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The Benefits of Air Pollution Control: Where's the Beef?

By Fred Lipfert, PhD and — January 23, 2020

It's been 50 years since cleaning up the air in the United States began in earnest. Skies are much clearer now than in the mid-20th century. Leaded gasoline is gone, power plants have been abandoning coal and sulfur dioxide has dropped by 91%. Despite these growing improvements, why have epidemiologists been unable to show the demonstrable public health benefits that their computer models predict?

Image by Walter Albertin courtesy of the United States Library of Congress's Prints and Photographs division on Wikimedia [1]

Here are some possibilities.

Maybe we're looking at the wrong pollutants.

EPA has been monitoring essentially the same air pollutants for 50 years. Since 1980, lead in gasoline dropped by 99%, carbon monoxide from traffic by 83%, and nitrogen oxides by 63%. Concentrations of ozone and airborne particulate matter have decreased by about 30% [1]. Traffic is an important source of air pollution and, since 1970, miles driven have more than quadrupled while fuel economy nearly doubled. The composition of engine exhaust has changed but we have only sparse data on the relevant trace metals, various carbon compounds, or the nanometer-sized particles that can enter the bloodstream. Ambient air quality monitoring has been focused on regulatory rather than scientific priorities.

Maybe we're looking in the wrong places.

EPA regulations, by law, are limited to outdoor air quality. But we spend 85% of our time indoors where air quality can be significantly better or worse, depending on building construction, air conditioning and ventilation, and indoor sources. Indoor air quality is impacted by smoking, cooking, household cleaning, air "fresheners", and is neither monitored nor controlled, established health effects notwithstanding.[2] For example, the underlying cause of asthma is an allergic reaction often linked to indoor air pollution that is thought to exacerbate other respiratory effects as well.

Maybe we've been looking at the wrong people*.*

Not everyone is affected by polluted air. Excess mortality during the major smog episodes such as the notorious 1952 smoky fog in London was largely limited to those with previous cardio-respiratory conditions.[3] No individual death has been linked with long-term exposure to air pollution, which preferentially impacts the frail and susceptible, often the very young and elderly. Most of the key epidemiology studies were based on healthy middle-class, middle-aged white adults.[3] By and large those studies focus on specific outcomes like mortality and hospitalization rather than identifying mechanisms and interactions that could lead to these events.

Maybe we've been looking at the wrong time frames*.*

Adverse health outcomes, such as cardiac arrest, stroke, asthma attack, hospitalization, and death are best studied as changes over time. Causality may be inferred when a health event is preceded by a temporary spike in air pollution if other possibilities such as heat waves or cold snaps are eliminated. [4] Longitudinal air pollution studies of progression from healthy to vulnerable status in individual human subjects have not been published. Long-term mortality associations with air pollution have largely been inferred from geographic distributions [3] as if moving from a rust-belt city to a beach resort could rapidly increase longevity. However, improving or diminishing health statuses are time-dependent processes that may require decades to become evident, as with the effects of smoking. Chronic obstructive pulmonary disease (COPD) develops slowly as lung architecture is destroyed after many years of smoking or occupational exposure. Heart disease may follow from decades of arterial calcification. However, nearly all of the key long-term air pollution studies have been based on the spatial distributions of exposure *coincident* with adverse outcomes, rather than exposures *accumulated* over a lifetime.[4] This distinction is critical over periods of exposure reduction, during which rates of accumulation decrease. Linking estimated future benefits with current exposures rather than accumulations inflates risk estimates [5]. The overarching lesson here is that *any* change in health status, good or bad, is necessarily time-dependent, regardless of geographic gradients.

Maybe we've been relying on the wrong models.

Epidemiologists develop models of the real world for long-term studies; they necessarily involve simplifications that cannot account for all possible confounders of air pollution effects. Air pollution can affect millions of people, for example in China and India, and the smoke from the Australian bush fires has circled the globe. However, in the developed world, the role of air pollution upon our health amounts to only a few percentage points.[3] Even according to these problematic models, cutting U.S. $PM_{2.5}$ by half could reduce mortality by less than 3% and extend lives by about 14 weeks [6]. Large populations or long exposure periods are required to achieve statistically significant findings. *Cohort* studies of specific individuals are difficult to follow over sufficiently long periods; early exposure data may be lacking as well as the information that describes socioeconomic status like personal income.[7] As a cohort ages its most vulnerable members are lost and lifestyle changes occur. While *population* studies may allow larger samples, they can tell us less about the individuals and their critical information, especially smoking habits. Personal (individual) exposures have never been available in sufficient numbers for any air pollution epidemiology study.

"Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful." - George Box

When indoor exposures are not considered, ambient air quality data can only describe the *places* where they were measured and not necessarily the *inhabitants.* Studies show more exposure variability within a city than among city averages [8]. In order to compare *places*, long-term models must consider other geographic characteristics including climate, altitude, traffic density, and green spaces. This has seldom been the case among the hundreds of published long-term studies; it is important to recognize that replication implies that the calculations are correct, but cannot validate a model. Without validation, the usefulness of a model remains open to question.

Given these basic questions, what now?

This much we know. Clean air is a good thing; mindless regulation, improperly directed, is not. In any event in the developed world, the public should clean up indoor environments, stop fearing the outdoors, and get outside. Further progress towards public health will depend on scientific investigations of basic mechanisms, especially with respect to cardiovascular and pulmonary diseases. It's time to return to the lab.

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