Air Quality

What is the issue and why is it important for Norfolk?

Air pollution is a local, regional, and international problem caused by the emission of pollutants, which either directly or through chemical reactions in the atmosphere lead to negative impacts on human health and ecosystems. Poor air quality is the largest environmental risk to public health in the UK. In 2016, costs to UK society were estimated at more than 20 billion pounds every year[1], this would equate to over 270 million pounds for Norfolk. The government has stated aims to meet legally binding targets to reduce emissions of five damaging air pollutants, this should halve the effects of air pollution on health by 2030.[2]

Air quality is managed through a complex array of policies, guidance, and regulation that apply at different levels. They address the problem bottom-up through limiting emissions sector by sector, and top-down through setting national targets for ambient air quality and a maximum ceiling on national emissions. In Norfolk statutory duties for controlling air pollution fall on Borough, City and District Councils together with County Council Trading Standards. As the Chief Medical Officer makes clear in his 2022 Annual Report, no single sector or organisation can deliver clean air in isolation; instead, controls must work across the spectrum of sources[3].

Executive Summary

Poor air quality is the largest environmental risk to public health in the UK and the costs to society are estimated at more than 20 billion pounds every year. Vulnerable groups, including children, pregnant women, people with pre-existing conditions, older people and deprived communities are more adversely affected.

In Norfolk 4.9% of deaths are attributable to particulate matter ranging from 4.5% in North Norfolk to 5.5% in Norwich. The proportion of deaths in the county attributable to particulate matter may be more substantial than those caused by preventable respiratory disease, preventable liver disease or suicide. It is estimated that in Norfolk fine particulate matter ($PM_{2.5}$) and Nitrogen Dioxide (NO_2) could be causing over 2,000 new cases of non-infectious diseases including chronic heart disease, stroke, asthma, lung cancer and bronchitis.

In the most recent ten-year period of emissions estimates, there has been mixed progress in reducing emissions of air pollutants in the UK. Levels of sulphur dioxide (SO_2) and oxides of nitrogen (NO_x) have continued to decline but decreases in emissions of particulate matter from many sources have been partially offset by increases in emissions from domestic combustion. A concern in Norfolk where a significant proportion of homes are off the gas grid, especially in rural areas.

In Norfolk, NO_2 concentrations are clearly associated with the main urban areas and the network of A roads which connect the towns and city of the county. Concentrations of Particulate Matter (PM_{10}) are associated with urban areas with high emissions particularly in Norwich and Great Yarmouth. Concentrations of $PM_{2.5}$ are associated with King's Lynn, Norwich, and Great Yarmouth. However, areas of Broadland, and Swaffham and Thetford in Breckland also show rates above the rest of the county. Concentrations of SO_2 are associated with Norwich and Great Yarmouth, although there are also higher rates in King's Lynn, some rural areas and along the North Norfolk coastline. Concentrations of ammonia (NH_3) are associated with rural areas where agricultural activity is greater.

Types of Pollution

The principal types of pollution monitored in the UK and targeted in the Clean Air Strategy are-

Particulate Matter (PM)

Defined as particulate matter of 10µm diameter or less (PM_{10}) and particulate matter of 2.5µm or less ($PM_{2.5}$). $PM_{2.5}$ can enter the blood stream through the lungs and is then transported around the body to become embedded in organs. Sources can be emitted directly (Primary PM) such as domestic smoke or vehicle break dust or formed due to complex chemical reactions in the atmosphere (secondary PM).

Nitrogen Oxides (NO_x)

Consisting of Nitrogen Oxide (NO) and Nitrogen Dioxide (NO_2). NO_x exacerbates symptoms of lung and heart conditions. Short term exposure to high concentrations can cause inflammation. NO_x can react with other pollutants to produce ground level Ozone (O_3) which can cause inflammation of eyes, nose and the respiratory tract and also impact biodiversity. NO_x can also affect biodiversity in sensitive habitats.

Ammonia (NH_3)

NH_3 reacts in the atmosphere to produce particulate matter. In addition, NH_3 can acidify habitats and lead to excessive nitrogen in soils which reduces biodiversity.

Non-methane volatile organic compounds (NMVOCs)

NMVOCs react with other pollutants to form particulate matter and ground level ozone.

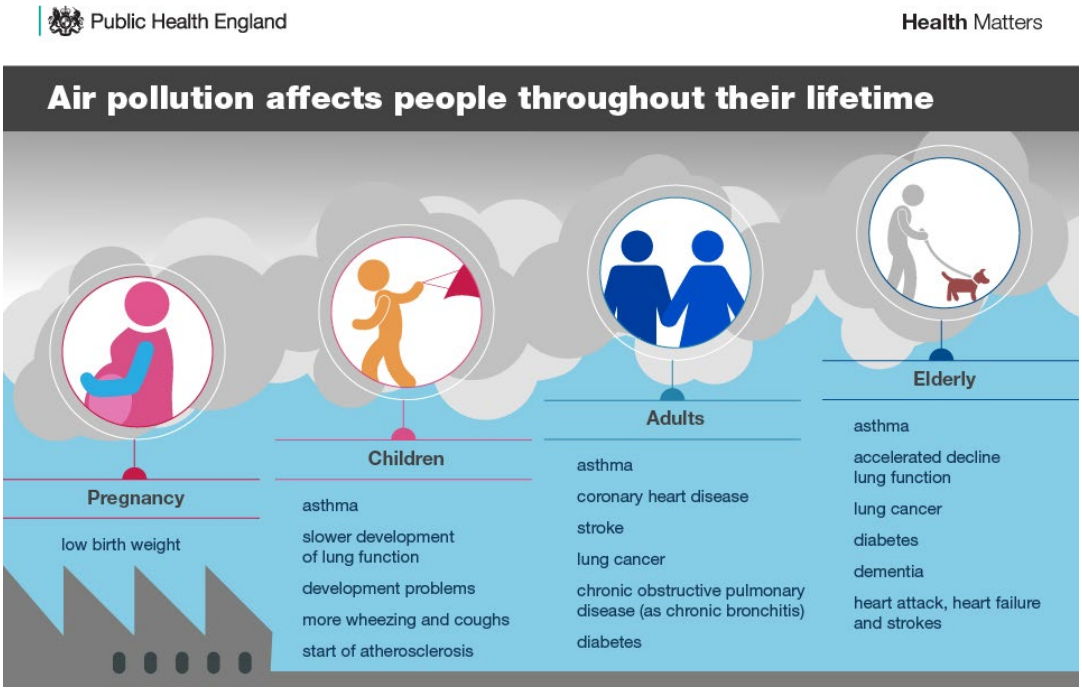
Sulphur dioxide (SO_2)

SO_2 can irritate airways and people with asthma are particularly sensitive. It also contributes to the formation of acid rain which affects biodiversity.

