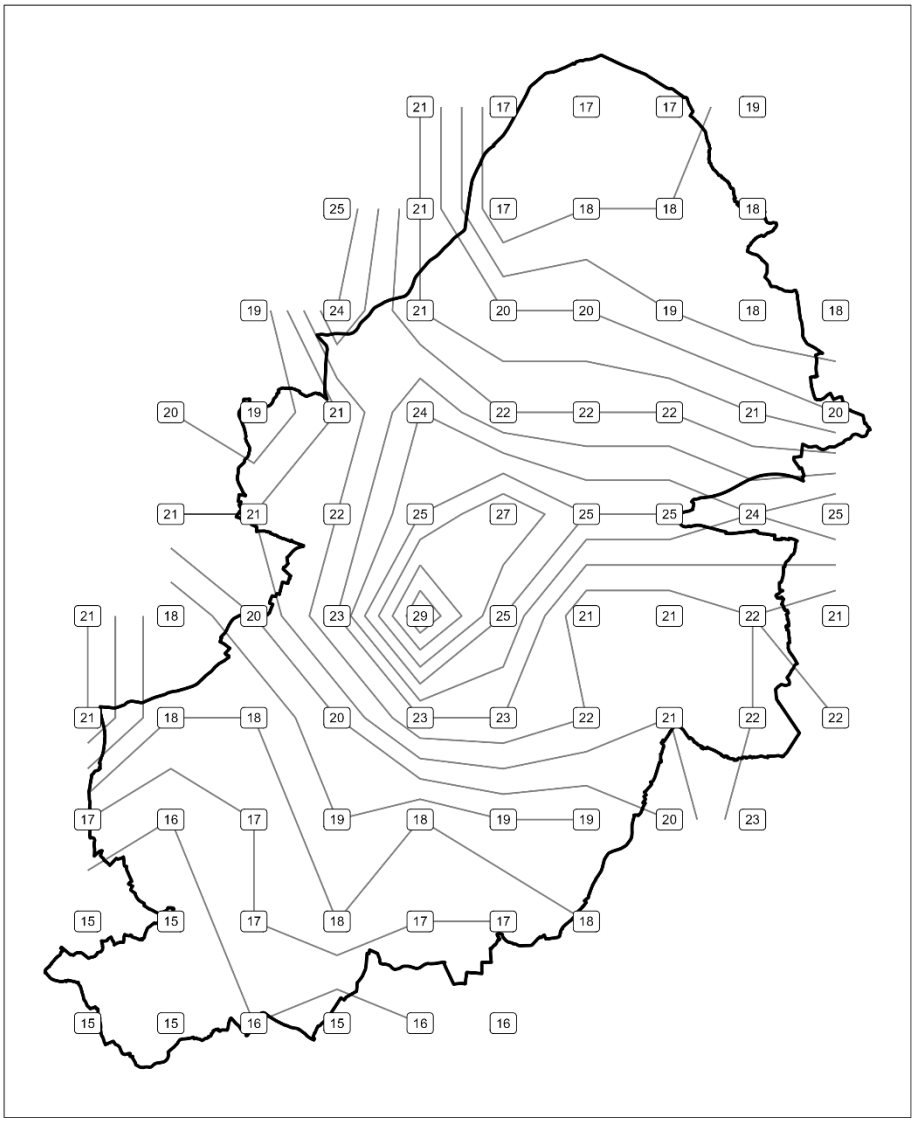


Figure 7.3: Air pollution level contour exercise. Annual mean concentration of NO_2 in Birmingham. Data are from WM-Air modelling.

Section 2: Collect data to understand air pollution

Lesson 8: Introducing data collection methods

Data can either be:

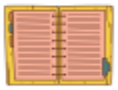
- **Human** - information about people and places (for example cities and tourism)
- **Physical** - information about natural landscapes (for example rivers and coasts)

Data can also be either:

- **Primary** - first hand information that is collected by yourself, e.g. tallies, measurements and photographs
- **Secondary** - information that someone else has previously collected and made accessible, e.g. on the internet

Finally, data will also either be:

- **Quantitative** - information that can be measured and recorded with numbers
- **Qualitative** - information that describes (uses words) but does not measure



Sampling Methods

1. **Random sampling** - choosing a site to measure or person to interview, at random. It is an unbiased methods as particular places or individuals are not specifically selected.
2. **Systematic sampling** - regulated methods of collecting data in an ordered way, for example, every 2 metres or every sixth person.
3. **Stratified sampling** - dividing sampling into groups, e.g. three sites from each region of the country, or six people from each age bracket. You can also combine random and systematic sampling with stratified sampling.
   - ***Stratified random sampling*** - random samples are taken from within specific categories.
   - ***Stratified systematic sampling*** - regular samples are taken from within specific categories.

