Indoor Air Pollution and Mortality in Belgium: A 30-Year Retrospective Population Study (1991–2021)

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Introduction

Air pollution remains the largest environmental health risk in Europe. According to the European Environment Agency, exposure to fine particulate matter and nitrogen dioxide levels above World Health Organization recommendations caused an estimated 253,000 and 52,000 premature deaths, respectively, in 2021.

Respiratory and cardiovascular diseases are the conditions most directly linked to air pollution. In recent years, their incidence has declined, likely due to improved air quality and lifestyle changes, such as reduced smoking and improved working conditions, and medical interventions (Ezzati et al., 2015).

A significant component of overall air pollution is indoor air quality. Indoor pollution acts as a distinct risk factor, occupying a middle ground between highly individual exposures, like smoking, and collective, population-level exposures, like general outdoor air pollution. While workplace indoor pollution has been identified as a major contributor to mortality -particularly among men - household indoor pollution has often been overlooked (Cincinelli & Martellini, 2017; Gbd, 2025; Mannan & Al-Ghamdi, 2021). Over the past decades, however, a growing body of evidence has highlighted household air pollution as a persistent and substantial global risk factor for a range of adverse health conditions (Gbd, 2025).

Several studies on mortality by cause, by social class and by geographical entity related to air pollution have recently been published for Belgium (Aerts et al., 2020; Bauwelinck et al., 2022). Less is known about the potential impact of household indoor pollution in Belgium. Data on the number of housholds involved and on the levels of dangereous indoor pollution do not exist for Belgium. Potential sources of indoor air pollution are smoking, cooking and heating, dust, building materials and some furniture. We used the type of heating to investigate the effect on respiratory and cardiovascular mortality.

In Belgium, a clear socio-economic gradient in mortality from respiratory and cardiovascular diseases persists. These inequalities are also geographically evident, reflecting not only the spatial distribution of socio-economic status but also the likely unequal distribution of risk factors such as indoor air pollution.

The regional pattern of premature male mortality of COPD by district is relatively similar to the regional pattern of indoor heating with a coal stove as illustrated in the following maps, suggesting a possible correlation and contribution of indoor heating to inequal mortality distributions.

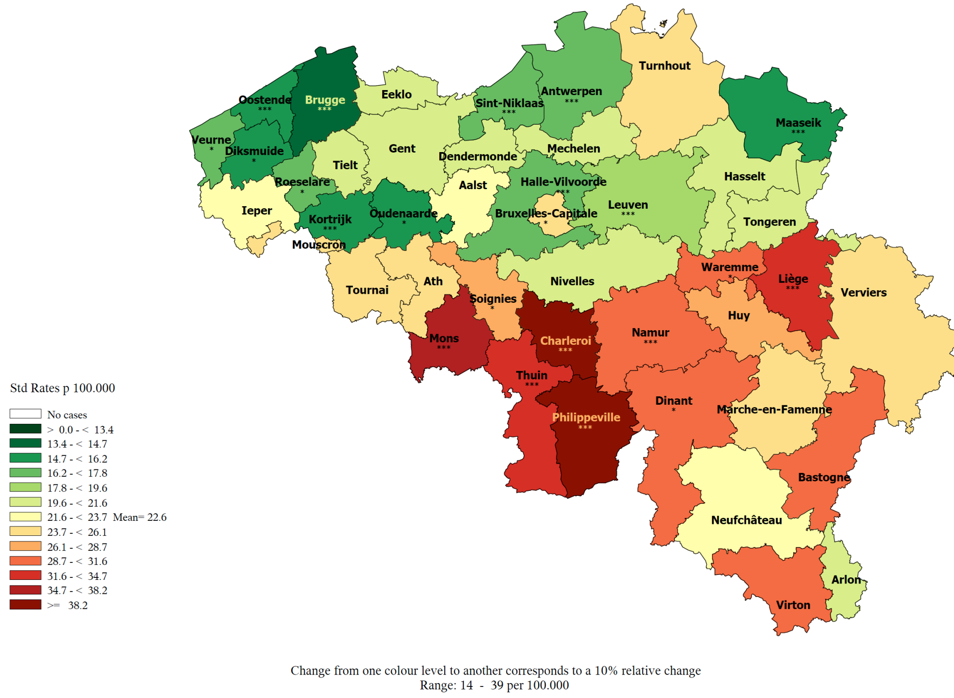

Figure 1: Premature COPD Mortality in Men (1-74 yr) by district in Belgium 2003-2009 (Renard, Tafforeau, & Deboosere, 2015).