Impacts of air pollution on health

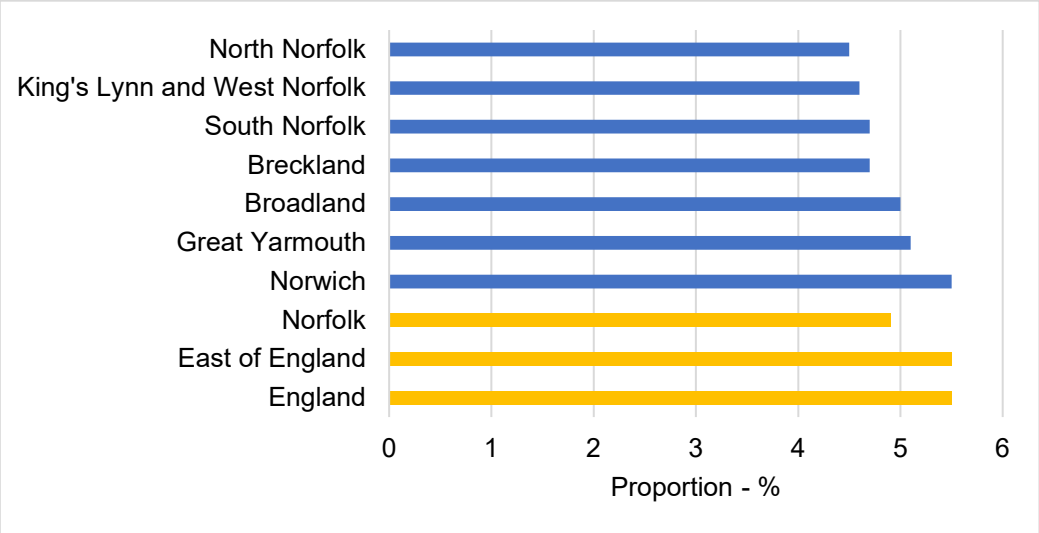
More recent research is recognising that the systemic effects of pollutants extend beyond the cardiopulmonary system to affect many other organs, increasing the risk of disease that begins from conception and persists across the life course[1] from pregnancy through childhood and adolescence to adulthood[4]. This is illustrated in Figure 1

Figure 1 Air pollution affects: - source Public Health 2018[5]



Epidemiological studies have shown that long term exposure to air pollution (over several years) reduces life expectancy, mainly due to cardiovascular disease, respiratory causes, and lung cancer. New estimates suggest that the burden of long-term exposure to air pollution in 2019 in England was an effect equivalent to 26,000 to 38,000 deaths for adults aged 30 and over[6]. Short-term exposure (over hours or days) to elevated levels of air pollution can also cause a range of effects including exacerbation of asthma, effects on lung function, increases in respiratory and cardiovascular hospital admissions and mortality. In Norfolk 4.9% of deaths are attributable* to particulate air pollution[7], this is less than the proportion in England of 5.5%. However, Norwich is also 5.5% whilst North Norfolk is lower at 4.5% see Figure 2.

Figure 2 **Fraction of mortality attributable* to particulate air pollution (new method) 2021**



Source Public health profiles - OHID (phe.org.uk)

To put this into context, using a methodology described in 'Air Quality a Briefing for Directors of Public Health'[8], mortality due to particulate matter can be ranked against other preventable diseases (Table 1). For all Norfolk districts particulate mortality is third behind preventable cancer and preventable cardiovascular disease but can be attributed to more deaths than preventable liver disease, preventable respiratory disease, or suicide.

Table 1 **Ranking of Public Health Outcome Framework Mortality Indicators for Norfolk**
Directly Age Standardised Mortality Rate per 100, 000 population.

Public Health Outcomes framework indicator	Norfolk	Breckland	Broadland	Great Yarmouth	Kings Lynn & West Norfolk	North Norfolk	Norwich	South Norfolk
Preventable Mortality <75	131.9	115.7	101.6	190.8	144.4	113.2	197.9	91.9
Preventable Cancer <75	50.4	47.2	35.4	74.7	56.7	46.6	66.9	37.9
Preventable CVD<75	24.7	22.5	18.5	40.2	22.5	20.9	39.5	17.0
Mortality attributable to PM*	**18.1**	**15.9**	**15.1**	**23.7**	**18.3**	**16.1**	**26.8**	**14.0**
Preventable Respiratory Disease <75	13.7	10.7	10.7	20.4	18.0	6.4	23.7	10.2
Preventable Liver Disease <75	13.5	15.3	11.2	21.5	13.3	13.4	17.0	no data
Suicide Rate	10.6	10.7	8.1	10.9	11.6	14.2	12.9	7.0

*Long term exposure to anthropogenic particulate air pollution is estimated to have an effect on mortality risks equivalent to the number of attributable deaths. Air pollution is likely to contribute a small amount to the deaths of a larger number of exposed individuals rather than being solely responsible for the number of deaths equivalent to the calculated figure of attributable deaths[9].

Public Health England (PHE) developed a tool[10] to model the number of cases in England caused by two principal pollutants $PM_{2.5}$ and NO_2. From that data estimates can be made of the number of new cases caused each year in Norfolk (Table 2) which indicates potentially over 2,000 new cases of various non-infectious diseases each year.

Table 2 **Estimated number of new cases each year caused by air pollution in Norfolk**.

Pollutant	Chronic Heart Disease	Stroke	Asthma	Lung Cancer	Chronic Bronchitis	Diabetes	Low Birth Weight	Dementia	Total
$PM_{2.5}$	**270**	**74**	**93**	**28**	**195**	242	158	n/d	1060
NO_2	n/d	n/d	**307**	37	n/d	499	93	84	1020
Total	270	74	400	65	195	741	251	84	2080

Figures in bold represent more robust evidence linking pollutant to disease

Chronic Pulmonary Obstructive Disorder (COPD) can be linked to air pollution and certainly poor air quality may exacerbated COPD triggering the need for a hospital admission[11]. Emergency hospital admission rates for COPD in Norfolk at ward level range 469.1 for Gaywood Clock ward in Kings Lynn to 19.4 for Taverham North in Broadland.

Children and pregnant women

Children are particularly susceptible to the health effects of air pollution, as their lungs and other organs are still developing, and they inhale more air per body weight than adults[12]. A modelling study reported that, in 2017, around one-third of schools in England, representing around 3.4 million pupils, were located in areas with $PM_{2.5}$ levels exceeding the guideline of 10 µg/m3 set by the World Health Organization in 2005[13]. Schools in areas with high $PM_{2.5}$ tended to be more ethnically diverse and claimed more free school meals.

