The World Health Organization (WHO) estimates that in 2012 there were 3 million deaths attributable to outdoor air pollution. Seventy-two percent of deaths were due to ischaemic heart disease and stroke; 14% were due to chronic obstructive pulmonary disease or acute lower respiratory infections; and 14% were due to lung cancer. In addition to premature death, outdoor air pollution causes considerable ill health in both adults and children. While air pollution in much greater in Africa, Asia and the Middle East, in Scotland there are still an estimated 2,000 excess deaths per year due to particulate matter in outdoor air pollution which is much greater than the estimated 865 deaths per annum attributed to exposure to second hand smoke prior to the introduction of Scotland’s smoke free legislation. As such, the Cleaner Air for Scotland strategy has the potential to have a significant impact on the health of the Scottish population. I am responding to the Health and Sport Committee in my capacity as Professor of Public & Population Health at the University of Stirling and as Coordinator of the CLEAN Air Collaboration which evaluated the impact of Scotland’s smoke free legislation. The focus of the response is on evidence of the health benefits associated with interventions designed to reduce both outdoor and indoor air pollution and issues relevant to the development of an effective monitoring and evaluation strategy.

Q1: To what extent do you believe the Scottish Government’s Cleaner Air for Scotland – The Road to a Healthier Future and the approach by Integration Authorities and NHS Boards towards clean air is preventative?

The Clean Air for Scotland report sets out a national strategy with a range of measures to reduce outdoor air pollution and improve air quality. The focus of the measures is on reducing transport emissions, ensuring compliance with Scottish and EU legislation, promoting the use of low emission materials in construction and maximising the benefits that can be achieved through reducing greenhouse gases. It is anticipated that these measures will confer health benefits on the Scottish population, both directly by reducing exposure to harmful air pollutants and indirectly by, for example, increasing physical activity through the promotion of use of public transport and of active travel.

There is reasonably consistent evidence from different jurisdictions that legislation to reduce levels of outdoor air pollution is associated with improvements in health. For example the evaluation of the United States Clean Air Act through the Harvard Six-Cities cohort study found that reductions in air pollution resulted in a large decline in mortality risk. Policies to curb diesel emissions in Tokyo between 2006 and 2008 resulted in modest reductions in PM$_{2.5}$ from 22.8 μg/m$^3$ to 20.3 μg/m$^3$; and in NO$_2$ from 36.3 ppb to 32.1 ppb. These reductions were tentatively associated with decreased rates of
cerebrovascular mortality. Radical measures to improve air quality in Delhi, which included the conversion of all commercial vehicles to compressed natural gas and the closure of polluting industries in residential areas between 2000 and 2002, were associated with a significant improvement in respiratory health, with the strongest effects found amongst those spending a large part of their time out-of-doors.  

Evidence on the impact of the introduction of low emission zones (LEVs) is more mixed. LEVs introduced in Rome in 2006 were found to improve air quality (reduction in PM$_{10}$ and NO$_2$) and improve the health of residents living along busy roads. The improvements were modest with 921 years of life gained per 100 000 population (3.4 days per person) and were associated with a reduction in NO$_2$ exposure. Years of life gained were greater in higher socioeconomic groups, compared with lower ones. In contrast LEVs introduced in the Netherlands in 2007/08 that restricted the access of older trucks to the inner city did not significantly reduce air pollution, although PM$_{2.5}$ levels in urban streets did fall compared with streets in the suburbs.  

The Stockholm congestion charging trial was introduced for a period of 7 months in 2006 with the specific intention of improving air quality. At the same time public transport was expanded, increasing frequency and capacity. Traffic flow across the cordon during charging hours, was reduced by 22% compared with 2005 and air quality improved. NO$_2$ fell by 10.0%, total PM$_{10}$ by 7.6% and the PM$_{10}$ fraction from vehicle exhausts by 10%. A public health impact assessment was conducted and it was estimated that over a 10-year period 206 years of life would be gained per 100,000 population from Greater Stockholm. A more recent study found that the air quality improvements persisted after the scheme was made permanent in 2007. The results from the Stockholm study are very similar to estimates of the health impact of London’s congestion charge which was introduced in 2003.  