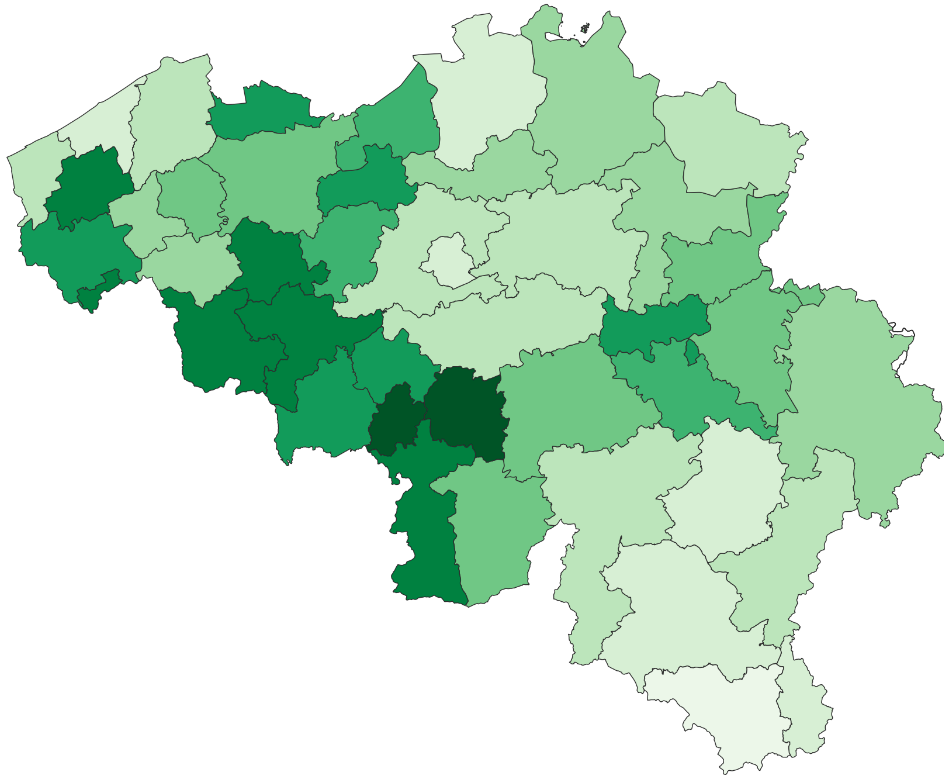

Figure 2: Indoor heating with coal by district Belgium 1991, districts classified by equal interval.

Data and Methods

According to the 1991 census, 60% of Belgian households used a central heating system, 34% did not, and data were missing for 6%. Among households without central heating, the most common alternative was gas heaters, followed by coal stoves. The latter still represented more than 8% of the population in 1991. Indoor coal combustion produces fine and ultra-fine particles and a wide spectrum of other noxious chemicals (Hays, Geron, Linna, Smith, & Schauer, 2002). Approximately 1.5% of the population used wood combustion, another source of potential indoor air pollution (Vicente et al., 2020). Although only 10% of households used coal or wood combustion, their regional distribution was highly uneven, with high concentrations in specific districts.

The census population aged 31 and older in 1991, who were still alive in 2001, was linked to a mortality follow-up from 2001 until 2021. Of the 5,835,068 surviving residents, 85,717 died from chronic lower respiratory disease (ICD-10: J40-J47) and 167,319 from ischemic heart disease (I20-I25) over this 20-year period. Households were classified into four categories based on the 1991 census: central heating, wood burning, coal stoves, and all other heating types. While we lack information on heating system changes after 1991, by selecting individuals who were at least 30 years old in 1991, we assume most had been exposed to their declared heating type for several years prior to 1991.

We used a Cox regression model with days survived as the time variable to examine the relative risk of mortality from ischemic heart disease and chronic lower respiratory disease by heating type, controlling for sex, age, and educational level. In a second step we introduce geographical area and analyse how regional disparities in COPD mortality are partially explained by indoor air pollution.