Exercise 1: Traffic Count

The number of cars on the road increases pollution as cars release several air pollutants including $PM_{2.5}$ and NO_2 which humans can breathe in, causing harm to health. A traffic count is a method of data collection. You stand in one place and count the number of cars which pass you in a set amount of time. Repeating the experiment increases reliability of the results. You can then compare sites.

Can you identify what data and sampling techniques are used in Exercise 1? Please use the information in Lesson 8:

Student should answer as follow:

Type of data: Human, Primary, Quantitative

Type of sampling method: Random

Exercise 1 data collection form

Fill in the data collection form. This exercise can be done on the school ground. Find a spot near the school gate where you can safely stand and observe traffic.

SITE 1: **SITE 2:**

HYPOTHESIS:

DATA COLLECTION

SITE 1

Number of cars that pass a specific point in 5 mins	
1st Count:	
2nd Count:	
3rd Count:	

SITE 2

Number of cars that pass a specific point in 5 mins	
1st Count:	
2nd Count:	
3rd Count:	

How reliable is the data collection method?

Exercise 1 result form

Fill in the result form.

SITE 1: **SITE 2:**

BRIEF EXPLANATION OF METHOD:

CALCULATE THE AVERAGE FOR EACH SITE:

1st count + 2nd count + 3rd count = Answer Answer / 3 = Average

SITE 1 AVERAGE = SITE 2 AVERAGE =

Do your results prove or disprove your hypothesis?

Why do you think the traffic was higher in one site compared to the other?

What do you think were the limitations? What do you think you could have done better?

Exercise 2: Idling cars

Idling is when a driver leaves the engine running while the vehicle is parked. This means that pollution is still being emitted into the environment, reducing air quality. For this data collection method, you will count the number of idling cars present on a road (or section of road, make sure this is the same for both sites) over a certain period of time.

Can you identify what data and sampling techniques are used in Exercise 2? Please use the information in Section 3.

Student should answer as follow:

Type of data: Human, Primary, Quantitative

Type of sampling method: Systematic

Exercise 2 data collection form

Fill in the data collection form. This exercise can be done on the school ground. Find a spot near the school gate where you can safely stand and observe idling cars.

SITE 1: **SITE 2:**

HYPOTHESIS:

DATA COLLECTION

SITE 1

Number of idling cars present	
no. of cars at site at arrival	
1min	
2 min	
3 min	
4 min	
5 min	
6 min	
7 min	
8 min	
9 min	
10 min	

SITE 2

Number of idling cars present	
no. of cars at site at arrival	
1min	
2 min	
3 min	
4 min	
5 min	
6 min	
7 min	
8 min	
9 min	
10 min	

How reliable is the data collection method?