There is growing evidence worldwide that the health of pregnant women and their babies could be affected by air pollution[14]. In the UK, the Avon Longitudinal Study of Parents and Children found links between prenatal, early-life and childhood exposure to particulate matter from road traffic and reductions in lung function during childhood[15].

Deprivation

Areas of high deprivation frequently have higher levels of traffic or industrial activities and these more heavily polluted areas may be more affordable to live in[16]. People in lower socio-economic groups are more likely to have pre-existing health conditions earlier in life, and the higher exposures to air pollution may add to the greater burden of poor health.[17] Studies of hospital admissions and mortality show increased health risks associated with exposure to air pollution among those living in areas of higher socio-economic deprivation.[18]

Proximity to air pollution sources

Factors that influence people's exposures to air pollution include: the proximity to traffic or to industrial sites; whether the location is urban or rural; and indoor air pollution, which can be affected by the building quality. Traffic-related particulate air pollution has been shown to be higher in more deprived areas. On the contrary, ozone concentrations generally decrease as socio-economic deprivation increases[19]. Commuters from low-income areas rely more on public transport, which can have high pollution exposure (depending on the type of public transport). Evidence suggests that pollutant exposure is particularly high in public transport hubs[20].

Urban areas tend to have high population exposure to outdoor air pollution, due to high population density. However, people in rural areas may also be exposed to harmful air pollution – for example, exposure to indoor air pollution when homes are not connected to the gas grid and are reliant on solid fuel burning to heat the home.

One study[21] found that young adults who lived in highly polluted areas were more likely to suffer from long COVID compared to those living in areas with low levels of pollution.

Major sources of pollution[22]

Particulate Matter ($PM_{2.5}$)

Domestic wood & coal burning	38%	
Industrial combustion	16%	
Road transport	12%	
Industrial processes	13%	

Nitrogen Oxides (NO_x)

Road transport	34%	(near roadsides 80%)
Energy generation	22%	
Domestic and industrial combustion	19%	
Other transport	17%	

Ammonia (NH_3)

Agriculture	88%

Non-methane volatile organic compounds (NMVOCs)

Industrial processes	22%
Household products	18%
Agriculture	14%

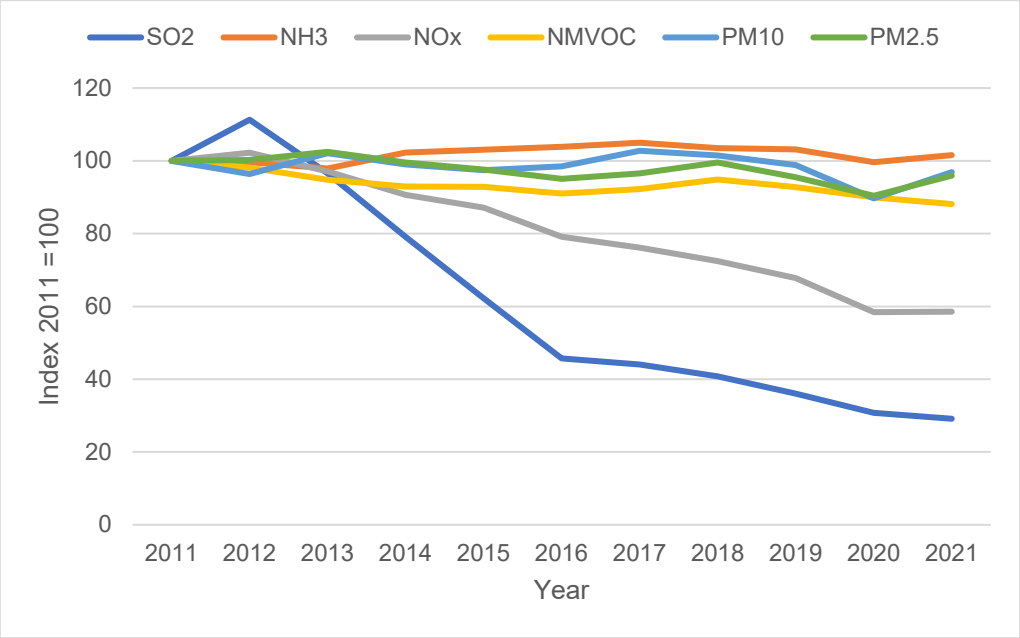
Sulphur dioxide (SO_2)

Energy generation	37%
Industrial combustion	22%
Domestic burning	22%

Trends in air quality

In the most recent ten-year period of emissions estimates, there has been mixed progress in reducing emissions of air pollutants, see Figure 3.

Figure 3 **Trends in the emission of pollutants in the UK since 2011**



Source Emissions of air pollutants in the UK - Summary - GOV.UK (www.gov.uk)

For SO_2 and NO_x, emissions have continued to fall in line with the long-term trend with much of the reduction because of the decreasing dependence on coal for energy generation (emissions of SO_2 and NO_x from energy industries has fallen by 87 and 60 per cent respectively between 2011 and 2021).

Emissions of NO_x and NMVOC from road transport also decreased by 51 per cent and 66 per cent respectively between 2011 and 2021. This is largely because of tighter emissions standards being introduced for petrol and diesel cars.

For PM, decreases in emissions from many sources have been partially offset by increases in emissions from domestic combustion (emissions of $PM_{2.5}$ from this source increased by 50 per cent between 2011 and 2021). This reflects the increasing popularity of solid fuel appliances in the home such as wood-burning stoves. Industrial combustion of biomass also represents a growing source in recent years.

Total annual emissions of NMVOC have decreased by 12 per cent since 2011, however the sources of these emissions are changing. Emissions from the food and beverages industry have risen by 30 per cent, and there has been a 11 per cent increase in emissions from domestic combustion. Emissions from fugitive sources (that is unintentional releases) have decreased by 43 per cent, and there has been a decrease of 40 per cent from coating applications.

Annual emissions of NH_3 increased by 2 per cent between 2011 and 2021.

Air Quality Targets

The National Air Quality Objectives and Air Quality Standards Regulations limit and target values with which the UK must comply are summarised in the National Air Quality Objectives[23]. New Targets for $PM_{2.5}$ were set in May 2023[24]. Current limits relevant to the main pollutants are shown in Table 3.