Results

All non-central heating systems were associated with a significantly higher risk of respiratory mortality compared to the central heating reference group. The use of a coal stove posed the greatest risk, with an 85% increase in mortality from chronic lower respiratory disease. While controlling for educational level—as a proxy for socioeconomic status—attenuated these relative risks, all associations remained statistically significant.

		Exp(B)	95.0% CI		Exp(B)	95.0% CI	
sex	men	2.664	2.627	2.702	2.763	2.720	2.806
	women (ref)						
age		1.109	1.109	1.110	1.106	1.105	1.107
heating	other	**1.534**	1.512	1.557	**1.360**	1.337	1.382
	wood	**1.541**	1.454	1.634	**1.332**	1.249	1.422
	coal	**1.843**	1.804	1.883	**1.547**	1.509	1.585
	central heating (ref)						
education	unknown				3.131	2.973	3.297
	primary				2.900	2.767	3.040
	lower secondary				2.254	2.143	2.372
	lower secondary professional				2.219	2.113	2.331
	higher secondary				1.789	1.693	1.891
	higher secondary technical				1.595	1.504	1.692
	higher secondary professional				2.190	2.060	2.327
	post secondary				1.743	1.567	1.939
	higher education				1.265	1.194	1.340
	university (reference)						

Table 1: Cox regression with days surviving between 2001 and 2021 as time variable. Relative risk for COPD mortality by type of heating controlled for sex and age and for educational attainment.

While the impact on cardiovascular mortality was less pronounced than on respiratory mortality, it remained significant. The use of a coal stove was associated with a 48% higher risk of death from ischemic heart disease, and other non-central heating types increased the risk by more than 30%. After controlling for education, these associations persisted, with coal stoves still linked to a risk more than 35% higher than the central heating reference group.

		Exp(B)	95.0% CI		Exp(B)	95.0% CI	
sex	men	2.159	2.138	2.180	2.267	2.242	2.292
	women (ref)						
age		1.115	1.114	1.115	1.114	1.114	1.115
heating	other	**1.306**	1.293	1.320	**1.233**	1.219	1.248
	wood	**1.306**	1.250	1.365	**1.193**	1.135	1.253
	coal	**1.483**	1.460	1.507	**1.353**	1.329	1.378
	central heating (ref)						
education	unknown				1.712	1.657	1.769
	primary				1.660	1.613	1.707
	lower secondary				1.474	1.428	1.520
	lower secondary professional				1.497	1.453	1.542
	higher secondary				1.296	1.253	1.341
	higher secondary technical				1.275	1.229	1.323
	higher secondary professional				1.483	1.427	1.542
	post secondary				1.261	1.176	1.353
	higher education				1.056	1.019	1.093
	university (reference)						

Table 2: Cox regression with days surviving between 2001 and 2021 as time variable. Relative risk for IHD mortality by type of heating controlled for sex and age and for educational attainment.

For both causes of mortality male mortality has been for many decades always higher than female mortality and this is still observed in this analysis.

Adding individual information on district of residence the relative risk of COPD mortality by district can be mapped. The district of Antwerp with a relative low mortality of COPD is used as reference. The Flemish districts, especially in the coastal regions, have a lower COPD mortality in general. This is also true for the Walloon districts in the southern province of Luxembourg.

