AIR POLLUTION RESEARCH IN BRITAIN *c.*1955–*c.*2000

The transcript of a Witness Seminar held by the History of Modern Biomedicine Research Group, Queen Mary University of London, on 19 May 2015

Edited by E M Jones, C Overy and E M Tansey

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WHAT IS A WITNESS SEMINAR?

The Witness Seminar is a specialized form of oral history, where several individuals associated with a particular set of circumstances or events are invited to meet together to discuss, debate, and agree or disagree about their memories. The meeting is recorded, transcribed, and edited for publication.

This format was first devised and used by the Wellcome Trust's History of Twentieth Century Medicine Group in 1993 to address issues associated with the discovery of monoclonal antibodies. We developed this approach after holding a conventional seminar, given by a medical historian, on the discovery of interferon. Many members of the invited audience were scientists or others involved in that work, and the detailed and revealing discussion session afterwards alerted us to the importance of recording 'communal' eyewitness testimonies. We learned that the Institute for Contemporary British History held meetings to examine modern political, diplomatic, and economic history, which they called Witness Seminars, and this seemed a suitable title for us to use also.

The unexpected success of our first Witness Seminar, as assessed by the willingness of the participants to attend, speak frankly, agree and disagree, and also by many requests for its transcript, encouraged us to develop the Witness Seminar model into a full programme, and since then more than 60 meetings have been held and published on a wide array of biomedical topics.[1] These seminars have proved an ideal way to bring together clinicians, scientists, and others interested in contemporary medical history to share their memories. We are not seeking a consensus, but are providing the opportunity to hear an array of voices, many little known, of individuals who were 'there at the time' and thus able to question, ratify, or disagree with others' accounts – a form of open peer-review. The material records of the meeting also create archival sources for present and future use.

The History of Twentieth Century Medicine Group became a part of the Wellcome Trust's Centre for the History of Medicine at UCL in October 2000 and remained so until September 2010. It has been part of the School of History, Queen Mary University of London, since October 2010, as the History of Modern Biomedicine Research Group, which the Wellcome Trust

[1] See pages 121–7 for a full list of Witness Seminars held, details of the published volumes and other related publications.

funds principally under a Strategic Award entitled 'The Makers of Modern Biomedicine'. The Witness Seminar format continues to be a major part of that programme, although now the subjects are largely focused on areas of strategic importance to the Wellcome Trust, including the neurosciences, clinical genetics, and medical technology.[2]

Once an appropriate topic has been agreed, usually after discussion with a specialist adviser, suitable participants are identified and invited. As the organization of the Seminar progresses and the participants' list is compiled, a flexible outline plan for the meeting is devised, with assistance from the meeting's designated chairman/moderator. Each participant is sent an attendance list and a copy of this programme before the meeting. Seminars last for about four hours; occasionally full-day meetings have been held. After each meeting the raw transcript is sent to every participant, each of whom is asked to check his or her own contribution and to provide brief biographical details for an appendix. The editors incorporate participants' minor corrections and turn the transcript into readable text, with footnotes, appendices, and a bibliography. Extensive research and liaison with the participants is conducted to produce the final script, which is then sent to every contributor for approval and to assign copyright to the Wellcome Trust. Copies of the original, and edited, transcripts and additional correspondence generated by the editorial process are all deposited with the records of each meeting in the Wellcome Library, London (archival reference GC/253) and are available for study.

For all our volumes, we hope that, even if the precise details of the more technical sections are not clear to the non-specialist, the sense and significance of the events will be understandable to all readers. Our aim is that the volumes inform those with a general interest in the history of modern medicine and medical science; provide historians with new insights, fresh material for study, and further themes for research; and emphasize to the participants that their own working lives are of proper and necessary concern to historians.

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[2] See our Group's website at www.histmodbiomed.org

ACKNOWLEDGEMENTS

The subject of air pollution was independently suggested by Professor Bob Maynard, Dr Christopher Derrett, and Professor Jonathan Grigg at different times and we are very grateful to them all for their help in planning this Seminar. We thank Professor Anthony Seaton for his excellent chairing of the event, and Professor Jonathan Grigg for writing his apposite introduction to the volume. Our gratitude also goes to Ms Claire Daley for supplying and granting permission to reproduce the graphs in Appendix 1 on behalf of the Royal College of Physicians, and to the Wellcome Library, London, for permission to use photographs taken at the meeting.

As with all our meetings, we depend a great deal on Wellcome Trust staff to ensure their smooth running: the Audiovisual Department, Catering, Reception, Security, and Wellcome Images. We are also grateful to Mr Akio Morishima for the design and production of this volume; the indexer Ms Cath Topliff; Mrs Sarah Beanland, and Ms Fiona Plowman for proofreading; Mrs Debra Gee for transcribing the proceedings; Mr Adam Wilkinson who assisted in the organization and running of the meeting. Finally, we thank the Wellcome Trust for supporting this programme.

Tilli Tansey

Emma M Jones

Caroline Overy

School of History, Queen Mary University of London

ILLUSTRATIONS AND CREDITS*

* Unless otherwise stated, all photographs were taken by Thomas Farnetti, Wellcome Trust, and reproduced courtesy of the Wellcome Library, London.

ABBREVIATIONS

AURN	Automatic Urban and Rural Network
CO	Carbon monoxide
COMEAP	Committee on the Medical Effects of Air Pollutants
Concawe	Conservation of Clean Air and Water in Europe
Defra	Department for Environment, Food and Rural Affairs
DoE	Department of the Environment
EPAQS	Expert Panel on Air Quality Standards
HEI	Health Effects Institute
MAAPE	Medical Aspects of Air Pollution Episodes
MRC	Medical Research Council
NSCA	National Society for Clean Air
NO_x	Nitrogen oxides
SO_2	Sulphur dioxide
WHO	World Health Organization

INTRODUCTION

To ask the generation who lived in London during the Second World War about air pollution elicits memories of the infamous smogs. Christine Corton in her book *London Fog* impressively links the historical and literary aspects of the great London fogs.[1] She quotes from the 1960s novel by Lynne Reid Banks, *The L-shaped Room*, in which the main character Jane walks out into the smoke and '… felt my way along, a few steps at a time … clinging to whatever bit of masonry was under my hand. … Far, far away I could hear the slow, grinding sounds of traffic – but muffled, as if I were wearing ear plugs'.[2] This Witness Seminar on 'Air Pollution Research in Britain *c.*1955–*c.*2000', covers the dying gasps of the London pollution events called 'pea-soupers' (so thick you could drink it) or 'London ivy' (it clung to everything), and provides some answers to the questions that researchers ask today such as: why did scientists after the Clean Air Act of 1956 assume that there was nothing more to do?, and when did the penny drop that particulate matter at concentrations an order of magnitude lower than the London smog's could both kill and cause long-term health effects?

The formation of the MRC Group for Research on Atmospheric Pollution (later Air Pollution Research Unit) at Barts Hospital in 1955, was a major opportunity for the UK to be at the forefront of investigation into air pollution. The MRC Group certainly contributed to the elimination of the great London smogs, with tremendous benefits to public health. It also developed research methods that resonate today. For example, the study in which Robert Waller and Pat Lawther walked into the Unit from London Bridge station then immediately had their airways resistance measured, has parallels to the 2007 study that found lung function in adult asthmatics decreased after walking up and down Oxford Street.[3] With hindsight, the closure of the Unit was a missed opportunity to re-focus UK research on the modern pollution mix. But by the 1970s, the appetite for new air pollution research had faded, as Bob Maynard recalled: 'The feeling was that the problem was over. … It wasn't worth pursuing it any further'.[4] We know now, of course, that even very low

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1 Corton (2015).

2 Banks (2004), pages 143–4; first published 1960 by Chatto & Windus.

3 McCreanor, Cullinan, Nieuwenhuijsen *et al.* (2007). For the London Bridge study see pages 18 and 31.

4 Page 29.

concentrations of diesel soot (compared with the concentrations of coal soot in the London smogs) not only penetrate into the deepest parts of the lower airways and exacerbate respiratory conditions such as asthma, but also trigger a wide range of extra-pulmonary effects such as heart attacks. However, at the time, this concept must have appeared counter-intuitive. Indeed, the Royal College of Physicians' Report on Air Pollution (1970) concluded that 'diesel fumes may constitute no direct threat to health, but they are dangerous in traffic because they obscure visibility'.[5] Christine Corton points out in her book that the modern air pollution mix has failed to capture the imagination of writers in the same way as traditional pea-soupers.[6] One wonders if it had, would it have shortened the 'quiet time' for air pollution research from 1965 to 1990?[7]

The major legacy of the MRC Unit was that it primed a small cadre of investigators to continue thinking about air pollution. These pioneers led the 'great rejuvenation' of UK air pollution research triggered by data from large US epidemiological studies that emerged in the late 1980s early 1990s.[8] The major milestones in this explosion of inquiry and policy initiatives identified by this seminar include the WHO Air Quality Guidelines for Europe, Bob Maynard's push for the Department of Health to focus on air pollution, Anthony Seaton's 1995 paper in *The Lancet* on particles,[9] and the development of advisory bodies.

What lessons can we draw from these fascinating discussions about end-of-the-twentieth-century air pollution research in the UK? First, researchers should not be disheartened when their area falls out of fashion – there is always the possibility that it will become cutting edge again. Second, collaborations are probably a more efficient way of generating research capacity (i.e. virtual research units) compared with single small units. Finally, scientists should not take their brief too literally. As Roy Harrison points out in the Seminar, it was wrong for investigators to ignore the deposition into dusts and soils, and directly into

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[5] The Committee of the Royal College of Physicians of London on Smoking and Atmospheric Pollution (1970).

[6] Corton (2015).

[7] Professor Roy Harrison refers to this 'quiet time' on page 55.

[8] See pages 55 and 58–9.

[9] World Health Organization (1987); Seaton *et al.* (1995).

crops when considering the effects of aerosolized lead.[10] Unfortunately, some of these lessons are still to be learnt. To date, no single committee provides advice to UK Government covering real-life emissions, emissions testing, personal exposure, and health effects. Indeed, the failure of scientific advice to prevent London being the most polluted city in Europe is a potential subject for a future Witness Seminar.

Professor Jonathan Grigg
Queen Mary University of London (Blizard Institute)
December 2015

Figure A

[10] See page 45.

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AIR POLLUTION RESEARCH IN BRITAIN *c.*1955–*c.*2000

Participants*

Professor H. Ross Anderson
Mr Simon Birkett
Dr Brian Commins
Dr Christopher Derrett
Professor Richard Derwent
Professor Roy Harrison
Mr Philip Lord
Professor Alison Macfarlane
Professor Robert Maynard
Professor Anthony Seaton (Chair)
Professor Tilli Tansey
Professor Peter Tavner
Professor Dafydd Walters
Dr Heather Walton
Professor Martin Williams

Also present: Mrs Ann Commins, Dr Brigitte Rudd

Apologies include: Mr Brian Biles, Professor Peter Brimblecombe, Professor Anthony Dayan, Dr Nigel Derrett, Dr Geoff Dollard, Professor Jonathan Grigg, Professor Steve Holgate, Professor Frank Kelly

* Biographical notes on the participants are located at the end of the volume

Professor Tilli Tansey: First of all, may I welcome everyone. I'm Tilli Tansey and I head the History of Modern Biomedicine Research Group in the School of History at Queen Mary University of London. This format of Witness Seminars was something I started some years ago when I was working for the Wellcome Trust. We attempt to bring together a group of people who were involved in particular discoveries, debates, or programmes of research, to get behind the published literature, to find out what really happened, what went right or, perhaps more importantly, what went wrong. We have a broad ranging discussion, you have each already been sent an outline programme of how we hope today's meeting will go, but this is by no means a rigid, fixed programme – often participants' reminiscences and ideas will take us off in different directions, so please don't worry too much about sticking completely to this programme. This is a flexible outline (Table 1).

1955–1978
• 1955 – MRC Group for Research on Atmospheric Pollution (later Air Pollution Unit), Barts, London
• Air Pollution Policy and Government Legislation
• Ethics, Health and Safety and Supervision
• Laboratory Techniques
• 1978 – Closure of Air Pollution Unit
1978–*c.*2000
• 1990 – Air Pollution Unit, Department of Health
• Advisory Group on the Medical Aspects of Air Pollution Episodes
• The Committee on the Medical Effects of Air Pollutants (COMEAP)
• Expert Panel on Air Quality Standards (EPAQS)
• UK air pollution initiatives

Table 1: Outline programme

An important part of organizing any such meeting is obviously finding the participants, and I'm enormously grateful because this meeting is what zoologists call 'polyphyletic': it has its origins in several different formats. First of all, I knew Bob Maynard through the Physiological Society and Dafydd Walters and I recently interviewed Bob for the Physiological Society Oral Histories Project and obviously he talked a great deal about his work in air pollution, which got filed in a synapse somewhere in the back of my brain. I also knew Chris

Figure 1: Professor Anthony Seaton, Professor Tilli Tansey

Derrett, not as a former member of the Air Pollution Unit, but as a GP and medical historian in the East End, and then I remembered that, actually, he had started his career in the Air Pollution Unit. Then I also remembered that in 1955 the Air Pollution Unit in St Bartholomew's Hospital was created by the MRC. Being a 'bear of little brain', it took me a long time to put these three things together and to realise that this was an ideal opportunity to use people's experiences to have a Witness Seminar on air pollution.[1] So Bob Maynard and Chris Derrett have been incredibly important and helpful in trying to find some of you people to invite to this meeting.

Another really important part of any meeting is identifying someone appropriate and willing to chair, and I'm delighted that Anthony Seaton has agreed. He did actually offer, because I think I wrote such a broad appeal for advice he felt compelled to offer his services. Anthony will need little introduction to this group: Director of the Institute of Occupational Medicine in Edinburgh until 1990 and an expert on the Royal Society's working party on nanotechnology. So without further ado I'm going to hand over to Anthony.

Professor Anthony Seaton: Thank you, Tilli. I did indeed offer; it was to avoid Bob being chairman. [Laughter] A certain amount of pressure was put on me

[1] 'A bear of little brain' is a reference to the character of Winnie the Pooh created by the children's author A A Milne.

in this respect. Well, most of you know me, but I suppose my main role in air pollution was to chair EPAQS (Expert Panel on Air Quality Standards), which was Bob's fault. He proposed me as chairman of EPAQS many years ago. My early life was spent in a highly polluted environment in Liverpool just before and during the war, and I knew nothing about air pollution except that it obscured the view, until I got involved in EPAQS. We've got to start the first two hours of this meeting talking about the first surge of research in this area in the UK, and that was the MRC group at St Bartholomew's Hospital. I'm just interested: who are the people here who were actually in that unit? [Half of the participants raised their hands.] Quite a lot. Who would like to say why they think it was founded?

Mr Philip Lord: Well, we all know it was founded because of the 1952 Great Fog, when very many cattle and other animals died at Smithfield.[2] And incidentally to that, a lot of other people, a lot of humans died too. They died prematurely rather than were poisoned, as it were, on the spot. People with existing respiratory diseases succumbed to the stress caused by the fog.[3]

Seaton: How influential were the cattle in Smithfield? I've heard that story before. Is it true?

Lord: This is what we were led to believe. Whether it was true or not, does anybody know? Alison, you've got a view.

Professor Alison Macfarlane: I don't know if it's true but it was certainly reported in the Ministry of Health report on the London fog of 1952.[4] Then I presume there was some verification done before the Ministry published it.

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[2] For a history of London air pollution, including the infamous 1952 London fog, see Brimblecombe (1987), Chapter 8, 'The Great Smog and after', pages 161–78. See also Corton (2015).

[3] Ministry of Health (1954): 'To the great majority of normal, healthy individuals the fog was little more than a nuisance; the increased morbidity, of which there is clear evidence, occurred mainly among people with pre-existing respiratory or cardiac disorders and, so far as can be ascertained, there were no deaths attributable to fog among previously healthy people', quoted from page 38.

[4] Ministry of Health (1954): 'The Smithfield Club's Show was held at Earl's Court, London, from 8th to 12th December, 1952 … The onset of fog on the Friday was followed by acute respiratory symptoms in a number of cattle, some sixty needing major veterinary treatment and about one hundred others requiring some form of minor attention. Twelve of the more serious cases were slaughtered and one died.' Quoted from Appendix A of the report, 'The effect of the fog on cattle at the Smithfield Show. Summary of a report by J R Hudson', page 45.

Figure 2: Professor Robert Maynard, Professor Roy Harrison

Professor Ross Anderson: It could possibly have been an explanation that was invented subsequently, because the theory was that it was only the prize-winning cattle that died because they had clean straw and so they did not have a lot of urinary ammonia in their stall to neutralize the acid in the air.[5]

Professor Robert Maynard: That's certainly the story that Pat Lawther told me on many occasions when we discussed the start of the Unit at St Bartholomew's.[6] He pointed out to me that it wasn't the first time that deaths among cattle had been reported. Indeed, he referred to studies done in the late Victorian period, and you can find references to that.[7] He harped on, I think that must be the phrase, about the ammonia and he pointed out to me that at that time they had installed smog bottles in hospitals in London. I don't know whether they were in all hospitals, but I certainly have one of the bottles at home from Robert Waller's collection, and it's an Airwick bottle, and it says on it: 'In time of smog, raise wick until a faint smell of ammonia can be

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[5] This explanation is suggested in a brief article on the anti-smog bottle in Anon. (1955).

[6] Professor Patrick (Pat) Lawther (1921–2008) was Director of the MRC Air Pollution Unit from 1955 to 1977 at St Bartholomew's Hospital Medical College. See page 92 for further biographical information.

[7] See, for example, Anon. (1874).

detected.'[8] That's the instruction. And the assumption, I think, was that to neutralize the sulphur dioxide, probably neutralizing it as sulphurous acid in liquid droplets, I guess that was the idea.

I wonder whether it would be helpful to say something about the start of the Unit and the Beaver Committee? There are people here who might remember that. The smog of 1952 called for a government committee report and that committee was set up under a man called Beaver.[9] It recommended formal research in the area of air pollution science and that led on to the Clean Air Act of 1956, so the Unit was formed before the Clean Air Act but, if you like, as part of the Government response to the smog of 1952.[10] The report on the smog that formed the basis for the calculations of the number of people affected was written by Edmund Martin from the Department of Health – it's not often recorded because his name is not in the official publication.[11] It's a government publication from the then Ministry of Health, but it's an important landmark in that he was the first person to study the effects of air pollution on health in this country on behalf of the Government.

Macfarlane: An article that I wrote when I was in the Unit documented historical accounts of earlier fogs, so the idea was not new that fog could cause ill health.[12] If I could just document a parallel thing that came out of the Beaver Committee: my father, Angus Macfarlane, who was a chemist working in, what was called in those days, fuel efficiency for the London Midland Railway, then the Ministry of Health during the war; and then we had five years of a change and we all went off to Washington while he and other scientists from the British Commonwealth

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[8] Professor Robert Maynard added: 'The label on the bottle also reads: "St Bartholomew's Hospital Dispensary 1956". The bottle is indeed an ordinary Airwick bottle. The writing on the cap reads: "Airwick contains chlorophyll".' Note on draft transcript, 20 October 2015. For a discussion of the anti-smog bottle see Anon. (1955). Mr Robert Waller was a founder member of the MRC Air Pollution Unit; see further biographical details on pages 96–7.

[9] Sir Hugh Beaver (1890–1967) was Chairman of the Committee on Air Pollution from 1953 to 1954. An interim report was published by the Beaver Committee in 1953 and the full report in 1954: Committee on Air Pollution (1954).

[10] The Clean Air Act of 5 July 1956 was 'an Act to make provision for abating the pollution of the air'; see www.legislation.gov.uk/ukpga/Eliz2/4-5/52/contents/enacted (accessed 5 October 2015).

[11] Ministry of Health. (1954). Alec Edmund Martin (d. 1991) was a principal medical officer in the Department of Health (1947–1974) where his environmental health portfolio included air pollution. See Shaw (1992).

[12] Macfarlane (1977).

Figure 3: Professor Alison Macfarlane

exchanged goodness knows what with the Americans. I think military secrets and secrets of ice cream. [Laughter] He then came back because he was appointed to turn the fuel efficiency section into a quango, the National Industry Fuel Efficiency Service, and it is still going as a huge consultancy: NIFES Consulting.

Mr Simon Birkett: I didn't come to this subject until about 2006, but I think what I would find particularly interesting and valuable in this discussion is to understand what people were thinking and understood at the time, but also, separately, a different perspective, which is looking back now with the knowledge of hindsight, what lessons people might draw looking forward. Because I suspect that we've moved from short-term exposure to visible pollution, to long-term exposure to invisible pollution, and there's probably another train coming down the track at us in terms of other problems. I think those two perspectives would be valuable as we go through this session.

Dr Brian Commins: Is it appropriate to talk now about the start of the Air Pollution Unit? We've referred to the justification for it, but I was a founder member of this Unit.

Seaton: Yes.

Commins: Three of us, Pat Lawther, Robert Waller, and I, started in December 1955, and it was a very exciting period and very challenging at Bart's Hospital.[13]

[13] See biographical notes for Professor Patrick Lawther and Mr Robert Waller on pages 92 and 96–7.

Figure 4: Mr Simon Birkett

We have referred to the high pollution in 1952, and I am providing a graph to demonstrate that air pollution can be extremely high, much higher than figures normally published.[14] I remember, I think it was in early January of 1956, there was a period then of an hour's measurement of some 10 milligrams of smoke per cubic metre of air. Astronomically high, and you'll see it on the graph.[15] Referring to the ammonia bottles, they were used in bronchitic wards in the hospital, and it was the most harrowing experience I've ever had as a young chemist. I'd have only been 25 then. I went into this ward and saw all these patients with terrible breathing problems – you can't imagine what it's like – all fighting for air. The ammonia bottles may have helped, but my chemistry would say it probably didn't help with respect to SO_2 (sulphur dioxide), but it would have helped with respect to any sulphuric acid. I would like to refer to

[14] The graph of 'Concentration of smoke and sulphur dioxide in the City of London during periods of high pollution, 1955–59' is reproduced in Waller and Commins (1959), page 175. See also the discussion on page 15.

[15] Dr Brian Commins wrote: 'These data show hourly changes in smoke and sulphur dioxide during some high pollution episodes measured at St Bartholomew's Hospital in the 1950s. Rapid changes in pollution levels with very high peaks are observed at times. Average 24-hour concentrations recorded were approaching 3mg per cubic metre air for smoke (maximum 10), and around 1ppm of sulphur dioxide (maximum 1.5ppm). 24-hour averages markedly mask some of the peak and trough levels. Although in general the smoke and sulphur dioxide levels followed each other, the relative proportions of these pollutants fluctuated.' Email to Ms Emma Jones, 2 December 2015.

Figure 5: Dr Brian Commins

some of our work in deference to Pat Lawther and Robert Waller, who were very supportive and wonderful colleagues who sadly have died. I'd like to dedicate what I'm going to say today to them.

Seaton: Can I just stop you for a moment? What were the main questions? Do you remember the main scientific questions that were asked of the Unit when it was founded?

Commins: Well, to try and find out what were the sources and the health impact of various pollutants, and, of course, we had to make airborne measurements. In those days we were pioneers, we had only limited measuring methods so we had to develop these. I developed methods for measuring polycyclic aromatic hydrocarbons in smoke, and for carbon monoxide in blood, and sulphuric acid in air, and those were essential to try and find out what was the cause of the problem.[16]

Seaton: Was there a hypothesis behind this? I mean, was there an assumption that it was acid aerosols or particles?

[16] See Commins (1958); Commins and Lawther (1965); Commins (1963).