Table 3 **National Air Quality Objectives and Target Values**

Pollutant	Applies	Objective	Concentration measured as	To be achieved by
PM_{10}	UK	50 µg/m3 not to be exceeded more than 35 times a year	24 hour mean	31/12/2004
		40 µg/m3	Annual mean	31/12/2004
$PM_{2.5}$	UK (except Scotland)	10 µg/m3	Annual mean	31/12/2040
Exposure Reduction	UK Urban areas	Target of 35% reduction in Exposure compared to 2018	Annual mean	31/12/2040
NO_2	UK	200 µg/m3 not to be exceeded more than 18 times a year	1 hour mean	31/12/05
		40 µg/m3	Annual mean	31/12/05
Ozone	UK	100 µg/m3 not to be exceeded more than 10 times a year	8 hour mean	31/12/05
SO_2	UK	266 µg/m3 not to be exceeded more than 35 times a year	15 minute mean	31/12/05
		350 µg/m3 not to be exceeded more than 24 times a year	1 hour mean	31/12/04
		125 µg/m3 not to be exceeded more than 3 times a yea	24 hour mean	31/12/04

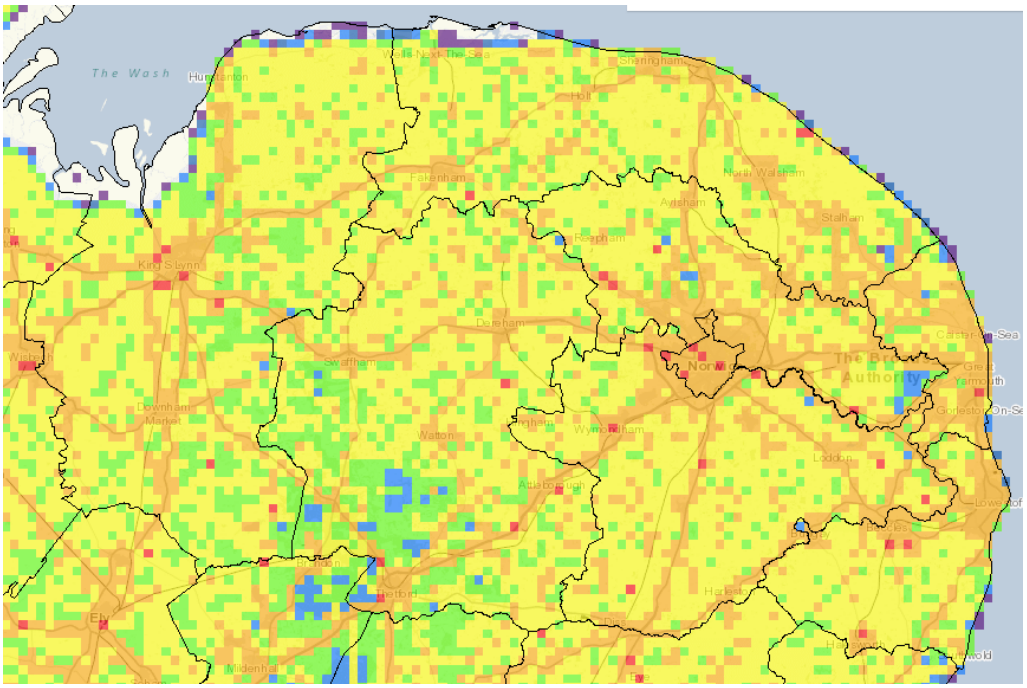
Emissions of pollutants in Norfolk

District Councils are required to monitor and report levels of PM_{10} and NO_2. Real time data of the Air Quality Index is published from monitoring stations at Envista - Air Resources Manager (norfolkairquality.net)

Nationally air pollution is forecast at Pollution forecast - Defra, UK

The National Atmospheric Emissions Inventory (NAEI)[25] compiles estimates of emissions to the atmosphere from UK sources such as cars, trucks, power stations and industrial plant. These emissions are estimated to help find ways of reducing the impact of human activities on the environment and our health. The NAEI is made up of the Greenhouse Gas Inventory (GHGI) and the Air Quality Pollutant Inventory (AQPI). Emissions of pollutants are given in the form of maps on a 1x1 km resolution. One set of maps is produced each year for the most recent NAEI year.

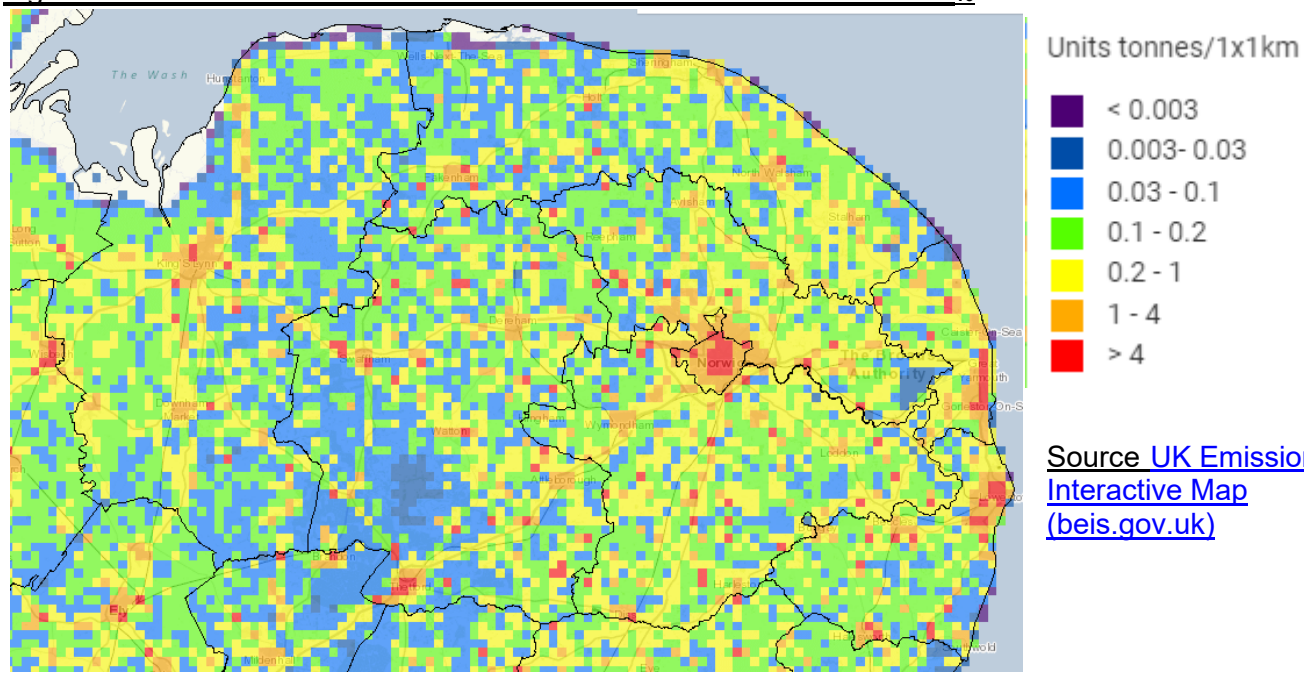
Figure 4 **Total Emissions from all sectors of Nitrogen Oxides as NO_2**



Source UK Emissions Interactive Map (beis.gov.uk)

NO_2 concentrations are clearly associated with the main urban areas, particularly King's Lynn, Norwich and Great Yarmouth and the network of A roads which connect the towns and city of the county.