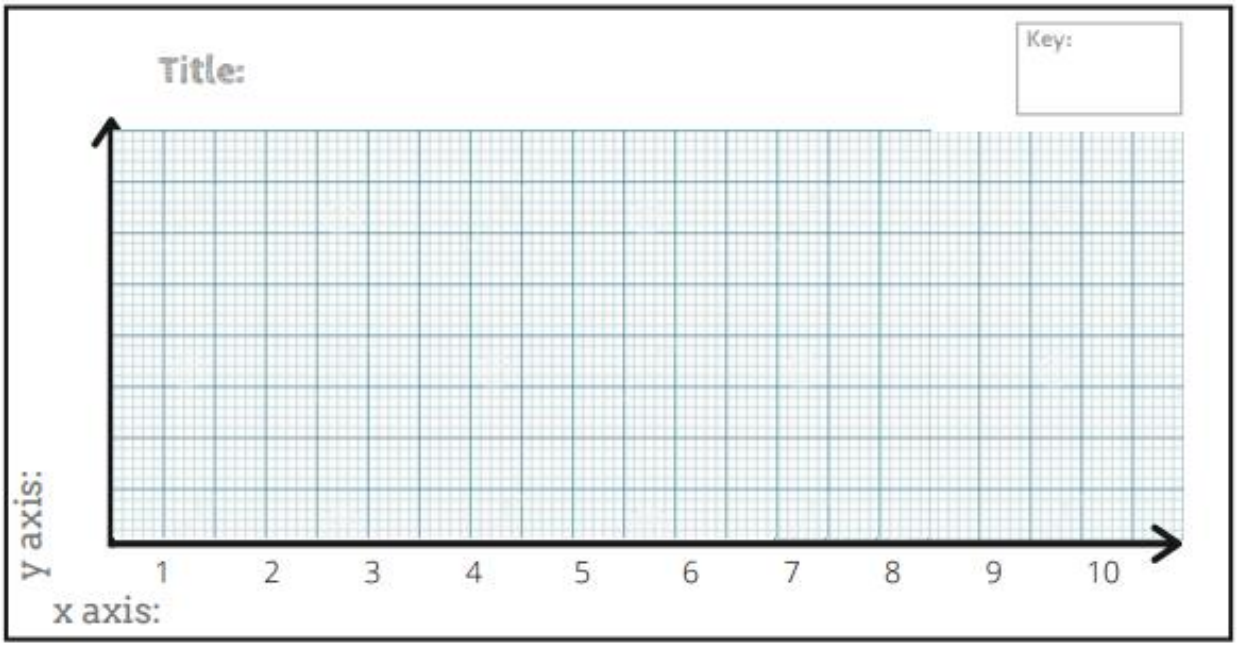
Exercise 2 result form

SITE 1: **SITE 2:**

BRIEF EXPLANATION OF METHOD:

CALCULATE THE AVERAGE FOR EACH SITE:

SITE 1 AVERAGE = **SITE 2 AVERAGE =**



Do your results prove or disprove your hypothesis?

If there was a difference between the two sites, why do you think this is?

If the idling cars changed overtime, why do you think this occurred?

What do you think were the limitations? What do you think you could have done differently?

Exercise 3: Visual indicators

Air pollution can be affected by the type of vehicles on the road (e.g. busses are very polluting, and bikes do not cause the release of much pollution at all), as well as the type of buildings around the area (tall buildings trap more air pollution). Finally, the types of pavements are important, as wider pavements allow for people to walk further away from the road and breathe in less pollution particles.

Can you identify what data and sampling techniques are used in Exercise 3? Please use the information in Lesson 8:

Student should answer as follow:

Type of data: Human, Primary, Quantitative (part 1) and Qualitative (part 2)

Type of sampling method: Stratified random sampling

Exercise 3 data collection form

Fill in the data collection form. This exercise can be done on the school ground. Find a spot near the school gate where you can safely stand and observe.

TYPE OF VEHICLES (SITE 1)

Number of vehicles you see on your set stretch of road in 10 minutes	
Lorry	
Van	
Bus	
Car	
Bike	

TYPE OF VEHICLES (SITE 2)

Number of vehicles you see on your set stretch of road in 10 minutes	
Lorry	
Van	
Bus	
Car	
Bike	

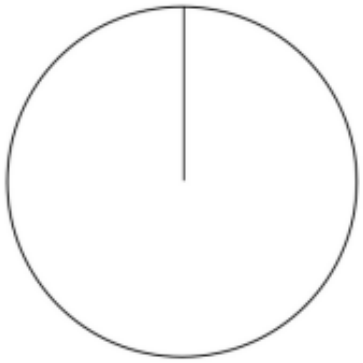
		SITE 1							SITE 2						
Height of buildings 1 or 2 story = small, > 20 story = tall	*Small*	**1**	**2**	**3**	**4**	**5**	*Tall*		*Small*	**1**	**2**	**3**	**4**	**5**	*Tall*
Space between buildings <1m = small, >20m = large	*Small*	**1**	**2**	**3**	**4**	**5**	*Large*		*Small*	**1**	**2**	**3**	**4**	**5**	*Large*
Width of pavement <1m = narrow, >5m = wide	*Narrow*	**1**	**2**	**3**	**4**	**5**	*Wide*		*Narrow*	**1**	**2**	**3**	**4**	**5**	*Wide*
Number of trees	*Scarce*	**1**	**2**	**3**	**4**	**5**	*Many*		*Scarce*	**1**	**2**	**3**	**4**	**5**	*Many*
Amount of green space	*Little*	**1**	**2**	**3**	**4**	**5**	*A lot*		*Little*	**1**	**2**	**3**	**4**	**5**	*A lot*