Following temporary traffic restrictions introduced during the 2008 Beijing Olympic Games, improvements in air pollution levels were reported as well as a significant reduction in adult outpatient visits for asthma. During the 2002 Summer Asian Games in Korea, when 14 days of traffic restrictions were introduced, air pollutants also fell and the relative risk of hospitalization for asthma in children < 15 years during the post-Games period fell to 0.73 (95% CI: 0.49–1.11) compared with the pre-games period.  

It is believed that PM$_{2.5}$ (fine particulates) is a major contributor to ill health caused by outdoor air pollution. PM$_{2.5}$ is also a major contributor to indoor air pollution both through the burning of biomass fuels for heating and cooking and through exposure to second hand smoke (SHS). In developed countries PM$_{2.5}$ from SHS accounts for about 80% of indoor PM$_{2.5}$. A significant and consistent body of evidence has accumulated from around the world that a comprehensive ban on smoking in enclosed public and work places space can improve health. These findings are supported by a large body of epidemiological evidence.
from studies of both long- and short-term exposure to air pollution.\textsuperscript{17,18} This makes the results of evaluations of the impact of smoking bans particularly relevant to the regulation of outdoor air pollution.

The national evaluation of Scotland’s smoke free legislation, conducted by the CLEAN Collaboration, included analyses of routine health and behavioural dataset as well as the conduct of a series of bespoke studies designed to answer specific questions.\textsuperscript{19} The evaluation found that the implementation of a comprehensive ban on smoking in enclosed public places improved air quality, reduced population level exposure and improved the health of both adults and children mostly within one year of implementation. Specifically, the evaluation found:

- An 86\% reduction in PM2.5 in bars two months after the introduction of the smoking ban, which was maintained at one and five years post implementation.\textsuperscript{20} This was accompanied by an 89\% reduction in salivary cotinine at one year follow-up in non-smoking bar workers.\textsuperscript{21} Cotinine is a metabolite of nicotine and a specific biomarker of exposure to SHS.
- At a population level, there was also a 39\% reduction in SHS exposure in representative samples of adults\textsuperscript{22} and 11 year old school children\textsuperscript{23}, as measured by salivary cotinine.
- The reduction in SHS exposure in both bar workers and the general population was accompanied by measurable improvements in health. In bar workers there was an improvement in reported respiratory health at one year follow-up.\textsuperscript{24} The proportion of non-smoking bar workers who reported phlegm production and eye irritation more than halved. However, unlike findings from some other studies there was no improvement in bar workers’ lung function. There was also a fall in the proportion of smokers reporting wheeze and cough, which was probably associated with a fall in the consumption of tobacco in this group.
- However, perhaps the most significant health improvement was identified by a prospective study of admissions to hospital for acute coronary syndrome (this includes a diagnosis of heart attack and unstable angina).\textsuperscript{25} Comparing admissions in a 9 month period prior to the ban with a 9 month period after the ban, the study found:
  - A 17\% reduction in total admissions for ACS after the ban
  - A 21\% reduction in admissions of never smokers
  - A 19\% reduction in admissions of ex-smokers
  - A 14\% reduction in admissions of smokers
  - 67\% of admissions prevented were in non-smokers
- The overall 17\% reduction in ACS admissions compared with an average 3\% reduction in ACS admissions in Scotland in the 10 years prior to the ban and a concurrent 4\% reduction in ACS admissions in England, where a ban had not yet been introduced. The very large observed reduction in ACS admissions could not be
accounted for by an increase in deaths in the community before patients got to hospital, which also fell by 6%.

- A meta-analysis of 17 studies, many of which were retrospective and used routine hospital data concluded that smoking bans reduce heart attacks by 10%. The prospective Scottish study, which applied a standard case definition and collected data on smoking status and self-reported and biomarker assessment of exposure to SHS was instrumental in the US Institute of Medicine concluding that there was a causal relationship between the implementation of smoking bans and a reduction in acute MI.