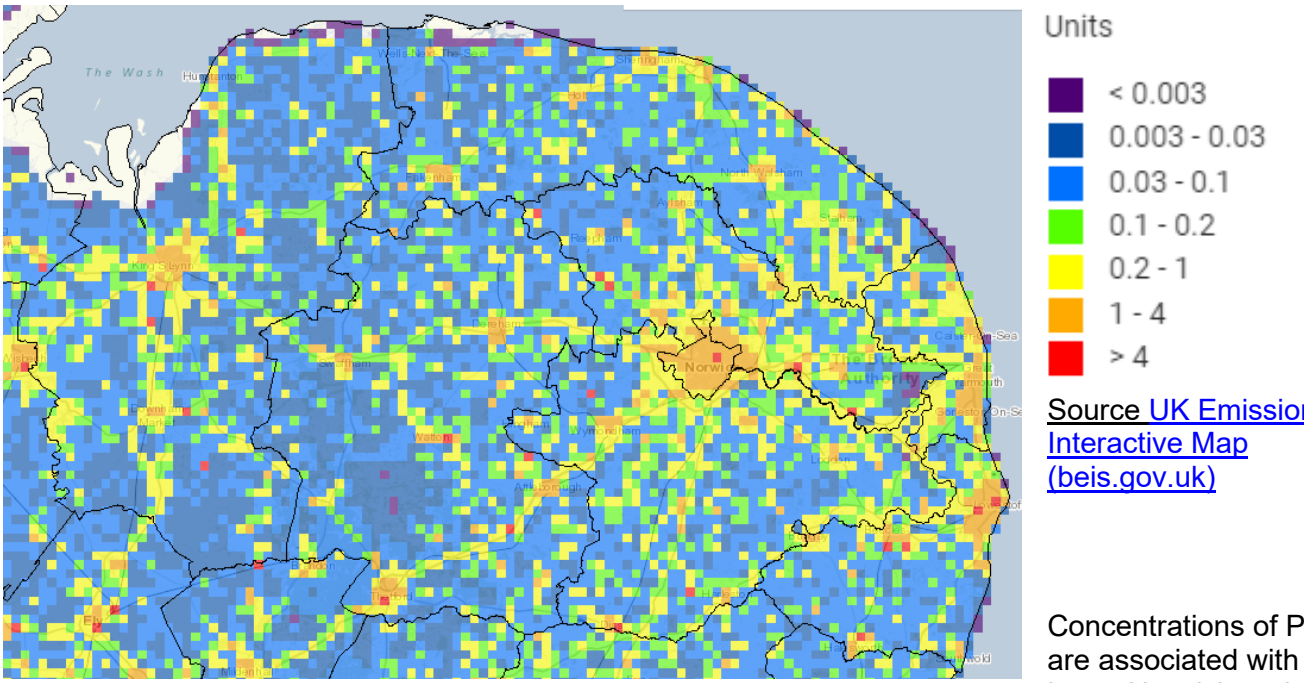
Figure 5 **Total Emissions from all sectors of Particulate Matter as PM_{10}**



Source UK Emissions Interactive Map (beis.gov.uk)

Concentrations of PM_{10} are associated with urban areas with high emissions particularly in Norwich and Great Yarmouth, the latter possibly associated with shipping activity at the Port of Great Yarmouth. In the year to March 2021 the port handled over 6,000 commercial shipping movements[26].

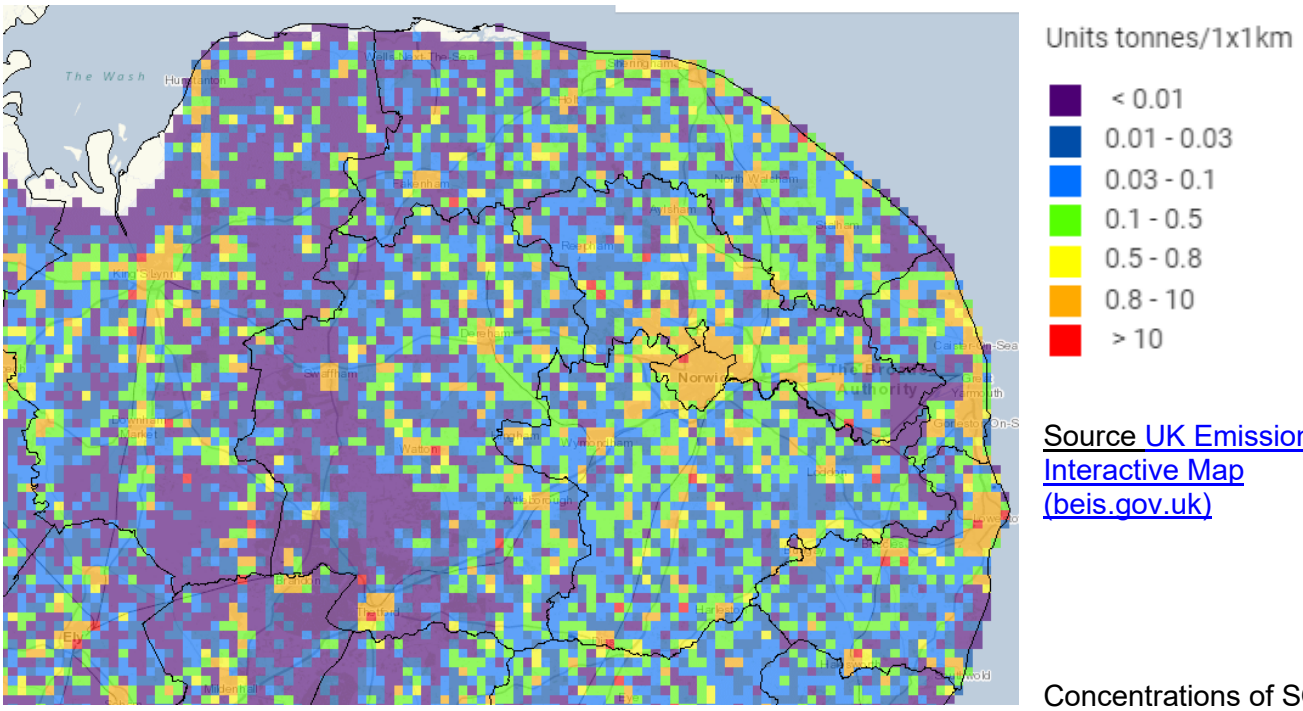
Figure 6 **Total Emissions from all sectors of Particulate Matter as $PM_{2.5}$**



Source UK Emissions Interactive Map (beis.gov.uk)

Concentrations of $PM_{2.5}$ are associated with King's Lynn, Norwich and Great Yarmouth. However areas of Broadland, and Swaffham and Thetford in Breckland also show rates above the rest of the county.

