Institution: University of Birmingham

Unit of Assessment: 7 – Earth Systems and Environmental Sciences

Title of case study: Science-based policy for cleaner air

Period when the underpinning research was undertaken: 2000 - present

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Professor R.M. Harrison	Professor	1991–present
Professor F. Pope	Professor	2012–present
Dr X. Cai	Senior Lecturer	1995–present
Professor A.R. MacKenzie	Professor	2011–present

Period when the claimed impact occurred: January 2014 – December 2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

Air pollution is globally the largest environmental cause of disease and premature deaths, and our research has **shaped the global policy debate around air quality, leading to changes in legislation, guidelines and practices**. In the UK, our research **has underpinned new regulations** on wood burning, the emission of ammonia from farming and the control of particulate emissions from road vehicles. Our work also underpins the latest **practitioner guidance** which notably has reduced pollutant exposure on the railway network. Overall, our impacts have led to improved air quality and consequent **impacts on the health and wellbeing of the population**.

2. Underpinning research

Air pollution is a major threat to public health and, according to WHO, leads to 4.5 million premature deaths worldwide annually, more than malaria and HIV-AIDS combined. There exists a substantial body of research on air pollution from the University of Birmingham (UoB) which spans the last 20 years. The research extends from sources of pollution through atmospheric processes to personal exposure and effects upon health. Much of the work can be viewed as pioneering with individuals recognised for contributions to the discipline, which has subsequently impacted upon international policy and practice (Harrison: OBE for services to environmental science, 2004; Royal Meteorological Society Fitzroy Prize, 2012; RSC Environment Prize, 2015; FRS, 2017).

Although the research extends across a range of pollutants, our work on nitrogen dioxide and particulate matter is broad and has been particularly highly influential. The key contributions within the body of work are as follows:

KF1: We have provided better quantitative knowledge of the significant detrimental impact on human health of particulate matter, sulphur dioxide and nitrogen dioxide through collaborative

studies of the health effects of air pollutant exposures, including both population-based epidemiology, human challenge studies and health burden estimation [e.g. R1, R2].

KF2: Sources of particulate matter are numerous. Harrison has led UK research on non-exhaust emissions from road traffic, generating the only currently available quantitative information on brake wear, tyre wear and road dust resuspension particles in the UK atmosphere, which demonstrated the important contribution of this source and which now exceeds exhaust emissions, to urban pollution [R3]. Importantly, low carbon heating options (e.g. biomass burning) can result in significant increases in airborne particulate matter. The first data on wood smoke concentrations in UK urban areas were generated by the group, which highlighted its significance as a growing urban problem [R4].

KF3: Ammonia plays a major role in the formation of airborne $PM_{2.5}$. The group were leaders in detailed field studies of the contribution of semi-volatile ammonium salts to the concentrations of airborne $PM_{2.5}$. As a result, numerical modelling studies, funded by and reported to DEFRA, have demonstrated the importance of ammonia emissions abatement in reducing $PM_{2.5}$ concentrations in the UK atmosphere [R5].

KF4: Air quality issues and consequent exposures can also be significant in enclosed environments such as railway stations. Cai collaborated in a study of nitrogen dioxide pollution at New Street station Birmingham, which was the first to highlight the significant 'indoor' air quality problem that existed due to a combination of poor ventilation and diesel trains, although particulate matter from electric trains can also play a significant role [R6].

3. References to the research

R1. Anderson, H.R., Bremner, S.A., Atkinson, R.W., Harrison, R.M., Walters, S., 2001. Particulate matter and daily mortality and hospital admissions in the West Midlands conurbation of the United Kingdom: Associations with fine and coarse particles, black smoke and sulphate, *Occupational and Environmental Medicine,* 58, 504–510.

R2. COMEAP, 2018. Associations of long-term average concentrations of nitrogen dioxide with mortality, Committee on the Medical Effects of Air Pollution, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734799/COMEAP_NO2_Report.pdf

R3. Harrison, R.M., Jones, A., Gietl, J., Yin, J., Green, D., 2012. Estimation of the contribution of brake dust, tire wear and resuspension to nonexhaust traffic particles derived from atmospheric measurements, *Environmental Science & Technology*, 46, 6523–6529.

R4. Harrison, R.M., Beddows, D.C.S., Hu, L., Yin, J., 2012. Comparison of methods for evaluation of wood smoke and estimation of UK ambient concentrations, *Atmospheric Chemistry and Physics*, 12, 8271–8283.

