Title
Lost in the archive

Journal
Indoor Air, 26(2)

ISSN
0905-6947

Author
Nazaroff, William W

Publication Date
2016-04-01

DOI
10.1111/ina.12280

Peer reviewed

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A few years after completing my PhD, I made a startling (and distressing) discovery. One of the claims that I had made in my dissertation about the prior state of knowledge was wrong. On indoor aerosol modeling, I wrote that "the current state-of-the-art approach is based on a mass balance that only determines the total concentration of suspended particulate matter… no information on aerosol size or chemical composition is incorporated…" (Nazaroff and Cass, 1989). To support this claim, I cited Alzona et al. (1979), missing an earlier article by Lum and Graedel (1973) that explicitly and effectively incorporated particle size into a mathematical model of indoor airborne particles. Fortunately, no one suggested that this error warranted revoking my PhD!

At that time, when accessing a journal article required physically visiting a library, the bibliographic aspects of scholarly research entailed considerable effort. A key, effective step was to identify an influential article on the topic and then build a bibliography by tracking backwards (using reference lists) and forwards (e.g., using the print edition of the *Science Citation Index*). The article by Lum and Graedel escaped my attention in part because it had only been cited twice. Although the explanation is reasonable, the excuse is poor. Lum and Graedel's work was published in a prominent journal and directly pertinent. I should have found, through whatever necessary effort, that article prior to publishing my own work.

This episode was called to mind recently, when I received by e-mail an article by Mosley (2003). He presents a thought-provoking thesis about air quality in Britain in the late 19th century, arguing that, "deep-rooted fears about air pollution inside the home obstructed efforts to improve air quality outdoors in Britain's large towns." The underlying reason: coal combustion in the open fireplace, which "despite its many defects, was recognized to be the primary ventilating agent in most homes." The theme of Mosley's article resonates with my interest in how building attributes influence the relationship between indoor and outdoor air pollution. Becoming aware of the work only a decade after its publication startled my reflexes along several lines: I had no prior knowledge of the author; I wasn't acquainted with the journal in which he published; and (most disturbingly) I was unfamiliar with a large proportion of his references.

Among Mosley's primary sources were the writings of Francis Albert Rollo Russell (1849-1914). According to an obituary published in the *Quarterly Journal of the Royal Meteorological Society* (**40**, 246, 1914), Russell "took a great interest in the question of London fogs, and was a strong advocate for the abatement of coal smoke." His book-length report, *The Atmosphere in Relation to Human Life and Health* (Russell, 1896), was "awarded honorable mention with a silver medal" in the "Hodgkins Fund Prize competition of the Smithsonian Institution." Thanks to Google Books, I easily and immediately acquired a digital copy of Russell's monograph.

The volume contains strange elements, such as a discussion about modifying fog and precipitation patterns through the postulated construction of very large walls. It contains ideas subsequently shown not to be true, for example that, "the activity of ozone is so great and its function so beneficial that its presence in normal quantity is … a fair guaranty of the purity of the air and of healthy conditions so far as breathing is concerned." It also contains disturbing statements about the presumed superiority of the white race.

What I found valuable, though, is that Russell's monograph provides a fascinating account of the state of knowledge ca. 1900 regarding constituents in the atmosphere, the influence of physical geography on climate, the nature of major infectious diseases, and the relationships of these and other features to human health and wellbeing. Three quotes illustrate some of the insights that remain pertinent at or near today's frontier of knowledge.

"In schools, the loss of attention, the difficulty of keeping on long at a task, and the sympathetic weariness, are very frequently the result of bad ventilation. The schoolmaster has great power to improve the quality, or rather the scope, of his pupil's brains by the admission of plenty of air."

"The strict regulations of dress and washing enjoined upon nurses are almost equally applicable to medical attendants, and the use of clothes of a washable material and smooth surface by all persons in the presence of infectious cases would give greater security to all patients visited, and, indeed, to the general population."

"[Ozone's] oxidizing power is the reason of its absence from confined spaces where organic matter, dust, or smoke is present, for such matter quickly uses up the small portion of ozone which enters with the fresh air. The walls, furniture, etc., are also covered with fine dust, which the ozone attacks."

The writings of Mosley and Russell led me directly and indirectly to several other articles published during the second half of the 19^{th} century. In a few cases, I knew already of the authors, but not in the specific context of their contributions to knowledge about indoor air. For example, John Aitken, well known in aerosol science for inventing the condensation nucleus counter, may have reported the first ever measurements of particle number concentrations in indoor air (Aitken, 1889). John Tyndall, a seminal contributor on radiant heat transfer by atmospheric gases, also made early suggestions about the use of fibrous filtration for respiratory protection from airborne particulate matter, including infectious agents (Tyndall, 1871).

The meander through this century-old literature circled back to another theme from my doctoral dissertation: thermophoresis, the mechanism inducing airborne particles to migrate down a concentration gradient, from warm to cold (Nazaroff and Cass, 1987). Both Tyndall and Aitken were early contributors, with Aitken (1884) noting that thermophoresis, "explains the reason why stove and hot-air heated rooms are always so much dirtier than those warmed by open fires. In a stove-heated room the air is warmer than the walls and than the objects in the room, the dust therefore tends to leave the air, and to deposit itself on every object colder than itself in the room; whereas, in a room warmed with an open fire, the heating being principally done by radiation, the walls and furniture are hotter than the air, they therefore tend to throw off the dust…"

During the past few decades, advances in information technology have enabled us to efficiently access scholarly writings, including older works. Our community would benefit from an increased awareness that the older literature has considerable value. Some of the concerns identified then have not yet been resolved. The need to make reliable inferences from limited empirical evidence demanded strong logic and a mechanistic perspective that remains valuable today. Early studies exhibit a human-centered perspective about the environment that would continue to serve well the interests of the multidisciplinary community concerned with indoor environmental quality and health. We would do well to invest some of our effort so as to prevent important knowledge and insight from remaining lost in the archive.

William W Nazaroff
Editor-in-Chief

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