Commins: Well, it was a possibility, both were important, but I'll refer to that in a minute, if you like. In the early days we couldn't detect much sulphuric acid except occasional red particles on a thymol blue slide.[17] But in about 1957, I took a filter and dunked it in water and found it very strongly acid, and what was happening in those days, I think, was we got catalytic oxidation of sulphite (dissolved sulphur dioxide) with transition elements like manganese and chromium and iron, turned it into sulphuric acid, and we found astronomical levels. In 1962 we had nearly 700 micrograms per cubic metre of air of sulphuric acid, and I developed a method for this and tested it out, and this represented something like 15 per cent of the total particulate matter.[18] Now, whether, in fact, that was important I don't know, but it could well have been relevant in terms of health effects. Then, of course, we had to test out all these sampling methods, and we had to go to various high spots like in the middle of a street, gasworks retort houses, road tunnels, to try and see what the impact was from very high levels of exposure and extrapolate those down to ambient air levels.[19] Then we had the diary studies of Pat Lawther and Robert Waller, which demonstrated, very significantly, that there was a massive impact when pollution was high in relation to worsening health for bronchitic patients.[20]

Seaton: So from the beginning you had Robert Waller, a physicist,[21] Pat Lawther, who was a physician, and yourself, as a chemist. And you were chosen as a chemist presumably because of this interest in acid particles?

Commins: Well, no, I had just done an MSc and they wanted somebody to act as a chemist.

Seaton: Right, fair enough. [Laughter]

Commins: And, of course, I was very lucky to be chosen.

Seaton: Yes, interesting, it was multidisciplinary…

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[17] Dr Brian Commins elaborated: 'Particles from the air were collected by impaction onto thymol blue coated slides and sulphuric acid particles appeared as red spots.' Email to Ms Emma Jones, 21 October 2015.

[18] Commins and Waller (1967).

[19] Waller, Commins, and Lawther (1965); Lawther, Commins, and Waller (1965); Waller, Commins, and Lawther (1961).

[20] Waller and Lawther (1957); Lawther, Waller, and Henderson (1970).

[21] Dr Christopher Derrett added: 'Although Robert Waller had a first degree in physics, he was employed as an epidemiologist for most of his time with the APRU.' Note on draft transcript, 17 June 2015.

Figure 6: Mr Philip Lord

Commins: Oh, absolutely, all disciplines, but perhaps a bit amateur in some ways. [Laughter]

Lord: I'm grateful to Brian for bringing that up. A lot of methodological issues were ironed out initially in the Air Pollution Unit. This was before Chris [Derrett] and I joined in 1968.[22] What we were doing, I think, was exploring one of the hypotheses that air pollution was affecting daily mortality and morbidity figures, and we were trying to correlate the air pollution levels on a daily basis with these measures of mortality and morbidity. The science behind it – well I'm no chemist, but my understanding was that sulphuric acid droplets in the air were adhering to particulate matter, were inhaled, and were damaging the lungs in some way that perhaps we didn't understand. One of the ways that I understood it, it was causing bronchoconstriction, and the other effect might have been the stimulation of the mucus glands in the lung. In fact, I was, later in my time there, doing work on the morphology of the lungs and the mucus glands, which was fascinating work.[23]

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[22] Mr Philip Lord wrote: 'Exploring new methodologies did not end in the early years of the Unit, for example, Chris Derrett and I did a lot of work on computing methodologies and developing techniques for automating the measurement of lung function: the Unit was probably the first to do this.' Note on draft transcript, 5 July 2015.

[23] See, for example, Kollerstrom, Lord, and Whimster (1977).

Figure 7: Professor Richard Derwent, Professor Dafydd Walters

Seaton: In those days I was a medic, well a young doctor at the start of this, and I well remember the wards were full of patients with chronic bronchitis, which we always attributed to smoking, correctly, but it was the winter pollution episodes when they came in and died. So I can well understand this focus of interest on respiratory disease.

Lord: Just to follow up on another point of Brian's: when I arrived at the Unit in 1968 – Chris and I actually arrived on the same day, I believe – another key person there was John McKean Ellison, a physicist who was working on particulate matter and the physics of particulates. I always saw Professor Lawther, Brian Commins, John Ellison, and Robert Waller as the core of the Unit really.[24]

Seaton: Yes. And the development of equipment for measuring air pollution.

Professor Richard Derwent: I just wanted to make some comments about the measurement methods. Modern air pollution measurements began in about 1912 under the Meteorological Office at the Kew Observatory. They passed to

[24] Mr Philip Lord wrote: 'John McKean Ellison was nicknamed "Boots" – his habitual footwear … We drafted a paper on what we called the Ellison–Lord lung model of bronchial airflow, but events overtook us and it was never published … We should not forget that the Unit relied on the backbone of wonderful technical support from a group of very gifted technicians: Cyril Brown (instrumentation), Leslie Hampton (chemistry), Alan Brooks (physiology), Brian Biles (electron and light microscopy). Another pillar of the Unit while I was there was Lawther's secretary, Ann Kingdon.' Note on draft transcript, 5 July 2015.

the Fuel Research Station in about 1945.[25] The Fuel Research Station was set up in Greenwich and they were doing measurements of sulphur dioxide using lead peroxide candles. These were like sticks of lead peroxide, and the sulphur compounds accumulated on the surface of them and they were taken away for measurement. They were measuring smoke by filters, looking at the blackness of filters. And so there was a series of pollution episodes after the war, 1948 for example, and at the Fuel Research Station, a chap called Wilkins really got his act together when he realised that these lead peroxide candles weren't any good for the episodes, and they started measuring with bubblers and Dreschel bottles and such things as that. The actual data that was used for the 1952 smog by the Beaver Committee was produced by the Fuel Research Station; Wilkins published his results in the *Journal of the Royal Sanitary Institute*,[26] so that's a good way of burying data, isn't it? They could only do the episodes with these Dreschel bottles, and they observed extremely high concentrations of smoke and SO_2 and these were the measurements that Pat Lawther and yourself [Commins] used in the diary studies.[27] The background to the measurements was based on the work going on at the Fuel Research Station, Greenwich. Eventually this work was taken over by Warren Spring Laboratory in 1959.

Seaton: Thank you. In fact, I remember digging out an old journal from the nineteenth century of someone in Scotland who had gone up to the top of Ben Nevis and measured, and actually counted, dust particles. Measurement of the particles in the environment goes back a really long way.[28]

Commins: In answer to your question about developing methods, when we moved in 1962 to the medical college in Charterhouse Square,[29] we had a rooftop sampling facility, which we designed ourselves, and also an exposure chamber. So what we did was we exposed people and measured the effect on them.[30] We also generated various pollutants to check out the sampling methodology that we were using.

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[25] The Fuel Research Station was part of the Department of Scientific and Industrial Research, and absorbed the 'Investigation of Atmospheric Pollution' brief in 1945 that had been founded in 1912; see Mosley (2009).

[26] Wilkins (1954).

[27] See note 20.

[28] Rankin (1893); Buchan (1876, 1880). The latter paper compares London with New York.

[29] Charterhouse Square, London, the site of St Bartholomew's Hospital Medical College.

[30] See the short film on the Air Pollution Unit in the British Pathé archive. British Pathé (1968) *Air Pollution*: www.britishpathe.com/video/air-pollution/query/Air+Pollution (accessed 7 September 2015).

I'd like briefly to refer to some of the possible errors in the early measuring methods. The only measurements we have for high air pollution in the 1952 smog were made at County Hall, i.e. 4.46 milligrams of smoke per cubic metre of air, or over four thousand odd if you want to make it more alarmist, in micrograms. Now, for those measurements, it's not well known, the filters got saturated and so the filters on the face became clogged, smoke had to come through the filter edges; so they were underestimates. Also, it's not well known that, because people didn't work on Sundays in 1952, and they didn't change the filter on Sundays, the measurement there refers to a 48-hour period. If you'd like to quickly look at the graph I've given you showing peak concentrations, it will be clearly visible that you can get some very short-period, high levels of pollution, which are not reflected in 24 hours, let alone in 48 hours.[31] I think it's important in those pollution episodes to observe that pollutant levels went up sometimes and then down as the contributing sources were drifting across. If the breeze came from the east it was probably mainly coal smoke; if it came from the west it was probably a power station, or something like central heating plants. We did a lot of work on testing out methodology and published a lot because we were, if you like, doubting Thomases – as a chemist I regard myself as a doubting Thomas. You check everything as best you can, and we even checked the volatility of things like 3:4 benzpyrene on filter papers.[32] And I'm afraid my poor wife here suffered an awful lot because I had to spend many hours working in the laboratory.[33] I felt very dedicated to do this because it was new ground, and I was delighted to be involved.

I'd just like to refer to another matter when we talked about effects in the diary studies, and the exposure of people from 1950 to 1970. The exposure source was outside pollution. In those days we had poorly fitting windows and doors so the indoor pollution was very similar to the outdoor pollution, and so the exposure from outside was correlated very well with that.

Seaton: Did you measure the indoor levels?

Commins: Yes, we did some measurements indoors. There's one reason why, and those who understand combustion a bit will recognize that the coal fire demanded air to work, so it had to suck air from outside into the room. I don't know if you've ever seen that, if somebody smokes in a room with a coal fire,

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[31] See note 14.

[32] Commins and Lawther (1958).

[33] Mrs Ann Commins attended the Seminar; see Appendix 2.

Figure 8: Professors Martin Williams, Dafydd Walters, Robert Maynard, and Roy Harrison

the smoke drifts towards the fire and is taken away up the chimney. These days, the exposure is not easy to define because we have much better fitting doors and windows, and indoor sources of pollutants are more relevant. In the past it was the outdoor pollution that was more important. But the other important factor, bearing in mind it was b….. cold, I'm not going to use the longer word, but it was very, very cold, it was sub-zero for several days in 1952, and that could have had a contribution to health impacts.[34]

Seaton: Yes. Well, certainly, that's the experience of most of the people in this room who lived through those years, lighting the coal fire, drawing it to get it going. You knew that *The Times* newspaper was useless for lighting fires with. [Laughter] You had to get the *Daily Mail* or something if you wanted to light your fire. Did everyone know that?

Commins: *The Financial Times* was worse. [Laughter]

Maynard: Well, we certainly didn't take *The Times* in South Wales. The *Daily Worker* probably served very well. [Laughter] I wanted to ask some of the people who were in the Unit originally to say something about the studies of very high

[34] An anticyclone over the region with sub-zero temperatures contributed to the formation of smog in December 1952. For discussion of the meteorological factors of the fog, see Ministry of Health (1954), pages 3–5.

concentrations, because at that time the emphasis was on air pollution episodes and the episodes were characterized by very high peaks of pollution, and it was the study of those peaks and their relationship to effects on health for the changing numbers of deaths, or whatever, that really was the main focus of the work of the Unit, at least in my reading of its work. In about 1960 Pat Lawther attended a meeting in the States, and he published his report of the meeting in a book called *The Air We Breathe*; it was a set of comments on air pollution.[35] He made a very interesting comment, and that was that he thought that the episodes were being over-emphasized. He thought that it was the long-term exposure to lower concentrations of air pollutants than those that occurred in episodes, which was actually the cause of respiratory disease seen in populations like the UK. Now, of course, the picture is blurred because we know that cigarette smoking is the main cause of chronic bronchitis, but in those days the search for a causal agent for the British disease of chronic bronchitis was pretty acute, and you remember that, Anthony.[36]

Seaton: I do.

Maynard: We were looking for that in this country. Now Pat's point was about long-term exposure, that's been borne out in recent years extremely clearly, so he was well ahead of the field in the thinking on that. The Americans, by the way, were very surprised in the discussion session at the end of the chapter in that book. He was asked whether long-term exposure affected people not suffering from disease, and he replied that he thought it did. It's obvious that they were concerned with episodes, which really is what we had been concerned with here.[37] But that focus on high levels led to the high-level chamber exposures that were done, and it would be interesting, I think, to hear what people have to say about those because you were exposing people to 30mg of sulphur dioxide per cubic metre. It's a lot by any standards.

Seaton: Yes, so who played a part in these human experiments?

Dr Christopher Derrett: I think it's important to add to what's already been said about the people that were there; there were also a number of people who

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[35] Lawther (1961).

[36] See, for example, Palmer (1954).

[37] See the discussion of the session to which Dr Pat Lawther contributed (urban living and air pollution: smog and fog) in Farber and Wilson (eds) (1961), pages 224–37, in particular pages 234–5 for Pat Lawther and Professor Hatch's comments.

Figure 9: Dr Christopher Derrett

were involved in physiological work; Ann Commins was one of them.[38] There was quite a large physiological laboratory in the Unit – that was the largest room – and it had a number of instruments, including a whole-body plethysmograph, which was quite a unique instrument for the time.[39]

One of the studies they did involved measuring airways resistance. Both Robert Waller and Pat Lawther walked into the Unit from London Bridge station, exposed themselves to the London air every day, and then they immediately went into the body plethysmograph and had their airways resistance measured.[40] That went on for several years. There was also, as people have said, an exposure chamber, and when I think about it now it was extraordinary that it was possible for somebody to design a room with a fire in it, an unventilated fire, to which people were exposed. Though, interestingly, while I was at the Unit, I never saw that fire lit. A lot of the gases that people breathed, and certainly the gases that I breathed, were taken from cylinders and put into bags. The experiments were generally done in the exposure chamber and then measurements were made either of airways resistance or FEV_1 (forced expiratory volume in 1 second), or something like that.

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[38] See note 33.

[39] See pages 26–7 for further discussion about the plethysmograph and an illustration of the instrument (Figure 13).

[40] See page 31 and note 61.

Figure 10: Carbon monoxide monitoring apparatus: MRC Air Pollution Unit, St Bartholomew's Hospital Medical School, *c.*1968[41]

Lord: I do remember being exposed in that chamber, if I can use that expression. [Laughter] There was a petrol engine installed on the roof and the exhaust from that was fed into the chamber, and I do remember sitting in there doing psychological tests, breathing in the carbon monoxide and all the particulates that came out of this device.

Seaton: Did they actually measure carbon monoxide or did they ignore it?

Lord: No, no, at that time it was measured. In fact, I think it was Professor Maynard who said something about chronic exposure rather than episodic exposure, and I think that became much more of a feature of the Unit's thinking, or Professor Lawther's thinking, as time went on.[42]

Maynard: The Unit is remembered now mainly for its work on sulphur dioxide and particles, I think that's fair, but a lot of work was done on carbon monoxide as well. Certainly Pat Lawther was involved in contributing to one of the definitive monographs in the field on carbon monoxide toxicology, so there was

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[41] Still from British Pathé film: *Air Pollution* (see note 30). The subject is Alan Brooks, the operator is Dr Tom Emerson (a chemist who worked in the MRC Unit). Emails from Mr Philip Lord to Ms Caroline Overy, 5 July 2015, and Dr Chris Derrett to Ms Emma Jones, 4 December 2015.

[42] See page 17.

Figure 11: Professor Martin Williams

great interest in carbon monoxide and there was great interest in the effect of petrol engine-generated carbon monoxide at that time.[43]

Lord: Yes, to come back to earlier comments about the exposure that people had to pollutants. It's not quite clear what that meant, and I remember discussions at the time, because you have to remember that people breathe both in and out, so you breathe the pollutants in and you breathe them out again. There must be some balance between the two. Do you subtract the levels from the breath drawn in from the breath pushed out? What exactly is the exposure? This led to a more physiological approach to measurement, what was in the blood stream and so forth.

Seaton: Right, so you were looking at exposure and dose.

Lord: I always remember that discussion in terms of what I think is a later failure of the Unit, and which we might come on to, which is its involvement in the lead-in-air saga, petrol lead that is.[44]

Seaton: We'll try to remember to come to that later, the lead story, which I hadn't appreciated.

Professor Martin Williams: I remember talking to Robert Waller about the extremely high levels of SO_2 that they used to expose themselves to, and he then

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[43] Coburn (ed.) (1970).

[44] For discussion on lead see page 42–6. See also the comments by Dr Peter Elwood on environmental lead studies between 1976 and 1982 at the MRC Epidemiology Unit in South Wales in Ness, Reynolds, and Tansey (eds) (2002), pages 124–6.

turned to me and said, 'Well, we never used ozone because we thought it was too aggressive.' Is there any truth in that?

Seaton: Does anyone remember ozone coming up? Was anything published from ozone?

Lord: I do remember some discussions about ozone but I don't think any research was done on it or anything published, but I may be incorrect.

Macfarlane: This was later on. I didn't arrive in the Unit until 1972, and there was awareness of what was, at that time, called the 'new pollution', which included ozone. I'm not talking now about exposure experiments, I'll pass to Brian for that, but certainly it was on the agenda and how we should investigate that. Robert Waller and I wrote an article about mortality in two hot summers and we were speculating about the distribution of ozone. We didn't actually have any data. It was before Warren Spring had started measuring ozone, or any other places,[45] so it was being thought about but perhaps as a new item on the agenda because by then the old level of heavy particulates had declined.

Seaton: Does anyone remember how the thinking in the Unit developed as time went by? Starting with particles and obvious deaths and sulphuric acid, and then gradually changing as time went by? Can anyone give us an insight to that?

Commins: I'd like firstly to refer to what Bob Maynard says about long-term periods of pollution. Firstly, in the high periods I'm sure it maimed people and they became slowly impaired, if you like, over the months or years, but in addition, he's right, we hadn't the facilities for studying long-term exposures. I'm so glad that in more recent years, people have done that, but I'd like to refer briefly now to the exposure chamber experiments. I was responsible for generating and controlling the levels of pollutants. What a responsibility, and we didn't kill anybody! As far as I can remember, we didn't use the fire – we put it there in case we needed it. We generated periods of high carbon monoxide levels and we did psychometric tests on people to see whether they were affected and measured the blood levels of carbon monoxide. I developed a finger prick method of doing this.[46]

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[45] Professor Richard Derwent wrote, 'In 1976, Alison MacFarlane and Robert Waller published a paper on the short term increases in mortality during a heatwave in the summer of 1975: Macfarlane and Waller (1976); and Hampton and Waller were joint authors with Derwent and Williams of a study on ozone levels during a heatwave in 1976: Apling *et al.* (1977).' Note on draft transcript, 29 June 2015.

[46] Commins and Lawther (1965).

One very interesting study, it wasn't work we did in the Unit, but we were called in by the authorities responsible for the nuclear submarines in Faslane. We went there, and we discovered that submariners were exposed for several months to high levels of carbon monoxide. Although there was some form of absorber for carbon monoxide, the submariners were allowed to smoke; astronomically high blood levels were measured using finger prick samples. This was really alarming because we got up to 20 per cent carboxyhaemoglobin for smokers, with somewhat lower levels for non-smokers. Fortunately the Navy then improved its equipment for absorbing carbon monoxide from the submarine air.

We had to adapt to the changing pollution. In the early days, of course, it was mainly coal smoke. Gradually we had better quality fuels available, smokeless fuels, oil, thank God we had North Sea gas otherwise we wouldn't have got anywhere very fast.

Seaton: How were the experiments constructed? When you started doing human experiments, if you like, human toxicology, how did you get your subjects? Was there a discussion about who should be studied and how?

Commins: Yes, we hoiked in people from various sources and brought them in.

Seaton: How did you do that?

Commins: Well, Pat Lawther had charm and he managed to call people in. We measured carbon monoxide in their blood when they arrived at the laboratory, and we also performed psychometric tests on them to see whether the levels were significant, but they weren't. Even at 5 per cent carboxyhaemoglobin we couldn't detect any effects with psychometric tests, but at about 8 per cent carboxyhaemoglobin we could. We wanted to know the response to various pollutants. At about two parts per million of sulphur dioxide you could get bronchospasm in some subjects. At five parts per million, which we never got in the outside air, you could get bronchospasm very easily.[47]

Seaton: I guess we're talking about two slightly different things.

Commins: Sorry.

Seaton: The ambient air pollution: of course there is carbon monoxide in that, but it's at pretty low levels, so the carbon monoxide levels were clearly related to industrial situations, I would have thought, and accidental poisoning, suicide,

[47] Dr Brian Commins added: 'The maximum sulphur dioxide level we recorded in the air was two parts per million.' Note on draft transcript, 27 June 2015. See Commins and Waller (1967).

Figure 12: Professor Peter Tavner

and that sort of thing. Whereas the thing I'd like to know a bit about is the experiments on ambient pollution, if you like, particles, sulphur dioxide, things that, at that time, were seriously thought to be the cause of the bronchitis that we saw in the hospitals.

Maynard: May I ask a question? Brian, I'd like to know what was the approach used in the Unit to the high concentration exposures? Did you all volunteer or was it just assumed that everybody would volunteer, and so everybody was exposed? Pat Lawther, you, Robert Waller, and anybody else who happened to be in the Unit at the time: were you all exposed and what explanations were you given about possible risks to health of being exposed to what were, in fact, I don't think we have to call them heroic, but they're close to heroic, concentrations? 30 milligrams per cubic metre of sulphur dioxide; bronchospasm was inevitable. What did you do? Now, when I was a medical student we were expected to volunteer for things, and I remember objecting to that most strongly and being told that, actually, I was in a minority of one: 'All right-thinking medical students would, of course, volunteer.' How strange that I still seem to be in that minority after a long time.

Seaton: There was, in those days, a tradition in physiology that people did experiments on themselves. Everyone, and I include myself, we all experimented on ourselves and it was before [the days of] ethics committees. [Laughter] We did things that we couldn't have done nowadays.

Professor Peter Tavner: I was an electronics technician working with Chris Derrett from 1972 to 1973. I do remember the smoking in nuclear subs issue at Faslane because I'd just joined the Unit from the Navy, and I remember

Brian telling me about it and being amazed that we had still allowed smoking in submarines, but a point I wanted to make was about measurement. The physiological work at the Unit meant that we were trying to collect information from Professor Lawther's patients, who were paraded through the Unit and submitted to various chambers for respiratory measurement. Chris and I were trying to transform these measurements into online electronic signals that could be recorded on computer, stored and subsequently analysed. Because I wasn't used to the physiological background, I became very interested in it.

Just a bit of context: after I left the Unit I went to work for the Central Electricity Generating Board and understood about the SO_2 parts-per-million measurements made at power stations. I've got my Air Pollution Unit lab books here so I know the sort of measurements we got. I worked in the south-eastern region of the generating board during the miners' strike in 1984/5, when our oil-fired power stations were working at maximum output. There are two large oil-fired stations in the south east: Grain and Littlebrook. Our headquarters were in Bankside House, behind Bankside Power Station in London. During the strike – I remember, because I seemed to be the only person in our Scientific Services Department who understood about the physiological significance of these SO_2 measurements – staff were talking to me and saying: 'We're getting five parts-per-million of SO_2 on the roof of Bankside House. What's the cause of this, and is it bad?' I said, 'Well, it's bad, and what direction is the wind in?' It was basically coming from the east, which, if you drew a line on a map, showed a direct link between Grain, Littlebrook, and Bankside House. So, in other words, this massive dose was coming from the stations, being injected up into the air by their plumes, then falling down onto London in the region of Bankside House.

Commins: We were, if you like, willing volunteers in all the exposure experiments. I think we were sensible because we discussed very carefully all our experiments before we actually conducted them. In answer to your question about carbon monoxide, yes we did measure levels in street policemen, and various people exposed in streets.[48] The levels we found were up to 20 parts-per-million for a few hours. We never got very high levels in the blood, and that's the best estimate of exposure, except in smokers. Smokers absorb a lot of carbon monoxide, and so this is an important factor to bear in mind. But it was a fascinating area.

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[48] Waller, Commins, and Lawther (1965).

Talking about volunteers, Pat Lawther had a scientific background and there was one famous day when he said, 'Look, I want to increase the level of carbon monoxide in my blood so that I can find whether I'm affected.' So we took a big plastic bag and we had a cylinder of carbon monoxide gas, and we calculated that the level of carbon monoxide, once diluted with air in the bag, would not be too dangerously high. We did all the calculations. He was a bit impetuous on this day, we put the mixture in, and I said, 'Yes, I can check your calculations, it should be all right as long as it dilutes.' He said, 'It'll dilute!', and he became unconscious, briefly. The carbon monoxide hadn't mixed sufficiently enough – gases will diffuse and mix, but over a short timescale they don't necessarily do so. He recovered, fortunately.

Seaton: You think he learnt his lesson?

Commins: You know, a high dose of carbon monoxide can have an impact on the brain.