R5. Harrison, R.M., Jones, A.M., Beddows, D. and Derwent, R.G., 2013. The effect of varying primary emissions on the concentrations of inorganic aerosols predicted by the enhanced UK photochemical trajectory model, *Atmospheric Environment*, 69, 211–218.

R6. Thornes, J.E., Hickman, A., Baker, C, Cai, X., Delgado-Saborit, J.M., 2017. Air quality in enclosed railway stations, *Proceedings of the Institution of Civil Engineers - Transport*, 170, 99–107.

4. Details of the impact

Air quality policy decisions have been informed by research evidence

We have shaped UK and international policy debate around air quality, leading to changes in legislation, guidelines and practice. In the UK, our **research recommendations are frequently taken up by policy makers as a result of Harrison's contribution as a member to key government advisory committees**. Specifically, Harrison has been a member of DEFRA's Air Quality Expert Group (AQEG) since 2002 and a member of the Department of Health and Social Care Committee on the Medical Effects of Air Pollutants (COMEAP) since 1996 (with a short break between 2003–2006). He also chaired COMEAP's Quantification Working Group on Nitrogen Dioxide (2015–2018).

Recent contributions to policy development and implementation can be seen in the 2019 government policy paper, UK Clean Air Strategy [EV1]. This includes a number of examples where policy change has derived directly from our research:

1. The development of **new standards for tyres and brakes to address toxic non-exhaust particulate emissions**. The inclusion of this measure in the Clean Air Strategy directly followed an AQEG report [EV2]. This report drew heavily upon our research [KF1 and KF2: 14 UoB citations in the report] which **highlighted an issue of concern to parliamentarians and contributed a new analysis of existing issues**, in particular the fact that non-exhaust sources of particles now exceed exhaust emissions of particles.
2. The introduction of **a ban on burning wet wood and domestic coal**, along with associated new powers for local authorities, was announced by DEFRA in February 2020, with staged implementation starting in February 2021. Concern about such emissions was an issue highlighted by AQEG [EV3]. This consideration drew directly on UoB measurements and associated data interpretation [KF1 and KF2: four UoB citations in the report] which established the large contribution of woodsmoke to $PM_{2.5}$ concentrations (38%) in the UK atmosphere.
3. The introduction of **new regulations to reduce ammonia emissions from farming**. The government has made legally binding commitments to reduce ammonia emissions from 2005 levels by 8% by 2020 and 16% by 2030 to reduce the negative impacts of ammonia emissions on human health and biodiversity in sensitive habitats. The associated AQEG report [EV4] used numerical modelling from UoB to explain how ammonia, emitted mainly by agriculture, contributes to the formation of airborne particles, which are deleterious to public health [KF3].

The Head of Evidence for Air Quality and Industrial Emissions at DEFRA testified:

> The reports of AQEG provide the evidence base for many of the actions set out in our Clean Air Strategy published in 2019. […] Specific contributions from Professor Harrison, which have been very important, include the only UK measurements of brake and tyre wear particles in the UK atmosphere, the first measurements of wood smoke particles at urban and rural locations, and modelling of the production of secondary particles from ammonia emissions. His measurements and interpretation of ultrafine particle concentrations in the UK atmosphere are also a major component of the AQEG report on this topic, which informs the current policy position on this pollutant. [EV5]

UoB contributions to COMEAP have been similarly impactful. For example, the implementation of Clean Air Zones (CAZ) in UK cities represents **a decisive action in the management of the health risk of nitrogen dioxide**. The policy was underpinned by evidence presented to government by COMEAP [R2; EV6]. Their report highlighted the health and mortality burden of

nitrogen dioxide exposures and cited five University of Birmingham papers to evidence this harm [KF1]. The same COMEAP Working Group report also influenced **government policy on development planning**. Air quality damage costs prescribed by DEFRA for application in the evaluation of planning applications were modified in 2019 as a direct response to new coefficients recommended by COMEAP [EV5 and EV6]. The Head of Evidence for Air Quality and Industrial Emissions at DEFRA testified:

> the work on nitrogen dioxide by the sub-committee which [Harrison] chaired has strengthened the evidence position on this pollutant by providing updated exposure response functions which has led to a revision of the damage functions used to evaluate development proposals and confirmed the need for the policy on Clean Air Zones. [EV5]

Policy guideline targets for air quality have been influenced

Policy change in the air quality space has long-term implications. For example, the guideline values recommended in the 2005 WHO Air Quality Guidelines [EV7] **continue to make significant impact today, underpinning changes to air quality legislation across the world**. Our contribution to these 2005 guidelines includes the citation of five research papers and a chapter on particulate matter and sulphur dioxide published since 2000 [KF1]. A WHO regional advisor (now retired) testified:

