

### 3.2. TEMPORAL VARIABILITY OF THE EXPOSOME

#### *Individual temporal variability - short-term variations*

Various factors, including lifestyle changes, seasonal variations, and geographic mobility, cause environmental exposures to fluctuate over short periods of time. For instance, studies of air pollution exposure report significant intra-individual variability, with individuals experiencing fluctuations in pollutant levels depending on such factors as commuting patterns. Individual temporal variability is particularly pronounced in the case of chemicals with short biological half-lives (e.g. non-persistent chemicals) which are rapidly cleared from the body. Studies have shown, for instance, fluctuations in exposure to phthalates and bisphenols, with levels varying over weeks, days, even hours as a result of such factors as dietary intake, personal care product use, and indoor environment conditions.

Panel studies have been critical in investigating the temporal variability of exposures and its impact on health, as they provide insights into how individuals' environmental exposures fluctuate in relation to such factors as daily activities, seasonal variations, and life events. Panel studies exploit a longitudinal study design in which a group of individuals – the panel – is repeatedly measured over time to assess changes in exposure to environmental factors and their health outcomes. These studies typically involve collecting samples and data from the same individuals at multiple time points, thereby allowing researchers to examine how exposures vary within individuals over time and how these variations may influence health outcomes. As discussed above, the HELIX Project is an example of one such study conducted, in this instance, in children and pregnant women (Casas et al., 2018).

#### *Long-term variations*

Longitudinal cohort studies provide valuable data on temporal trends in environmental exposures, allowing researchers to track changes in the exposome over time. For example, analyses of historical air pollution data have documented declines in levels of particulate matter and nitrogen dioxide in urban areas, attributed to regulatory interventions, technological advances, and shifts in energy sources. Conversely, emerging contaminants, such as per- and polyfluoroalkyl substances (PFAS), present upward trends in exposure due to their widespread use in consumer products and industrial processes.

A persuasive example of the temporal variability of environmental exposure, including across society, is provided by that of lead exposure. Accurate historical analyses are possible by examining ice cores and their encapsulated air bubbles. These studies reveal a marked escalation in mercury and lead emissions attribut-

able to human activities since the conclusion of antiquity, following a temporary decline during the Middle Ages (McConnell et al., 2019).

Historically, lead has been associated with varying degrees of exposure across the different social classes. In ancient Rome, lead exposure was prevalent among the affluent who used *defrutum*, a costly syrup made from cooked grapes stored in lead containers, to sweeten their food. Over time, the widespread use of lead-based paints and, later, leaded gasoline, resulted in a more ubiquitous exposure across the population. However, as the wealthier nations phased out leaded gasoline, older, unrenovated housing emerged as a significant source of lead exposure, primarily affecting the socio-economically disadvantaged. This historical trajectory of lead exposure highlights the complex interplay between environmental hazards and social dynamics, underscoring the importance of sociological perspectives in understanding how environmental exposures intersect with broader social determinants of health and contribute to health inequities, even in affluent societies.

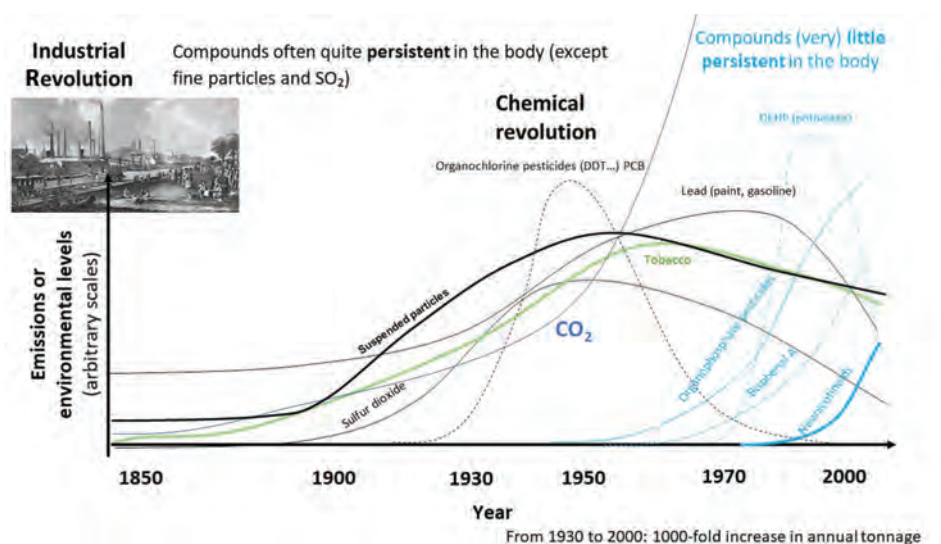


FIGURE 8. Historical evolution of the chemical exposome.