Seaton: Not good for you. I mean the ethics, I well remember a man called Pappworth who wrote a book called *Human Guinea Pigs* about this time, and pointed out that a lot of unethical experimentation was going on in notable units around the UK.[49] This gave rise to a great furore and that gave us ethics committees, and since ethics committees came in people have had to be much more careful about these sorts of studies.[50]

Derrett: I remember being involved in experiments breathing sulphur dioxide, and I don't recall any mention of safety at all. In fact, I can't remember anybody ever suggesting that there might be a possible hazard.

Seaton: What date was this, roughly, if you can remember that?

Derrett: This would be about 1969. I think for most of the time I was there, Pat was the only medically qualified person in the Unit. There were one or two medical people who popped in and out but it was mainly Pat. I recall breathing this sulphur dioxide and getting bronchospasm. There was no resuscitation facility from what I remember. There was a spray of isoprenaline, I think that

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[49] Pappworth (1967). In addition to his contribution to medical research ethics, Maurice Pappworth (1910–1994) focused his interests on postgraduate medical teaching to private students, preparing graduates for the Membership of the Royal College of Physicians (MRCP) exam; see Lock (2000).

[50] For a discussion of the impact of the publication of *Human Guinea Pigs*, see, for example, Pappworth (1990).

was the reliever, and that was the only thing that was available. But I think what was most interesting really was that we never talked about what would happen if we did get a serious event. It was just something we never, ever thought about. At least, certainly, I never thought about it. It's only now so many years after that I think, 'gosh, that was a dangerous thing to be doing'.

Seaton: Yes, it was a different era altogether, and the doctor was trusted by his patients and also by the colleagues who worked with him, and he could do pretty well anything he wanted. It was people like Bob, you know the odd one out, who might say, 'come on, what's going on?' I've got an anecdote, it's completely irrelevant. As a medical student we were all invited to take a new sleeping tablet, which was meant to be much safer than the barbiturates we were given before. So we queued up to do this and we got paid, I think, five shillings for doing it, and we swallowed the pills and went to sleep peacefully for about 24 hours and they occasionally drew blood from us. It was only after we'd finished this that we heard about this new drug that they were trying. It was called thalidomide.

Maynard: Having made my token protest as a student, of course, I volunteered [laughter], and what we were asked to do was to drink radioactive chicken soup, which I drank and I spent some time in the whole-body monitor so they could see which part of me the radioactive isotope had migrated to.

Seaton: Which part had it gone to?

Maynard: Bone, as far as they could tell me. No doubt where it's still glowing away quietly today.

Seaton: Okay, that's enough anecdotes.

Lord: Going back, you used the word 'trust', and I think that was a key word there. We trusted each other. When I was talking to Chris in preparation for this meeting a month or so ago, I recalled that the whole-body plethysmograph didn't have an internal handle inside it, so you were locked in this tiny chamber and you could not get out (Figure 13). This was an air-sealed chamber. There was an element of trust in all of what we were doing.

Seaton: Yes. They didn't put gas into the plethysmograph though, did they? Oh, they did?

Lord: I seem to remember we did put gases in though I can't remember the details of the experiments then.

Figure 13: Whole body plethysmograph, MRC Air Pollution Unit, St Bartholomew's Hospital Medical School, c.1968[51]

Derwent: I'd heard Pat Lawther give a talk on carbon monoxide, I don't know where, National Society for Clean Air, I think.[52] He talked about the diary studies; apparently there was a group of people in the Unit – I asked Ann [Commins] about this but she didn't know the answer – who measured carbon monoxide every morning as soon as they got into the Bart's Unit.[53] There was someone on a bike, there was someone walking, and there were a couple of others, but one of them always had much, much higher carbon monoxide than any of the others, and apparently Pat had worried about this for a long time. Finally they'd come to the conclusion that was the person who had had a cooked breakfast every morning. [Laughter] Perhaps you know which one of you actually had the cooked breakfast, Ann never told me that Brian had, so who was it?

Macfarlane: One of the things I remember being discussed was the fact that Robert Waller was asthmatic and that he reacted differently from other people because of his long-term asthma. I don't know if anybody's got any more precise

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[51] Still from British Pathé film: *Air Pollution* (see note 30). The operator of the plethysmograph in the photograph is Alan Brooks, the subject is unknown. Email from Mr Philip Lord to Ms Caroline Overy, 5 July 2015.

[52] The National Society for Clean Air was a non-governmental organization and charity founded in 1898 (the Coal Smoke Abatement Society) that campaigned for the removal of visible smoke, particularly that produced by coal, from the urban landscape. Its functions are now part of the Environmental Protection UK; see www.environmental-protection.org.uk/ (accessed 15 July 2015). See also page 65.

[53] For the diary studies, see note 20.

memories of that? About a later environmental exposure, this was the 'new pollution', it was thought to effect a release of catecholamines into the urine, and there was an experiment planned that people would walk from the station and then they would give a urine sample. What I do remember particularly about that was the discussion about the size of the bottle that they needed [laughter]. It got bigger and bigger, and finally someone said, 'I think some people are boasting.' It was only the men in this experiment.

Seaton: You mean the inlet into the bottle, you are talking about?

Macfarlane: Yes.

Seaton: Yes, rather than the amount of urine. [Laughter]

Commins: It's important to emphasize the importance of carbon monoxide, and the justification for us going into road tunnels and the middle of the streets was to see what the maximum exposure could possibly be. Then we measured levels of carbon monoxide in the blood of people as they came in from being exposed in the street. In the end we thought that for most people carbon monoxide really wasn't a problem, but it was important to go on further to see what was the importance of lead. I was heavily involved in lead in the air, and whether it was harmful.

Seaton: Before we go on to that, have we said all we need to say about the other pollutants? No. Let's save lead toward the end.

Maynard: One of the major contributions of the Unit, of course, was the early time-series studies, which were the studies done with a panel of chronic bronchitic patients who were asked – the 'diary studies' you called them – to record their health on a simple scale every day: 'better than yesterday'; the 'same as yesterday'; or 'worse than yesterday'. That was plotted against the sulphur dioxide concentration in the air, and that gave us those early graphs.[54] Now a little underrated but, at the time, it was most important work which showed a clear relationship, and by the time that the levels of sulphur dioxide and particles had declined, that relationship began to disappear. In fact, it was very interesting that it almost disappeared in the 1960s when the particle levels had come down despite the fact that the sulphur dioxide levels were still quite high. So that relationship was slipping away, and eventually slipped away completely.

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[54] See Waller and Lawther (1955, 1957).

Now, it isn't a criticism of those studies, but the analysis was primitive; the analysis was essentially a visual analysis of the studies. An important research worker in the area who visited the Unit, whom the older members of the Unit will remember, was Morton Lippmann from New York.[55] I've forgotten exactly when that was, it must have been in the 1970s, not long before the Unit closed, and he spent some months in London collecting and examining the data.[56] When the data were re-analysed there was still an effect, so that conclusion that you could no longer see the day-to-day effect between levels of pollutants and effects on health, that actually wasn't true. It was right that you couldn't see it, but it was still there on closer analysis. The Unit rather gave up on that, it didn't apply the latest statistical methods. I remember saying to Robert Waller: 'Was it that you weren't keeping up with the latest techniques of analysis, or what?', because Robert was a mathematician himself and a very talented epidemiologist. He said to me: 'The feeling was that the problem was over, that the sulphur dioxide and particle problem was over, and that anything that you now did was nitpicking. It wasn't worth pursuing it any further. There wasn't anything significant left to find.' I'd like to know what the older members here, forgive me for saying older, think of that?

Seaton: Before the more 'senior' members speak, Ross, you were about to interject something there, were you?

Anderson: Just to mention, the implication of the results of those diary studies and their publication, I think it was in *Thorax*, of the change to no visible effect, was extremely influential in the 1987 determination of the WHO as to what was a safe level of a combination of SO_2 and black smoke.[57]

Seaton: In what year was that published in *Thorax*?

Anderson: There were two publications, one showing association and then several years later, a second one. I don't have it offhand, I think it was 1966 and 1972, something like that.[58]

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[55] Professor Morton Lippmann is Research Professor, Department of Environmental Medicine at NYU School of Medicine.

[56] Thurston *et al.* (1989).

[57] Lawther, Waller, and Henderson (1970). See the chapter 'Sulfur dioxide and particulate matter' in World Health Organization (1987), pages 338–60: 'Significant changes in patients' conditions were observed when black smoke exceeded 250 $\mu g/m^3$ and sulfur dioxide exceeded 500 $\mu g/m^3$. Taking into account indications from some other studies, as in the earlier WHO report, the minimum level of smoke and sulfur dioxide needed to produce effects was taken as 250 $\mu g/m^3$'; quoted from page 350.

[58] Waller and Commins (1966); Lawther, Waller, and Henderson (1970).

Figure 14: Mr Simon Birkett, Professor Ross Anderson

Seaton: I'm just asking because, if the misleading one was published then, I was the Editor and responsible for it. [Laughter]

Maynard: It was not at all misleading, it was entirely correct.

Macfarlane: Just winding back a bit, because when I arrived in 1972 I was told that smoke and sulphur dioxide were then virtually below harmful levels, and you couldn't detect a difference in terms of daily mortality. I remember there was great activity in December 1972 because it was the twentieth anniversary of the 1952 fog, and there had actually been a severe fog in 1962 on the tenth anniversary. Everybody was rushing around in case there should be another ten-year repeat, and it didn't happen.

Seaton: There was in 1992, though, wasn't there?

Macfarlane: Yes, ironically. I took over the daily mortality studies from Robert Waller. I think there were two things: I arrived just at the time of the beginning of technology for automatic plotting, so instead of having to draw the graphs by hand you could do it on a microfilm plotter at the University of London Computer Centre. For anybody who's used to just drawing a graph on screen these days, this involved writing a Fortran programme, which was run on the mainframe, and then this wrote a file, which then was inputted into the microfilm plotter, and you got a piece of microfilm out. It might have worked, and you might have had a lovely graph. On the other hand, you might

immediately see that you needed to look at your Fortran output because you made a mistake and you had to resubmit. So it was like a 24-hour cycle in this. If it was a text slide, it was examined by Brian, another Brian (Biles), who taught photography evening classes, who told you you'd got at least three copies of the Bible on that slide and to make it much simpler[59] – pity he's not around to sort out some people's PowerPoint slides these days.

So we had the visual display, and, while I had been told that pollution had gone away, I looked at temperature and saw some heat effects, which we hadn't detected before. I remember giving a talk about it at the Association for British Climatologists, and an eminent medical geographer, Melvyn Howe, went on before me and talked generally about medical geography, and said: 'Of course we don't have any heat effects in this country.' Being eminent, he then left and I went on and showed the heat effects. I learnt from that, however old you get, make sure you listen to the young people. [Laughter] The other thing in terms of analytical techniques, I was trying to work out how to analyse the data but it was some years after that that [statistical] techniques of Poisson regression, which is what has been used in modern daily mortality studies, were developed.[60] I was too soon for that, and not a clever enough mathematician to invent them myself.

Lord: I came into the Unit a little bit before Alison and I was lumbered with this study of the people walking from London Bridge to the Unit – the London Bridge Walk experiment – and then having these physiological measurements done on them.[61] And yes, we did a lot of work, I think quite pioneering work in lab computing as well as using the mainframe computer for time-series analysis, and I do remember using the plotter at University of London Computer Centre too.[62] I had all the London Bridge Walk graphs along one wall of the physiology laboratory so that I could examine the peaks and the troughs in pollution against physiological measurements.

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[59] See further comments on Brian Biles on page 41.

[60] For Poisson regression analysis as a statistical method, see, for example, Frome, Kutner, and Beauchamp (1973). See also page 56 and note 136.

[61] See page 18. Mr Philip Lord commented: 'There were three people who did the "London Bridge Walk" – I think the other was Alan Brooks (the senior technician).' Email to Ms Emma Jones, 8 December 2015. Lawther *et al.* (1973a, 1977).

[62] Mr Philip Lord wrote: 'I also used the University of London Computer Centre microfilm plotter later to produce movie clips showing 3-D views of modelled lung alveolae as part of an exploration of lung morphology and hydrodynamics.' Note on draft transcript, 5 July 2015.

Getting back to the point that was made earlier, yes, there was a sense as we went into the 1970s and throughout the decade that the [air pollution] problem had gone away, or rather the original [sulphur dioxide and particle] problem had gone away and the Unit should be looking for more: 'What next?' I mentioned atmospheric lead earlier. There was also the asbestos issue that came up.[63] That was another issue that was treated by the Unit.

Macfarlane: Walter Holland actually wrote a report in about 1978 or 1979 saying the problem had gone away and no more research was needed, and clearly that contributed towards the closure of the Unit.[64] So that's why it stopped.

Lord: Just one rider there. I think one of the things which is not coming through in the discussion is the overwhelming importance of smoking to everything, nearly everything, we did. There was always a discussion about smokers and smoking. I remember when I joined the Unit I was a smoker. Within six months I'd given up. Never went back to it. But this was an overwhelming theme throughout my time at the Unit. Two levels: one is smoking per se, and its effect on people; it was an interest in the Unit I felt. Secondly, we were interested in the way in which smoking interfered with the studies that we were undertaking.

Going back to the sampling that we did, and it's just an anecdote if I may. I remember participating in an exhibition in the City of London where we did physiological measurements on people, and I remember taking physiological measurements on the Lord Mayor of London of the day. I'm afraid I had to tell him he'd better go and see his doctor. [Laughter] He was a smoker, he was a very heavy smoker.

Seaton: The smoking story: I suppose public awareness of smoking came about just about the time the Unit was set up.[65] It was known before that that smoking was a major cause of chronic bronchitis, as we called it in those days.[66] But at

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[63] Mr Philip Lord wrote: 'This reminds me of a habit of Lawther's – to produce a sample of some dangerous substance, or thought-provoking sample at staff meetings. I remember him variously producing a large bottle of nicotine (seemingly enough to poison the whole of London), a bottle of a particularly dangerous form of asbestos, and dried inflated human lungs.' Note on draft transcript, 5 July 2015.

[64] Holland *et al.* (1979).

[65] Anon. (1957).

[66] See note 36.

the same time, of course, that was the time of the great pollution, and pollution was also thought to be a cause of it. They were both thought to be causes, and as pollution went down for a long time, smoking didn't until people realised that it gave them cancer as well. It was in the 1950s that Richard Doll published his papers on cancer and so on.[67]

Commins: I've given our Chairman a copy of the results of the diary studies. For those who have not seen them, pass it round to observe how it [the relationship between the symptoms of chronic bronchitic patients and air pollution] changed over the years. I think it's important to try and understand the reason behind the changes over the 10-year period from 1959/60 to 1969/70.[68] I'd like to refer to these changes. In the early days, the major source of exposure was a lot of smoke and SO_2, and it pervaded everywhere. This situation has disappeared. Other effects, which are 'noise', if you like, are relevant in relation to the question 'Are you feeling better than yesterday?'[69] For example, 'My wife's nagging me' [laughter], and infections – there are so many factors involved, which make it very difficult to discern the impact of the declining, lower levels of pollution.

Seaton: Did you discuss the confounding effects of temperature, for example?

Commins: I think Alison referred to this. That's another important factor; not only cold but high temperatures too.

Macfarlane: Yes, I think the thing about winter mortality was cold, and even what you could see with the naked eye when the first cold spell of winter came, but also what was very obvious was the impact of flu epidemics and the fact

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[67] Doll and Bradford Hill (1950).

[68] See the graphs reproduced in Appendix 1 from Waller (1971) and the discussion in Lawther, Waller and Henderson (1970). Dr Brian Commins wrote, 'Data relates to 24-hour average concentrations of smoke and sulphur dioxide in London and the corresponding day-by-day health conditions of bronchitic patients. The results of two winter periods 10 years apart are provided i.e. 1959–60 and 1969–70 (October to March). In the earlier period, 24-hour levels of both smoke and sulphur dioxide exceeded 1 mg per cubic metre air on some days. Air pollution was declining during that period and in the winter of 1969–70 levels were much lower; smoke concentrations never exceeded 0.3 mg per cubic metre air and the sulphur dioxide levels exceeded marginally 0.5 mg per cubic air for one short period only. The comparison of the two periods demonstrated a striking correlation between pollution and daily changes in the condition of bronchitic patients for the winter 1959–60. However, the correlation markedly faded for the winter 1969–70 due to the lack of sufficient air pollution.' Email to Ms Emma Jones, 2 December 2015.

[69] See Bob Maynard's comments on page 28.

that there are usually two peaks in a winter: Type A Influenza and Type B. The report on the London fog referred to this, and Dr Martin was wrongly accused at the London School of Hygiene and Tropical Medicine Witness Seminar about the 1952 fog by an American, Devra Davis, of having tried to cover up the impact of the fog, whereas in fact he started the daily mortality study to study it.[70]

Derwent: I was invited to visit Pat Lawther in November of 1973 and it was on the occasion he'd had a letter from the World Health Organization inviting him to join in the writing of the Environmental Health Criteria documents for oxides of nitrogen and photochemical oxidants.[71] I was most surprised, he's the only professor that I'd ever come across by then who realised that he didn't know much about the subject and was prepared to pass the invitation on. So I was quite overwhelmed.

Seaton: That's a characteristic of professors, Dick. [Laughter] Didn't you know that? We all know a lot about something but the rest of knowledge, we don't have any.

Derwent: I was so impressed with Pat that he was so humble and he was able to admit that it was a subject beyond his area.

Seaton: So oxides of nitrogen: any comment on that from the MRC participants? Did they get a mention?

Commins: Yes, we measured oxides of nitrogen in Fleet Street, and we deliberately chose the site so it was right in the middle of the street and, of course, the exhausts in those days were pointing towards the middle, so that was the maximum exposure you'd get in streets. We found levels of nitric oxide to be much higher than nitrogen dioxide, and that was shown in road tunnels too.[72] These levels did not appear at the time to be a problem, from the basis of toxicological data that we knew. But they are important ingredients in photochemical pollution; I'd like that raised.

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[70] Berridge and Taylor (2005). For recent reassessments of the health impacts of the 1952 fog by Devra Davis, see, for example, Bell and Davis (2001) and Bell, Davis, and Fletcher (2004). The latter refers to the Conference with the Witness Seminar.

[71] United Nations Environment Programme and the World Health Organization (1977); World Health Organization Task Group on Environmental Health Criteria for Photochemical Oxidants (1979).

[72] Waller, Commins, and Lawther (1961, 1965).

Derwent: Just an observation. Wasn't the site in Fleet Street in a gentlemen's toilet?[73] Is that right?

Commins: If I may answer that: it wasn't in the toilet. [Laughter] It's no longer there, it's underground by the way, don't worry. We had sampling equipment there for several years; we used one of the cubicles there to put the equipment in and we had a pipe running up four feet above the street level. So it was representative of the outside air rather than what went on inside.

Seaton: It didn't sample the ammonia?

Maynard: Two points: One was an additional anecdote to that because Pat used to say, 'Come and see me at my convenience.' [Laughter] The more important point was, and this will lead on into the second half of the discussion today, I think, that people found it difficult to believe that levels of pollution which didn't produce effects in toxicological studies and were acceptable in industrial settings, that levels lower than that could produce effects in an ambient setting. We've heard that said already and Brian, a moment ago, said the nitrogen dioxide levels were not high in comparison with what we knew from toxicological studies, and what we knew from, what we accepted as, industrial exposure standards. I well remember you, Chairman, and me wondering about the effects of current levels of particles because what we both had in our minds were the industrial standards for particles. I remember wondering that. We didn't wonder for very long but we did wonder about it.

Seaton: No, but we did.

Maynard: We did, I worried about it certainly. The other thing I wondered about were the levels of ozone that we now have in the UK, and whether they could produce effects on health. They seemed to be low when we began our work, but that's for the second half of this discussion. I wanted to ask members, or senior members, how much influence toxicology had on what you thought because Pat Lawther was not an animal toxicologist at all. He read the animal literature but he wasn't an animal toxicologist. His interests were in medicine, human toxicology, the sort of thing done with volunteer studies, and in epidemiology. Those were Pat's interests, and industrial medicine, of course, he was very strong on industrial medicine. I wonder how much animal toxicology was discussed in the Unit at that time? I know there was a link between it

[73] The Fleet Street conveniences in the City of London were elaborate underground facilities opened in 1904 and designed by the George Jennings Company. See Penner (2013), pages 73–5.

and my old establishment at Porton Down, where we were doing an enormous amount of animal toxicology in the 1970s.[74] The Air Pollution Unit was still running at that time and there was a link between the two – Pat Lawther sat on one of our committees[75] – but did you discuss animal toxicology to any extent?

Seaton: Well, now Bob's rightly taken over the chairmanship [laughs] and Ross had his hand up. Were you predicting his question and going to answer it?

Anderson: No, no, I thought he was going to come clean about his use of volunteers when he was at Porton Down.[76] It's a question: I'm interested to know from members of the Unit what their concept of the mechanism of health effects was thought to be at that time, particularly because we now know that cardiovascular effects are very prominent, but this was not something that was really thought of, and I'd be just very curious to know what people thought was actually going on mechanistically?

Derrett: If I could just answer the question about animal experiments because I think it's quite interesting that animal experiments weren't really on the cards. There was one guy from Porton who came up to the Unit called Pattle. He was the chap who pioneered the work on surfactant.[77] He came up, I remember, with a cage of guinea pigs, stuck them in the exposure chamber on the roof for the day, and then brought them down and killed them, and took them back to Porton to dissect. I think that was the only example of an animal experiment that I can recall. There were a lot of animal lovers there. I think we were all a bit squeamish about animal experiments; it was a personal thing. A number of individuals preferred that we were not involved, but there may have been some animal models that would have been very appropriate.

Lord: I think Chris is right. I don't remember there being animal models and I have no recollection of any animal experiments at all, but I stand to be corrected on this. My recollection is that they were never discussed.

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[74] For the history of Porton Down see Carter (2000).

[75] Patrick Lawther sat on the medical committee at Porton Down 'dealing with research into mechanisms of physical injury (trauma studies) and the effects of organophosphorus compounds': Maynard (2008).

[76] In 2001 the Ministry of Defence launched an inquiry into the use of volunteers in experiments with chemical nerve agents at the Chemical Defence Establishment at Porton Down. This was brought about by public concern following the reopening of an inquest into the death of an airman in 1953. Adam (2001); Ministry of Defence (2006).

[77] Richard Pattle was a biophysicist working at Porton Down whose research focused on the pulmonary surfactant system; see Hughes (2001).

Tavner: I don't remember any animal experiments in my two years at the Unit, 1972 to 1973, but I do remember animal experiments going on in our building at Barts, and it was an issue. Professor Joseph Rotblat was working at Barts on radiation effects on animals, and people in the Unit talked about it in a very disparaging way.[78] I do remember that.

Seaton: That's very interesting.

Maynard: It's an insight, isn't it, into the isolation that you get in units where most people nowadays would accept that you can study the effects of pollutants on cells, in in vitro systems or in living animal models, human volunteers, or epidemiologically, in that you try and tie the whole thing together if possible. In the Unit then, perhaps because Pat Lawther was not an animal experimentalist himself, the thinking was biased away from animal experimentation and away from that sort of literature. It's worth adding that Dr Pattle, who was mentioned a minute ago, his name was Richard Pattle and he was from Porton Down where he spent most of his career, and he did discover surfactant, the material that lowers the surface tension in the human lung. It was a discovery of enormous importance in respiratory physiology. I knew him well, and he was a friend of mine; an outstanding physicist by training and later an outstanding biophysicist.

Lord: We did employ a microbiologist in the Unit for some while, Theresa Block, who was looking at *Haemophilus influenzae.* So we did some microbiological work and I can remember Chris Derrett's brother doing some, coming in for a vacation job or similar to model the way pollutants acted on growth on agar plates or something like that.[79]

Maynard: Can I ask about electron microscopy? One of Robert Waller's major contributions, certainly in the later years, was that he introduced the use of electron microscopy into the examination of airborne particles. Robert can't

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[78] Professor Peter Tavner wrote: 'One occasionally saw experimental sheep with stomach stomas being brought up in the lift.' Note on draft transcript, 4 July 2015. Joseph Rotblat was Professor of Physics at St Bartholomew's Hospital Medical School from 1950 to 1976. In 1995 he was awarded the Nobel Peace Prize jointly with Pugwash Conferences on Science and World Affairs 'for their efforts to diminish the part played by nuclear arms in international politics and, in the longer run, to eliminate such arms'; see www.nobelprize.org/nobel_prizes/peace/laureates/1995/ (accessed 8 September 2015).