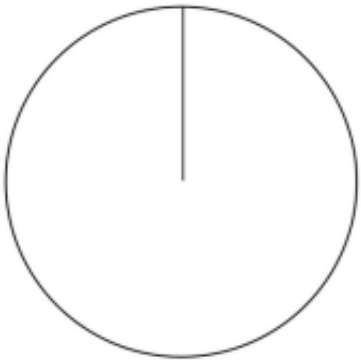
Exercise 3 result form

SITE 1: **SITE 2:**

BRIEF EXPLANATION OF METHODS:

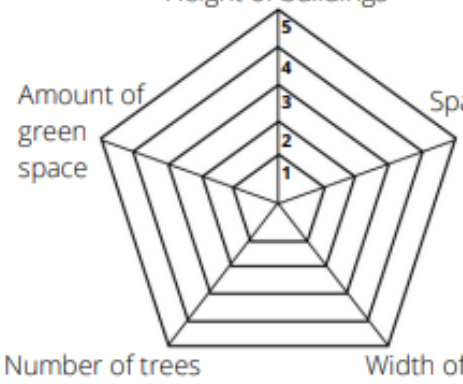
PIE CHART
Types of vehicle





RADAR CHART
Survey results

Add both site 1 and site 2 to the same radar graph for easy comparison (use a different colour)



Do your results prove or disprove your hypothesis?

If there was a difference between the two sites, why do you think this is?

If the idling cars changed overtime, why do you think this occurred?

What do you think were the limitations? What do you think you could have done better?

Exercise 4: Secondary data

Table E4.1 report annual mean concentrations of NO_2 in the UK from 1997 to 2021 at roadside monitoring sites, urban background sites, and rural background sites.

These data are published by the Department for Environment Food and Rural Affairs (DEFRA) and can be accessed from: https://www.gov.uk/government/statistical-data-sets/env02-air-quality-statistics.

The description of site environment types by DEFRA can be found at: https://uk-air.defra.gov.uk/networks/site-types

Table E4.1: Annual mean concentrations of NO_2 in the UK from 1997 to 2021 at roadside monitoring sites, urban background sites, and rural background sites by DEFRA.

Year	Annual Mean NO_2 concentration ($\mu g\ m^{-3}$)		
	Roadside sites	Urban background sites	Rural background sites
1997	60	46	18
1998	59	41	14
1999	62	40	16
2000	57	36	14
2001	54	36	15
2002	49	33	13
2003	55	35	15
2004	52	32	11
2005	54	32	10
2006	54	32	10
2007	53	28	10
2008	50	28	9
2009	46	29	9
2010	46	31	9
2011	41	27	9
2012	41	27	10
2013	39	25	9
2014	38	25	8
2015	36	23	7
2016	38	23	9
2017	34	22	8
2018	33	20	7
2019	31	20	7
2020	23	15	5
2021	25	16	6

Write a brief statement about the importance of secondary data:

Secondary data are important because they are ready-made information that can save time and resources and provide useful knowledge in various fields. However, it is also important to ensure that data sources are reliable and trustworthy.

Present the data from Table E4.1 in suitable charts. Make sure the data is visually clear and present the most important information. You can use methods that you have used earlier in the project.

Use this space to show your results:

Section 3: Final Report

This report brings together all the work you have done across the project. You will need to use the research you have done as well as primary data you have collected and come up with a logical discussion and a clear conclusion.

Fill in the data collection form. The report should be completed within 3 weeks.

LITERATURE REVIEW:
(Provide background information about air pollution using resources available to you and find information related to your area and your results)

AIMS AND OBJECTIVES:
(Purpose of the project)

METHODOLOGY:
(Description of the methods you have used in the project that you wish to include in your report (this could be all of them))

RESULTS:

(Neatly redraw/sketch/print your most important results (data presentation, e.g graphs and charts) from your project with a brief description beneath.

DISCUSSION OF RESULTS:

(What do your results show? Why do you think they show this? How do they relate back to the literature?)

LIMITATIONS:
(What limitations are there? What could have been done better/differently?)

CONCLUSIONS:
(This can be done in bullet points, be very clear and specific)