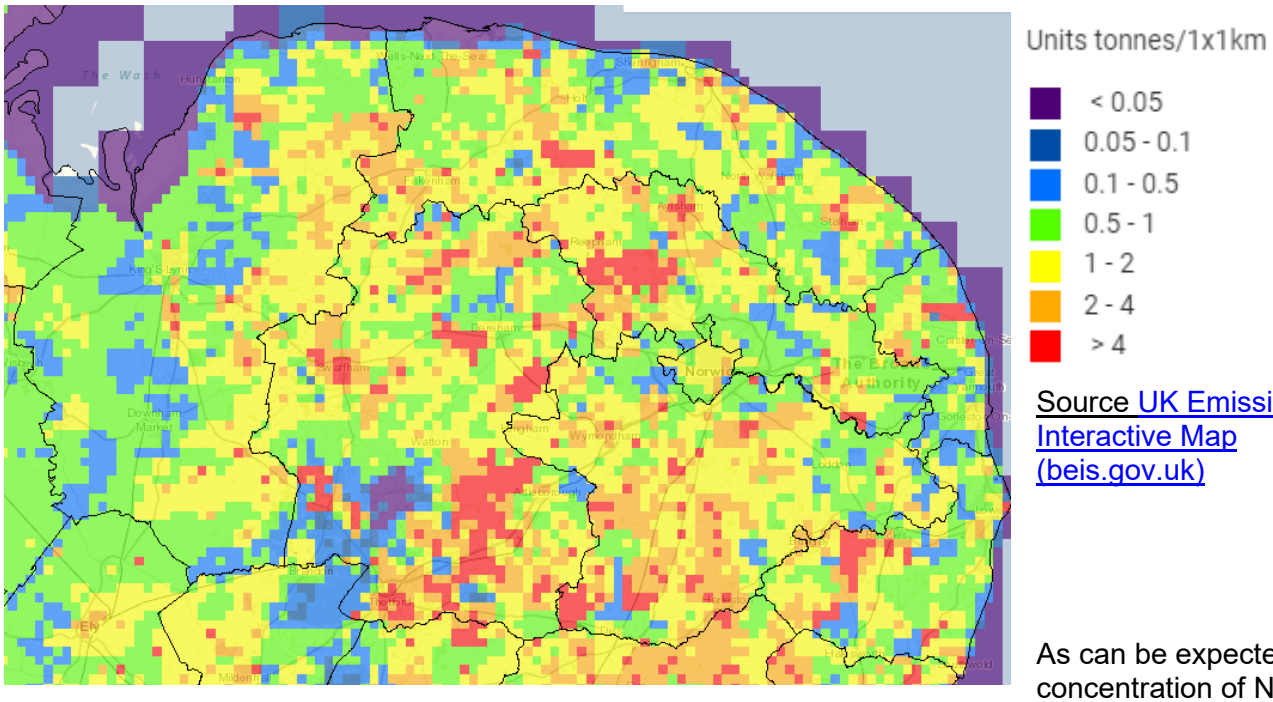
Figure 7 **Total Emissions from all sectors of Sulphur Dioxide as SO_2**



Source UK Emissions Interactive Map (beis.gov.uk)

Concentrations of SO_2 are associated with Norwich and Great Yarmouth. Although there are also higher rates in King's Lynn, some rural areas and along the North Norfolk coastline.

Figure 8 **Total Emissions from all sectors of Ammonia as NH_3**



Source UK Emissions Interactive Map (beis.gov.uk)

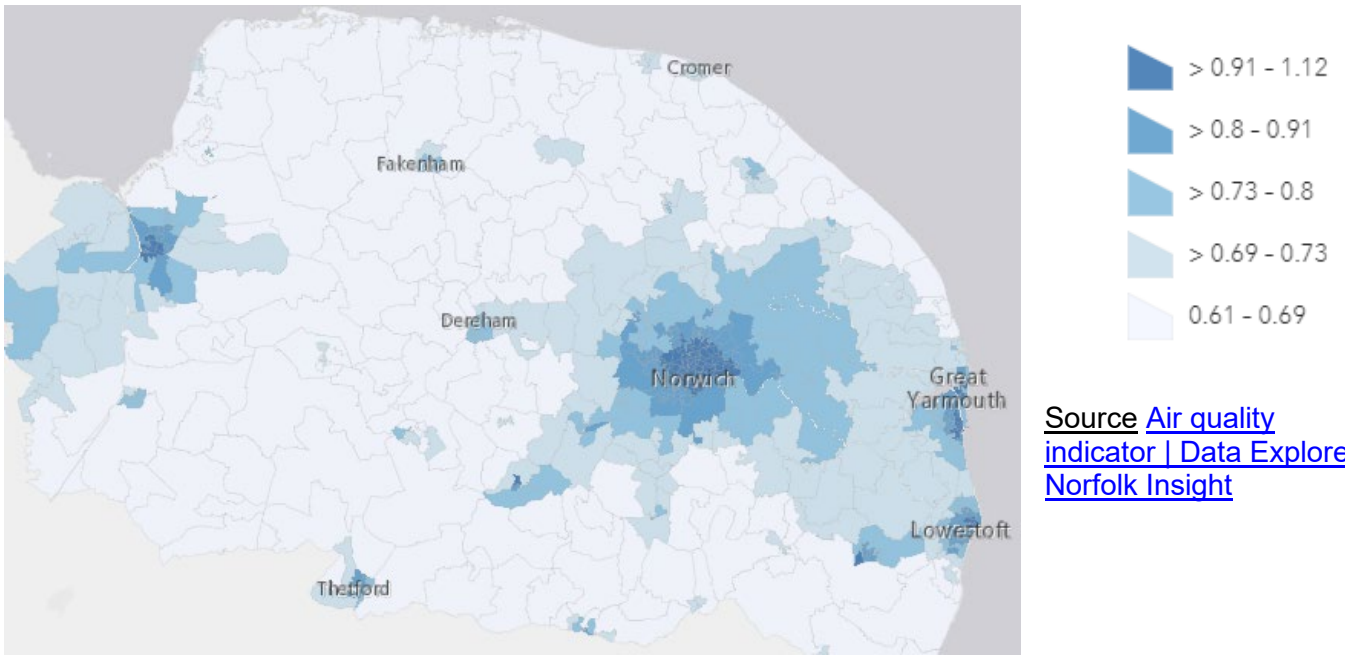
As can be expected concentration of NH_3 are associated with rural areas where agricultural activity is greater. Higher level areas are associated with Broadland and Breckland

Air Quality is an underlying indicator for the Living Environment Deprivation Domain and is based on data from the UK Air Information Resource.[27] [28] using the estimated concentration of four air pollutants (nitrogen

dioxide, benzene, sulphur dioxide and particulates). A higher value (or darker colour) indicates a higher level of deprivation.