- Using time series analysis of hospital discharge data (SMR01) it was also found that there was a 15% reduction in admissions for childhood asthma associated with the ban, as well as an improvement in perinatal outcomes which included a 12% reduction in pre-term deliveries; 4.5% reduction in small for gestational age; and a 10% reduction in low birth weight. The improvement in perinatal outcomes was contemporaneous with the introduction of the smoking ban but it cannot be ruled out that some of the improvement in outcomes was associated with a reduction in the prevalence of smoking in pregnancy, which also fell sharply over the study period.

- Some changes in smoking behaviour were also identified. For example time series analyses of over the counter (OTC) nicotine replacement therapy (NRT) and NHS prescribed NRT showed that there was an increase in use of NRT in the 3 month period immediately prior to the introduction of the smoking ban but this was not maintained after this. Similarly smoking prevalence fell in the lead up to the smoking ban but after a year had returned to the pre-ban level. This highlights the difficulty of maintaining voluntary behaviour change, which is particularly relevant to aspects of the strategy relating to the use of public transport and active travel.

The factors that contributed to the success of the legislation in reducing exposure were:

- **The simplicity of the intervention** and the relative ease of enforcing a comprehensive compared to a partial ban. In Spain, where a partial ban (allowing smoking in bars) was first introduced, compliance was poor and reductions in population exposure relatively small. Later a comprehensive ban was introduced and reductions in exposure were similar to those observed in Scotland. A **comprehensive public information campaign** that included: a heavy weight TV mass media campaign on dangers of SHS; a website explaining the legislation and the responsibilities of employers; a household leaflet drop explaining the smoking restriction that would be put in place, led to high levels of awareness of the dangers of SHS and strong support for the legislation from the general public, particularly among non-smokers. Support amongst smokers only increased after the legislation came into force.
• **High levels of compliance by businesses and the general public.** A qualitative study of bar managers found that in spite of a rapid fall off in the rate of inspections by environmental health officers within 6 months of the legislation coming into force, compliance by businesses was driven by concerns about being caught and thus compliance was sustained. ³²

Studies from other jurisdictions have reported similar health outcomes associated with the implementation of comprehensive smoke free legislation.

The remarkable impact on health of reducing SHS exposure is associated with both the acute and long term effects of SHS exposure. While a range of different mechanisms are involved, with specific reference to CHD risk, studies have found SHS exposure has a short term effect on blood clotting – with a maximal effect at low doses, ³³ while long term follow-up of active and passive smokers over 20 years has found that heavy passive smoking confers the same risk of CHD as light active smoking.³⁴

**Q2: Is the approach adequate or is more action needed?**

*A Cleaner Air for Scotland* focuses appropriately on PM₂.₅ and nitrous oxides NOₓ for which there is the greatest evidence of harm. However, there is growing evidence of the short-term and long-term health effects of coarse particles (PM₁₀ – PM₂.₅) at concentrations below the current European limit values. Coarse and fine particles deposit at different locations in the respiratory tract, have different sources and composition, act through partly different biological mechanisms, and result in different health outcomes. Therefore, PM₁₀ should not be considered just a proxy measure of PM₂.₅ but an independent contributor to adverse health effects caused by air pollution. This has implications for the monitoring of particulates.

Table 1 on page 25 of *Cleaner Air for Scotland* outlines the main sources of emissions by sector for Scotland. Considering the two key pollutants PM₁₀ (which include PM₂.₅) and NOₓ, the table shows that 35.2% of PM₁₀ comes from other combustion sources compared with only 16.4% from transport sources, while 34.6% of NOₓ emissions come from the energy industries. Agriculture also contributes 21.1% of PM₁₀ emissions. While the present strategy may well directly and indirectly contribute to reductions in emissions from these sources (for example by the production of greener energy), given the level of contribution further consideration should be given to how the strategy will address emissions from agriculture and other combustion sources.