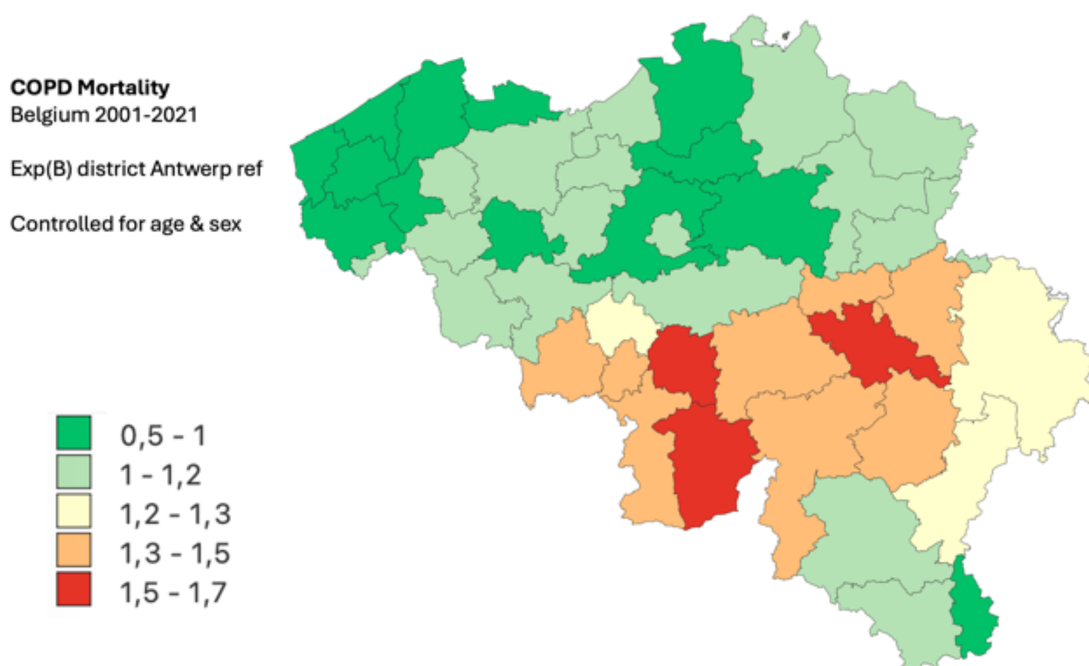

Figure 3: COPD mortality by district controlled for age and sex, Belgium 2001-2021.

When controlling for indoor heating type, the socio-economic and geographical mortality gradients persist, but their magnitude is significantly attenuated. While adding educational level does not change the pattern by district anymore.

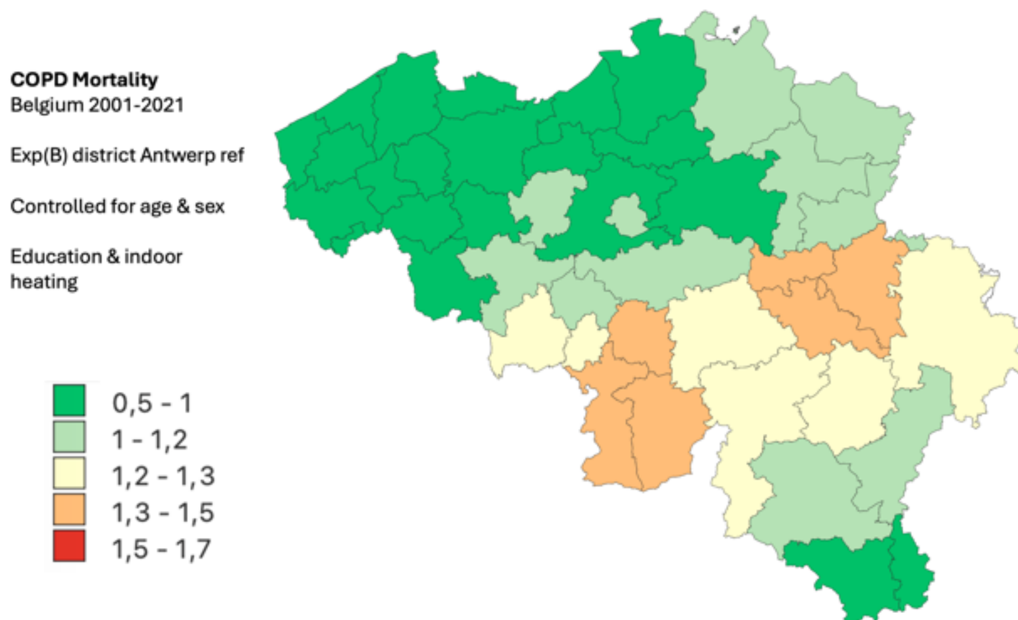

Figure 4: COPD mortality by district controlled for age and sex, indoor heating and educational level, Belgium 2001-2021.

Discussion

The historical decline in respiratory mortality over the past three decades (figure 5) reflects a substantial reduction in key risk factors. This trend is particularly pronounced among men, in whom exposures to major risks have declined in parallel. In contrast, the trend among women has been much flatter, likely due to a differing and more complex risk profile. While improvements in outdoor and indoor air quality benefited both sexes equally, a much smaller proportion of women were exposed to hazardous occupational conditions. Reenforcing this, smoking prevalence among women in Belgium increased sharply beginning in the 1970s, concurrent with a steady decline among men.