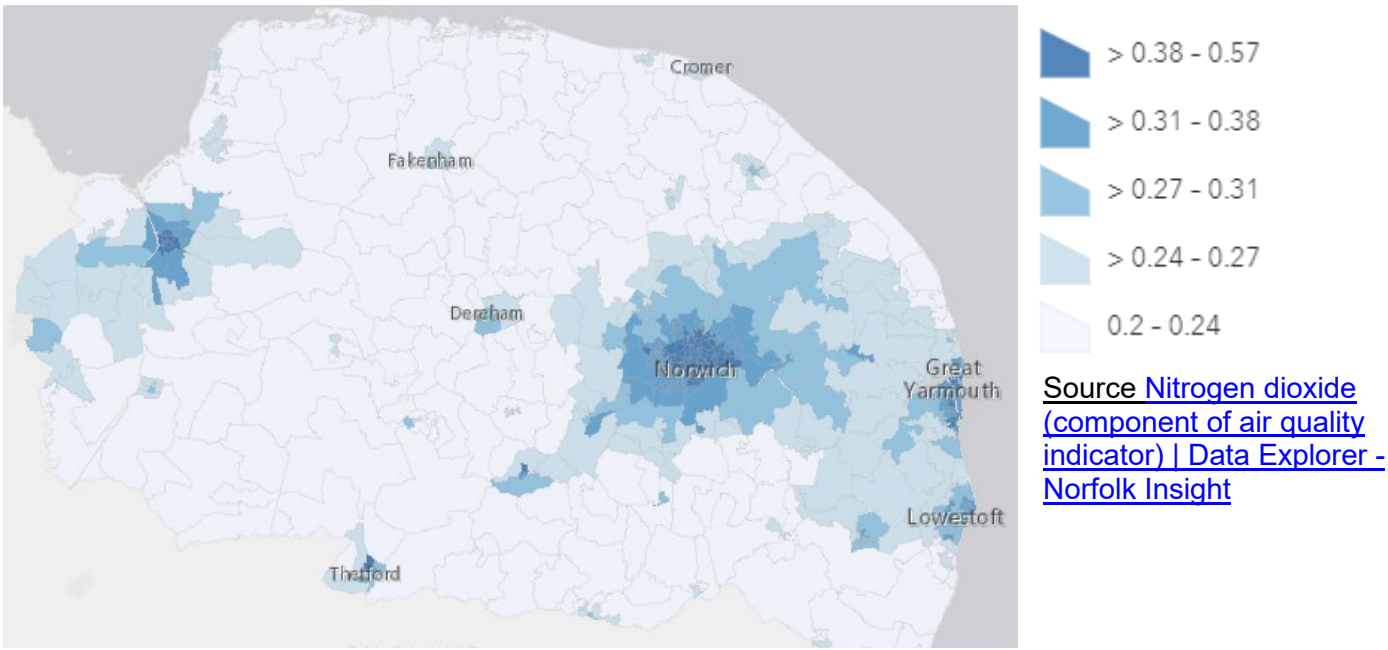
Modelling data for Air Quality for Norfolk at the Lower Super Output Area (LSOA) is shown if figure 9. Similar data for NO_2 and PM is shown in figures 10 and 11 respectively.

Figure 9 **Air Quality Indicator for LSOA in Norfolk (2016)**



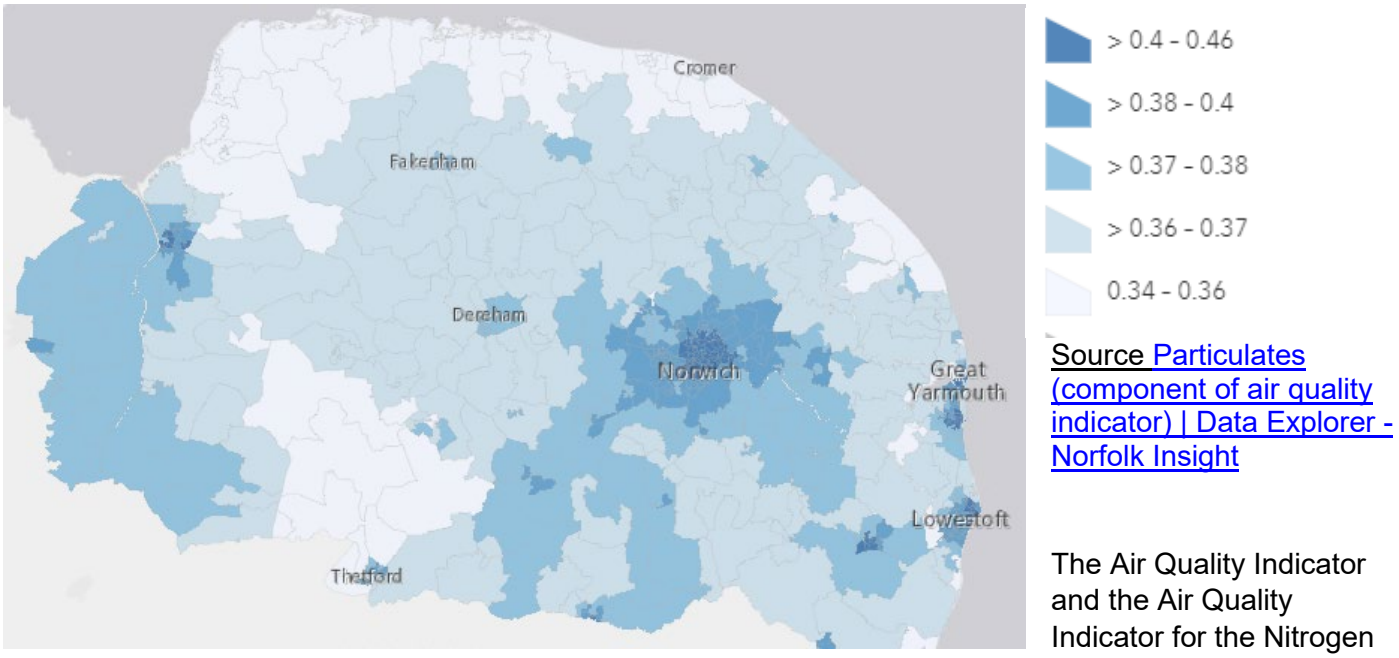
Source Air quality indicator | Data Explorer - Norfolk Insight

figure 10 **Air Quality Indicator for LSOA in Norfolk Nitrogen Component (2016)**



Source Nitrogen dioxide (component of air quality indicator) | Data Explorer - Norfolk Insight

Figure 11 **Air Quality Indicator for LSOA in Norfolk Particulate Component (2016)**



Source Particulates (component of air quality indicator) | Data Explorer - Norfolk Insight

The Air Quality Indicator and the Air Quality Indicator for the Nitrogen Component are clearly associated with areas of deprivation found in urban centres and suburban areas particularly Kings Lynn, Norwich and Great Yarmouth and also to some extent the smaller towns of Thetford, Dereham and Fakenham.