The current strategy focuses on outdoor air pollution. However indoor air pollution continues to pose a health risk for some. Children who live in homes where both parents smoke may be exposed to SHS at levels equivalent to bar workers’ exposure prior to the
introduction of the smoking ban. Some progress has been made in encouraging parents to restrict or ban smoking in the home but reducing SHS exposure remains a priority as part of the Tobacco Control Strategy. However, as noted above, the policy locus of the use of biomass fuels (coal and wood) which contribute to both indoor and outdoor air pollution is unclear.

Q3: Is the Scottish Government’s Cleaner Air for Scotland – The Road to a Healthier Future being measured and evaluated in terms of cost and benefit?

Scotland’s smoke free legislation was a simple intervention that was implemented nationally on a specific date. Objective, SHS specific measures of air quality (PM$_{2.5}$) and of smoking status and recent SHS exposure (salivary cotinine) were available making it easier to associate changes in SHS exposure with improved health outcomes. However, the Scottish Strategy for Clean Air includes a wide range of measures, which will be implemented incrementally over time. This makes the development of an effective monitoring policy more complicated. Key to the development of an effective monitoring and evaluation of the Clean Air Strategy is likely to be:

- **The establishment of an interdisciplinary team with appropriate expertise to develop a monitoring and evaluation strategy and to oversee its delivery**: In addition to expertise in the fields of air quality measurement, transportation, construction, behaviour change, social marketing and climate change for example, the team should also include members with expertise in policy evaluation and health impact assessment.

- **The development of appropriate metrics for air quality**: The strategy focuses on the measurement of PM$_{2.5}$ but given the growing evidence of the independent contribution of coarse particles to adverse health consequences, particularly respiratory health, it is important that PM$_{10}$ continues to be monitored. The consequences of short and long term exposure may also be different. For example a short term moderate rise in PM$_{2.5}$, PM$_{10}$, or NOx may have few adverse health consequences, but long term exposure to moderate levels may have. Thus it is important to measure both daily levels and annual averages.

- **The development of measures of exposure**: As part of the evaluation of Scotland’s smoke free legislation it was possible to obtain objective SHS specific measures of exposure by measuring salivary cotinine, as well as a less objective measures – self reported frequency, duration and location of exposures. There are a number of biomarkers of exposure to air pollution, for example biomarkers of oxidative stress and platelet aggregation. Although these are not air pollution-specific, data on relevant biomarkers may already be being collected as part of on-going cohort studies such as the Biobank Project, and it may be possible to link these to data on air quality.
• **Identifying appropriate and measurable health outcomes:** WHO recommend\(^{35}\) the following mortality outcomes should be assessed:
  - Premature attributable death (all causes) due to acute (one or more days) exposures, all ages;
  - Attributable death (all causes or cardiovascular or cardiopulmonary and lung cancer) associated with long-term exposure for adults over 30 years;
  - Years of life lost in association with long-term exposure of adults older than 30 years;
  - Attributable cases of infant mortality (0–1 year of age).

They go on to recommend the following morbidity outcomes:
  - Bronchitis symptoms in children under the age of 18 years;
  - Chronic bronchitis in adults older than 30 years;
  - Asthma attacks, all ages;
  - Cardiovascular, cerebrovascular (possibly) and respiratory hospital admissions, all ages;
  - Urgent care visits due to asthma (and possible other respiratory outcomes) and cardiovascular disease, all ages;
  - Restricted activity days, adults.

Some of these or similar outcomes could be derived from existing routine health and mortality data and would provide the basis of a cost benefit analysis. However, for a comprehensive evaluation of the strategy specially designed studies will be required.

• **The timely collection of baseline data** for an appropriate period prior to the introduction of key elements of the strategy, **together with an appropriate duration of follow-up** within which health outcomes could be expected to occur.

**Q4:** To what extent do NHS Boards and local authorities’ reference air quality and health in their Joint Health Protection Plans?

No comments

**References**


34. Pechacek T, Babb S. Effect of public smoking ban in Helena, Montana: Can law really make a difference? BMJ 2004; 328 doi: https://doi.org/10.1136/bmj.328.7452.1379c