Socioeconomic Evaluation of Breast Cancer Attributable to Benzo[a]pyrene (BaP), Nitrogen Dioxide (NO$_2$), and Polychlorinated Biphenyls 153 (PCB-153) Air Pollutants

EPH21

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Objectives

Breast cancer (BC) is the most common cancer in women worldwide. Exposure to air pollutants is suggested to increase BC risk. The aim of the present study was to estimate the proportion of BC attributable to benzo[a]pyrene (BaP), nitrogen dioxide (NO$_2$), and polychlorinated biphenyls 153 (PCB-153) and the economic impact of these air pollutants in France.

Methods

- **Study population:** The XENAIR case-control study (5222 breast cancer cases & 5222 matched controls) nested in the French national E3N-Generations cohort *(epidemiological study among women from the Mutuelle générale de l'Éducation nationale, a national health insurance plan that mainly covers teachers)* were used [1].

- **Exposure assessment:** Annual atmospheric concentration levels of BaP, NO$_2$, and PCB-153 from 1990 to the index date *(date of cancer diagnosis)* were estimated using geocoded residential addresses. Land Use Regression models were used to estimate the annual mean concentrations of NO$_2$. For BaP and PCB-153 exposure, concentration data from CHIMERE, a regional chemistry-transport model, were used.

- **Attribuable Burden of Disease:** Attributable fractions of BC due to each air pollutant were multiplied by incidence and mortality estimates from the Global Burden of Diseases (GBD) study 2018 [2;3].

- **Economic evaluation:** The method as reported by the socio-economic evaluation of health effects of the public investment project was used [4]. Medical costs were obtained from the French national health data system (SNDS). Daily sickness allowances were used as a proxy for production losses. Estimated tangible costs per incident breast cancer case were €47,031 in 2018. Intangible costs were estimated by calculating the value a of statistical life year *(cf. Tables 1 and 2)*.

Value of a Life Year	Discounted disease duration	Disability coefficient	Intangible morbidity costs per case
131,413 €	9.96	0.067	88,259 €

Table 1. Estimated intangible morbidity costs per case

Value of a Life Year	Number of years of life lost per death	Number of years of life lost per updated death	Intangible mortality cost per death
131,413 €	23.7	17.9	2,352,007 €

Table 2. Estimated intangible costs of mortality per death

- **One-way sensitivity analyses** were conducted by varying resource consumptions and unit costs parameters by plus or minus 20% and illustrated graphically in a tornado diagram using Treeplan SensIt®.

Results

- **Estimated attributable fractions** are displayed in Table 3.

Air Pollutants	BC Attributable fractions [95%CI]	Threshold	Source
NO$_2$	8.90% [0.75%; 17.02%]	10 µg/m^3	2021 World Health Organization (WHO) air quality level for long-term NO2 exposure based on all non-accidental mortality and cause-specific, respiratory mortality
BaP	2.49% [2.15%; 2.97%]	0.4 ng/m^3	Concentration below which the 2004 European air quality directive does not require monitoring
PCB-153	13.70% [0.00%; 64.26%]	-	In absence of regulatory threshold for airborne PCB, we assumed that subjects had been continuously exposed from 1990 to index date to levels observed for 2010.

Table 3: Estimated attributable fractions in the XENAIR population

- **Breast Cancer Cases and Deaths (year 2018):** The annual breast cancer burden in France due to NO$_2$, BaP and PCB-153 includes 3,772, 1,055, and 5,806 cases, respectively, and 899, 251 and 1,383 deaths.

- **Economic Costs of Breast Cancer Attributable to Air Pollutants (in €2018):** The total cost of BC attributable to air pollutants (in €2018) were €2.6 billion for NO$_2$, €734 million for BaP and €4 billion for PCB-153 *(cf. Table 4)*. Healthcare expenditures, intangible morbidity, and intangible mortality costs accounted for 7%, 13%, and 80% of the total economic burden, respectively.

Air Pollutants	Scenario	Total healthcare expenditure (€)	Total intangible morbidity costs (€)	Total intangible mortality costs (€)	Total cost (€2018)
NO2	WHO recommendations (2021)(10 µg/m3)	177,403,155	332,913,833	2,113,683,182	2,624,000,170
BaP	(0.4 ng/m3)	49,633,018	93,141,061	591,356,306	734,130,385
PCB-153	If women had been exposed since 1990 as they were in 2010	273,081,262	512,462,867	3,253,647,145	4,039,191,273

Table 4: Total cost of breast cancer attributable to air pollutants (in €2018), XENAIR study, 1990-2011

- **Sensitivity Analyses:** The most sensitive parameter on costs was the estimated attributable fraction *(cf. Figure 1)*.
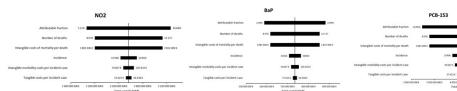

Figure 1: One-way sensitivity analysis

Conclusion

This study confirms substantial BC burden attributable to air pollution, and reports major economic impact. Nevertheless, due to collinearity, individual attributable fractions should not be summed.

References:
[1] Amadou et al. 2020 « Chronic Low-Dose Exposure to Xenoestrogen Ambient Air Pollutants and Breast Cancer Risk: XENAIR Protocol for a Case-Control Study Nested Within the French E3N Cohort ». JMIR Research Protocols 9 (9): e15167. https://doi.org/10.2196/15167.
[2] Barendregt, Jan J., et J. Lennert Veerman. 2010. « Categorical versus Continuous Risk Factors and the Calculation of Potential Impact Fractions ». Journal of Epidemiology and Community Health 64 (3): 209-12
[3] GBD 2021 Diseases and Injuries Collaborators. 2024. « Global Incidence, Prevalence, Years Lived with Disability (YLDs), Disability-Adjusted Life-Years (DALYs), and Healthy Life Expectancy (HALE) for 371 Diseases and Injuries in 204 Countries and Territories and 811 Subnational Locations, 1990-2021: A Systematic Analysis for the Global Burden of Disease Study 2021 ». Lancet (London, England) 403 (10440): 2133-61.
[4] France Stratégie. L'évaluation socioéconomique des effets de santé des projets d'investissement public. Mars 2022. » https://www.strategie.gouv.fr/publications/evaluation-socioeconomique-effets-de-sante-projets-dinvestissement-public-0