However the map for the particulate component shows a more diffuse pattern with larger areas of West Norfolk, Breckland, South Norfolk and Broadland and evens parts of North Norfolk showing some degree of being affected.

National plans and strategies

The Clean Air Strategy 2019 published by DEFRA[17] outlines the governments intentions and ambitions for improving air quality in the following sectors: transport, in homes, farming and from industry.

An updated National Air Pollution Control Programme was published in draft[29] for consultation in July 2022. This sets out commitments for reductions in SO_2, NO_2, NMVOC, NH_3 and PM $_{2.5}$ and outlines current policy and potential future policies under consideration for; domestic combustion and solid fuels, agriculture, industry, road transport, and 'net zero' for decarbonising all sectors of the UK economy by 2050.

In July 2017 Defra published a UK plan for tackling roadside nitrogen dioxide concentrations[30] which sets out measures already undertaken and also made the following commitments to help local authorities by

- Setting up a £255m Implementation Fund, available to support local authorities to prepare their plans and deliver targeted action to improve air quality.
- Establishing a Clean Air Fund, which will allow local authorities to bid for additional money to support the implementation of measures to improve air quality.

In May 2023 the Government published an Air Quality Strategy[31] for local authorities and other partners. It sets out their powers, responsibilities, and further actions the government expects them to take and enables local authorities to deliver for their communities and contribute to long-term air quality goals, including ambitious new targets for $PM_{2.5}$.

Local plans and Air Quality Management Plans

DEFRA publish Local Air Quality Management Policy Guidance (PG22).[32] The guidance is statutory and all relevant Local Authorities (both district and county level), the Environment Agency and all designated relevant public authorities must have regard to it. Local authorities are required to submit an Annual Status Report (ASR) each year and are expected to report on NO_2, PM_{10} and SO_2 as standard.

If a local authority finds any places where the objectives are not likely to be achieved, it must declare an Air Quality Management Area (AQMA) there. This area could be just one or two streets, or it could be much bigger.[33] The local authority will put together a plan to improve the air quality - a Local Air Quality Action Plan (AQAP).

Currently there are four active plans in Norfolk, one in Breckland (Swaffham), two in Kings Lynn and one in Norwich, all for NO_2.

Those authorities who have not had to designate AQMAs will from 2023 be required to draw up a local Air Quality Strategy. These strategies will not have a set format and authorities will be able to draw on content within their ASRs and local transport plans to produce them.

Conclusions

Air pollution remains a significant risk to the health of the population of Norfolk. Particulate matter is estimated to make a small contribution to the deaths of a large number of people at an equivalence larger than deaths due to preventable respiratory or liver diseases. Fine particulate matter and nitrogen dioxide could be contributing to the onset of over 2,000 new cases of chronic disease in the county each year. There is emerging evidence that air pollution has effects beyond the cardiovascular system and may exacerbate disease such as diabetes and dementia. The leading causes of death in 2020 in Norfolk were Heart Disease, Dementia and Alzheimer's, COVID-19, Stroke and Lung Cancer[34], therefore actions to improve air quality have the potential for major benefits to health of residents.

Pregnant women, children, the elderly and people with pre-existing health conditions are at increased risk from air pollution as are deprived communities and those living or working close to sources of pollution.

In the most recent ten year period, there has been mixed progress in reducing emissions of air pollutants. Levels of SO_2 and NO_x have continued to decline but decreases in emissions of particulate matter from many sources have been partially offset by increases in emissions from domestic combustion. A factor which will be of concern in Norfolk where a significant proportion of homes are off the gas grid, especially in rural areas.

However, currently there are only four active air quality action plans in operation across the county, all for NO_2 and all associated with urban traffic issues.

Glossary

Air Quality Action Plan (AQAP).
A plan produced by a Borough City or District Council with support from the County Council to improve air quality within an AQMA.

Air Quality Management Area (AQMA)
An area where a council finds national air quality standards are not being achieved.

Ammonia (NH_3)
NH_3 reacts in the atmosphere to produce particulate matter. In addition NH_3 can acidify habitats and lead to excessive nitrogen in soils which reduces biodiversity

Annual Status Report (ASR)
A report prepared each year by Borough City and District Councils on the local air quality for DEFRA report on NO_2, PM_{10} and SO_2 as standard.

Chronic Obstructive Pulmonary Disorder (COPD)
Is the name given to a progressive disease that affects the lungs and makes it increasingly more difficult to breathe. The condition includes chronic bronchitis - long-term inflammation of the airways and emphysema - damage to the air sacks.

Fraction of mortality attributable to particulate air pollution
Long term exposure to anthropogenic particulate air pollution is estimated to have an effect on mortality risks equivalent to the number of attributable deaths. Air pollution is likely to contribute a small amount to the deaths of a larger number of exposed individuals rather than being solely responsible for the number of deaths equivalent to the calculated figure of attributable deaths.

Nitrogen Oxides (NO_x)
Consisting of Nitrogen Oxide (NO) and Nitrogen Dioxide (NO_2). NO_x can react with other pollutants to produce ground level Ozone (O_3) which can cause inflammation of eyes, nose and the respiratory tract and also impact biodiversity. NO_x can also affect biodiversity in sensitive habitats.

Non-methane volatile organic compounds (NMVOCs)
NMVOCs react with other pollutants to form particulate matter and ground level ozone.

Particulate Matter (PM)
Defined as particulate matter of 10µm diameter or less (PM_{10}) and particulate matter of 2.5µm or less ($PM_{2.5}$). Sources can be emitted directly (Primary PM) such as domestic smoke or vehicle break dust or formed due to complex chemical reactions in the atmosphere (secondary PM).

Public Health England (PHE)
Was an executive agency of the Department of Health and Social Care, providing government, local government, the NHS and the public with delivery expertise and support. It was replaced by UK Health Security Agency (UKHSA) and the Office for Health Improvement and Disparities (OHID) on 1 October 2021.

Sulphur dioxide (SO_2)
SO_2 can irritate airways and people with asthma are particularly sensitive.

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