SOURCE: Rémy Slama (personal communication).

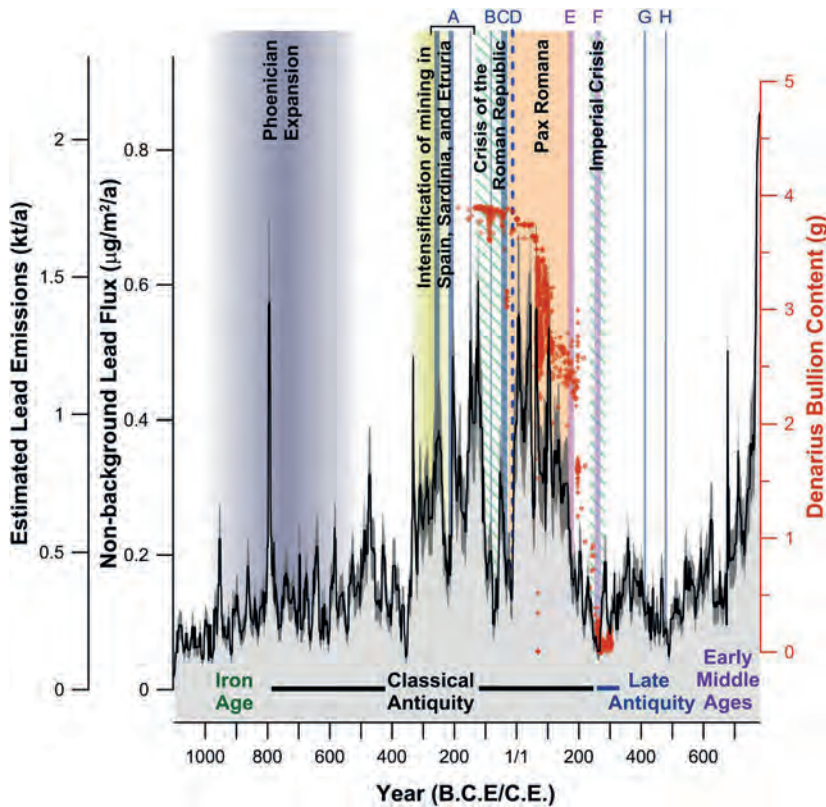


FIGURE 9. Annual lead pollution deposition during the past 2,200 years has been documented in an array of ice cores spanning nearly half the Arctic, including 12 ice cores from Greenland and one from Severnaya Zemlya in the Russian Arctic.

SOURCE: Joseph R. McConnell et al. (2018), Lead pollution recorded in Greenland ice indicates European emissions tracked plagues, wars, and imperial expansion during antiquity, *PNAS (Proceedings of the National Academy of Sciences)*, 115(22) (29 May), 5729, <https://www.pnas.org/doi/pdf/10.1073/pnas.1721818115>.



FIGURE 10. In Roman times, the wealthy classes were “privileged” in being able to sweeten their food with *defrutum*, a costly grape syrup cooked in a lead container that released lead acetate, a potentially deadly sweetener.

SOURCE: Image by HerrBudlanski in *Wikimedia Commons*, [https://commons.wikimedia.org/wiki/File:Beuverie\\_Latine.jpg](https://commons.wikimedia.org/wiki/File:Beuverie_Latine.jpg), under Creative Commons Licence Attribution-ShareAlike 4.0 International, <https://creativecommons.org/licenses/by-sa/4.0/>.

### 3.3. THE EXPOSOME AND HEALTH INEQUALITIES

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Health inequalities are commonplace and can be found virtually anywhere, occurring in low- and middle-income countries as well as in their high-income counterparts. Such inequalities are not only manifest across a range of medical factors, including genetic predisposition, access to health care, and health service quality, but they also occur in association with a slew of non-medical factors, including gender, race, education, income, housing, and food security, the so-called *social determinants of health* (Neufcourt et al., 2022). Health inequalities are an outcome of the conditions in which people live, work, and age, which are in turn shaped by broader political, social, and economic forces (World Health Organization & UN-Habitat, 2010). Moreover, health inequalities are not distributed randomly across the population but show consistent patterns according to socio-economic standing. In 2010, Sir Michael Marmot and colleagues published a seminal report on health inequalities in England entitled “Fair Society, Healthy Lives”, and, in so doing, created awareness for an issue often overlooked by policy