[79] Dr Chris Derrett wrote: '[My] brother Nigel was a mathematics undergraduate at Oxford and he worked in the Air Pollution Unit during a vacation. His work involved mathematical modelling of diffusion of chemicals on an agar microbiology plate. Nigel subsequently took a PhD in information technology and spent his career working in both universities and the IT industry.' Email to Ms Emma Jones, 13 November 2015.

be with us, but other people here might be able to say something about the use of electron microscopy and in particular the use of it for particle counting, counting particles of specifically identified sizes. I'm interested because, at one time, I had all Robert's photographs pinned up in the corridor, which Heather Walton will remember. All the pictures taken in London at that time of particles using the electron microscope, so it's an interesting area.

Seaton: It's a question and we'll get an answer to it, but I think Ross had a perhaps slightly more fundamental question, which was about whether people just looked at respiratory disease, or did they consider cardiac disease as well?

Anderson: Well, there seemed to be a general assumption, which was that air pollution had respiratory effects and actually, if you look at the London smog data, then you get quite clear effects on cardiovascular disease, and the autopsies that were done showed that these were not deaths that were associated with chronic respiratory disease. So the idea that the cardiac event occurred in someone who was already vulnerable through respiratory problems was not supported. Some of the epidemiology, the work by Daly, for example, on mortality and air pollution, didn't bother to look at cardiovascular disease at all.[80] And with all these experiments that were going on, I'm interested to know in a way, what sort of hypothesis was being tested, what was the postulated mechanism that they were trying to investigate? What was the concept that was underlying this work, really?

Seaton: Yes, that was really my very first question when we started. What was behind it?

Macfarlane: As soon as it was possible to get more than overall counts, and I think that's going back to 1965, which is before my time, when data were got from the London County Council – they had probably just bought a computer – the daily mortality studies looked at deaths with 'cardiovascular' underlying causes separately from 'respiratory' and 'other', which is mainly cancer. But, of course, what we didn't have at that time was multiple-cause coded data, so that you could separate the death certificates, which mentioned both cardiovascular causes and respiratory conditions on them, from those which only mention one or the other. I did try to look at multiple-cause coding, which didn't really come in until much later on, but it certainly wasn't available at my time at the Air Pollution Unit.

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[80] See, for example, Daly (1959).

Seaton: And did that observation lead to any studies, any questions about the possible causes of death?

Macfarlane: I don't think it went on to other research; other people might correct me. It was just noted that the deaths with cardiovascular underlying causes did increase with air pollution.[81]

Commins: Firstly, I'd like to answer a question about toxicology. Yes, we did very little on toxicology. But we were well aware of the mechanisms.

Seaton: Can we pursue the question that was asked directly, please, which relates to speculation about causes of cardiac associations with air pollution? Have you a comment on that?

Commins: Yes, a very brief comment. Well, there were questions – we didn't investigate those in any detailed way.

Seaton: Do you remember talking about it and wondering?

Commins: Oh, yes we did. But we had limited resources in terms of people. The thing that we did do, talking about gassing people, we carried out work with Dr Lynne Reid at the Brompton Hospital, and set up an exposure chamber for her guinea pigs exposed to sulphur dioxide.[82] But in reference to the specific point as regarding the effects, we had no real idea what caused the effects on people. It could be a combination of all the ingredients in the air, and added to the very cold conditions but we couldn't discern the differences between them. It's very complicated.

Derrett: Regarding this question about whether the heart was being considered at all, I don't think it was because there was a chap called Bill Whimster, who was a pathologist at Barts who did research on lungs, and I remember him bringing post-mortem specimens – and they were just the lungs, there were no hearts involved – and he brought them over to the Unit to work on.[83] I'm sure he wasn't interested in hearts. Rather ironically, a few years later he died suddenly

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[81] Martin (1964).

[82] See Reid (1963). This article thanks Brian Commins and Pat Lawther for their help with the exposure chamber.

[83] William Whimster (1934–1997) left the Air Pollution Unit in 1974 to become Senior Lecturer in Morbid Anatomy at King's College, London; from 1983 he was Reader, and, from 1991, Professor and Head of the Department of Histopathology. See Paton (1997).

from a heart problem after skating along the prom [while] at a conference in Brighton. I think the whole preoccupation of the Unit was around respiratory things and other organs didn't seem to feature.

Maynard: I think that's probably right. The Unit was set up to investigate pollutants that were inhaled from the air. The recruiting was along the lines of people who could measure levels of air pollutants, people who could devise sensors to measure levels of air pollutants, and the use of volunteer studies. It seemed obvious, I assume, to Pat Lawther at the time, because I knew Pat very well, that the effects were going to be respiratory, and that was borne out by the high concentration studies with sulphur dioxide. So when they exposed volunteers, they saw respiratory effects. That was perfectly reasonable. When you lowered the concentration, the respiratory effects disappeared. When the ambient concentrations dropped, the respiratory effects disappeared. It seemed a perfectly valid conclusion that there was a threshold of effect and that the Unit had been quite right to focus on the respiratory effects of sulphur dioxide, the particles. I don't think it's even possible that the Unit could have switched to thinking about the cardiovascular system. I think the whole tone of the Unit was focused around the respiratory system. It's a bit like asking of the Pneumoconiosis Unit at Llandough, which you knew well, Chairman, what were their thoughts about cardiovascular disease? And the answer would have been, 'not very many,' I suspect.

Seaton: No, none.

Maynard: Not very many at all, in that the whole unit was tuned to respiratory physiology and respiratory industrial medicine.

Seaton: I'm sure we'll talk about cardiac disease in the second half of this, at length even, but the interesting thing is the observation that the MRC Unit made did show that more people died of heart attacks than of lung disease.[84] That was one of your observations. Interesting. Says something about how units run.

Derwent: Before you move off onto the new areas, could I make an observation about Pat? So I'm going back to December 1972, to the NSCA (National Society for Clean Air) conference, 20 years after the London smog, and Pat Lawther gave the keynote address.[85] I went up to the meeting in London with Irene Earp. She led the records section in Warren Spring Laboratory and Pat was giving his standard talk, I guess, about the London smog and he made this comment about

[84] Cardiovascular mortality and morbidity data is discussed in Martin (1964).

[85] For NSCA, see note 52.

how the London smog harvested the 'tatty grannies'. I remember looking at Irene Earp and she was in quite a state, and afterwards I said, 'What has happened?', and she said, 'Well, my grandmother, she died in the London smog.' So that's what I remember about Pat's language at times – it could be unembroidered.

Seaton: Yes, well it was an observation that it was the older people, younger than most of us here, but older people who died particularly, wasn't it?

Macfarlane: Well, it wasn't just the older people, it was just that more people were in a near terminal state in that age group. Certainly I had Pat telling me to write a paper on 'you can't kill granny twice', and what he was saying was if you got successive insults then people might be likely to succumb to the second one. If you've had a cold winter then they might be likely to die in a heatwave, but, of course, we couldn't possibly prove that from the data we had, it was just a hypothesis. As far as electron microscopy is concerned, it was the other Brian (Biles) that did it. Yes, the teaching of photography evening classes and getting us not to put too much on the slides was his hobby and sideline, and he was the electron microscopist in the Unit. I don't know if anyone's still in touch with him?

Seaton: What came out of the electron microscope studies?

Derrett: I think you were asking about counting things – I don't recall very much counting of things. I think it was mainly asbestos that was looked at. That was certainly Brian Biles' interest and my feeling is that we probably didn't do enough microscopy. Brian Biles had two jobs: he was an electron microscopist and he was a photographic technician. At that time there was an enormous amount of work in the Unit doing photography, because when you published anything the production of the images was a really lengthy business and involved quite a lot of photography. He was a very talented guy who was rather split, and I think mainly the work he did ended up being asbestos-based.

Seaton: Was there something else behind your question, Bob, on that?

Maynard: He certainly did some asbestos work. Robert (Waller) had published figures on concentrations of particles, determined number concentrations with the electron microscope: 10,000 per cc under normal conditions rising to 100,000 in the Blackwall Tunnel, that sort of thing. He also showed photographs of droplets spreading out onto the surface of filters, and talked to me about the sulphuric acid content of the droplets. There was great interest in it. Robert Waller's work was published in 1963.[86]

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[86] Waller, Brooks and Cartwright (1963).

Commins: Yes, we had electron microscopes. We were very privileged to have one, and yet another one later. In reference to particles, I have a paper here: 'Airborne lead and uptake by inhalation'. The authors were Pat Lawther and myself, John Ellison and Brian Biles.[87] There are some fascinating pictures of particles and the size of particles in here from both diesel engines and petrol engines.[88] I'm very grateful to Brian Biles and all the work he did.

Seaton: Lead has been raised and it was another interest of the Unit. Would you like to say a word or two about lead? Where did that start?

Commins: That started really from the pressures we had from certain people about lead in petrol and its release to the air. Dear old Professor Bryce-Smith caused a lot of problems for us.[89] He had a bee in his bonnet, if you like, about lead, and justifiably. It's not a good chemical. Alkyl leads, which are added to petrol, are really nasty toxicologically. So we looked into the contribution that lead makes to the body when you're exposed to it, and we did a fascinating experiment on taxi drivers in London.[90] In those days some taxi drivers preferred to work at night, some during the day. Naturally, the exposure of the night taxi drivers was lower than the day ones, and we proved that by measuring the carboxyhaemoglobin level in the blood, which was lower for the night drivers. Also, we again detected the impact of smoking on carboxyhaemoglobin levels, but then we looked at the blood levels of all these drivers and they were roughly the same. Therefore, the contribution made by airborne lead was quite small in comparison with the total lead input regarding our exposure overall. We measured lead in air in streets and the levels were quite low, being just a few micrograms per cubic metre of air.[91]

Regarding Bryce-Smith, I had to appear on television against him once where George Porter was the chairman. It was at the Royal Institution and I had to battle against him because he considered that Spaghetti Junction was a serious

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[87] Lawther *et al.* (1972). See also Lawther *et al.* (1973b).

[88] Dr Brian Commins wrote: 'Both types of engines emit very minute particles which can be inhaled into the depths of our lungs.' Note on draft transcript, 27 June 2015.

[89] Derek Bryce-Smith (1926–2011) was Professor of Organic Chemistry, University of Reading from 1965 to 1991. He was the first to draw attention to the toxicity of tetraethyl lead additives in petrol and actively campaigned for unleaded petrol; see Gilbert (2011). See further discussion on page 44 and note 95.

[90] Jones, Commins, and Cernik (1972).

[91] Waller, Commins, and Lawther (1965).

health problem: 'All this lead coming out is poisoning us all.'[92] But there was no firm evidence that we could identify to justify that petrol lead was a significant health issue. As you know, lead alkyls were added to petrol to stop the engines knocking. They now add other ingredients which do just as good a job, but lead wasn't a problem really as far as we could judge for the general public.[93] It can be a problem for young children sucking or chewing lead-containing toys and painted surfaces, thereby ingesting lead, and it can be a problem for people exposed to lead in industry, but for the general population we were happy in the end to say that lead in the general air was not a problem. We did a lot of work on that issue.

Derwent: Just to say that Pat Lawther's work on lead culminated in the Lawther report, and a member of his committee was Arthur Chamberlain from the UKAEA (UK Atomic Energy Authority) in Harwell.[94] Arthur persuaded Associated Octel to make some leaded petrol with a different isotopic ratio in the lead, which they then burnt in a Honda petrol engine. They filled a chamber into which Arthur walked and breathed and he went out like a light, because they'd forgotten to take the carbon monoxide out, hadn't they? Anyway, they recovered Arthur and put him back in the chamber, having taken the carbon monoxide out, on the next day, and he breathed the isotopically labelled lead. He then went down to the whole body monitor and they followed the lead for a period of two months. The upshot was to find that the lead went, as Pat Lawther had guessed, into the blood, but then the whole body monitoring showed that it went straight into the bone. There it formed a pool of exchangeable lead, which then fed the blood and the excretion system over the next few months.

Seaton: And the brain.

Derwent: And the brain, yes. In a sense, that result was quite disappointing for the Lawther committee because what it showed was there was absolutely no difference between the lead, which came by inhalation through air and the lead, which could have been taken up by drinking water or food, or such as that, because it all fed the same exchangeable pool. So Lawther, in his report,

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[92] BBC Two television programme 'Controversy: Health Hazards from Lead Pollution', broadcast 30 August 1971.

[93] See, for example, an account of the MRC Epidemiology Unit's Environmental Lead Studies from 1976 to 1982, and its conclusions that lead in water was a significant public health problem in comparison to lead in air: Ness, Reynolds and Tansey (eds) (2002), pages 124–6.

[94] Department of Health and Social Security (1980).

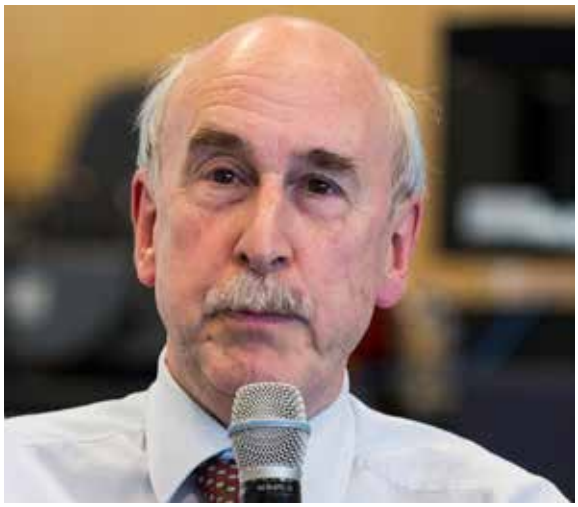

Figure 15: Professor Roy Harrison

faced an inevitable conclusion that all sources of lead were more or less the same and it was just a question of the total dietary intake. That was too much for this Professor Bryce-Smith, who thought that that was a complete fudge. Unfortunately, Bryce-Smith had the media on his side, particularly the *New Scientist*, and so the Lawther report was really, well it went down like a lead balloon, that's the only way you could describe it.[95] [Laughter]

Lord: I think he didn't play the politics of this quite right. I think he had far too close a contact with the lead industry, the people that were actually producing tetraethyl lead. I can't remember the name of the company now: Associated Octel?[96] He had close associations with that company and I think that probably also spoiled his case. He lost the politics of it.

Professor Roy Harrison: I came into this field in 1972 to work on a project on lead in air at Imperial College, and I had some contact with the Unit. I remember meeting Brian in those days, among others, and, of course, Pat Lawther and other members of the Unit.[97] I think there probably wasn't an

[95] For a commentary on the Lawther report, see Bryce-Smith and Stephens (1980, 2nd edition 1981). For Bryce-Smith see note 89.

[96] The Associated Octel Company Limited (now Innospec Inc) produced and sold an 'anti-knock' compound (formed from tetraethyl lead and dibromoethane) which, when added to petrol, increased an engine's power.

[97] The project's title was 'The Contribution of Organolead compounds to Lead Concentrations in Urban Air'. Note on draft transcript from Professor Roy Harrison, 23 October 2015.

adequate perspective in Pat Lawther's thinking about the environmental cycling of lead and the fact that you could show through these kinds of measurements on taxi drivers that respiratory exposure was not having a large impact on blood lead directly. But what was being ignored was the fact that the lead in air was then depositing into dusts and soils, directly into crops and thereby cycling around and contributing more substantially to lead exposures, although there were other very important sources like lead in solder in cans and things like that. So lead in air through petrol use was only one of many sources. Nonetheless, it was much more important than one would have assumed purely from looking at respiratory uptake, although the Harwell work that Arthur Chamberlain led that Dick was referring to was quite important in showing that was a significant route of exposure because the absorption through the respiratory system was much more efficient than that through the gastrointestinal tract.[98]

So this was important, but, to put it in perspective, the occupational exposure limit at the time was 80 micrograms per decilitre of blood, and in the general population levels were around 20 or so, so they were really quite an appreciable proportion of the occupational exposure limit. I think there was a fair argument that, in adults, they were largely without effect but once the epidemiology got really to grips with studying children and the effects on intellectual development in children, it would seem that much much lower exposures were having an effect.[99] Nowadays they don't measure in micrograms per decilitre, they measure in micrograms per litre. They worry about levels of around 10 micrograms per litre, which would be one microgram per decilitre, a tiny fraction of the levels that I grew up with. So I hate to think what kind of intelligence I might have had if I hadn't grown up with 20 micrograms per decilitre. [Laughter] I'm not sure that the Unit really distinguished itself in this area, possibly by having too narrow a perspective on it, by focusing on the inhalation exposures. It comes back to that I think.

Macfarlane: I certainly remember the links with Associated Octel and the horrors of the Bryce-Smith bandwagon, but I've a memory of a study that was to measure lead in the air in the Hendon area before and after the opening of the extension of the M1 to Staples Corner. I remember going around Hendon, scoping it, looking for sites to put measurement equipment with, I think his name was, Tony Turner from Warren Spring. It was during a general election

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[98] Chamberlain (1985).

[99] See, for example, Koller *et al.* (2004).

campaign and Tony Turner was a keen supporter of Stevenage Labour Party, and his car was well decorated with the name of the candidate Shirley Williams; the residents of Hendon were rather confused and couldn't quite see the link with lead.[100]

Maynard: I think it's just another example, isn't it, that the Unit was focused on respiratory matters and on inhalation, and what Pat Lawther thought he'd been asked. Whether it was exactly what he'd been asked I don't know, but he thought he'd been asked to find out how important the intake of lead from the air was, and that's what he did. The answer was: not very important, not in comparison with other sources of lead. I think that is true, but it also reflects the perception of thresholds. That perception was universal at the time: that you could reduce the level of exposure to a toxic compound to a safe level as long as it wasn't a genotoxic carcinogen. You could reduce the level of exposure such that it would have no effect on health at all, and that was generally believed by everybody in the field. Even things like lead, it wasn't a genotoxic carcinogen, we didn't know, people didn't know in those days very much about its effects on IQ, and so the assumption was that there would be a lower level at which there would be no effect. I think that reflects the thinking of the 1960s and 1970s.

Seaton: Well, it reflects the difference in thinking between a clinician, who is concerned with an individual, and an epidemiologist, who is concerned with populations. The clinician finds it difficult to believe that there isn't a threshold, because individuals can be exposed to low concentrations of everything and survive.

Maynard: Do you know, Anthony, it's extraordinary, just for a moment I thought you were going to admit that clinicians could occasionally be wrong. [Laughter] Is that right? And you have?

Seaton: Have I not just done that?

Maynard: Forgive me, you have; brilliantly.

Anderson: Bob just made the point that I was going to make. Thinking back to that period, there are two things. One is the idea that there is a threshold – that came from theoretical considerations and from the occupational hygiene thinking for protection of workers. But the other concept, which is

[100] Professor Richard Derwent commented that this was Dr A C Turner, a skilled chemical analyst in the Air Pollution Division at Warren Spring Laboratory. Email to Ms Emma Jones, 24 November 2015.

very important here, which might have been internalized, but has been used much more recently to explain the health effects of air pollution – because I think there's a parallel here with air pollution – that is the idea of multifactorial causation of disease, that many of these pollutants are an added factor to a whole group of other risk factors, which, if they come together, lead to a clinical event.[101] On their own they can't do it. We appreciate that much more now, and that is the main explanation for most of the health effects. Thinking back at that time, I don't think that this was very clearly articulated. So these two things come together to give a very reasonable explanation for why the Unit had this approach.

Seaton: Yes, I can understand that completely from my knowledge from how one thought at that time. It was one cause for one endpoint, and you focused on that.

Derrett: There's one other issue that you haven't dealt with, which I think is relevant to the previous discussion, and that's the passive smoking issue. I think this is another area where I wonder whether the Unit had a very one-sided approach. Pat Lawther was very much of the opinion that there was no danger to children if their parents smoked.

Seaton: Brian doesn't agree.

Derrett: Brian doesn't agree, but certainly there was not a great deal of work on passive smoking going on when I was there.

Seaton: Was there work on active smoking?

Derrett: No, not really.

Seaton: No, maybe smoking was being dealt with by others. I was just going to ask about the eventual closure of the Unit, and I'd like to hear some views on that.

Williams: It may seem surprising that I step in to talk about the closure of the MRC Unit, but I just wanted to point out the wider context of what was going on at the time in the mid-to-late 1970s. We've already heard about a view from the Holland report that suggested that the problem had been solved.[102] I think that was a fair reflection of what was going on. There was also the concern

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[101] See Anderson (2009).

[102] See page 32.

about the new pollutants; we've heard about NO_x, and so on.[103] Dick has already referred to the Fuel Research Station in Greenwich, which moved out to Warren Spring Laboratory – part of it became Warren Spring Laboratory in Stevenage in 1967, I think, Dick?[104] It was set up as a sort of multidisciplinary laboratory but looked at air pollution too.[105]

Derwent: It was 1959.

Williams: Oh right, well gosh, it's even earlier than I thought. At that time, Dick was there and had gone when I arrived, but the Department of Environment had then set up research into the new pollutants and the so-called Five Towns Survey, which was measuring effects of vehicle pollution: NO_x, CO, hydrocarbons, and so on.[106] Measurements of ozone were going on, and so you had that whole scenery changing. I can't speak for the internal thinking of the MRC, but I suspect there was probably a view that there weren't going to be many Nobel Prizes in air pollution research at that time.

Seaton: I remember that time very well, because of the MRC Unit at Llandough Hospital in Cardiff, and the MRC, of course, reviewed its units when the directors retired or were about to retire and closed them down if they didn't seem to have a viable future.[107] I think it may have been in this context that the Unit closed.

Commins: Quite right, I got out in 1975 because it was due to close with Pat Lawther retiring in a few years. At the time I could not see a future for me because we'd investigated many issues, we found that there was no evidence that motor vehicles were causing a significant public health problem for the situation as it was at the time, in the 1970s. There was a lot of concern about diesel engines and cancer, but we could see no justification for that; we only found tiny amounts of 3:4 benzpyrene coming out of diesel engines based on

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[103] Nitrogen oxides: NO (nitric oxide) and NO_2 (nitrogen dioxide).

[104] See page 14.

[105] The Warren Spring Laboratory in Stevenage was the government's environmental research laboratory established in 1958/9 with research and development into chemical engineering, mineral processing, and atmospheric pollution. Records are held at the National Archives; http://discovery.nationalarchives.gov.uk/details/r/C865 (accessed 21 September 2015).

[106] Apling, Potter, and Williams (1979); Apling *et al.* (1979 a–f).

[107] See the discussion on the closure of the MRC Pneumoconiosis Research Unit and the MRC Epidemiology Unit in Ness, Reynolds, and Tansey (eds) (2002).

our bus garage and road sampling work.[108] In addition, the studies with respect to air pollution and lung cancer, which Robert Waller and I and Alison got involved in, we couldn't detect a significant effect from air pollution causing lung cancer per se.[109] So we really got to the stage where we couldn't justify our existence in some ways unless we made a change in another direction, but what I'm so pleased about is that modern thinking has shown that air pollution seems to have an important role on long-term exposure to people. Of course, the pollution is now different, I mean we talk about it being different these days.

Seaton: MRC Units were very dependent, they were built around the director, as I recall it; a person of great eminence who had a strong research background who had his team around him, and when he retired they thought seriously whether it was going to continue. Also, the Air Pollution Unit itself, from what I've gathered from the discussions, was beginning to be a bit sceptical about the importance of air pollution as a public health issue at the time.

Lord: It was also a small multidisciplinary unit; in fact, this was one of its characteristics and people working there had a lot of freedom to follow their research programmes, but they were working on their own and so there was just one physiologist or one physician there and so forth. You were working in some isolation. I am wondering, it just occurred to me, if the issues which were coming forward at that time were becoming too complex for such a unit, which had good people but they were working individually and they couldn't tackle these larger issues.