> Roy Harrison […] contributed to both sets of guidelines and authored background material. […] Research papers led by, or contributed to, by University of Birmingham authors related to the health effects of particulate matter, sulphur dioxide, PAH and benzene are included. The research cited in the Air Quality guidelines is key to underpinning the recommended guideline levels. […] The 2005 recommendations have remained highly influential in shaping air quality policy in the European Union as well as many countries and cities across the world right to the present day. [EV8]

As such, this body of work still has significant impact in this REF period, where the influence of these guidelines and targets can clearly be identified in the latest policy documents. For example:

1. The Clean Air Strategy of 2019 states that "by implementing the policies in this strategy, we will reduce $PM_{2.5}$ concentrations across the UK, so that the number of people living in locations above the WHO Guideline level of 10 µg m-3 is reduced by 50% by 2025." [EV1];

2. The London Environment Strategy, May 2018, states that "the Mayor has set new emission limits for full compliance with WHO for $PM_{2.5}$ to be achieved by 2030" [EV9];

3. Article 1 of the 2016 revision of the National Emissions Ceilings Directive - 2016/2284/EC states that, "[the guidelines provide] progress towards the [European] Union's long-term objective of achieving levels of air quality in line with the air quality guidelines published by the World Health Organisation" [EV10].

Practices have changed to improve air quality

A range of **practitioners have used our research findings in conducting their work**. A notable example is provided by our work at Birmingham New Street station [KF4], also featured in a Channel 4 Dispatches programme, which has seen Network Rail **change methods and practices** to improve air quality at Birmingham New Street station. Changes include a £1M

upgrade to the ventilation system to replace CO_2 sensors with NO_2 sensors, enhance the fan system, reduce train idling times and introduced occupational health screening. Subsequently, the Office of Rail and Road has **updated the professional guidance** document for its inspectors regarding health risks associated with Diesel Engine Exhaust Emissions at railway stations and the action to take in securing compliance with air quality legislation [EV11].

We have actively **translated our research findings into guidance for practitioners**. One example is our *First Steps in Urban Air Quality* publication which is now available in two languages. It has underpinned a programme of investment from HS2 to improve air quality at its new interchange station on the outskirts of Birmingham and featured as **best practice** in the 2020 Public Health England review *Improving Access to Greenspace* and the 2019 *West Midlands Combined Authority regional air quality review and action plan*. We have also co-authored European-level best practice guides. For example, *Measures to Improve Air Quality, AIRUSE (2017)* documents a state-of-the-art compilation of measures to improve air quality in cities and is available in five languages. The website hosting the report has received an average of 4,000 visitors per month over the last three years. In another example, our body of work on airborne particulate matter [KF2], via the European Commission contributed to *European Guide on Air Pollution Source Apportionment with Receptor Models* which is a best practice guide to harmonise procedures across member states [EV12].

Overall, our research has led to widespread **impacts on the health and wellbeing of the population, who have directly benefitted as a result of improved air quality**. The latest estimate by COMEAP of premature deaths in the UK arising from exposure to nitrogen dioxide and fine particles is between 28,000 and 36,000. Reductions in fine particle concentrations following directly from the proposals in the Clean Air Strategy 2019 will reduce that toll by up to 25%. Air quality is slowly improving across Europe, largely as a result of the tightening limits imposed by the National Emissions Ceiling Directive. Despite this, the EU estimates a total of 456,000 premature deaths attributable to air pollution across the EU-28 in 2016.

5. Sources to corroborate the impact

EV1: Department of Environment, Food & Rural Affairs, Clean Air Strategy 2019.
EV2: Air Quality Expert Group, Non-Exhaust Emissions from Road Traffic
EV3: Air Quality Expert Group, The Potential Air Quality Impacts from Biomass Production
EV4: Air Quality Expert Group, Air Pollution from Agriculture
EV5: Testimonial from the Head of Evidence for Air Quality and Industrial Emissions at DEFRA.
EV6: Testimonial from the Scientific Secretary for COMEAP.
EV7: WHO Air Quality Guidelines, Global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide
EV8: Testimonial from World Health Organisation Regional Advisor.
EV9: The London Environment Strategy, May 2018.
EV10: National Emissions Ceilings Directive (2016/2284/EC)
EV11: Testimonial from HM Inspector of Railways.
EV12: European Commission, European Guide on Air Pollution Source Apportionment with Receptor Models (2014)