By 2021, very few Belgian households still used wood or coal burners, and other individual heating systems emitting noxious gases have also been significantly reduced. Our study mainly illustrates the historical impact on mortality in older populations untill today. This has of course still relevance for the remaining small group of persons using indoor heating systems with noxious gas emissions. It remains also an explaining factor for higher mortality in some countries where many households are still using older heating systems.

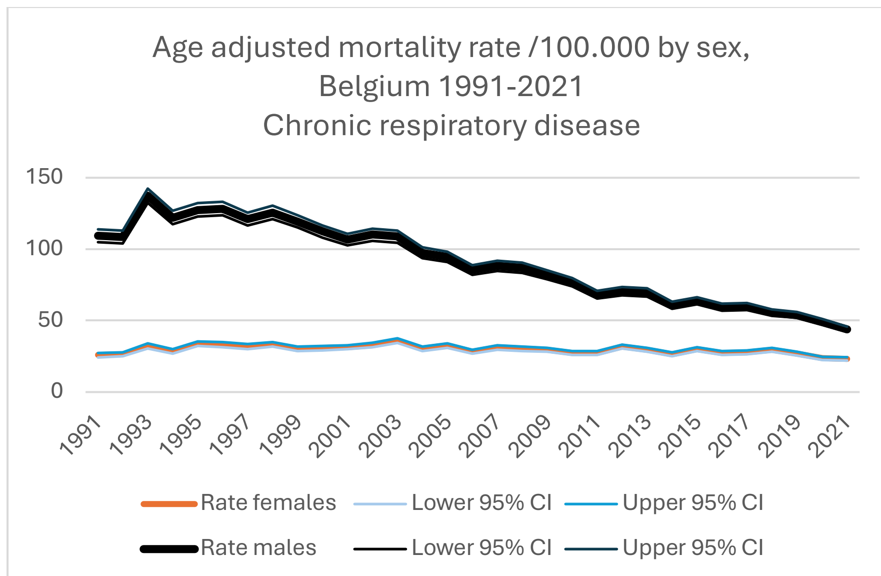

Figure 5: mortality data Sciensano, (ICD9 490-494, 496, ICD10 J40-J47)
reference: European Standard population (EU27 + EFTA, July 2013)

As coal stoves were primarily used by older and poorer populations, the increased risk we observed is likely partially attributable to factors beyond indoor pollution. This socioeconomic group has a higher probability of adverse health behaviors (e.g., smoking) and exposure to worse working conditions. A key limitation of this study is the inability to control for smoking behavior, occupational exposures, and outdoor air pollution. The impact of these unmeasured factors is a probable reason why male mortality from ischemic heart disease and chronic obstructive respiratory disease is substantially higher than female mortality.

Controlling for educational level only partially explained the relationship between in-home combustion and the risk of both diseases. Inversely, the observed health inequalities according to educational level are partially explained, at least for the older age groups, by the contribution of indoor pollution.

The geographical distribution of indoor heating types and COPD mortality are strongly correlated. Our analysis suggests that regional inequality in mortality is partially explained by socio-economic status (SES), as measured by education, with indoor pollution potentially acting as an intermediary factor in this relationship.

The elevated risk associated with "other heating types" as observed in table 1 and 2 suggests that most older indoor heating systems likely posed a significant health hazard.

Finally, our study likely substantially *underestimates* the true effect of indoor pollution. Our control group (central heating) is contaminated, as many individuals within it may have used coal stoves or other polluting heating systems before upgrading to a healthier option. A decade earlier, the 1981 census showed that less than half of all Belgian households had a central heating system, underscoring the widespread reliance on more polluting heating types in the recent past.

Conclusion

This study demonstrates the significant health risks associated with coal and wood heating for the Belgian households that still used them in 1991. A policy to eliminate remaining solid-fuel stoves and other noxious heating systems should be implemented, given the clear long-term health consequences.

Indoor pollution is linked to socio-economic position, and heating type is an important intermediate factor explaining mortality differentials by socio-economic position in Belgium.

This research adds to the growing evidence of indoor pollution's impact and can encourage other countries to phase out these types of heating systems.

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