Seaton: Very reminiscent of the MRC Pneumoconiosis Research Unit in Cardiff.

Lord: Possibly, but I don't know. I do remember, I think I got out just before the end, that it had actually changed its name by the time I left to the Environmental Hazards Unit. It was going to be incorporated somewhere else, but then I disappeared.[110] Another thing I'd like to say about it, being multidisciplinary, it was also seen as a bit of a window into the scientific world. I do remember at some time during my time there, a film was made of the Unit and its work. It

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[108] Commins, Waller, and Lawther (1957).

[109] Waller and Commins (1967).

[110] Mr Philip Lord wrote: 'I think it was to become, or to be absorbed into, the Toxicology Research Unit at Carshalton.' Note on draft transcript, 5 July 2015.

was a promotional film for British science.[111] Ah, yes, it's the only time I've ever been in close contact with Maggie Thatcher, because she was sitting behind me in the auditorium of whatever Ministry we were at where we saw the finished product. I'll say no more, I am just wistful of the opportunities missed.

Seaton: What we haven't mentioned really, except in passing, is that air pollution was decreasing rapidly over the period of the existence of the Unit, and quite dramatically and so there was a feeling around that the problem had been solved by appropriate enforcement of legislation.[112]

Maynard: To reflect on some things; I saw a great deal of Robert Waller because I worked with him, and I'll talk about that in a minute, but I saw a lot of Pat Lawther in the last two years of his life. I used to visit him in the old people's home that he was in and we talked a great deal about air pollution and about other things too. The impression I got, and, of course, it may be wrong, and senior colleagues should correct me if they like, was that Pat himself was quite convinced that the great problem that he'd been given had been dealt with. It wasn't that he thought that all air pollution problems had been dealt with; that was slightly different. He thought that the great problem that he'd been given, and that was the high sulphur dioxide; high particle concentrations; coal smoke; the London smog problem, that's what he thought he'd been asked to sort out, and he thought his team had sorted it out. That's where he got to. Then, when I used to ask him, 'What do you think about what's happened since?' he used to say, 'Well, that's different; that's not the same problem.'

We agreed to differ on many things but I agreed with him that he had driven the sulphur dioxide and particles problem into submission as far as he could using the techniques that he had at the time. Not everybody would have agreed with him, and certainly Morton Lippmann in the States would have said that

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[111] In addition to the British Pathé film (see note 30) Philip Lord wrote that a '… second film was made *c.*1973, and I remember the filming of it and the first showing at the Department of Education and Science with Thatcher (who was Secretary of State, 1970–74). My recollection is that the film was made for promotional purposes – perhaps to boost careers in science. … I seem to remember it was about 30 minutes in duration. I do not know if this still exists.' Email to Mr Adam Wilkinson *et al.*, 5 July 2015.

[112] See note 10 for the Clean Air Act of 1956. This was followed by a further Clean Air Act in 1968, regulating chimney height in industry and the emission of black smoke; and the Control of Pollution Act of 1974 regulating the composition of, and amount of sulphur in, motor fuels. Other EC directives controlled emissions from petrol and diesel engines, and the sulphur and lead contents of fuels; see the timeline at www.air-quality.org.uk/02.php (accessed 22 September 2015).

he had not used the modern techniques of multiple regression analysis, which were available for looking at the time-series work.[113] Morton would have been critical about that, and still is critical about it, but that at least was Pat's view.

Remember, it was Pat Lawther who agreed to the closure of the Unit. He didn't actually retire, he moved from the Unit to Carshalton and he was in what was called the clinical research section of the MRC Toxicology Unit at Carshalton for two or three years, I guess, before he took complete retirement.[114] So his view was that it was right to close the Unit when it was closed.

Williams: Well, there are some who would argue that it was probably Gerald Nabarro who solved the problem back in 1956, actually, but that's another story.[115] I just wanted to point out the fact that, yes, there was the perception that pollution was going down, problem solved. The problems were actually changing. At that time, in 1978, the negotiations were beginning on the first EU Directive on air pollution. It covered smoke, or particulate matter as it was known, and that meant the problem was a shift not from some of the basic science that the Unit was looking at, but more the issue of how you dealt with the problem and how you went armed into negotiations in Brussels.[116] Dick already referred to Irene Earp and the Records Office in Warren Spring.[117] Their big role was servicing some twelve hundred measurement stations across the country for the National Survey of Air Pollution.[118] They were a team in Warren Spring mapping by hand, I have to say, using tracing paper and so on

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[113] See page 29.

[114] The MRC Toxicology Unit was set up at Porton Down in 1947 and moved to Carshalton in 1950. See their website at http://tox.mrc.ac.uk/ (accessed 22 September 2015).

[115] Sir Gerald Nabarro (1913–1973) was a Conservative MP for Kidderminster from 1950 to 1964, and for South Worcestershire from 1966 until his death. In 1955 he introduced the Clean Air Act as a Private Member's Bill. For the second reading see http://hansard.millbanksystems.com/commons/1955/feb/04/clean-air-bill#S5CV0536P0_19550204_HOC_79 (accessed 22 September 2015).

[116] EC Directive 80/779/EEC: Air quality limit values and guide values for sulphur dioxide and suspended particles (http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31980L0779 (accessed 4 November 2015). For a list of EU directives on air pollution see www.air-quality.org.uk/02 (accessed 4 November 2015).

[117] See page 40.

[118] The National Survey of Air Pollution was set up in 1961 to monitor black smoke and sulphur dioxide at nearly 1200 sites across the UK. The purposes of the survey, the choice of sites, and methods of measurement are discussed in Clifton (1964).

of what the potential limit values in that new Directive were going to mean for the UK. That's where I started. That's where the problem was shifting from some of the more basic science to a more legislative implementation problem.

Macfarlane: Just saying about the different analysis of the data: after I left the Unit, I was going to do further analyses for a PhD, which I never completed I have to confess, but I was working with the Office of Population Census and Surveys, and I sent the daily mortality data to a number of people in the States, of whom I think Mort Lippmann was one[119] – certainly my correspondence with Robert on the subject is now in the Wellcome.[120] I'm trying to think who analysed it after the Unit had closed. Of course, they were concerned about closing nuclear power stations and burning a different sort of coal in the States so there were questions about how transportable their results would be. They probably pioneered the techniques, which then Ross's group and various European collaborations have developed, but I don't think that was quite Poisson regression at the time.

Seaton: We've heard the early story of air pollution in the UK context, and now we're going on to the rather later one, but we'll be starting in 1978, which was the year I went up to Edinburgh to direct the Institute of Occupational Medicine, so I remember it quite well – it was a traumatic 13 years that I spent there. Air pollution was not an issue that I was particularly concerned about at that time because, like most other people, I thought it had largely been solved. So I don't know where we should start. I have a feeling that Martin was starting the post-1978 discussion so why don't you just continue, Martin? Tell us what you were doing at the time and what was going on.

Williams: Well, I joined Warren Spring at the end of 1975, soon after Dick had left. There was actually a big episode in December 1975 that had not quite as high smoke and SO_2 levels as previously, but fairly substantial NO_x levels, and we were then starting to measure these new pollutants. There was a small ozone network; there was the Five Towns Survey measuring vehicle pollution;[121] there was also a measurement at 20 sites across the UK of sulphate because there

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[119] See page 29.

[120] Professor Alison Macfarlane's papers, including those from her time working in the Air Pollution Unit, have been deposited in Wellcome Library, Archives and Manuscripts: PP/AMF.

[121] See note 106.

was a famous epidemiology paper by Lave and Seskin that found associations between sulphate and adverse health effects.[122] I can't remember what the health outcomes were.

So that was going on – the Directive was being negotiated in Brussels and people were arguing about smoke and SO_2 levels: what the limit values ought to be, where you ought to measure, and I remember there was great argument in Brussels. There was a very firm line on the UK side that you weren't going to measure at the roadside because, as somebody once put it: 'If you want me to measure you high levels, I can measure you high levels in the central reservation of a motorway, but let's look at where people are exposed.' The feeling at the time was that roadsides didn't actually reflect exposure, it was urban background stations. That was the kind of flavour, and where a lot of the problems were: 'How big is the problem going to be in the UK? What are the projections going to be like for the next 20 years?'

One of my first jobs was to model smoke and sulphur dioxide 20 years into the future, and all this kind of thing, to see what compliance might be like. That was the context that I was working in at the time. Dick was working at Harwell on, I guess, more basic science, of ozone particularly and atmospheric chemistry. That's where we were.

Derwent: Yes, Warren Spring was set up in 1959. In 1962 they wrote their first comprehensive report on the National Survey of Air Pollution.[123] The next important date was 1969, when the Ministry of Local Government and Housing was faced with the Teesside problem, where there were reports of serious health effects from industrial pollution on Teesside.[124] Her Majesty's Alkali and Clean Air Inspectorate[125] wanted a survey doing so they turned to the United Kingdom Atomic Energy Authority in Harwell – Arthur Chamberlain, Frank Pasquill, and Philip Goldsmith – to do a report on the Teesside mist.[126] That eventually

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[122] Lave and Seskin (1972).

[123] Ministry of Technology, Warren Spring Laboratory (1962). See also note 118.

[124] Teesside is an industrial area in north-east England. See, for example, Teesside County Borough Council (1969), and the TV programme *Teesside: We Only Live Here*, director David Elstein (1969) (BFI catalogue: http://explore.bfi.org.uk/4ce2b6d08aa75 (accessed 10 November 2015)).

[125] Papers of the Alkali Inspectorate are available at the National Archives: http://discovery.nationalarchives.gov.uk/details/r/C3364 (accessed 3 November 2015).

[126] Eggleton and Atkins (1972). Documents on the Air pollution research programme 'Working Party on Teesside Mists, 1966–1972' are held by the National Archives at Kew.

turned out to be caused by the ammonia and the sulphur dioxide releases from the ICI Billingham works, which I remember visiting as a schoolboy on a school trip, and seeing this grossly polluted place.[127] It was like hell on earth really. I don't know how people lived there.

That was 1972 when that report was published, and that's really how Harwell got into the business as well as Warren Spring Laboratory. In the early 1970s, the Department of Environment set up the Interdepartmental Committee on Air Pollution Research to take some of these wider issues other than smoke and sulphur dioxide further. I well remember the Director of Warren Spring Laboratory, Alan Robinson, talking to this committee. I'd only recently joined Warren Spring, and he was under intense criticism about the National Survey of Air Pollution:[128] Why was this not more successful? Why was this not more quoted? I think it's a reflection of the old days after the War in that, although the Department of Scientific and Industrial Research was tackling issues of gross importance like fuel supply, it didn't attract the highest quality of people. Alan Robinson was always disappointed at the level of staff and the level of interest that his Survey got from government and from local authorities. So what Martin was talking about were the new initiatives that started in the early 1970s, mainly to take the issue on from the National Survey into these new pollutants like NO_x and ozone, and that Warren Spring carried through to, basically, its completion in 1994.[129] Then Warren Spring Laboratory was closed and moved from Stevenage to the Harwell site.

Harrison: Just to give a personal perspective on the same time period. Clearly, research on air pollution and health effects was at a very low level at that point after closure of the Unit and the feeling that the majority of the problems had been resolved. There was an interest in the atmospheric science aspects of ozone, and in those days there were much higher ground level ozone concentrations being measured than we see nowadays, but I think the main research that was going on was in the USA, and there was essentially none in the UK at that time.

The big interests were in heavy metals, lots of work on lead, and the DoE (Department of the Environment) was funding a lot of work on lead in dust. I remember Iain Thornton's group at Imperial College was doing a lot of work

[127] The chemical works at Billingham, Stockton-on-Tees, were established in 1918, and became part of ICI in 1926, producing ammonia for fertilizers, and plastics.

[128] See pages 51 and 53.

[129] Apling (1980).

on dusts and soils, which were seen as major vectors for children's exposure.[130] Cadmium was high on the agenda with the issues of Shipham and the smelter at Avonmouth and possible issues around that.[131] Acid rain was also absorbing the interest of the atmospheric science community, which was very much an ecological rather than human health issue.[132] So it was a very quiet time, and it wasn't really until 1990 when we started hearing, from North America, the results of the application of Poisson regression methods to health effects data that things began to liven up a bit on the health front. I think that's the time when Bob moved to the Department of Health and the UK started to wake up again about these issues. So that was a perspective of someone who was actively involved in the atmospheric science side at the time, but who really had no engagement in the health effects side because it just wasn't happening.

Seaton: At the same time, to the clinicians smoking became a dominant issue. People were beginning to be persuaded not to smoke, and chronic bronchitis was becoming somewhat less of a problem in the seventies,[133] but, yes, this transition, the message took a long time to get to the medical community that something was going on. Bob, you can tell us about that because you were really central to what happened.

Maynard: Let me say something first about that period 1978 to 1990. I wasn't involved, I was in the Chemical Defence Establishment at Porton Down, but I met Pat Lawther at that time so I knew something about what was going on in the Air Pollution Unit, and I knew it was being closed. When I moved to the Department of Health in 1990 I met Robert Waller, who had been transferred from the MRC Air Pollution Unit to the Department of Health and was still formally an MRC employee working at the Department. Ellison, I don't

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[130] See, for example, Thornton *et al.* (1990).

[131] From the seventeenth to the nineteenth century, zinc was mined on the land around the village of Shipham in Somerset, contaminating the soil with high levels of cadmium. See Elliott *et al.* (2000). The report concluded that although the concentrations of cadmium were high the risk to human health was low. The lead and zinc smelter at Avonmouth, which closed in 2003, was the largest source of atmospheric cadmium in the UK, along with emissions of lead, arsenic, and mercury. For health implications, see, for example, Thomas *et al.* (2009).

[132] See, for example, the reports of the United Kingdom Review Group on Acid Rain (1983, 1987, 1990, and 1997) and the United Kingdom Terrestrial Effects Review Group (1988).

[133] Ball (1995) notes of chronic bronchitis: 'Since the Clean Air legislation in the United Kingdom, mortality from this disease has been dropping among younger people, death rates in the 1970s falling by 40 to 60% compared with those of the 1960s among patients aged 35 to 74 years'; quoted from page 44.

remember, he must have left before I arrived. Retired? I asked Robert what had been going on and the message was that very little had been going on as far as research was concerned in the UK except for a study on sulphur dioxide by Jon Ayres.[134] It was a study from Birmingham, which, Martin, you were involved with and published on, I think.[135] Sulphate, was it? An episode? Anyway, that was about all that had been published then. Robert was sceptical of the multiple regression techniques and wrote a paper with a colleague called Swan, who was a statistician, I think – it was a paper that came out soon after one of the early Joel Schwartz papers from Steubenville.[136] They published a commentary on it in which they accepted the results, but they cast doubts on the causality of the relationship, and I re-read it recently, feeling that other factors such as temperature might not have been taken adequately into account. This created a great difficulty, certainly in Robert's mind, and in other people's minds as well. I remember Robert saying to me, 'If only we knew how to take temperature into account properly there might be no effect of air pollution at these low concentrations.' The critical word is 'properly'. The trouble with that statement, of course, is that if you reverse it what it means is you will never believe in effect because you will always persuade yourself that you have not taken temperature into account properly. So it's not an easy statement.

I asked Robert what he'd been doing. In my usual, cheerful, way I said, 'Well, what have you been doing this last 10 years then?' He'd been travelling. The UK had made a large input to air pollution legislation in other countries and he'd travelled to most European countries, and he'd been to South America, advising on the effects of air pollutants on health. Robert had been using the expertise built up in the Unit, and he'd been disseminating that widely. In 1985 or thereabouts, work began on the first edition of the WHO's *Air Quality Guidelines for Europe*, and Robert was a key figure in the production of the

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[134] Jon Ayres was Consultant Physician at the East Birmingham Hospital, now Professor of Environmental and Respiratory Medicine at the University of Birmingham.

[135] Ayres *et al.* (1989).

[136] Schwartz and Dockery (1992); Waller and Swan (1992). Professor Ross Anderson wrote: 'Tony Swan was a medical statistician working in Professor Walter Holland's Department at Guy's and St Thomas' Medical School … Walter Holland was referred to earlier as the author of the review which concluded that current levels of air pollution were not a health risk [see page 32].' Professor Anderson also noted that the report was supported by the American Iron and Steel Institute. Email to Ms Emma Jones, 15 December 2015.

Guidelines.[137] He was the rapporteur, I think, for most of the meetings that generated the Guidelines. The Guidelines came out in 1987 and they set the tone for new thinking about air pollution and health. But if you looked at the chapter on sulphur dioxide and particles, and they were still dealt with in one chapter, not in two, they were based, essentially, on the London data with the addition of a safety factor to it. There was some American data as well, but the figures that were used for the standard always insisted that sulphur dioxide and particles had to be treated together, and that neither figure, the figure for sulphur dioxide nor the figure for particles, meant anything on its own. The two had to be treated as a combined exposure. That was partly because of this concern about sulphur dioxide forming acid on the surface of the particles, so there was a great deal of enthusiasm for that.

Martin Williams is better placed than I am to talk about the legislative side of the work in that period up until 1990. When I arrived, I came from the Ministry of Defence and I was asked to take over the air pollution group.

Seaton: When did you arrive?

Maynard: 1990.

Seaton: And you were recruited to take over air pollution?

Maynard: That's right.

Seaton: On the basis of what experience?

Maynard: I'm not absolutely sure.

Seaton: Just curious to know.

Maynard: Perhaps because of my experience of war gases, and the fact particles and gases were very much a part of the everyday work of the Chemical Defence Establishment at Porton Down.[138] The Establishment had been doing distinguished work in that field since the First World War.

Seaton: And who was it that knew about you?

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[137] The WHO Regional Office for Europe published the first edition of *Air Quality Guidelines for Europe* in 1987, followed by a second edition in 2000. A global update was published in 2006: World Health Organization (1987, 2000, 2006).

[138] Marrs, Maynard, and Sidell (1996).

Maynard: I don't remember, Pat Lawther possibly. He sat on one of our committees.[139] When I arrived, Robert was in charge and I didn't take it over. Heather might remember. I don't think I took it over, except on a day-to-day basis, of course. I didn't take it over formally, I think Robert was still formally in charge of the air pollution work, and I joined him and we worked together, and there were two other scientists in the group, Andrew Wadge and Kathleen Cameron who worked with us.[140] That's up to that point. I can talk then, as you wish, about advisory groups.

Seaton: We'll move on.

Anderson: Bob's mentioned Jon Ayres, and I think it was about 1987 there was an acid transport event coming from the Continent.[141]

Seaton: 1985.

Anderson: Ayres teamed up with Fleming, who was in charge of the Royal College of GPs Research Unit in Birmingham that reported the weekly returns from a sample of general practices, and it was really an influenza monitoring alert system. He wrote a paper, which I've got somewhere.[142] The results were a bit inconclusive; it was like an episode analysis. I knew Jon, because as part of the Thoracic Society we were interested in monitoring trends in data on asthma and so on.[143]

Seaton: You were to become Professor of Public Health at St George's Hospital Medical School, London, having worked at the MRC Pneumoconiosis Unit.

Anderson: I was made professor in 1985. At the summer meeting of the Thoracic Society around 1989/90, Jon had asked Frank Speizer from Harvard to come over because he was involved with this Six Cities cohort study in the USA, which is a study to look at the long-term effects of air pollution exposure

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[139] See note 75.

[140] Andrew Wadge worked in the Department of Health on the effects of environmental pollution, became Head of the Food Standards Agency's Chemical Safety and Toxicology Division, and then Chief Scientist until 2013. Kathleen Cameron worked in the Chemicals and Biotechnology Division in the Department of the Environment.

[141] In January 1985, in exceptionally cold weather conditions, a pollution cloud of sulphur dioxide formed in Germany and moved over the Netherlands and the UK. See Simpson *et al.* (1987).

[142] Ayres *et al.* (1989).

[143] For the Thoracic Society, founded in 1945, see Scadding (1983).

on the cohort.[144] They were very excited about acid particles. There were only six cities but Frank could draw a fairly straight line through the annual concentrations of acid particles and mortality, and so on. Incidentally, that all died away eventually but that was presented to the Thoracic Society meeting and Jon was really trying to generate interest. I think full credit goes to Jon for trying to bring that to clinicians. There was a lot of interest by the clinicians. The other thing around that time, I would say, is that you had the development of the capacity to handle large data sets using more sophisticated statistical techniques and better computing power. I think the early statisticians knew the obstacles but they didn't have the tools to overcome them, and this is where the method of data analysis, using routinely available data, came together. I think this is what began in the USA, but, of course, it could easily be picked up here because we had really good mortality data sets and reasonably good pollution data by those standards. That was basically where it was around the time that Bob appeared.

Seaton: Yes. And that study in America was the first longitudinal study, I think, wasn't it?

Anderson: Probably. There was the American Cancer Society study as well around about the same time; that's the Arden Pope study.[145] Both studies were set up quite early on in the 1980s, and they were reporting, Speizer was reporting, I think, on the results for children's lung function. I don't think they had a mortality follow-up at that stage.

Seaton: Yes, he had been involved in studies of mortality for asthma in the UK, hadn't he, while he was there with Richard Doll.[146]

Dr Heather Walton: I didn't actually start working on air pollution until 1996, and we're not quite at that stage yet in our discussion, but I was working for the Department of Health when Bob arrived. My impression was that Robert Waller was still involved, but Bob was certainly taking a lot of initiatives at that

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[144] A group of 8,111 adults from six US Cities were followed from 1974–1977 to 1991, to assess the effects of air pollution on mortality. Results showed that there was a statistically significant association of air pollution with fine particulates and sulphates. See Dockery *et al.* (1993).

[145] The Cancer Prevention II study by the American Cancer Society enrolled 1.2 million adults in 1982 'to assess the relationship between long-term exposure to fine particulate air pollution and all-cause, lung cancer, and cardiopulmonary mortality'. See Pope *et al.* (1995, 2002).

[146] See, for example, Speizer, Doll, and Heaf (1968) and Speizer and Doll (1968).

Figure 16: Dr Heather Walton

point. I don't remember exactly when it was that Robert Waller went off to work on the Technical Advisory Group on additives in tobacco, so he stayed on at the Department of Health a bit longer than the time he was actually working on air pollution.[147]

Williams: A couple of points, just to fill in some gaps: although acid rain at that time, as Roy said, was getting most of the headlines, and a lot of the media attention, there was still an undercurrent of what you might call 'classical air pollution' issues going on. We had the lead in air Directive from Brussels,[148] as well as the smoke and SO_2 Directive,[149] and in 1985 there was a Directive on NO_2, interestingly, which was the very first actually to embody any kind of legal definition of exposure. It had a clause in the annex, which was due to the UK

[147] The Technical Advisory Group of the Department of Health's Scientific Committee on Tobacco and Health; see http://webarchive.nationalarchives.gov.uk/+/www.dh.gov.uk/ab/SCOTH/DH_095371 (accessed 18 November 2015).

[148] Council Directive 82/884/EEC of 3 December 1982 on a limit value for lead in the air; available online at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31982L0884&rid=1 (accessed 28 September 2015).

[149] Council Directive 80/779/EEC of 15 July 1980 on air quality limit values and guide values for sulphur dioxide and suspended particulates; available online at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31980L0779&rid=1 (accessed 28 September 2015).

intervention that said you should measure where people are likely to be exposed over the duration of the averaging period.[150] That was the first time that had actually entered into the legislation.

There was interest in conventional air pollutants too, urban air pollutants related to health. On the acid event paper that Jon Ayres started, I was a co-author on that and it was actually Frank Speizer who visited us at Warren Spring, and then a couple of days later went to visit Jon Ayres in Birmingham and said, 'Hey, you ought to go and talk to those guys'; so the following week Jon came down and we thrashed out all that stuff.[151] Another co-author was a guy called Gordon McInnes from Warren Spring, who did the sulphate survey and eventually became Deputy Director of the European Environment Agency, so a lot sprang from that little collaboration.[152]

Professor Dafydd Walters: I want to ask a question on this discussion: where did the pressure come from for this impetus for air pollution? You've mentioned European legislation, you've mentioned American studies: was nothing happening in this country to push it along? I mean, where do you think the pressure came from?

Seaton: I have a feeling that I know but let Bob have a go first. Where did it come from, Bob?

Maynard: I can only say where it came from as far as the Department of Health is concerned, the bit I was involved with. When I joined the Department in 1990 there was a perception that air pollution had been ignored. I think that perception was being picked up from Martin Williams at Warren Spring, and whoever was at the Department of the Environment at exactly that time. The feeling was that the Department of Health was not showing sufficient interest in air pollution and I was instructed by my boss, Graham Matthew, to take a strong interest in air pollution. In 1991 we were promised an air pollution episode, or perhaps it was

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[150] The Council Directive 85/203/EEC of 7 March 1985 on air quality standards for nitrogen dioxide (85/203/EEC), Annex III; available online at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31985L0203&rid=1 (accessed 28 September 2015).

[151] See notes 134 and 142.

[152] Mr Gordon McInnes (b. 1952) was Head of Air Pollution Modelling, Inventories and Monitoring Group at Warren Spring Laboratory from 1984 to 1992, after which he moved to the European Environment Agency as part of a task force, then becoming Head of Programme in 1995 and Deputy Director from 2003 until his retirement in 2012.

Figure 17: Professor Dafydd Walters

1990, I've forgotten which one, with the high ozone level – in 1976 there had been an extraordinary episode with high ozone levels in London.[153]

Williams: Well, all the south east.

Maynard: All the south east of England. It seemed likely there would be another one, and the feeling was that we didn't know enough about ozone, that we didn't know enough about modern air pollution episodes. Our thinking was based on the Lawther period, thinking about sulphur dioxide and particles, we didn't know anything about ozone episodes or indeed nitrogen dioxide episodes. All the talk was of episodes. Then I set up, or I suggested we set up, the first of our three advisory groups. This was the Advisory Group on the Medical Aspects of Air Pollution Episodes (MAAPE),[154] so this wasn't to do

[153] Professor Robert Maynard wrote: 'It was in 1990 that high levels of ozone were expected but did not appear. The highest ever hourly mean ozone concentration observed at an urban monitoring site was 212ppb, in London, during the heatwave of 1976. In rural areas, concentrations were higher, peaking at 258ppb (hourly mean concentration) in rural Oxfordshire.' Note on draft transcript, 20 October 2015. For a discussion of the ozone levels during the summer of 1976, see Apling *et al.* (1977).

[154] The Advisory Group on the Medical Aspects of Air Pollution Episodes was set up in 1990 to provide advice to the Chief Medical Officer, with the following Terms of Reference: 'To consider whether advice about personal protective measures during air pollution episodes should be given by Central Government and, if so, what that advice should be, to whom it should be addressed, and the criteria which should be adopted for the issuing of any advice.' See http://webarchive.nationalarchives.gov.uk/20140505104658/http://www.comeap.org.uk/documents/archive (accessed 29 September 2015).

with long-term effects, this was to do with episodic air pollution. We recruited Ross Anderson and Martin Williams onto it, and a number of other people: Stephen Holgate chaired, Anne Tattersfield led on the clinical evidence and volunteer studies, and Roy Richards from Cardiff did the toxicology.[155] Robert Waller was a member too. So it was a very small group, an *ad hoc* group set up by invitation, not by application or competition for membership, to produce a series of reports on episodes of different air pollutants.[156] We did ozone as our first one, we took sulphur dioxide as the second, and nitrogen dioxide as the third. We took combinations of air pollutants as the fourth, I think, and then – did we have economics from that group or was that something separate? Heather always remembers these things better than I do.

Walton: Well, it was a separate *ad hoc* group, but it was later.

Maynard: It was later. We did mixtures certainly, a combination effect.

Seaton: Just before we get deeper into this, because it's obviously a central part of the discussion, I have a memory as a clinician. This was a time when there was a very rapid increase in asthma in children.[157] Dafydd, you'll remember, and Ross. I think there was a public perception that this was due to increasing numbers of motor cars on the roads and pollution from them, and I think this was picked up by politicians at the time. I just wonder if anyone has a memory, as I do, of politicians pressing for more money to be spent on air pollution, or at least more effort being put into air pollution research?

Maynard: There was certainly pressure in the Department of Health.

Seaton: In relation to asthma?

Derrett: I remember, by this time I was a general practitioner, and I remember when they were building the Limehouse Link tunnel, there was a great deal of political flak with regard to children's asthma. I wonder if Bob Maynard would

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[155] Stephen Holgate is Medical Research Council Clinical Professor of Immunopharmacology and Honorary Consultant Physician at the University of Southampton, with research focused on the development and treatment of asthma. He is a former Chair of the Department of Health Committee on the Medical Effects of Air Pollutants (COMEAP)/Member of COMEAP's Standards Advisory Subgroup. Anne Tattersfield is Emeritus Professor of Respiratory Medicine at the University of Nottingham. Professor Roy Richards worked at Cardiff University's School of Biosciences.

[156] The reports of the Advisory group are available online at www.comeap.org.uk/documents/archive (accessed 29 September 2015).

[157] See, for example, Ayres, Noah, and Fleming (1993).

be able to tell us how much political drive there was for taking up particular projects at that time because I certainly remember a number of east London GPs getting very heated about children's asthma.[158]

Seaton: What sort of date are you talking about?

Derrett: Probably in the 1980s; I can't remember when the Limehouse Link Tunnel was built but it was Canary Wharf time.[159]

Derwent: In the 1980s, the Department of the Environment's interest in these issues was really at an all-time low, and it was as a result of Nicholas Ridley and Mrs Thatcher that there was some really seething hatred of the German approach to air pollution; that is to say, a highly prescriptive approach based on 'best available technology', particularly through the large combustion plants Directive.[160] We had to get the Select Committee on the Environment, which Mrs Thatcher had set up, to expose the problems with the Department of the Environment, and very quickly we set up things like the Photochemical Oxidants Review Group, the Review Group on Acid Rain, the Terrestrial Effects Review Group, and the Building Effects Review Group. But at that time, the decision was made to leave the health effects very much to the Department of Health. There was a common understanding between the Department of the Environment and the Department of Health that that's the way it should be.

This all culminated, in 1990, in the first environment White Paper, *This Common Inheritance*, and this laid the Department of the Environment's foundation of what later was called the Expert Panel on Air Quality Standards

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[158] The community video *The Other Side of Docklands: A counter viewpoint to the official story about Docklands development* (1992) includes footage of Dr Anna Livingstone discussing the rise of childhood asthma in the Isle of Dogs area associated with the construction project; available at Tower Hamlets Local History Library and Archives. For further details see the catalogue of the London's Screen Archives (Film London); www.londonsscreenarchives.org.uk/public/details.php?id=2977&searchId= (accessed 16 November 2015).

[159] Dr Chris Derrett wrote: The Limehouse Link tunnel is a 1.1 mile long tunnel in the Limehouse area of east London on the A1203 built between 1989 and 1993.' Note on draft transcript, 17 June 2015.

[160] Council Directive 88/609/EEC of 24 November 1988 on the limitation of emissions of certain pollutants into the air from large combustion plants (http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31988L0609 (accessed 4 November 2015). Nicholas Ridley (Lord Ridley) (1929–1993) was MP for Cirencester and Tewkesbury from 1959 to 1992. He was Secretary of State for Transport from 1983 to 1986, for the Environment 1986 to 1989, and for Trade and Industry from 1989 to 1990, in Margaret Thatcher's government. He was forced to resign in 1990 following an interview published in the *Spectator* in which he made anti-German and anti-Europe comments. See also comments on page 67.

(EPAQS).[161] It also led to the setting up of the Automatic Urban and Rural [monitoring] Networks (AURN).[162] So, really, the environment side started from quite a low ebb in 1985 and built up, and got something really going by the early 1990s. But we were a long way behind, I must say, a long way behind.

Seaton: So politics was not favourable to this sort of thing at the time, but what about public opinion? Does anyone remember the National Society for Clean Air, or pressure groups?

Maynard: Yes, the National Society for Clean Air, when it was still called that; I remember being taken by Robert Waller down to Brighton in those days to visit their headquarters, and they lobbied us as to how important air pollution was.[163] They were still holding conferences at the time, but the whole thing about the National Society for Clean Air was that it started as the Coal Smoke Abatement Society, I think, and the coal smoke problem was over.[164] So the feeling was that the National Society for Clean Air's main reason for existence was slipping away. It was tangible even at the Brighton headquarters, at least I felt that at the time there. You're quite right, the pressure on the Department of Health to explain the rising trend in asthma, that was strong, and the suggestion that air pollution episodes could be associated with increases in asthma episodes in kids.[165] We were getting a lot of flak then [early 1990s] about that in the Department as well. So that and the *This Common Inheritance* report, as Dick Derwent rightly says, put pressure on the Department of Health to respond with a formal position on air pollution.[166]

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[161] Department of the Environment (1990).

[162] The Automatic Urban and Rural Network is the largest air pollution monitoring network in the UK, measuring nitrogen, sulphur dioxide, ozone, carbon monoxide, and particles, at stations across the UK; see the government website at http://uk-air.defra.gov.uk/networks/network-info?view=aurn (accessed 29 September 2015). For a brief history of the Network see Clark *et al.* (2012).

[163] See note 52.

[164] The Coal Smoke Abatement Society was formed in 1898 to address the problems caused by coal smoke in London. The records of this society are held in the Wellcome Library, London (Archives and Manuscripts: SA/EPU/A/1/1).

[165] See, for example, Higgins *et al.* (1995).

[166] The report *This Common Inheritance* was followed by annual progress reports, and the Government's policies on air pollution were set out in *Air Quality: meeting the challenge*; *the Government's strategic policies for air quality management*; see Department of the Environment (1990, 1995). The legal framework of the National Air Quality Strategy was established by the Environment Act 1995 (c. 25), part IV; available online at www.legislation.gov.uk/ukpga/1995/25/part/IV/enacted (accessed 29 September 2015).

Seaton: Okay, so that's the genesis of the interest. I remember arguing forcibly that asthma had increased as air pollution had decreased and so it was rather illogical to blame one on the other.[167] I still have to make that argument, and people just don't believe me that the increase in asthma was not due to air pollution. Even Ross Anderson.

Anderson: I was just going to say that there's no evidence that air pollution causes asthma, end of story.

Seaton: No one believes you.

Anderson: But it's not believed because it goes against the religion. Anyway, what is interesting to note here, I'm hazy on the details, but around about this time the petroleum industry started to get interested and I remember talking at meetings organized by the industry. There was an organization set up in Europe – Concawe (Conservation of Clean Air and Water in Europe).[168] You'd go to meetings and there would be an industry representative. It was arguing against the idea that there are health effects and so on, and I think we should not forget that side of it. Then, ironically, I think that put us on our mettle and ended up in us doing perhaps a more thorough job to actually make the case rather than everyone just singing from the same hymn sheet, as it were. Concawe still exists, but I think the argument that even low levels of air pollution are important tends to be accepted quite widely now.

Maynard: Ross makes a very good point there. Maintaining the balance between those who argued that low levels of air pollution did not have an effect on health, and also argued at that time that there was something wrong with the statistical evidence, was difficult. This was the period of what we called the American 'hired guns', the people who wrote papers to show that other people's papers were wrong. They seemed to have no particular ideas of their own but they were busy attacking other people's papers. They were industry-sponsored to a large extent and, of course, some of their work was excellent, but they were industry-sponsored. To steer a line between that and the enthusiasts for the effects of air pollutants upon health, who would believe, in my view, almost anything about the effects of air pollutants on health, to steer that line was one of the main purposes of setting up the Department of Health committees, so that we would look at the evidence in detail and try to produce a rather cold-

[167] Seaton, Godden, and Brown (1994).

[168] Concawe was set up in 1963 to conduct research on environmental issues and the oil industry. For the organization's remit, see its website at www.concawe.eu/about-us (accessed 30 September 2015).

blooded report. A clear but not excitable report, and that's what we tried to do in the early MAAPE reports. We tried to steer a line between the enthusiasm for believing the latest thing you've been told and the industry view that there was nothing actually going on.

Anderson: There was no advocacy.

Maynard: No, there was no advocacy and we were keen that there should be no advocacy in our reports. We produced those first three or four and then, at about that time, we hadn't actually finished producing the MAAPE reports when we launched the Committee on the Medical Effects of Air Pollutants, (COMEAP), a much bigger committee to give broader advice on the effects of air pollutants on health, not just episodes and not just the classic air pollutants, although that was our main focus. We launched the larger committee, we transferred Stephen Holgate from the chairmanship of the one to the chairmanship of the other.[169] At the same time as we launched COMEAP, Dick Derwent, with perhaps some help from me and the Department of Health – well it was your committee, Dick – launched the Expert Panel on Air Quality Standards (EPAQS) with you as the chairman, Chairman. Dick Derwent was in charge of air pollution in the Department of the Environment then, and it would be worth hearing from Dick what the purpose of the Expert Panel on Air Quality Standards actually was.

Derwent: Yes, I think in *This Common Inheritance* we were working from a background of anti-European feeling about air quality standards, which we had inherited from Nicholas Ridley.[170] I mean he was most colourful in his hatred of all things Europe, all things German, so it was quite clear that if we were going to have environmental standards, and the Department of the Environment was reluctant to have them, but if they were to have them, then they would have to be British. So, we approached the Department of Health and said, why can't we do British standards for British people? That was the approach and hence the Expert Panel on Air Quality Standards (EPAQS). We left the difficult choice of chairman to the Department of Health, and I think that was an excellent decision because we ended up with an excellent chairman.

Seaton: Oh Dick, how kind.[171]

Maynard: I have nothing to add to that.

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[169] See note 155.

[170] Department of the Environment (1990). For Nicholas Ridley see note 160.

[171] Professor Anthony Seaton was Chair of EPAQS from 1991 to 2001.

Harrison: The early 1990s was a hugely busy time because one of the other committees that was set up by the Department of Environment – as it was when Dick was in charge of the air pollution science activity there – was the Quality of Urban Air Review Group, which I chaired for them.[172] I think the Group published its first report on urban air quality in the UK probably in 1992, which set the scene.[173] It brought together data that people hadn't previously brought into one place. Also around the same time, the committee advised on the setting up of the automatic monitoring network and we had had some automatic monitoring before, particularly NO_x and ozone, but this was far more comprehensive and it started off with twelve sites. It's now much larger but that began to give us the information that we needed on air pollution levels in the UK, and we could also study the processes that were driving them.

Importantly, the second report of that committee was on diesel vehicles. That was published in 1993 and it brought up exactly the issues for health reasons of NO_2 and particulate matter that are now high on the political agenda.[174] I think it was influential, probably in the long term, in cleaning up diesel emissions of particulate matter, which is certainly on the way down, but it failed on NO_2 because the industry, I think, cheated and got round the regulations there.[175] It is also worth mentioning, there was a third government department involved,

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[172] The Department of the Environment was replaced by the Department of the Environment, Transport and the Regions in 1997 and subsequently by the Department for Environment, Food & Rural Affairs (Defra) in 2001.

[173] Quality of Urban Air Review Group (1993a).

[174] Quality of Urban Air Review Group (1993b). For NO_2: 'Of the oxides of nitrogen only NO_2 is of such toxicity to raise concern at ambient levels. Exposure to high concentrations of nitrogen dioxide leads to constriction of the airways and an increase in airway resistance. At extreme levels of exposure, encountered in industrial accidents, pulmonary oedema and severe inflammatory damage to small airways may occur. At peak ambient levels only asthmatics are likely to experience any change in airway resistance when levels of NO_2 exceed 300 ppb.' For particulate matter: 'There are a number of concerns over possible adverse health effects of diesel particles. Potentially the most serious arises from recently published research in which mortality and morbidity have been shown to correlate with the concentrations of fine particles (termed PM_{10}) in the atmosphere …'; quoted from pages 33, 34–5.

[175] Professor Roy Harrison wrote: 'The motor industry has been manufacturing vehicles which meet the requirements of the European emissions tests, but emit much higher pollution levels during normal use on the road. This is mostly achieved through the mapping of the engine management system, but Volkswagen have admitted to the use of a "defeat device" which deliberately switches the engine into a different mode when it enters the European test cycle in the laboratory.' Note on draft transcript, 23 October 2015. For the Volkswagen diesel emissions' scandal, which erupted in September 2015, see, for example, Schiermeier (2015).

which was DTI (Department of Trade and Industry), which had a gentleman whose name I can't remember now but he was another one of these Welsh gentlemen…

Maynard: Let's record his name.

Harrison: Oh, Trevor Morris was it?

Maynard: That's the man!

Harrison: Whose sole purpose in life seemed to be going round rubbishing the air pollution epidemiology?[176] He was actually quite a clever guy but he didn't convince any of us that he was right. As someone else has mentioned, industry became very interested then, and companies like Johnson Matthey, which had a commercial interest in selling catalyst systems and so on, became quite influential both by leaning on government but by setting the public agenda to some extent.[177]

Just to mention, I went to Birmingham at the beginning of 1991 and rapidly met up with Jon Ayres.[178] They had a very clever Specialty Registrar there, a trainee public health doctor, Sarah Walters, who went over to the USA, worked with Joel Schwartz and picked up on the Poisson regression techniques and carried out a time-series study, which was then used by EPAQS under Anthony's chairmanship that led to recommendation of the 50 microgram per cubic metre, 24-hour standard for PM_{10}, which was almost pulled out of the air by Anthony.[179]

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[176] Dr Trevor Morris was a Department of Trade and Industry representative on the Government's Risk Assessment and Toxicology Steering Committee in 1999; see http://ieh.cranfield.ac.uk/ighrc/pdf/cr%20reports/cr2[1].pdf, and on the Interdepartmental Group on Health Risks from Chemicals (founded 1999), a sub-group of the Interdepartmental Liaison Group on Risk Assessment; see www.hse.gov.uk/aboutus/meetings/committees/ilgra/meetings/021101/nov0106.pdf (all websites accessed 1 October 2015). Professor Roy Harrison wrote: 'I am not aware of publications by Trevor Morris, although he did produce unpublished critiques. I don't think he did influence the debate significantly, as he was unable to convince independent scientific advisers that his views were correct.' Note on draft transcript, 23 October 2015.

[177] Johnson Matthey manufactured the first catalyst technologies for vehicle pollution control in the mid-1970s, and continued to develop and refine such technologies; see Acres and Harrison (2004), and www.matthey.com/about_us/history?era=85d46ffd8d0349c08c8784994d2df8e3 (accessed 1 October 2015).

[178] See note 134, and pages 58 and 61.

[179] Walters, Griffiths, and Ayres (1994); Expert Panel on Air Quality Standards (1995): 'The Panel recommend an Air Quality Standard for PM_{10} in the United Kingdom of 50 $\mu g/m^3$ measured as a 24-hour running average', page 21.

Seaton: It was.

Harrison: Which has been immensely influential worldwide ever since.

Seaton: For the record, it occurred to me in the middle of the night when I was worrying about how the hell we were going to find a standard.

Tavner: Can I just make a point? You're talking here a lot about departments and so on, but what was going on in our country when and after the Air Pollution Unit was set up was a massive change in fuel use. The original problem was domestic coal use and then a massive change took place in the 1960s and early 1970s in the electricity supply industry to huge coal-fired power stations, for which Pat Lawther advised on air pollution issues.[180] The UK then moved to privatize the electricity industry, and there was a further change in fuel usage to gas from electricity in the early 1990s.[181] The increase in car numbers and use of diesel vehicles also affected the pollution. Maybe some of these pollution change issues were driven by those fuel changes. These things are probably more important than the organizational way we responded to those changes.

Seaton: Yes, that's a very good point. I sort of alluded to it, that vehicles were perceived by the public as being the cause of the rise in asthma, and that air pollution was vehicular pollution.

Birkett: Perhaps just on a similar vein before Martin comes in; I think in terms of external influences, there was electricity privatization between 1988 and 1991, and I was actually involved in that. I was on the team at HSBC as it happened, advising the Department of Energy for those three years. That included the introduction of SO_2 scrubbers on power stations and also the 'dash for gas' which happened on the back of that. So that's one external factor. The other is, I think it was only in about the 1980s, I may be wrong, that the World Health Organization actually classified smoking as carcinogenic, finally.[182] I think it was

[180] Professor Peter Tavner wrote: 'Professor Lawther gave lectures on national air pollution policy and spoke specifically of the advice he had given in the 1960s to the Central Electricity Generating Board on the design of their newer, larger coal-fired power stations. In particular he used to show a slide of one of the newer coal-fired power stations, at Ratcliffe-on-Soar, depicting the large concrete chimney adopted because of this advice, and designed to accelerate exhaust gases and pollutants up high into the atmosphere.' Note on draft transcript, 25 October 2015.

[181] See, for example, Winskel (2002).

[182] International Agency for Research on Cancer (1986).

the 1980s. There was also, we haven't mentioned it yet though you mentioned longitudinal studies, the big shift to much more intensive cohort studies rather than time-series studies.

The final thing, just in this bit, and I'd like to come back to it later, is attributable deaths, which Bob and Heather and I have debated over the years. We'll perhaps deal with that later. The point is that the Labour Party said sorry in 2015 for favouring diesel in the early 2000s,[183] but my understanding is that, as we were hearing before, it was actually from the early 1990s that a decision was taken, perhaps after Rio, to favour diesel over petrol – to try and achieve carbon dioxide savings and focus more on that rather than some of these harmful pollutants. I think that's another aspect that we shouldn't forget here.[184] There was the start of this carbon dioxide obsession really in the early 1990s.

Williams: Around this time in the early 1990s, I was going to make a point, and it's quite an interesting one I think, about this issue of the UK, Britain, and Europe. The enthusiasm in the Department of Environment certainly started with *This Common Inheritance*, Chris Patten's White Paper, which was very imaginative for the time.[185] But there was a very, well, let's call it UK-centric attitude in the Department of Environment that resisted the idea of an air quality Directive coming from Brussels, which was mooted at the time.

When I first left Warren Spring and joined the Department of Environment, taking over Dick's role as Head of the science unit, the negotiations were just beginning on the Air Quality [Framework] Directive in Brussels,[186] and that really runs in parallel with what was going on in the UK because on the back of *This Common Inheritance* people were working up the Environment Act, which

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[183] The Labour Government announced in its Budget in 2000 that Vehicle Excise Duty would be banded to favour vehicles with lower CO_2 emissions, such as diesel cars, from 1 March 2001. See HM Treasury (2000). For the Labour Party's apology, see, for example, Hope (2015).

[184] Material from the early 1990s regarding greenhouse gases, the health effects of diesel, and government policy, obtained from the Department of Health by Mr Simon Birkett under the Freedom of Information Act, has been archived with the records of this meeting (Wellcome Library, Archives and Manuscripts, GC/253). For a discussion of the UK Government's introduction of car tax linked to CO_2 emissions, and the rise in diesel vehicles and particulate matter emissions, see Mazzi and Dowlatabadi (2007).

[185] Department of the Environment (1990).

[186] What is commonly known as the 'Air Quality Framework Directive' was enacted in 1996. See Council Directive 96/62/EC, 1996, 'on ambient air quality assessment and management'; available to download at http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31996L0062 (accessed 19 November 2015).

was finally promulgated in 1995, which set the whole framework for the UK, for EPAQS essentially.[187] It required the Government to establish standards for air pollution and to produce a strategy and so on. All that was going on, and was done, before the EU Directive was agreed. As things have turned out that's really provided something of a bit of a conflict, actually, that's still extant. But a lot of the enthusiasm wasn't necessarily UK-generated.

Some people have mentioned the big increase in the monitoring network in the UK; that was actually driven by Brussels. One of the first things I was faced with in the Department was an infraction on the fact that the UK, at the time in 1985 – there was a Directive on NO_2, don't forget – had seven monitoring stations for NO_2; I think Luxembourg had about 13. Now, this was not seen very favourably in Brussels, and we were being infracted. That's when the monitoring really started.

Seaton: We've talked about multifactorial causes of diseases and multifactorial reasons for the closure of the MRC unit, and multiple factors that led to this initiative on the research. Dick's got a last comment on this because I want to move on to what was actually done about it in terms of research, but Dick, if you can briefly make a comment.

Derwent: Yes, one of the things we wanted to do within *This Common Inheritance* was to inform the general public about air pollution episodes. That caused us two difficulties: the first was an instrumental one. We wanted to inform people about particles during episodes so we had to go to the Northeast States for Coordinated Air Quality Use Management, in Boston, USA, for their advice on continuous PM monitors, and that was how we introduced the TEOM (tapered element oscillating microbalance).[188] I don't know whether that was a good thing or not but that's what we did. Also, *This Common Inheritance*, as I said, gave us the opportunity to warn people about air pollution episodes, and that caused quite a lot of thinking within the Department of Health about what the health effects were, who the sensitive groups were. All that started from quite an early base in the early 1990s, thinking about what should we tell the general public, and how could we make the general public more aware of air pollution and more aware of what the health concerns might be to them as individuals.

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[187] See note 166.

[188] The Northeast States for Coordinated Air Quality Use Management was 'Founded in 1967 to address air pollution problems from New England power plants …', quoted from www.nescaum.org/about-us/history (accessed 1 October 2015).

Seaton: Thank you. So now, there we've got EPAQS, we've got COMEAP set up, and we've got Bob and Dick and Martin sitting at the centre of things, and some others of us involved in them. Where did it go, Bob? Where did it all go wrong?

Maynard: Where did it all go wrong? Thanks very much for that. [Laughter]

Seaton: I should make one point that Bob rang me up when I was doing a clinic, and he said he wanted to discuss me chairing a committee. I said, 'What on?', and he said, 'Air pollution', and I said, 'Well, I know nothing about air pollution', and he said, 'The ideal person!' [Laughter]

Maynard: Yes. That comes under the heading of 'accurate as far as it goes'. [Laughter] I knew something of you, of course, as you'd taught me in Cardiff and I knew of your reputation. I was going to say something about research.

In the early 1990s we noticed in the Department of Health that there was no research going on in the UK, in an organized sense, on the effects of air pollutants on health, and so we launched the first air pollution research programme and we did it by raising money within the Department and in collaboration with the Department of Environment – Martin, you were there then? – and also with the MRC. So it was a three-pronged attack, but we did it in what nowadays would be seen to be an unusual way; we did it via a system of central command and control. We did not ask people to send in bids for what they would like to do on the subject, we ran a meeting at the new Institute for Environment and Health in Leicester, which the MRC was funding at the time – an exciting time for air pollution work with a new institute in Leicester. That meeting was chaired by, then Professor, now Sir, Anthony Newman Taylor. You were there, Chairman, I've got the report in my briefcase. You were there, Roy, and many other people who are here were there as well.

The report on the meeting was entitled *Air Pollution and Respiratory Disease: UK research priorities* – the word 'respiratory' was on the cover.[189] We'd not yet made the jump to cardiovascular, and so the thinking was still the same as in the Air Pollution Unit: effects on the respiratory system. What we tried to do at that meeting was to knock out a series of ideas for epidemiological studies, toxicological studies, volunteer studies, and then we asked people to bid to carry out those studies. We defined the work that was needed centrally and asked university staff to send in their bids for doing that work, so they were buying

[189] MRC Institute for Environment and Health (1994).

into a programme, which had already been sorted out. That was successful and that led to a rejuvenation of air pollution research as far as health is concerned. I'll say nothing about other aspects of it, but as far as health is concerned in the UK, we ran on to a second programme and that work stopped. We ran out of money for that, in about, when, I'm going to have to guess at this, or Heather might know the answer, early 2000?

Walton: There was a small third one.

Maynard: There were two major research initiatives, and a small third one.[190] We must have funded 40 or 50 projects all told, some large, some small. We developed a technique for funding large projects but also funding small projects. We tried to balance the portfolio, as I called it, so that we had research across all aspects of the effects of air pollutants on health, using all available techniques that we could get bids in for large programmes and in small programmes.

If I'm asked to say what I'm proudest of that I was involved with in the air pollution field, it's the setting up of that research programme. More so than the setting up of the committees, which have been useful, certainly, but the research programme actually did change the feeling in the UK for research into air pollution on health. I think so, anyway.

Walton: Just to move on from that, one of the other aspects of that research programme was that it was tied to answering policy questions and policy difficulties, where we were trying to work out what to do in a policy sense and we didn't have the scientific answers for that. I think that was also a very helpful aspect of it. More widely across the whole government system at that time, the National Audit Office did a report in which they used air quality policy as a prime example of the input of science into policy, so we had a very good team at that time in lots of different places that were all pulling together towards one purpose.[191]

Anderson: A couple of other dimensions here, which I've been on the receiving end of. I've been one of the research workers and I've seen it right through. I just can't emphasize enough how important the European

[190] MRC Institute for Environment and Health (2000); Institute of Environment and Health, Cranfield University (*c.*2002).

[191] National Audit Office (2001).

connection was at this time in the 1990s. I think Martin was in there, and I then got involved with this European Concerted Action,[192] and met other interested people in Europe like Klea Katsouyanni and so on, and that led to the transfer of methodology to us that we were then able to use in applying for this money.[193] It was an interaction, and we have received a large amount of money periodically from Europe and also from the United States, much more than we've actually received from the UK, I would say. But the interaction was very, very important.

The second thing I'd like to say is that, as an epidemiologist, I came into this wondering whether air pollution had health effects. But as soon as the policy makers started to accept that it did, we were being asked different questions. We were being asked how much, how do we quantify that? That is a complete culture shock for most of the risk factor epidemiologists involved here, so the quantification, which is now built in to the decision-making and is incorporated in the modelling and scenario evaluation nowadays also stimulated research of a slightly different nature that brought the scientists into the real world of trying to connect with actual decisions. So I think these are two other strands that mesh with what Bob has said.

Seaton: Yes, that was more familiar to people who had been working in occupational epidemiology, where the aim was to provide evidence for standard setting, so it was not a complete culture shift.

Williams: I think the international dimension, as Ross has said, is really quite important, and, particularly, nobody's really mentioned the HEI (Health Effects Institute) yet, centred in Boston, which was set up deliberately to provide that kind of balance between the two extremes that Bob referred to earlier.[194]

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[192] See, for example, European Concerted Action: Indoor Air Quality & its Impact on Man (1991). Professor Ross Anderson wrote: 'This is the name of an EU exercise which brought research workers together to develop research [on urban air, indoor environment and human exposure].' Note on draft transcript, 20 October 2015. See also Joint Workshop of World Health Organization Research Center European Concerted Action 'Urban Air, Indoor Environment and Human Exposure' (2003).

[193] From 1997 to 2006 Klea Katsouyanni was Associate Professor in the Department of Epidemiology, University of Athens Medical School, then Professor of Medical Statistics and Epidemiology (2006–). She specializes in air pollution epidemiology. See, for example, Katsouyanni *et al.* (1995), and also Anderson *et al.* (1997).

[194] Founded in 1980, the Health Effects Institute is an independent, not-for-profit organization that researches the health effects of air pollution in the USA and internationally; see www.healtheffects.org/about.htm (accessed 2 October 2015).

One crucial factor in convincing the sceptics about the whole thing was the re-analysis of the American Cancer Society data.[195] That was really crucial, a game-changing moment, and from then on the whole issue became better established. I vividly remember when that report was put before COMEAP, the members were asked what they thought of it, and the immortal words of Peter Burney were, 'As someone once said of the Bible, if it's true then it's really quite important'.[196] Also the European dimension that Ross referred to. I got involved while I was still at Warren Spring to chair the sub-group on exposure assessment. That group actually is still providing a lot of the basic teamwork for most of the big European projects that are still going on, involving Klea Katsouyanni, Ursula Ackermann-Liebrich, Bert Brunekreef, and Michal Krzyzanowski, and they're still cooperating and doing the big studies like ESCAPE (European Study of Cohorts for Air Pollution Effects), and APHEA (Air Pollution and Health, a European Approach), and what have you.[197]

Harrison: Martin's made exactly the point about the HEI that I was going to make, so I'll make another one, which is that when we first started getting concerned about particles as a result of the epidemiological work that was coming through from North America, there was a big question mark over plausibility. We didn't actually know what the mechanisms were. My abiding memory from that Leicester meeting was actually that you, Chairman, came in and said you'd had insomnia the night before, or something, so you'd been reading *The Lancet* and it had given you this idea about how ultrafine particles might actually be driving the effects of particulate matter, something that was subsequently published, which has been hugely influential.[198] It may not be the whole story, and I guess it probably isn't, but it really stimulated thinking about mechanisms, and we now have lots of mechanistic information and we have real plausibility for the effects that we see. Up until that time, I think people were right to question whether the epidemiology was just confounded by inadequate

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[195] Krewski *et al.* (2009).

[196] Peter Burney is Professor of Respiratory Epidemiology and Public Health at the National Heart and Lung Institute at Imperial College London.

[197] ESCAPE is a study of the 'long-term effects on human health of exposure to air pollution in Europe'; see www.escapeproject.eu/ (visited 4 November 2015). The APHEA project established a European network of scientists in 1993 to investigate the short-term effects of air pollution on health, and to ensure that large amounts of data were analysed by agreed standards; see Katsouyanni (2006).

[198] For the Leicester meeting see page 73.

control for temperature, or whatever it might be because we didn't have the biological plausibility. I think it was quite an important moment, and things have moved on hugely since then and we don't question the causality now because we have that biological plausibility.

Seaton: Maybe I ought to say a little bit about this because I remember it so well. It was a COMEAP meeting and we were arguing, and I talked about the cardiac effects apparently in the epidemiology. I think Mr Waller was there and being sceptical, saying it was, I'm not sure, but someone was saying, almost certainly confounding. I went home puzzling over it, and I got home and it was a Friday and *The Lancet* had arrived in my mail that day. I just picked it up and looked through it and there was a paper in it by Kay Tee Khaw, who was Professor of Clinical Gerontology in Cambridge, on seasonal changes in fibrinogen, which she thought might be due to seasonal infections or something, that allowed for temperature.[199] I just suddenly thought, 'That's it! It's air pollution that is changing fibrinogen. Fibrinogen makes the blood clot and blood clots cause heart attacks.' I thought that and then I thought, 'It's such a small dose.' By about 2am that night, not being able to sleep thinking about it, I, of course, remembered Günter Oberdörster's work on particulate air pollution, which hasn't been mentioned yet but which was absolutely important to understanding air pollution, showing that nanoparticles or ultra-fine particles had quite different and much greater effects on lung inflammation, and so on, than the same stuff in a greater size but of the same weight.[200] I put those together in my head and rang up a couple of friends, Ken Donaldson being one of them, who started as a technician with me and ultimately became Professor of Toxicology in Edinburgh. We wrote a paper overnight, really the next night, which went to *The Lancet* and got published, and it was influential, it was very influential.[201] That's my memory of the episode and it's quite a vivid one.

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[199] See Woodhouse *et al.* (1994).

[200] See, for example, Oberdörster (1992). For details of Professor Günter Oberdörster's past publications and research, see www.urmc.rochester.edu/people/20180430-guenter-oberdoerster (accessed 20 July 2015).

[201] Professor Anthony Seaton wrote: 'For clarification, the discussions were at the meeting, the hypothesis came that evening at home, and I first presented the idea a few weeks later at a meeting in, I think, Leicester organised by Bob for members of COMEAP to discuss research ideas. I remember Ross who was speaking after me saying "How can one follow that!" That would have been when Roy first heard it. It was published a few months later in *The Lancet*.' Email to Ms Emma Jones, 27 November 2015. Seaton *et al.* (1995). Scopus recorded 1,164 citations of this paper on 19 November 2015.

Walters: Can I just expand a little bit on that and describe an incident in COMEAP – it must be about 2001 I should think – when our illustrious secretary, a certain R. Maynard, was trying to convince us that there was a cardiovascular effect of particles. I don't know if you remember this, Bob, but there were two clinicians there. One was the cardiologist Philip Poole-Wilson, and there was me, and we both argued vociferously that this was totally impossible because how on earth could you get a cardiac effect, it was obviously secondary to respiratory illness. We dug our heels in a bit, I think. I must say that you won the argument in the end because the data was all on your side, but what I found very interesting was that, in fact, the evidence for cardiovascular effects had been slowly mounting for some decades, as we heard this morning, yet Philip and I were totally opposed to accepting this. Maybe we just had closed minds because as clinicians we couldn't see heart disease coming *de novo* without respiratory disease preceding it. We had a certain way of thinking about pathology, which, of course, has been overturned. It's a pity really that Philip Poole-Wilson isn't here, sadly he's no longer with us, because in fact he became an evangelist for particles causing cardiovascular disease, and I think he should be at least mentioned in this transcript.[202]

Birkett: I would just add on that point that, even now, the general public view is that air pollution is a respiratory problem, not a cardiovascular problem, which is pretty astonishing given what we've heard earlier this afternoon. Just to mention one thing, which certainly has been important in my understanding of the subject and has often been quoted by others, is that, as well as starting to look at the long-term effects, there were many other very good studies by COMEAP, but one of them was on the short-term effects of air pollutants, and it actually published estimates of attributable deaths.[203] I think it was PM_{10}, sulphur dioxide, and ozone. That led to the Royal Committee on Environmental Pollution, and many others, often quoting this figure of 12,000 to 24,000 deaths 'from air pollution' – they were using sloppy language – rather than 'attributable to air pollution'. So I think there was that very important study, and articulation certainly, in communication terms. If we were going on beyond 2000 to 2010, I would be highlighting the fact that when COMEAP, 10 years later in December 2010, published its 29,000 attributable deaths from long-term exposure to $PM_{2.5}$, that was the first time really that we moved on in public understanding

[202] For an obituary, see Treasure (2009).

[203] Committee on the Medical Effects of Air Pollutants (1998).

terms from that summary view of 12,000 to 24,000 deaths from air pollution, which was really short-term exposure in certain periods and places.[204]

Seaton: Yes, and the understanding has moved on enormously since then, I think, in terms of short-term effects and long-term effects on the heart.

Maynard: Well, I'm just reflecting on how it's gone in three cycles. There's the initial cycle we talked about earlier, that's what we call the Lawther period: the MRC, sulphur dioxide, and particles. Then there's the period that we were all very much involved with but most of us are now retired, so there's that period. I wonder what the next period is going to be? I think it's going to be focused on a combination of nitrogen dioxide and nanoparticles, and that's just beginning to take off in the literature at the moment.[205] The UK has not got a research programme on that. Neither has it the sort of unit that Lawther had originally, nor has it the sort of combined central command and control research programme that we launched in the 1990s. We haven't got that any more either, so seeing where the push is going to come from for the next period of 20 years in the air pollution field seems vague to me at the moment. It's certainly not as clear as I would wish. I wonder what other people think about that?

Birkett: I'll give you a very quick answer. I think we need to separate out sources, exposures, impacts, and outcomes, and I think that nitrogen dioxide and nanoparticles certainly are things that will be seen as very significant and important. But we'll also have quite different impacts and outcomes, perhaps, so it may well be that genetic effects start to be identified and things like that, or more detail on cognitive impact. There's a whole degree of complexity at both ends of the spectrum that is likely to emerge, I would expect, in a way, as we've seen going from 1952 short-term exposure, visible pollution, respiratory effects through to long-term exposure, cardiovascular effects and so on for particles, to these other pollutants and other health effects perhaps.

Williams: Two points to make: one of the conventional air pollution things, I mean nanoparticles, NO_2, yes, but let's not forget ozone. I asked the question very early on in this debate about the aggressiveness of ozone in the eyes of Bob Waller in the MRC Unit.[206] It's one pollutant where the global baseline is potentially increasing. What's more, health effects are being reported at levels

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[204] Committee on the Medical Effects of Air Pollutants (2010).

[205] See, for example, research on air pollution and autism aetiology, Volk *et al.* (2013).

[206] See pages 20–1 and note 45.

that are around about the kind of tropospheric background, so there's a whole combination of issues involving mixtures of pollutants that we need to look at and not ignore.

Seaton: Ozone's particularly interesting, isn't it, for all sorts of reasons, but it's one of these things that shows a reduced effect with exposure, or tachyphylaxis, I think, technically. I am quite convinced there is a threshold for ozone, and when people say, 'You can't show a threshold' I say, 'Well, oxygen's got a threshold.'

Maynard: As far as you know. [Laughter]

Seaton: It has, it has got a threshold. Oxygen will kill you if you breathe it at 100 per cent, but you have to have it to survive.

Maynard: At ambient concentrations it kills us all eventually. [Laughter]

Walton: I think ozone will continue to be a significant issue over the coming years. Going back to filling in a bit of a gap, Bob has mentioned the economic side. The 1998 COMEAP report was, as Ross has said, a significant step change into actually quantifying the health impacts of air pollution nationally, not just saying 'Are there health effects?', but the size of the health effects. Following on from there, we set up an *ad hoc* group on the economic appraisal of the health aspects of air pollution, and one of the things that that fed into was starting to use monetary valuation in the air pollution context. That was something that the Department of Health didn't do at all because they only dealt with quality-adjusted life years, and that all fed into cost–benefit analysis, which subsequently fed into things like the Interdepartmental Group on Costs and Benefits, and the Air Quality Strategy.[207] If we're finishing in 2000, there was the QUARK (Subgroup on Quantification of Air Pollution Risks) report in 1998,[208] and the EAHEAP (Economic Appraisal of the Health Effects of Air Pollution) report in 1999.[209]

Seaton: Yes, it's not, of course, our remit to talk about the future, I don't think. It would be very interesting to talk about the future.

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[207] Department for Environment, Food and Rural Affairs; Scottish Executive; Welsh Assembly Government *et al.* (2007a); Department for Environment, Food and Rural Affairs; Scottish Executive; Welsh Assembly Government *et al.* (2007b).

[208] Department of Health, Committee on the Medical Effects of Air Pollutants. (1998).

[209] Ad-Hoc Group on the Economic Appraisal of the Health Effects of Air Pollution, Department of Health (1999).

Tansey: To historians it is interesting hearing you talk about the future because, just think, in 20/30 years' time, somebody's going to look and think, 'They thought that was going to happen?'

Seaton: They got it all wrong. We always get it wrong if we predict the future.

Commins: Whatever pollutants we think are important, we should bear in mind: what is the actual exposure to them? In the radioactive field we have film badges to assess exposure, but we can't do that for air pollution overall. If you take my life, what's been my exposure to various pollutants? Very difficult to know, it's a guess. As I said earlier today, in the past, outside air pollution was a massive problem and it affected us all. These days there's indoor pollution of all types, and how do you take that all into account? I think it's a massive problem for the future to assess exposure. What I do hope is that in the future, people will bear in mind the true, actual, exposure. When you talk of ozone, if you generate some ozone indoors it will very soon dissipate because it's a very reactive chemical. Out of doors it's there for a little while, it is very complex.

Seaton: Well, you'll be pleased to know that there are a lot of scientists who are very interested in retrospective exposure assessment, particularly in occupational circumstances, but it's also a part of environmental epidemiology as well.[210]

Macfarlane: Part a comment and part a question, because most research I've done since the Air Pollution Unit's mainly been in a different field, which is perinatal epidemiology. I was interested to find in the late 2000s research into the association between low birth weight and air pollution.[211] Indeed, a data linkage project I was funded to do was going to have a look at that for England and Wales if there had been time, but the Health and Social Care Information Centre held us up on data access so we never got to do that, but I'm still interested in pursuing it. At the same time, the group at the London School of Hygiene and Tropical Medicine has been looking at past data.[212] I have some past data, unfortunately the data layouts have got an archiving problem because I left them behind at the National Perinatal Epidemiology Unit and they fell into the Thames, or the Isis or the Cherwell or the Oxford Canal; I forget which was near the barns that were their so-called archives.

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[210] See, for example, Ahrens and Stewart (2003), and Raaschou-Nielsen *et al.* (2013).

[211] See, for example, Gehring *et al.* (2011).

[212] See Dolk *et al.* (2000).

Maynard: A last comment from me. There isn't any doubt that the effects of low concentrations of air pollutants on fetal development is going to be an important area for study; indeed, it is an important area for study all over the world at the moment.[213] A huge amount of information has appeared on the effects on birth weight, but also on degree, on rate of development, not just increase in weight but rate of development in embryo and fetus.

Macfarlane: Fetal growth restriction.

Maynard: That's right. That's really important. It may be that the adult cardiovascular effects are set up partly as a result of events occurring in utero; that may be true. The Department of Health is not currently, as far as I know, considering, or working on, that; at least I don't think so. But, if one were launching a new research programme, almost certainly that would be in it.

Seaton: Yes, so the whole spectrum of associations with air pollution has expanded and, for example, you didn't mention cot death but that's one thing that has been associated with air pollution.

Macfarlane: Yes, indeed.

Seaton: I have a personal hypothesis as to why that might be the case, which I have published, but it hasn't attracted much attention.[214] The other thing is intellectual or cognitive development, and cognitive decline in people like us, the elderly, seniors.[215] [Laughs]

Macfarlane: Well, if my cognitive decline survives the Health and Social Care Information Centre that is holding up our current data linkage project by over 14 months…

Anderson: Just to fill that out a bit. Following your (Seaton's) *Lancet* article,[216] or associated with it, that whole shift in our understanding of how air pollution can have effects on systems beyond the respiratory system has led not only to studies of perinatal outcomes, but to cognitive defects, rheumatoid arthritis,

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[213] See, for example, Dadvand *et al.* (2013), and, for research on air pollution and fetal health in Europe, see Pedersen *et al.* (2013). See also note 205.

[214] Seaton (2010).

[215] For cognitive development, see, for example, Guxens *et al.* (2014), and for cognitive decline, see, for example, Oudin *et al.* (2015).

[216] Seaton *et al.* (1995).

appendicitis. Anything is possible, and the nature of this literature is that people do studies and if they find an association it gets published. So there's a long list of non-respiratory outcomes, and it's an exploding area.

Seaton: Okay, well I think we've come to the end really.

Tansey: I think we have, yes. I would like to thank you all very much for coming. I think Ross, your final comment on associations, in saying anything is possible, just shows what an enormous area this is, and we've really only just touched very lightly on some areas. I'd very much hope that we could continue these debates and discussions in some forum. Thank you all once again, and in particular thanks to our Chairman for bringing you through such a very interesting and well-mannered and engaged meeting.

Seaton: Thank you as well.

Appendix 1

Graphs showing 'Daily changes in the condition of bronchitic patients in relation to pollution, 1959–60 and 1969–70' [217]

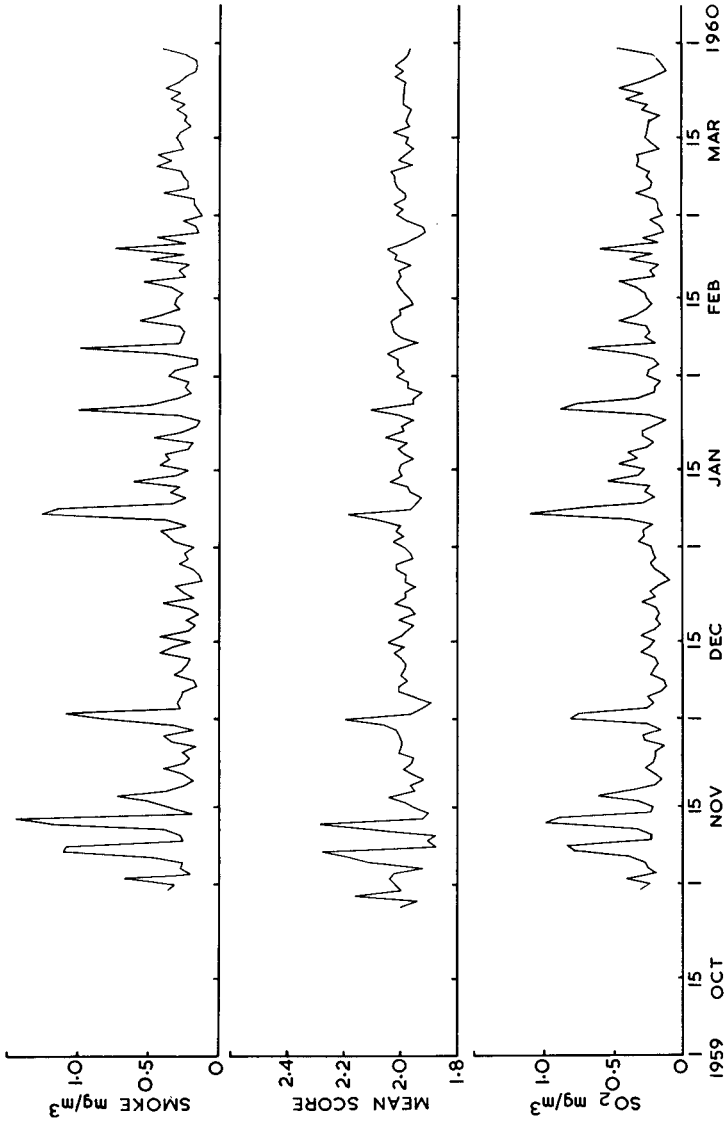

Fig. 2. Daily changes in the condition of bronchitic patients in relation to pollution, 1959–60.

[217] Reproduced from: Waller R. Air pollution and community health. *Journal of the Royal College of Physicians* 1971; 5: 362–8. Copyright © 1971 Journal of the Royal College of Physicians of London. Reproduced with permission. See page 33 and note 68 for discussion on these graphs.

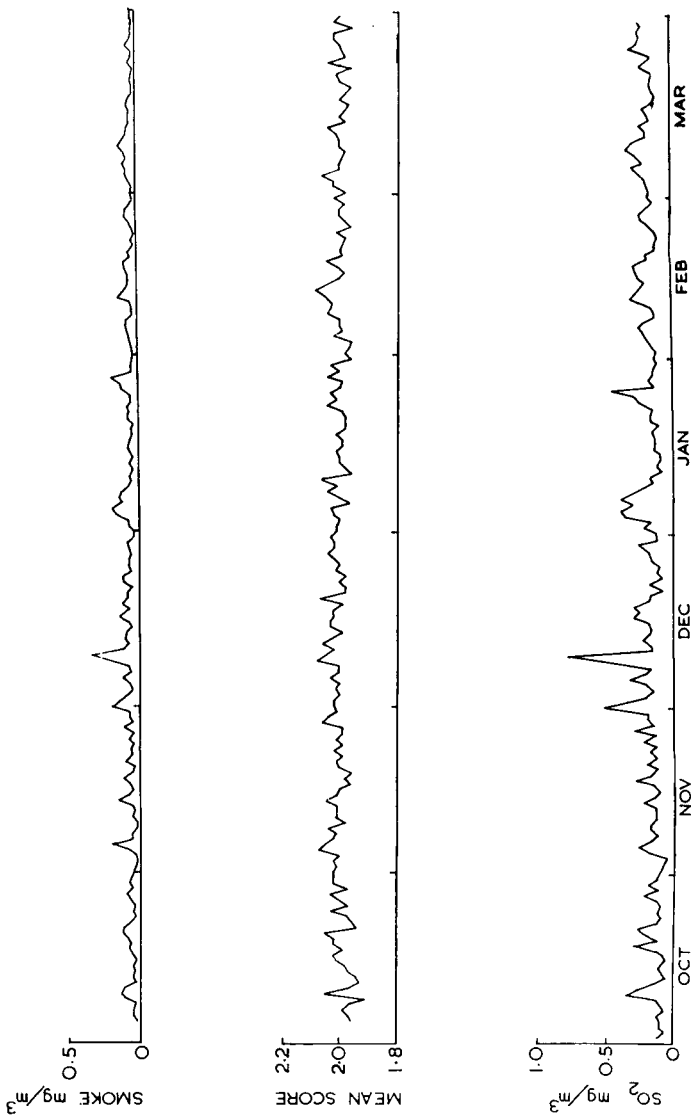

Fig. 3. Daily changes in the condition of bronchitic patients in relation to pollution, 1969–70.

Appendix 2

Group portrait of Witness Seminar participants and attendees at the Wellcome Trust, London, 19 May 2015

Key to photograph, left to right: Professor Richard Derwent, Dr Brian Commins, Professor Martin Williams, Dr Brigitte Rudd, Mr Philip Lord, Mr Simon Birkett, Professor Alison Macfarlane, Dr Heather Walton, Professor Anthony Seaton, Professor Peter Tavner, Professor Robert Maynard, Dr Chris Derrett, Mrs Ann Commins, Professor Dafydd Walters, Professor Ross Anderson
[Please note Professor Roy Harrison was absent from this photograph]

Biographical notes*

Professor H. Ross Anderson

MD MSc FFPH FRCP FMedSci (b. 1941) graduated in medicine from Melbourne University in 1964. He went to Papua New Guinea in 1966 where he held various medical officer posts before being appointed in 1969 to a research fellow post, in which he undertook research into chronic lung disease. From 1972 to 1974 he held a research post with the MRC Pneumoconiosis Research Unit in south Wales, where he obtained his MD based on the Papua New Guinea research. He studied for an MSc in Social Medicine at the London School of Hygiene and Tropical Medicine (1974–1976), and was appointed to a Clinical Senior Lectureship in Clinical Epidemiology and Social Medicine at St George's Hospital Medical School in 1976. He became Professor in 1985, and Emeritus Professor on his retirement in 2014. His main research interests have been in respiratory epidemiology and the health effects of air pollution. In the UK he has served on the DH Committee on the Medical Effects of Air Pollutants and the Expert Panel on Air Quality Standards, and internationally on various WHO groups and the US Health Effects Institute. He is Professor Emeritus of Epidemiology and Public Health at the Population Research Institute, St George's University of London, and of the Environmental Research Group, King's College London.

Mr Simon Birkett

BE (Civil) MSc (b. 1959) graduated in civil engineering from the University of Melbourne in 1981 before joining Consolidated Gold Fields Australia. He obtained his MSc from the London Business School in 1985. He then worked in corporate finance at Schroders in London for two years before joining HSBC to spend over 21 years in various roles, including corporate broking, general management, and latterly as Group Head of Financial Education within the Corporate Sustainability function. He is Founder and Director of 'Clean Air in London' which has campaigned since 2006 to achieve full compliance with World Health Organization (WHO) guidelines for air quality throughout London and elsewhere.

* Contributors are asked to supply details; other entries are compiled from conventional biographical sources.

He was appointed in 2015 as a member of the High Level Intergovernmental and Stakeholder Advisory Group for the United Nations Environment Programme's Global Environment Outlook. He is also a member of the Executive Council of the European Chapter of the International Society for Environmental Epidemiology. He is quoted frequently in the UK and international media, and has over 25,000 followers on Twitter and 35,000 on Facebook. He invented the 'Birkett Index' and app in 2013, which reports the health impact of long-term exposure to $PM_{2.5}$ based on WHO guidelines.

Dr Brian Commins

BSc MSc PhD CChem FRSC (b. 1930) graduated in chemistry in 1953. He obtained his MSc in chemistry on the condensable constituents of smoke in 1955, and his PhD in chemistry on the determination of polycyclic aromatic hydrocarbons in polluted air in 1962, all at the University of London. He was elected a Fellow of the Royal Society of Chemistry in 1964. He worked at the MRC's Air Pollution Unit as a chemist at Bart's Hospital Medical School from 1955 to 1976. From 1976 to 1980 he worked at the Water Research Centre, where he was head of the section involved with the health implications of chemical substances in drinking water. Thereafter he was a very frequent consultant to the WHO on air pollution and drinking water issues, and he was a consultant to other UN agencies and various industrial concerns. He was a WHO Consultant on the health impact of the Kuwait oil fires in the Gulf (1991). He is the author of the monographs *Asbestos Fibres in Drinking Water* and *The Significance of Asbestos and other Mineral Fibres in Environmental Ambient Air* (Commins, 1988; 1990). In the latter he concluded that airborne asbestos for the general public was essentially a 'sensibly zero risk'; the publication contained a very supportive foreword by Professor Sir Richard Doll.

Dr Christopher Derrett

MBBS MPhil (b. 1947) is a former general practitioner. He graduated in applied physics from Durham University in 1968, and his first permanent job was as a member of the non-clinical scientific staff at the MRC Air Pollution Research Unit. During his time at the Unit he helped develop instrumentation for the measurement and processing of respiratory signals and for the measurement of sulphur dioxide. After his MPhil, for a thesis entitled 'Respiratory Function: Some aspects of its measurement, analysis and interpretation' in 1977 (University

of London), he enrolled as an undergraduate medical student at the Royal Free School of Medicine. He qualified in medicine (MBBS) in 1982, and went on to GP vocational training in east London. In 1986, he became a GP partner in Newham, and later in Hackney. During his GP career, he has been a GP trainer, an appraisal lead, a senior clinical lecturer at Barts and the London School of Medicine, and also Head of GP Development for City and Hackney Primary Care Trust. Since retiring from clinical practice, he continues to teach medical students and practice support staff. He also conducts educational work with refugee doctors and GPs in Romania, and is a student of medical history.

Professor Richard (Dick) Derwent OBE MA PhD (b. 1947) was awarded a degree in 1968 and a PhD in 1971 in physical chemistry from the University of Cambridge. He worked on air pollution monitoring and atmospheric chemistry in the Air Pollution Division of Warren Spring Laboratory from 1971 to 1974, and then in the Environmental and Medical Sciences Division of the Harwell Laboratory of the UKAEA (UK Atomic Energy Authority) until 1990. From 1990 to 1993 he headed the Air Quality Science Unit of the Department of the Environment, with a brief spell in Her Majesty's Inspectorate of Pollution. Over the period 1993 to 2003 he became a Chief Research Scientist at the Meteorological Office in Bracknell, where he worked on air pollution, atmospheric chemistry, and the global scale build-up of greenhouse gases. In 2003, he took early retirement and set up his own independent consultancy on air quality and atmospheric chemistry. He holds, or has held, visiting professorships from Imperial College London, King's College London, and the University of Birmingham.

Professor Jonathan Grigg BSc MB BS MRCP(UK) MD FRCPCH (b. 1957) is the Professor of Paediatric Respiratory and Environmental Medicine at Queen Mary University of London. He was previously a Senior Lecturer in Paediatric Respiratory Medicine at the University of Leicester, moving to London in 2006. He is currently Vice Chair of the Royal College of Physician's Working Party on Air Pollution and a member of the UK Committee on the Medical Effects of Air Pollutants. His research includes the effects of air pollution on children's health, and ways of reducing exposure of asthmatic children to air pollution. He is also an honorary consultant respiratory

paediatrician at Barts Health NHS Trust, and leads the Trust's paediatric difficult asthma service.

Professor Roy Harrison

OBE DSc FRSC CChem HonFFOM HonMFPH HonMCIEH PhD (b. 1948) studied organic chemistry at the University of Birmingham, and was a postdoctoral researcher in the Department of Civil Engineering at Imperial College, London. Since 1991, he has held the position of Queen Elizabeth II Birmingham Centenary Professor of Environmental Health at the University of Birmingham, UK, and is also Distinguished Adjunct Professor at King Abdulaziz University, Saudi Arabia. His research focuses primarily on air pollutants in the urban environment, ranging from studies of emissions through atmospheric processes to personal exposure and effects on human health. He has also been heavily engaged at the science/policy interface as a member of several government technical advisory groups for the Department of Health and the Department for Environment, Food and Rural Affairs (Defra) in the UK, including membership of Defra's Science Advisory Council. He was a contributor to the WHO's *Air Quality Guidelines: Global update 2005* (World Health Organization, 2006) and the *WHO Guidelines for Indoor Air Quality* (World Health Organization, 2010). He is author of over 450 papers in the peer-reviewed literature, and is listed by ISI as a Highly Cited Researcher.

Professor Patrick Lawther

CBE DSc FRCP (1921–2008) studied medicine at St Bartholomew's Hospital Medical School from 1945 to 1950, following an aborted degree in chemistry at King's College London. At St Bartholomew's Department of Environmental and Preventive Medicine, he was Associate Chief Assistant (1952–1962), then Honorary Consultant/Physician-in-Charge (1962–1981). In 1955 he became Director of the MRC Air Pollution Unit at St Bartholomew's, later called the Environmental Hazards Unit, where he remained until 1977. From 1975 to 1977 he was President of the National Society for Clean Air, and Head of the Clinical Section of the MRC Toxicology Unit (1977–1981) in Carshalton. He also served on several government committees related to environmental toxicology. Until his retirement in 1981, he remained as Honorary Consultant in Environmental Medicine and Professor of Environmental and Preventive Medicine (appointed 1968) at St Bartholomew's.

Mr Philip Lord

MSc CMath FRSA (b. 1945) studied mathematics at Reading and London Universities, and also has a teaching certificate from the University of Sussex. He was a member of the MRC Air Pollution Unit's scientific staff between 1968 and 1978, after a brief spell teaching. In the MRC, he undertook research applying mathematics and computer techniques to the study of lung function, lung morphology, and respiratory flow dynamics. The research involved him in the development of techniques for the automation of lung function measurement. He went on to a post as Technical Manager for medical publishing at Elsevier Science Publishers in Amsterdam, where he later became closely involved in the development of new technologies for scientific publishing. Here he became Vice Chairman of the ISO and NISO committees, which determined the format standards for CD-ROM (ISO9660). In 1991 he joined the pharmaceuticals industry, first at SmithKline Beecham and then GlaxoSmithKline, in which companies he led projects for managing large-scale regulatory documentation and for archiving scientific data. As a leader in the developing science of digital archiving, he set up his own digital archiving consultancy in 2002, and worked internationally to promote best practice. He is now semi-retired, but still teaches digital archiving at the University of Dundee. He was elected a Fellow of the Royal Society of Arts in recognition of his contribution to archiving digital information.

Professor Alison Macfarlane

Dip Stat CStat FFPH (b. 1942) studied mathematics at Oxford (1961–1964) and took a Postgraduate Diploma in Statistics at University College London (1964–1965). She worked as a statistician in agricultural research at Rothamsted Experimental Station (1965–1967); on transportation studies for Hertfordshire County Council (1967–1970); the Planning and Transport Research and Computation Company (1970); at the Centre for Urban Studies, University College London (1970–1971), and as a programmer at the National Environmental Research Council's Experimental Cartography Unit (1971–1972). She joined the MRC Air Pollution Unit in 1972, and worked on, and developed, the daily mortality study initiated by Robert Waller and A. E. Martin. She left the Unit in 1975, and since then her work as an epidemiologist and

statistician at the London School of Hygiene and Tropical Medicine (1975–1978), the National Perinatal Epidemiology Unit in Oxford (1978–2001), and City University London, has focused on maternal and child health statistics and evaluation of perinatal care. She has been Professor of Perinatal Health at City University London since 2001, part time since 2011.

Professor Robert Maynard

CBE FRCP FRCPath FFOM FBTS (b. 1951) was educated at the Lewis School, Pengam in south Wales. He studied physiology and medicine at Cardiff University and the Welsh National School of Medicine. He taught physiology at Cardiff University, moved to lead a research group and then the Medical Division, at the Chemical Defence Establishment at Porton Down and to the Department of Health in 1990. He led the Department of Health's work on air pollution from 1990 to 2006, and the Air Pollution, Noise and Climate Change Unit of the Health Protection Agency from 1990 until 2011. He has edited monographs on air pollutants, environmental medicine, chemical warfare agents, and the scientific foundations of trauma, and has contributed to a number of other books; for example: Ayres, Maynard and Richards (2006); Holgate *et al.* (1999); Maynard and Howard (eds) (1999); Marrs, Maynard, and Sidell (1996). He edited the *World Health Organization's Air Quality Guidelines for Europe, 2nd edition* (World Health Organization, 2000). He was also co-organizer of a Royal Society meeting on nano-particles in 2005 and has published in the nano-toxicology field. He holds an Honorary Chair at Birmingham University.

Professor Anthony Seaton

CBE MD DSc FRCP FRCPE FMedSci (b. 1938) qualified from Cambridge in 1962. He trained at Liverpool in general medicine, cardiology, and neurology. After senior posts in respiratory medicine in West Virginia, USA, and Cardiff, he was Director of the Institute of Occupational Medicine in Edinburgh (1978–1990). He was Head of the Department of Environmental and Occupational Medicine at Aberdeen University from 1988 until his retirement in 2003 (now Emeritus). His research from 1969 to 1990 largely concerned asthma and occupational lung diseases, and led to the development of UK protective health standards in coalmining, asbestos work, and the silica, wool, and PVC industries. Throughout his career he worked as an NHS consultant, and taught respiratory and occupational medicine. He

has written seven books and over 300 papers on respiratory and occupational medicine, and other topics, and has lectured on these subjects internationally. He was the Editor for *Thorax* from 1977 to 1981, and in 1999/2000 he was President of the British Thoracic Society. He chaired the UK Government's Expert Panel on Air Quality Standards, and sat on the Committee on the Medical Effects of Air Pollutants from 1991 to 2003, and the Royal Society's Working Group on Nanoscience and Nanotechnology from 2003 to 2005.

Professor Tilli Tansey

OBE PhD PhD DSc HonMD HonFRCP FMedSci (b. 1953) graduated in zoology from the University of Sheffield in 1974, and obtained her PhD in *Octopus* neurochemistry in 1978. She worked as a neuroscientist in the Stazione Zoologica Naples, the Marine Laboratory in Plymouth, the MRC Brain Metabolism Unit, Edinburgh, and was a Multiple Sclerosis Society Research Fellow at St Thomas' Hospital, London. After a short sabbatical break at the Wellcome Institute for the History of Medicine (WIHM), she took a second PhD in medical history on the career of Sir Henry Dale in 1990, and became a member of the academic staff of the WIHM, later the Wellcome Trust Centre for the History of Medicine at UCL. She became Professor of the History of Modern Medical Sciences at UCL in 2007 and moved to Queen Mary, University of London (QMUL), with the same title, in 2010. With the late Sir Christopher Booth she created the History of Twentieth Century Medicine Group in the early 1990s, now the History of Modern Biomedicine Research Group at QMUL. She is an Honorary Fellow of the Society of Apothecaries' Faculty of the History of Medicine; an Honorary Member of the Physiological Society, of which she is also Honorary Archivist, and recipient of the Paton Prize in History of Physiology, 2015.

Professor Peter Tavner

PhD DSc (b. 1946) is Emeritus Professor of the School of Engineering at Durham University. He received a mechanical sciences degree from Cambridge University (1969), a PhD from Southampton University (1978) and a DSc from Durham University (2012). Following his PhD, he worked for the UK Electricity Supply Industry, and served as a Weapons Electrical Officer in the Royal Navy on Guided Missile Destroyers (1969–1971). He subsequently worked at the MRC Air Pollution Unit (1971–1973). He taught at

the University of Benin, Nigeria (1973–1975), and then held senior research, development, and technical positions in the manufacturing industry, eventually as Group Technical Director of FKI Energy Technology (1997–2003), an international business manufacturing electrical machines, drives, and wind turbines in the UK, Holland, Italy, Germany and the Czech Republic. He joined Durham University in 2003 where he was Principal Investigator of EPSRC Supergen Wind Consortium, Principal Investigator of EPSRC Sino-British Future Renewable Energy Network Systems (FRENS) Consortium, member of EPSRC Supergen Marine Consortium and of EU FP7 ReliaWind Consortium. His published work is on electrical machinery, power converters, and on the reliability and performance of wind farms and marine renewable resources.

Mr Robert Waller[218]

trained in physics and statistics at Imperial College during the Second World War and began his research career with Sir Ernest Kennaway in 1948. His work involved the chemical analysis of samples of smoke particles collected on filters in a variety of locations in the UK and showed that domestic coal smoke was a major contributor of the carcinogen benzo(a)pyrene in urban air. Much of Kennaway's work was transferred to the new Medical Research Council Air Pollution Unit at St Bartholomew's Hospital when it opened in 1955 and Kennaway maintained an interest in the work.[219] Waller moved to the MRC Unit at that time. The Unit was directed by Professor P. J. Lawther who, with Waller, Commins, and others, established a world-class reputation for air pollution research. Waller's work expanded into epidemiology, human physiology, and electron microscopy. The Unit closed in 1980 and Waller moved to the Department of Health where he worked until his retirement in the late 1990s. By then, Waller had acquired a unique position in the air pollution research field: he had been a major contributor to the WHO *Air Quality Guidelines* published in 1987 and to later WHO publications. His knowledge of the field was highly regarded not only in the UK but, also, across Europe and in the United States: his opinions were widely sought.

[218] Mr Robert Waller's biography was written by Professor Robert Maynard.

[219] Waller (1994).

Robert Maynard remembers Robert Waller as a fine scientist, an excellent colleague, and a delightful man with an engaging laugh and a truly Christian desire to help others.

Professor Dafydd Walters

BSc MB BS FRCP FRCPCH (b. 1947) was educated at the Lewis School, Pengam in south Wales and qualified from University College London in medicine in 1971 having taken an intercalated degree in physiology. After junior clinical posts in medicine, he was recruited by Professor Leonard Strang in 1974 as a lecturer in paediatrics at UCH Medical School on a research project investigating fetal lung development and pulmonary adaptation at birth. He was awarded an MRC Travelling Fellowship to work with John Clements on pulmonary surfactant at the CVRI in San Francisco (1980–1981), and then took up the post of Senior Lecturer and Honorary Consultant at UCH in paediatrics in late 1981. In 1994 he was appointed Professor of Child Health and Head of Department at St George's Hospital Medical School and continued research on ion and water transport across the pulmonary epithelium in the developing and postnatal lung. He retired in 2012, and is currently Emeritus Professor of Child Health, St George's University of London, where he still undertakes some research work.

Dr Heather Walton

BSc DPhil (b. 1962) graduated in biochemistry from the University of Manchester in 1983, and obtained her DPhil from Hertford College, Oxford, in 1987, where she studied modifications to glomerular basement membrane. She worked on food additives at both the Ministry of Agriculture, Fisheries and Food (1987–1989) and the Department of Health (1990–1996). She attended a part-time toxicology course at St Bartholomew's Hospital Medical College and subsequently became a member of the UK and European Registers of Toxicologists in 2006. She was a member of the Secretariat for the Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment from 1990 to 1996. She started working on air pollution at the Department of Health in 1996 as Scientific Secretary of the Committee on the Medical Effects of Air Pollutants (COMEAP) and Principal Scientific Officer in the Air Pollution Unit. Her job was transferred to the Health Protection Agency in 2006. In 2010, she joined the Environmental Research Group at King's College, London, as a

Senior Lecturer in Environmental Health. She specializes in health impact assessment of air pollution, and is now a member of COMEAP, Chair of the COMEAP sub-group on Quantification of Air Pollution Risk (QUARK), and a temporary adviser to WHO.

Professor Martin Williams

PhD (b. 1947) graduated with a first class honours degree in chemistry from Cardiff University (1968), and was awarded a PhD in theoretical chemistry from Bristol University in 1971. He worked as post-doctoral researcher at the University of British Columbia, Vancouver, before joining Warren Spring Laboratory, where he was Head of the Air Pollution Division from 1982 to 1993. There he led a team of 50 scientists in air quality research for government and business. In 1993 he was appointed Head of Science for Defra's Air and Environmental Quality Division (until 2002), and he was Defra's Head of Atmospheric Environment and Industrial Pollution from 2005 until 2010. He was, until 2014, Chairman of the Executive Body of the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP) and formerly chair of the CLRTAP EMEP Steering Body. He has authored papers on urban air quality, vehicle emissions and the links between air quality and climate change, and was lead author of the policy section of the United Nations Environment Programme Assessment of Short Lived Climate Forcers. He is Professor of Air Quality at King's College, London, with research interests in the application of science to policy in air quality and climate change.

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* Please note that references with four or more authors are cited using the first three names followed by *'et al.'*. References with *'et al.'* are organized in chronological order, not by second author, so as to be easily identifiable from the footnotes.

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